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GEOTECHNICAL EARTHQUAKE ENGINEERING EXPERIMENTAL FACILITIES:

# DEVELOPING A NATIONAL NETWORK WITH STRUCTURAL, SEISMOLOGICAL, AND COASTAL EARTHQUAKE ENGINEERING SEISMIC SIMULATION FACILITIES

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## ABSTRACT

Vulnerability to earthquakes resulted in tens of billions of dollars of damage in the 1994 Northridge and the 1989 Loma Prieta Earthquakes and more than one-hundred billion dollars in the 1995 Kobe, Japan, Earthquake. A significant portion of these losses were caused by soft or poor soils. These soils amplified the earthquake motions, or they liquefied, displacing and damaging foundations and port facilities. Mitigation of our earthquake vulnerability improves life safety and makes economic sense.

Geotechnical Earthquake Engineering requires an understanding of the propagation of earthquake vibrations through the ground, the dynamic interaction of the ground with man-made structures, and the ability to anticipate dynamic and permanent deformations of the ground and structural foundations. Many unsolved fundamental problems cause engineers to face tremendous uncertainties in earthquake resistant design and in retrofitting of soil and soil-foundation-structure systems. The unsolved problems involve nonlinear deformations of porous media coupled with movement of water in the pores and the dynamic interaction with foundations and structures.

This report presents findings of a workshop regarding the pending proposal for a Network for Earthquake Engineering Simulation (NEES)[*]. The workshop brought together experts on geotechnical earthquake engineering experimental research with emphasis on the use of major research equipment to discuss the importance and implications of the NEES. The goals of the workshop were to:

- discuss visions of new and upgraded facilities and their linkage via the NEES,
- develop a strategy to solve critical earthquake engineering problems using the major research equipment of the NEES,
- anticipate changes in the research culture required by NEES, and
- build the consensus required to make NEES successful.

Appendices to this report present valuable summaries of breakout group and newsgroup discussions on a wide variety of "technical" and Internet "research culture" issues.

By the conclusion of the workshop, participants were very enthusiastic about the importance and benefits of the NEES. The solutions to several critical earthquake engineering problems (e.g., "Liquefaction and flow phenomenon and the associated large deformation of earth dams, landfills, seawalls, embankments") would be efficiently and effectively tackled using the new network. The network will encourage a new culture of cooperation and efficient sharing of new and existing research infrastructure.

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[*] At the time of the workshop, the project was known as the National Network for High Performance Seismic Simulation (NHPS)

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# PREFACE

Several assessments of experimental earthquake engineering research needs have been undertaken in the last 25 years. In 1995, Congress mandated one such study, conducted by the Earthquake Engineering Research Institute (EERI), entitled "Assessment of Earthquake Research and Testing Capabilities in the United States. A common thread in these assessments has been the steady deterioration of experimental facilities in the US and the high priority assigned to improving the nation's earthquake engineering experimental research facilities.

The primary element of the EERI assessment was a workshop held in San Francisco July 31 to August 1, 1995. The proceedings of the workshop recommended that a plan must be developed to effectively utilize, modernize, and upgrade existing facilities and laboratories, and to pursue experimental research at an accelerated rate. The creation of a series of new, moderately sized regional centers was also recommended.

A National Network for High Performance Seismic Simulation (NHPS) was proposed within NSF as a Major Research Equipment (MRE) initiative to respond to the need to develop integrated experimental research facilities. The NHPS was envisioned to provide a means for the rapid exchange of ideas and information; offer immediate access to research data generated anywhere in the network; serve as a forum for researchers, practitioners, and students to share their expertise; and create an environment where students are learning through research that is supported by the latest experimental and communication technologies.

The NHPS would include the following new or enhanced equipment and facilities:

1. Advanced-design earthquake simulation facilities including simulation systems for structural testing, geotechnical centrifuges with shakers, and wave generators for study of tsunamis.
2. Large scale testing systems for testing structural elements, assemblies of elements, and response modification devices in full scale.
3. Field simulation facilities and mobile laboratories for field-testing installations and for monitoring constructed facilities before, during, and after an earthquake.

This document describes the proceedings of a workshop held at the University of California, Davis, in May 28-29, 1998. This workshop, with about 40 participants, involved the geotechnical earthquake engineering research community in in-depth discussions of the technological and cultural implications of the NHPS. Representatives from structural, seismological, and coastal earthquake engineering also attended because the NHPS would also encompass these disciplines. The workshop included invited lectures on advanced Internet networking technologies and experiences with networks developed for collaboratory research in other engineering and science disciplines. Breakout groups discussed changes in the research culture that would enable efficient use of the networked experimental facilities and discussed how networked facilities could help solve critical and challenging earthquake engineering problems. Diverse issues such as intellectual property rights, data sharing protocols, instrumentation technology, and outreach all generated stimulating discussions.

Prior to the workshop, written input from all participants was invited on an Internet newsgroup, and this input has been included as an appendix to this report.

Several developments in the MRE initiative have taken place in the period following the workshop at Davis. The acronym was changed from NHPS to NEES (National Network for Earthquake Engineering Simulation). From this point on, this report has adopted the new acronym. (References to NHPS may still be found in the appendices, however.) Within the National Science Foundation, the focus of NEES has been steered toward an ultimate goal of non-physical simulations; for example, numerical models will be expected to occupy an ever important and perhaps increasing role in earthquake engineering research. The major research facilities of NEES are needed to provide the experimental data that is necessary for development and verification of non-physical models.

The American Institute of Physics Bulletin of Science Policy News (Number 27, February 18, 1999) provided the following update on the official status of NEES:

> "The FY 2000 Request to initiate construction of the Network for Earthquake Engineering Simulation (NEES) is $7.70 million." "Total NSF funding for this project, including both the experimental facilities and the network is $81.90 million over the period FY 2000-2004." "The Network will be developed to include geographically distributed and network-interconnected physical facilities constructed under cooperative agreements with NSF." "The NEES project will transform earthquake engineering research from its current reliance on physical experiments to investigations based on integrated models, databases and model- based simulation."

The proceedings of this workshop highlight some important issues associated with such a major undertaking as NEES. It is hoped that this information will be useful during planning and implementation phases of the new network.

Bruce Kutter
Chair, Steering Committee

## ACKNOWLEDGMENTS

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# 1 INTRODUCTION

## 1.1 Urgency

In January, 1994, the Northridge Earthquake (magnitude 6.7) in California resulted in about 65 deaths and over 5000 injuries. Economic damage estimates were in the range of $15-30 billion (Housner, 1994).

In January, 1995, the Hanshin-Awaji (Kobe) Earthquake (magnitude 7.2 (JMA)) in Japan resulted in approximately 5500 deaths. Economic damage estimates were about $100 billion; this includes damage to residential and commercial structures, electric power facilities, gas delivery systems, hospitals, telecommunications facilities, transportation systems, water and wastewater systems, ports, rivers, and agricultural facilities (Shinozuka, 1995).

On the West Coast of the US there is a clear potential (and history) for earthquakes with magnitudes greater than 7.2, and furthermore, the earthquakes could occur close to heavily populated areas. Future damage in the US could exceed that observed in Kobe. And earthquake risk is not limited to highly seismic areas on the West Coast. While potential for shaking may be less severe in other areas, earthquake preparedness is also typically less while real earthquake risk remains significant. Due to the present day relatively strong economy, older cities may actually begin to deal with their massive infrastructure re-construction and rehabilitation needs. It would be unwise to proceed with massive investments in infrastructure without updating our consideration of earthquakes.

Several scientific challenges face geotechnical earthquake engineers attempting to reduce vulnerability to earthquakes. Geotechnical engineers deal with liquefaction, landslides, ground vibrations, and the dynamic interaction between structures, foundations, and soils. Engineers do their best to evaluate these problems when designing to minimize vulnerability, but several major uncertainties preclude accurate (i.e., well defined) assessment of vulnerability. Geotechnical earthquake engineers are concerned, for example, with evaluating how much will the ground move, and what forces will the ground apply to foundations, bridges, and buildings. This information is prerequisite for earthquake resistant design of soil and soil-structure systems. All of these problems involve dynamic nonlinear behavior of particulate media, with interaction between the groundwater and the soil as well as with the foundations and structures. These complex problems are far from solved, and in many respects even the basic mechanics underlying them are poorly understood.

Due to the complexity of the materials and systems involved including their dynamic interaction, a very significant role in their study is played by major seismic simulation experimental facilities in the laboratory and the field. The experience of the last 10-20 years shows clearly that, second only to much scarcer measurements during actual earthquakes, these major facilities are often the only way to effectively clarify and quantify the earthquake response of such complex soil-groundwater-foundation-structure systems. This is true if the objective is to develop simple engineering rules, or to provide the basis for reliable computer simulations of a family of systems. Very often a sustained effort involving major experimental facilities is the only way toward further reliable analytical or numerical simulations of such systems. It is anticipated that major seismic simulation experimental geotechnical facilities will continue to play such a key role in the foreseeable future.

Many major seismic simulation experimental facilities are in need of major renovation due to advancing age. These major facilities also stand to benefit greatly by leveraging rapid technological developments in computer and sensor technology. The quality of US seismic test facilities is, in many respects, lagging behind that of other major industrial nations. The NEES as a distributed network of earthquake engineering facilities will take advantage of advances in instrumentation technology, revitalize the earthquake engineering experimental research infrastructure, and establish a new research culture to efficiently use and share major facilities as well as data generated by these facilities.

Geotechnical earthquake engineering research in the NEES will also have spin-off benefits toward improved understanding of landslides and debris flows that are not seismically induced; landslide-induced tsunami; avalanches of ice and snow; tailings deposits from mines; and materials handling (e.g., transportation and storage of grain, coal, and other particulate materials). Research results, especially site characterization and ground response analyses, are applicable to other problems of national importance such as groundwater problems, underground structures, resource discovery and recovery; potential future exploration and exploitation of the deep ocean, arctic, and in space.

### 1.2 Scientific Challenges

In contrast to other fields of engineering, earthquake engineering is dominated by relatively large and one-of-a-kind structures. As extreme examples, the east span of the San Francisco-Oakland Bay Bridge is being replaced due to seismic loading demands at a cost of about $1.5 billion, and foundation remediation at Jackson Lake Dam cost about $100 million. Each site and/or structure has unique earthquake problems involving the proximity and type of earthquake faults, the size and shape of the structure, and the depth and properties of soil deposits, including the presence and depth of groundwater.

Natural soil deposits, being the result of different combinations and intensities of geologic processes, always have unique characteristics, even when compared to other similar deposits. This, in conjunction with the differences between structures and the natural variability between one earthquake and another, makes it very difficult to extrapolate directly the experience from one system or site to another. Methods of proof-testing and statistical analysis of identical systems to demonstrate future reliability, as often applied in industrial mass production, are thus limited. Careful site characterization, laboratory and field testing, theory, and general guidelines based on a combination of prior experience of performance of similar cases, analytical and experimental research, and judgement are typically used to evaluate future performance of soil and soil-structure systems in earthquakes and to make engineering design decisions.

The behaviors of soil and of soil-structure systems during strong earthquake shaking are very complex and strongly nonlinear. This is due mainly to the characteristics of the soil medium, which includes typically several phases (solid particles, water, and air), has pressure-dependent properties, and most often appears as layers of different materials. This complex medium exhibits strongly nonlinear relations between stresses and strains. The behavior is especially nonlinear in the most problematic soils for the stress levels typically induced by strong earthquakes, and often includes violent changes in soil properties, the most extreme case being liquefaction of an initially solid soil material. Additional complexities and nonlinearities appear due to the interaction between soil and structural elements at the foundations of structures and other interfaces, and by the dynamic and cyclic nature of the earthquake induced loads including the inertia forces due to the accelerations of the structural masses above ground.

### 1.3 A Vision of NEES

Figure 1 shows a concept for a possible structure of the NEES. The network research and facility developments will be driven by critical problems (for example: large ground deformations due to liquefaction). Each critical problem may be attacked using a variety of experimental facilities and by non-physical modeling or analysis. In Figure 1, these tools are represented by the ring of trapezoids around the critical problem.

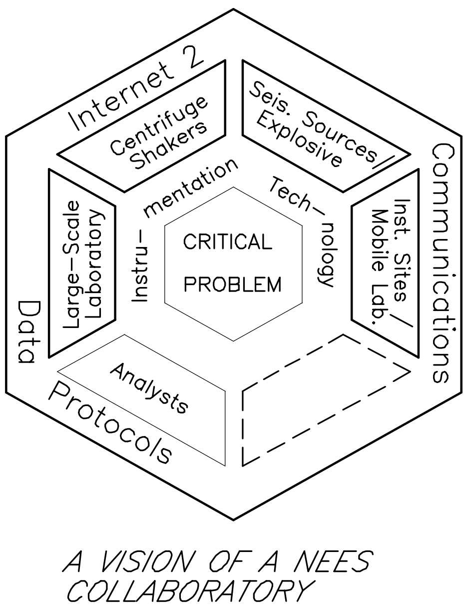


Figure 1. Concept for the structure of the NEES

The outer hexagon in Figure 1 encloses the new environment of the NEES. New instrumentation technology will be leveraged by the NEES ring of technology and portable equipment amongst all facilities (miniature instrumentation, high speed - high resolution video, robotics, and automation, for example). Data and communications will be transmitted and received with much improved convenience due to high bandwidth Internet2 using standard data protocols. Data must be transmitted in a manner that allows rapid visualization to local and remote researchers. Transmissions will be to other centers as well as remote researchers and analysts. Interactive collaboration between experimentalists and analysts will be beneficial in planning experiments and interpreting data.

The network would also establish decision making processes to determine optimized combinations of facilities required to tackle specific critical problems. By means yet to be determined, the network must also have some control over scheduling research and facility usage to assure that resources are shared fairly amongst the research community.

The trapezoids in Figure 1 represent broad components of the NEES:

1. Large Scale Laboratory: facilities such as very large diameter triaxial and torsional shear devices and large laminar shear boxes that may be placed on existing shaking tables. Due to their large size, these facilities avoid problems with scaling of particle sizes.
2. Centrifuge Shakers: Large capacity centrifuge facilities capable of testing models with prototype stress levels and realistic seismic wave propagation under controlled and repeatable laboratory conditions.

3. Seismic Sources / Explosives: These facilities enable shaking of full scale structures in the field using artificial earthquake motions. Mobile truck mounted shakers and sequenced detonation of explosives will be used as vibration sources.
4. Instrumented Sites / Mobile Laboratories: These facilities enable engineers to learn more from real earthquakes by carefully instrumenting sites where shaking is expected, and by enabling rapid deployment of mobile laboratories to the site of an earthquake quickly, before information is lost and to permit site and source characterization by monitoring of aftershocks.
5. The dotted trapezoid represents unforeseen facilities that will be added to the NEES.
6. The last trapezoid represents computational and analytical resources and facilities that will be used for interpretation and processing of data from NEES physical facilities or for analytical and computer numerical modeling of the critical problem.

The above facilities are described in more detail in a following section of this report. It is envisioned that the combined focus by a number of facilities and researchers over wide geographical areas, together with modern data collection and communication technology will enable rapid advances to and dissemination of solutions to the critical earthquake engineering problems.

### 1.4 NEES Background

A Network for Earthquake Engineering Simulation (NEES) has been proposed within NSF as a Major Research Equipment (MRE) initiative to respond to the need to develop integrated experimental research facilities in a new research environment, advance the scientific understanding of the impacts of earthquakes, and help avoid catastrophes caused by a lack of knowledge regarding the behavior of engineering materials, soils, and construction during earthquakes. It will provide a means for the rapid exchange of ideas and information, offer immediate access to research data generated anywhere in the network, serve as a forum for bringing researchers and practitioners together to share their expertise with students and professionals engaged in earthquake engineering, and create an environment where students are learning through research that is supported by the latest experimental and communication technologies.

The NEES would include the following new or enhanced equipment and facilities:

1. Advanced-design earthquake simulation facilities including simulation systems for structural testing, geotechnical centrifuges with shakers, and wave generators for study of tsunamis.
2. Large scale testing systems for testing structural elements, assemblies of elements, and response modification devices in full scale.
3. Field simulation and laboratories including field testing installations, mobile laboratory units for monitoring constructed facilities before, during, and after an earthquake.

The concept of a NEES has broad support from the earthquake engineering community. Since the 1970's several assessments of experimental research needs have been undertaken, from a 1973 National Research Council/National Academy of Engineering Workshop (sponsored by NSF) on Simulation of Earthquake Effects on Structures to a Congressionally mandated 1995 Earthquake Engineering Research Institute Assessment of

Earthquake Engineering Research and Testing Capabilities in the US (funded by NSF and NIST). The common thread in the assessments has been the steady deterioration of experimental facilities in the US and the high priority assigned to improving the nation's earthquake engineering experimental research facilities.

With the support of the entire research community, it appeared (at the time of this workshop) likely that the NEES would become a reality. The cost estimate for the entire network, including Capital Expenses, Operations, Maintenance and Replacement was $76.2 Million. Approximately, an additional $2 Million per year had been designated toward Management of the NEES. If everything went according to plan, funding for the NEES would be awarded to a non-profit consortium in January of the year 2000.

It is envisioned that the NEES will be administered by a non-profit consortium. Criteria will need to be developed to determine membership in the consortium. Decisions need to be made as to eligibility for membership. Should it be limited to universities (however large or small), or should private partners be allowed to join? Some workshop participants expressed the opinion that membership should be limited to academic institutions and that membership fees or dues should be high enough to be taken seriously but low enough to allow small institutions to join. Access to the facilities should be open to all types of organizations through an "affiliates" program that has a different fee or dues structure.

Approximately 30% of the $76.2 million was earmarked toward geotechnical earthquake engineering facilities. Based on proposals presented and discussions held at several meetings in 1996 and 1997, the geotechnical budget has been further subdivided to include the following facilities:

- Centrifuges with Shakers (upgrades)

  Centrifuge model tests of soil and soil-structure systems subjected to in-flight base shaking provide useful qualitative and quantitative information on the systems' earthquake responses. In combination with analytical modeling and with data from actual earthquakes, an increasing number of predictive engineering methods and guidelines rely on information provided by the centrifuge. This is especially true at large soil strains and soil failure, including liquefaction effects. Level soil deposits, mild and steep slopes, earth embankments, bridge abutments, waterfront structures, shallow footings and pile foundations in a variety of soils, and ground remediation and retrofitting schemes, are being successfully modeled. There are currently four large (100 g-ton or more) operational centrifuges in the US with in-flight earthquake shaking capability (to this it must be added 5-10 smaller size centrifuges, some of them also with shaking capability). The allotted NEES budget aims at enhancing these existing facilities and utilizing them better through a significant increase in their productivity toward the research of critical earthquake problems.

- Large Scale Soils Laboratory Devices

  Two types of large scale laboratory devices are envisioned for testing both material properties and for evaluating earth structure response on a prototype scale. The first type includes large diameter (90 cm) cyclic torsional triaxial devices and resonant column devices useful for testing gravels and gravelly soils, and for performing large scale tests on undisturbed frozen samples. Ideally the device(s) will be configured so that in-situ testing tools, such as a seismic cone, could be inserted into the samples in order to calibrate the tools and correlate measurements. Such measurements could be then directly used to correlate the laboratory data with field measurements. The second type of device is a large-scale (5+ m in height) uni- or bi-axial laminar shear box of the type pioneered in Japan placed on top of a shaking table. This device will be useful for testing soil liquefaction, pile response, and reinforced soil walls.

- Instrumented Field Sites

Instrumented field sites are required to measure ground response, soil-structure interaction, pore pressures and ground movements in response to real and artificially generated seismic shaking. These measurements are needed to better understand soil and structural responses, to develop quantitative data for development of theoretical and empirical criteria, and to provide measured field data for verification of predictive relationships. The allotted NEES budget will provide funding to develop three to four additional instrumented field sites or to upgrade several existing sites. These sites will be instrumented to provide specific high-priority information as determined at the workshop and to increase the probability of recording real earthquake responses over the lifetime of the project.

- Mobile Seismic Wave Sources

High-energy mobile seismic wave sources are needed to generate earthquake-type shaking at soil and rock sites. Both vertical and horizontal exciters will be developed. These exciters will be patterned after the Vibroseis units presently used on land in oil exploration. Loadings over wide ranges in force levels, frequency ranges, and pulse types will be possible. It will also be possible to apply input shaking directly to the ground surface, to structures embedded at depth, or to the exposed portions of surface structures (such as foundations or bridges). Support vehicles with the appropriate control and data acquisition equipment will be developed to accompany the high-energy sources during field testing. A total of five high-energy sources with support vehicles will be constructed. These systems will be stationed at various universities around the United States. Each source will represent a stand-alone system. However, the sources can also be brought together in any number and operated simultaneously with or without phase-locking.

- Post Earthquake Mobile Site Laboratory

These facilities include two mobile field laboratories located in two separate parts of the United States to enable deployment to the site of an earthquake, as soon as possible after an earthquake. The mobile laboratories will include capabilities for site characterization using static cone penetration testing, monitoring of aftershocks, and for forced vibration field experiments using 2.5 ton capacity field shakers. The facilities will enable installations of accelerometers on structures, the ground surface and in vertical borehole arrays. Clusters of instruments at various locations will be linked by a network to a central data acquisition van. Personnel and space to house and maintain the equipment is needed.

- Ground Motion with High Explosives

  Explosives would be used to simulate seismic ground motions to study soil-pile interaction, the response of underground structures, and base isolation of structures. Controlled ground motions can be triggered by programmed explosions at some distance from the test site and the dynamic response of full and near full-sized prototype structures can be monitored. A test site situated near existing open pit mines where explosions are used in the mining process has been suggested. The advance of the mine cut toward a test site will result in gradually increasing motions. Extensive instrumentation will be needed to monitor the response of soil, foundation, or super-structure. Remote sensors for monitoring excitations and response of systems will provide for safe and accurate capture of data.

Until the project is funded, it is considered desirable to continue discussing the NEES in a number of forums; the intention of the NEES is not only to enhance experimental facilities, it will also require major changes in the culture of the earthquake engineering research. A meeting for discussion of the NEES was held at the EERI National Conference in Seattle during the first week of June 1998. Another workshop to discuss tsunami and coastal earthquake engineering components of the MRE was also held in June, 1998.

The May, 1998, workshop at the University of California, Davis, was designed to engage the geotechnical engineering research community in in-depth discussions of the technological and cultural implications of NEES. Representatives from structural, seismological and coastal earthquake engineering also attended because the NEES will encompass all of these disciplines. By the conclusion of the workshop, participants were very enthusiastic about the importance and benefits of the NEES. The network will encourage a new culture of cooperation and efficient sharing of new and existing research infrastructure.

# 2 LEVERAGING RESOURCES IN THE NETWORK

## 2.1 Introduction

The geotechnical earthquake engineering community stands to benefit greatly by leveraging modern technology through the national network. The collaborative nature of the network will bring many minds and facilities to bear on the same problem. Attacking a problem from more than one direction and by using more than one experimental technique, analysis procedure, etc., can provide unambiguous and redundant solutions (to reduce or eliminate indeterminacy). Advances in Internet and Internet2 technologies will allow researchers to participate in and even control experiments remotely without physically attending the tests. Establishing a data repository and data management system will enable broader access to information. This new research culture of collaboration and cooperation at times will conflict with the current system, but the conflicts can be overcome. Finally, by leveraging new instrumentation technologies, experimentalists will be able to better define physical mechanisms of behavior through direct measurements.

## 2.2 Communication and Data Dissemination

### 2.2.1 Communications Technologies

Several new communications technologies will be available to the network. Internet2 will enable high speed data transmissions, including high quality video, to remote sites. Dedicated "chat rooms" will be considered to enable remote interaction during experiments and earthquake reconnaissance. Remote control of experiments via the Internet is already possible as long as sufficient reserved bandwidth is available. The new communications technologies will make it possible to explore remote control of experiments. An important question that must be answered before implementation of remote control capabilities is: How far away can the controller be without sacrificing quality, safety and efficiency?

Two special needs may be high-speed network access from remote locations (e.g. mobile post-earthquake field labs) and satellite-based communications in the event that land-based links are down after an earthquake.

There is a need to define various levels of "networking" and "linking". Restrictions to some of these links will be required. Possible levels include:

- non-real-time collaborative experiment design
- real-time observation and monitoring of experiment via video-conferencing ("remote observation")
- real-time access to data collection devices ("remote access") real-time control of experiments ("remote control")

### 2.2.2 Data Sharing Scenarios

The proposed Major Research Equipment of the NEES will produce very large data sets which cannot be completely analyzed by the team that produces the data. There will be a new and critical need to process and comprehend large data sets efficiently. New data visualization tools must be developed and implemented, and more researchers will need to be involved in the interpretation. So, it is critical to prepare for a new research culture that

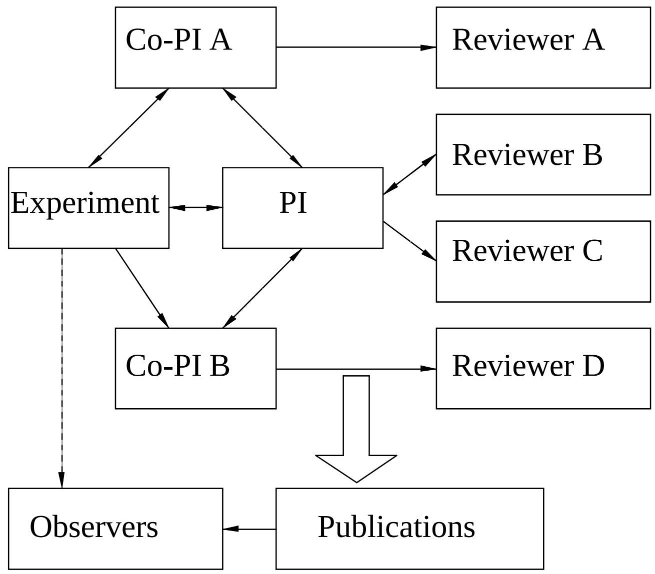


Figure 2. Complex data transfer and communication links in the NEES

facilitates and encourages rapid sharing and dissemination of large quantities of high quality data.

In the present culture, researchers are already burdened with information overload. To absorb more information it must be presented in more comprehensible formats such as intuitive multi-dimensional graphs and animations. Experts in data processing and visualization should be recruited from other disciplines and data processing specialists should be trained within the network to automate the creation of data presentations that can be more rapidly absorbed by the principle investigators, reviewers and observers.

Complex interactions requiring varying levels of communication are envisioned as indicated in Figure 2. For example, the Principal Investigator may interact closely with co-PI's and Reviewer B during the planning of an experiment (indicated by two-way arrows). Both co-PI's may observe the experiment locally or remotely in real time, but co-PI A may be interacting (transmitting and receiving data) with the experiment in real time, perhaps even participating in decisions to alter the experiment. He could therefore use complete real-time remote access to the same information available to the PI. Co-PI B may be observing the experiment, but may not be responsible for adjusting the experiment in progress. The data sharing and communications between the PI's and the experiment should be as rapid as possible and completely unrestricted. There may also be benefits to allowing informal observers to view video images and a limited amount of data in real time. However, complex data should not be widely released to observers until it is checked for procedural and/or hardware acquisition errors.

After the experiment, the PI's will then process the data to make it available in the form of data reports and publications. At varying stages, the Reviewers may be given data; the staging of the data release is to reduce the burden on the reviewers; the complex raw data should first be processed to filter anomalous information and make it more comprehensible. Certain reviewers may perform advanced analyses of the data, while others may check the data reports and publications for completeness and accuracy. At this time, publication of the data could take place in archived electronic formats in addition to conventional paper publications.

### 2.2.3 Impediments to Data Sharing and Dissemination in Present Research Culture

In the current research environment, the factors listed below restrict dissemination of data:

1. The time required to adequately document the experiment.
2. The time required to eliminate procedural and/or hardware acquisition errors in the data.
3. The time required to present the data in a useful, user-friendly format.
4. The existing academic promotion and tenure system, which emphasizes publications in refereed journals. This system encourages the experimentalist to hold the data until they have the first crack at analyzing and then publishing it. Workshop participants expressed different and strongly held opinions on the degree to which experimental designs, procedures, and results belong to those who develop and generate them.
5. The long time between submittal of publications and their appearance in a conventional academic or professional journal. Typically, it takes a year or more after submittal for peer-review, revisions, re-review, printing, and distribution.

### 2.2.4 NEES Data Protocols to Mitigate Existing Impediments

1. Documentation of the experiment will be given a higher priority by researchers because more credit will be awarded to those that perform the documentation. In present day academia, data reports would count for almost nothing in promotion or tenure review. Thus researchers often rush to publish with the best intentions of later documenting the data for others. Standards for documentation should be established by the NEES. Documentation will be much more efficient if the required format of the documentation is known. There is also a fear of going to the trouble of documenting something that will not be used by others. The NEES should also facilitate use of documented data by others.

2. The value of experiments will be improved if co-PI's and reviewers are involved in the planning of the complex experiments. Reliability of data will also be greater if data is shared with and analyzed by co-PI's and reviewers at an early stage. Viewing the data from different perspectives will allow resolution of inconsistencies (i.e. procedural and/or hardware acquisition errors) before general release of the data.

3. The establishment of standard data formats will provide a larger market for data processing and data visualization software tool kits. Software will be required to automatically process data and present it in more rapidly comprehensible formats. Automation of data collection, processing and analysis will be facilitated by standards for data formats. Existing examples of data formats include those established in the disciplines of exploration geophysics (SEG-Y format) and modal testing (SDF, Universal file format). NetCDF (network Common Data Form) is another interface for array-oriented data access and a library that provides an implementation of the interface. The netCDF library also defines a machine-independent format for representing scientific data. Together, the interface, library, and format support the creation, access, and sharing of scientific data. The netCDF software was developed at the Unidata Program Center in Boulder, Colorado. The freely available source can

be obtained by anonymous FTP from ftp://ftp.unidata.ucar.edu/pub/netcdf/ or from other mirror sites.

4. To balance the dual requirements of rapid dissemination of useful data with the constraints of intellectual credit for their generation, a Journal of Experimental Results in Earthquake Engineering (JEREE) should be established. JEREE would be a high-quality, peer-reviewed, electronic journal published on the Internet. JEREE publications would generally consist of relatively short papers describing the experimental design, instrumentation and data acquisition, facilities and equipment, and test procedures. The experimental results, in the form of both raw and processed data (with description of processing protocol), would be linked to the text. All descriptions and data would be sufficiently complete to allow interpretation by others. Preliminary conclusions, if available, could be included with the text of a JEREE publication. JEREE publication could be required for research projects that used NEES facilities, and would be available for experimental research generated using other facilities.

5. High bandwidth, user friendly telecommunications via chat rooms and video conferencing systems are needed to facilitate interactions and data transfer between researchers planning and conducting experiments. Successful interfaces are intuitive and self-documenting, so emerging standards from user interface design should be followed. Internet2 will provide the dedicated bandwidth for comfortable video conferencing and real time monitoring.

#### 2.2.5 The Journal of Experimental Results in Earthquake Engineering (JEREE)

The development and management of JEREE would require a firm commitment from the NEES program. Because of the strong potential and desire that the published data be used by others, JEREE submissions would require careful peer review of a type that is not performed by existing refereed journals. Review of data and accompanying descriptions will require the development of specific criteria by which the quality and completeness of data and supporting documentation are to be evaluated. The NEES organization would also need to establish guidelines for the format and content of JEREE publications. The strong potential benefits of rapid and wide dissemination of data would justify the investment of time and money that would be required to produce JEREE.

Establishment of the NEES and of JEREE as a mechanism for timely dissemination of useful data will require that careful attention be paid to data throughout the process of experimental design, testing, and interpretation. Research proposals involving the use of NEES facilities should be required to explicitly address the control and assurance of data quality and these aspects of research proposals should be carefully considered during the review process. Some projects could benefit from the inclusion of validation teams that would provide an independent review of the project from the experimental design stage to the time of publication of experimental results.

Data should be disseminated as soon as its completeness and validity has been established, though there was some disagreement in the workshop about exactly how that should be accomplished and how long the process should take. Different types of projects will undoubtedly produce different types and amounts of experimental data that will take different amounts of time to verify. Some projects, such as those involving instrumentation of sites prior to earthquakes, may be able to release data very soon after an earthquake and after checking of instrumentation. Others, such as those involving complex model testing programs, may require significant interpretation before the quality of the experimental data can be established. The timing of data dissemination will apparently need to be evaluated on a case-by-case basis, and may involve reporting requirements placed upon researchers by funding agencies.

### 2.3 Sharing Facilities

There is some experience in this area upon which the NEES should build. Geotechnical centrifuges centers have already established a record of sharing of facilities within the geotechnical earthquake engineering community. One of the most prevalent problems is deciding what to do when a given experiment occupies more facility time than originally planned. IRIS is another successful model which should be considered as a basis for the NEES. In IRIS, a committee reviews experimental plans and makes sure the experiment is viable and well planned. The need for the committee to be impartial and representative was recognized.

In order to ensure fair sharing of the facilities, an administrative structure and policies, such as those suggested below, need to be established.

1. Establish a representative committee (or committees). The committee will
   - review experimental design and establish priorities,
   - suggest or require participation of other investigators,
   - establish data presentation and archival formats and ensure proper dissemination of data,
   - share control with host institution of facility access and use. The membership and affiliate status of the facility users should be considered in the fee structure for use of facilities and access to data.
2. Establish responsibilities and rights of host institution.
   - While sharing of facilities amongst researchers will be a basic attribute of NEES, it is recognized that the host institution must have special responsibilities and privileges for the operation and maintenance of the facility. The host institution should not be simply another user of a facility managed by a third party.

### 2.4 Instrument Technologies

Recent advances in sensor and information technology makes possible a jump in our scientific understanding (or the verification of our current understanding) of the basic phenomena affecting the response of soil and soil-structure systems during earthquakes, providing the basis for better performance predictions and safer, more economical engineering decisions. These advances in sensors, which are still in rapid progress, include a dramatic reduction in the size and price of available sensors; the development of new types of sensors which may be embedded in the soil mass, in structural elements, or placed at soil-structure interfaces, and are capable of measuring stresses, strains, deformations, and pressures with minimum human interference; sensors having their own power; wireless sensors; and systems of sensors which can communicate with each other and with the monitoring system. The reduced sizes and costs, expanded availability, and ease of installation and monitoring of the sensors emerging today makes possible their massive installation and use, with a corresponding potential for the production of massive amounts of data in a given experiment. This massive nature of the data set could allow a given physical behavior to be uniquely defined by the data alone, thus providing precious detailed information to the analysts developing reliable numerical simulation techniques.

This rapid potential increase in data producing power is matched by the rapidly increasing data processing power, through the availability of the Internet and Internet2 systems and the ever-increasing availability of faster and more powerful computers.

All components of this NEES (Structures, Tsunami, and Geotechnical) have significant common interests in instrumentation. Extensive instrumentation is needed for continuous real-time monitoring, post-earthquake measurements, full-scale testing, and laboratory experimentation. Advanced Control and Smart-structures/materials are heavily dependent on accurate instrumentation as well.

The challenges are :

A. development and integration of instrumentation for seismic (and real-time condition assessment) purposes,
B. state-of-the-art data acquisition and data transmission,
C. automated data processing, system identification, and visualization technologies, and
D. monitoring-based decision-making, early response, and real-time risk assessment methodologies.

Item "A" includes:

1. small (Nano) sensors,
2. embedded sensors (e.g. within concrete, composite sections and soil/soil-structure systems),
3. "chip" sensors with associated signal conditioning and/or data transmission boards (nano or small-scales, and/or embedded),
4. lab testing applications,
5. improved special purpose sensors for direct measurements of displacement (cyclic and permanent), excess-pore water pressure, etc., and
6. technologies for massive sensor-deployment efforts in existing and new structures/soil systems, and in lab models.

Item "B" includes strategies/technologies for:

1. data collection from locations within a single extended civil-engineering structure,
2. data storage and transmission (via Cellular, Internet, Satellite,....),
3. control and interaction with remote monitoring stations,
4. routine full-scale testing, post-earthquake reconnaissance, small-scale lab testing, and networking,
5. role of GPS, cellular, and satellite technologies.

In addition to the US, it would be very worthwhile to find out more about similar efforts in Europe and Japan. Moreover, we might benefit from what may be ongoing in the Seismology, the Oceanography, and the Environmental-Engineering monitoring efforts.

# 3 OUTREACH

The primary benefits of the NEES will be to advance earthquake engineering research toward mitigation of vulnerability, and to train graduate and undergraduate researchers at universities. The sharing of the NEES facilities with researchers at various universities has already been discussed. This section describes outreach to elementary and secondary students, government agencies, private industry, and international researchers.

## 3.1 Kindergarten - 12

One of the primary goals of the NEES is to make advanced experimental facilities generally available via the Internet. As young students are rapidly adopting Internet technology it makes sense to present results of NEES research in a form accessible to the general public as well as students of all ages. A prime example of this was the interactive web site that allowed students to "virtually" control the movement of the Mars Rover.

Similar web sites will be made available regarding NEES earthquake engineering research. Animations of fault rupture, wave propagation, and ground shaking could be presented, and participants could "push the button" on a virtual shaking table experiment or a centrifuge model test. The participants could adjust the level of shaking on the shaking table, and video replays of experiments would be triggered.

## 3.2 Government Agencies

A liaison will be required to link with federal and state agencies concerned with the seismic vulnerability of infrastructure. This clearly includes agencies such as the Department of Defense, Federal Highways Administration, State Departments of Transportation, the Bureau of Reclamation, Bureau of Mines, Environmental Protection Agency, and others. These agencies will all be interested in effectively leveraging research dollars through research within the NEES.

On another level, networking between the NEES and government agencies will promote technology transfer and establish links to government facilities and researchers. It would be desirable for the NEES to make use of existing government facilities such as the large geotechnical centrifuge and wave tanks at the Waterways Experiment Station (WES). Collaborative links should also be established with the US Geological survey (instrumented sites and facilities), and Department of Energy (Nevada Test Site).

## 3.3 Private Industry

Some other nations, such as Japan and the European Economic Community (EEC), have already invested in large-scale testing equipment and are using it to their competitive advantage in the world market. Access to similar facilities could be advantageous to US industry. Industries that could benefit from testing at NEES facilities include construction firms; structural, geotechnical, and coastal engineering design and consulting firms; ground improvement companies; gas and oil companies; manufacturing enterprises; and insurance companies.

Traditionally, in U.S. private industry, engineering design is performed with competitive profit margins. It is often difficult to attract private research funding in this environment. In addition, private industry often has more interest in proprietary research that will produce a competitive edge. This is not really in the spirit of the shared data and facilities of the NEES.

But, there will be avenues for significant involvement of private industry. First, private industry will be willing to conduct open research if it is funded by the Government by programs such as the Small Business Innovative Research Program. Second, it is anticipated that academic research teams that conduct cooperative research will include prominent practitioners on oversight committees or as consultants on research projects. This interaction will be made more practical by advances in communication technology and will help transfer the technology to practice. Third, on a lower priority, NEES facilities could be made available for proprietary research if it does not displace non-proprietary research and if separate fee structures are established for proprietary and non-proprietary research.

### 3.4 International

As international communication increases, it is logical that NEES researchers will continue to expand connections to foreign researchers and facilities. In particular, there are several major earthquake engineering research facilities in Japan. Presently, Japan operates the world's largest shaking table facilities and several large geotechnical centrifuge facilities with in-flight shaking. Via US-Japan cooperative research programs, researchers from the US already participate in the use of these facilities.

The differences between research cultures in different countries may pose some problems that hamper international cooperation. For example, many of the major experimental facilities in Japan are operated by private industry and by government agencies, which may not be ready to adopt the NEES culture of sharing of facilities and experimental results. Advanced communication in conjunction with their systematic use by NEES may eventually break down these barriers.

NEES should reach out to the international community to establish mutually beneficial working agreements. The advantage to NEES would be to gain access to international facilities which we may not wish to duplicate and to integrate the expertise of foreign engineers into research conducted in NEES facilities. In many instances, formal agreements and memorandums of understanding between governments may be required. For example, NSF and other US agencies already have cooperative agreements with Japan, China, and other countries that likely could be amended to add NEES cooperation. Specific countries with which advantageous agreements could be developed include Canada, Mexico, Chile, Japan, and the EEC. Again, implementation of an international liaison committee would be a useful vehicle for outreach to the international community.

# 4. EXAMPLE NEES COLLABORATORY

## 4.1 Introduction

The success of the NEES proposal depends on developing a consensus of support from the research community. This consensus should be based upon research needs, and the role of the networked facilities in addressing these research needs. Four critical research topics, formulated by the workshop steering committee, were proposed to form the basis for discussions at the workshop. Within the framework of the selected research topics, each break out group outlined examples of "networked" research program(s), visualized specific examples of how specific facilities and researchers should be networked, and summarized the facility needs to address the selected research topic. Summaries from the breakout group discussions are included in the appendices of this report. A single example problem and the role of the NEES in solving the problem is discussed in detail below.

## 4.2 Large Deformation and Flow Phenomenon

Seismically-induced large deformation and flow of the ground is an important phenomenon in the evaluation and design of a wide variety of geo-systems, including dams, levees, embankments, bridge abutments, bridge and building deep foundations, solid waste landfills, marginal wharves, cut and fill slopes, and natural slopes. The slumping of the Lower San Fernando dam in the 1971 San Fernando earthquake, the landslides at Turnagain Heights and in downtown Anchorage in the 1964 Alaska earthquake, and the destruction of the marine laboratory at Moss Landing in the 1989 Loma Prieta (World Series) earthquake provide graphic examples of the damage and risk associated with seismically induced large deformation and flow.

Tens of millions of dollars can be spent on single projects to remediate foundation soils for dams and levees to mitigate the potential for seismically-induced large deformation and flow. Lack of a complete understanding of this phenomenon often leads to conservative designs that require expensive remediation that may, in some cases, be unnecessary. In other situations, this lack of understanding may put lives and property at risk. Improved understanding of this phenomenon and improved methods of predicting the large deformation and flow potential of soils can lead to substantial reductions in risk and associated cost savings. These risk reductions and cost savings would be realized by improvements in our ability to identify situations when lives and property are at risk due to seismically induced large deformation and flow and by more economical remedial action plan to mitigate the identified risks.

In current practice, the potential for large deformation and flow in soils is evaluated using the concept of residual shear strength. The state of practice for evaluation of residual shear strength is based upon the Seed - Harder correlation between the "equivalent clean sand Standard Penetration Test blow count" and residual shear strength back calculated from observed flow failures. Because the field data on which this correlation is based is subject to a high degree of uncertainty and subjective interpretation, this correlation provides a range of residual shear strength for a given blow count that is over an order of magnitude wide at low blow counts. Use of the bottom end of the range invariable results in the prediction of a high potential for large deformation and flow at a site susceptible to liquefaction, while use of the upper end of the range often results in a prediction of post-earthquake stability and relatively small deformations. Little to no guidance is provided to the practicing engineer on which part of the range to use in a given situation. Furthermore, this correlation ignores many factors which are known to influence the potential for seismically induced large deformation and flow, including initial confining pressure, initial static shear stress, and particle size (both absolute particle size and the distribution of particle size within the soil), and the importance of void redistribution.

The NEES network of facilities offers the potential for development of a coordinated, systems approach to studying seismically-induced large deformation and flow phenomenon. Basic studies on the many factors affecting large deformation and flow potential could be conducted in the centrifuge and at the explosive-induced excitation 1-g testing facilities. These facilities could also be used to develop "well-documented" case histories to supplement the existing data base and enhance its reliability. The large scale laboratory equipment, including the laminar box and large diameter cyclic triaxial testing device, could be used to study the influence of soil composition on triggering of seismically-induced large deformation and flow. The equipment could also be used to study in-situ testing methods for predicting large deformation and flow potential. The centrifuge and laboratory testing data could be supplemented with data on triggering of seismically induced large deformation and flow developed using the large shakers at instrumented field sites, with data collected by the mobile soils laboratory from large deformation and flow failures immediately following earthquakes, and with data collected from instrumented test sites during actual earthquakes.

The value of coordinating the planning and disseminating results of the research are excellent reasons for connecting all of the facilities and researchers in a network. Many aspects of the research would benefit from network interactions:

1. A network-convened panel of influential researchers and practitioners chosen to select or review plans for a particular suite of experiments would help ensure focus on critical aspects of the research, ensure that sufficient data is collected to prove or disprove validity of current practices, and encourage acceptance of the findings by the profession. Regarding the topic of residual strength, there are several common opposing viewpoints expressed by current "experts". For example, there are disagreements in interpretation of the Standard Penetration Test for silty sands, disagreements in the importance of void redistribution, and disagreements about the importance of taking "undisturbed" samples from the field.

2. Specifications for types of soil tested at each facility (e.g., composition, density and moisture content) should allow for repeatability at different laboratories and verification. More expensive tests might be done for one or two soil types and less expensive experiments could be conducted on many soil types.

3. There are several computer models and empirical procedures being developed for the purpose of predicting earthquake induced deformations. These models and procedures should be used to predict results of planned experiments during the planning phase. This may identify crucial parameters and measurements that should be accounted for in large experiments. Procedures could also be set up for objective blind comparisons between numerical calculations and experimental results.

4. Skeptical observers would be welcome to observe various stages of preparation for and testing of major model tests. Remote researchers would gain insight into the care taken during conduct of the experiments and a healthy knowledge of sources of error and uncertainty. Mechanisms for early interaction and acceptance of criticism will lead to improvements in the test procedures.
5. Results would be rapidly disseminated in standard formats that could be readily understood by others. Presently, data from dynamic experiments are initially presented in the form of a set of time histories (Acceleration or pressure as a function of time, for example). Expanding computational power and the increased volume of instrumentation that could be recorded in advanced testing facilities should allow intuitive images or animations of the experimental results to be observed quickly by many researchers. For example, animations of deformed shapes of a model embankment superimposed on animated pore pressure distributions will provide understanding of spatial and temporal cause and effect relationships.
6. Standard data formats developed by the network would allow data from various numerical simulations and various facilities to be cross-compared with relative ease. Standard plotting and animation software would become basic tools for communication between networked researchers.
7. In a recent collaborative research program called VELACS (Arulanandan et al. 1994), for example, the final deformed shapes of physical models were compared with numerical predictions of the deformed shapes. In some cases, the final shape was accurately predicted, but the sequence and mechanisms of deformation were in error. In other cases, the sequence and mechanisms were correct but the final deformed shape was in error. Advanced visualization technologies will allow for much more comprehensive assessments of validity of alternative procedures for non-physical simulation.

# 5 CONCLUSIONS

## 5.1 National Importance of the NEES

In two advanced industrialized nations alone, Japan and the US, earthquakes have caused thousands of deaths and well over $100 billion in damage in the last ten years. Much of this damage is directly related to the presence of soft or poor soils. Vital infrastructure components (highways, ports, and bridges for example) which facilitate trade and commerce are threatened by devastating earthquakes.

The solutions of several geotechnical earthquake engineering problems are hindered by difficult scientific challenges. The nonlinear response of heterogeneous soil deposits subject to strong shaking involves complex processes such as liquefaction, particle mechanics, large deformations, and fracture. Without understanding the ground response during earthquakes, it is not possible to understand the response of infrastructure founded on the ground. Major coordinated experimental research through a network such as the NEES would enable unprecedented advances in our efforts to find real and practical solutions to critical problems in earthquake engineering.

## 5.2 Summary of Workshop Goals

The Network for Earthquake Engineering Simulation (NEES) has been proposed within NSF as a Major Research Equipment (MRE) initiative to respond to the need to develop integrated experimental research facilities in a new research environment, advance the scientific understanding of the impacts of earthquakes, and help avoid catastrophes caused by a lack of knowledge regarding the behavior of engineering materials, soils, and construction during earthquakes. In May, 1998, an NSF-sponsored workshop was held at the University of California at Davis, bringing together experts on geotechnical earthquake engineering major research equipment and the associated research to discuss the importance and implications of the NEES. The workshop was designed to engage the geotechnical engineering research community in in-depth discussions of the technological and cultural implications of NEES. Representatives from structural, seismological, and coastal earthquake engineering also attended because the NEES will encompass all of these disciplines. The goals of the workshop were to:

- discuss visions of new and upgraded facilities and their linkage via the NEES,
- develop a strategy to solve critical earthquake engineering problems using the major research equipment of the NEES,
- anticipate changes in the research culture required by NEES, and
- build the consensus required to make NEES successful.

Discussions of these factors have been summarized in this report. The report appendices include newsgroup discussions and summaries of the breakout group discussions which address many of these issues from different perspectives and in more detail.

## 5.3 Facilities in the NEES

The NEES as a distributed network of earthquake engineering facilities will take advantage of advances in instrumentation technology, revitalize the earthquake engineering experimental research infrastructure, and establish a new research culture to efficiently use and share major facilities as well as data generated by these facilities. Broad facility components of the NEES include:

- Large Scale Laboratories: Facilities such as very large diameter triaxial and torsional shear devices and large laminar shear boxes that may be placed on shaking tables.
- Centrifuge Shakers: Large capacity centrifuge facilities capable of testing models with prototype stress levels and realistic seismic wave propagation under controlled and repeatable laboratory conditions.
- Seismic Sources / Explosive Simulation Facilities: These facilities enable shaking of full scale structures in the field using artificial earthquake motions.
- Instrumented Sites / Mobile Laboratories: Engineers can learn more from real earthquakes by carefully instrumenting sites where shaking is expected, and by rapid deployment of mobile laboratories to the site of an earthquake, before information is lost, to permit site and source characterization and monitoring of aftershocks.

## 5.4 NEES and the Changing Research Culture

The success of the NEES proposal depends on developing a consensus of support from the research community based upon research needs, and establishing the significance of networked facilities in addressing these research needs. Within the framework of selected research topics, workshop participants outlined examples of "networked" research programs, visualized specific examples of how specific facilities and researchers should be networked, and summarized the facility needs to address the selected research topic. It is envisioned that the combined focus by a number of facilities and researchers over wide geographical areas, together with modern data collection and communication technology, will enable rapid advances to and dissemination of solutions to critical earthquake engineering problems.

The NEES will establish a new research culture to efficiently use and share major facilities as well as data generated by these facilities. Several new communications technologies will be available to the network. Internet2 will enable high speed data transmissions, including high quality video, to remote sites. Dedicated "chat rooms" could be established to enable remote interaction during experiments and earthquake reconnaissance. Remote control of experiments via the Internet is already possible as long as sufficient reserved bandwidth is available. The new communications technologies will make remote control of experiments practical, at least at some level.

In the current research environment, many factors restrict the rapid dissemination of data. To balance the dual requirements of rapid dissemination of useful data with the constraints of intellectual credit for their generation, it was proposed that a Journal of Experimental Results in Earthquake Engineering (JEREE) should be established. JEREE would be a high-quality, peer-reviewed, electronic journal that would be published on the Internet.

In order to ensure fair sharing of the facilities, an administrative structure and policies need to be established. A representative committee (or committees) will be established to review experiment designs, establish priorities, facilitate collaborations, and establish data sharing protocols. The network will provide a means for the rapid exchange of ideas and information, offer rapid access to data generated anywhere in the network, serve as a forum for bringing researchers and practitioners together to share their expertise with students and professionals engaged in earthquake engineering, and create an environment where students are learning through research that is supported by the latest experimental and communication technologies.

## 5.5 A Successful NEES

The concept of a NEES has broad support from the earthquake engineering community. Since the 1970's several assessments of experimental research needs have been undertaken, from a 1973 National Research Council/National Academy of Engineering Workshop (sponsored by NSF) on Simulation of Earthquake Effects on Structures to a Congressionally mandated 1995 Earthquake Engineering Research Institute Assessment of Earthquake Engineering Research and Testing Capabilities in the US (funded by NSF and NIST). The common thread in the assessments has been the steady deterioration of experimental facilities in the US and the high priority assigned to improving the nation's earthquake engineering experimental research facilities.

The undisputed consensus of the UC Davis workshop participants supported the development of the NEES and ratified the importance, motivation and value of such a network. The network would trigger rapid progress toward solutions of many critical geotechnical earthquake engineering problems, solutions which save lives and protect the huge infrastructure investment in our Nation.

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# APPENDIX A. WORKSHOP SCHEDULE

## Final Schedule of NHPS Workshop

**Room 1065 Engineering Unit II (EU 2)**

**University of California, Davis**

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### Thursday, May 28

8.00: Registration and continental breakfast (EU 2, South East Entrance Lobby)

8.30: **Welcome and Introduction (Room 1065 EU 2)**

*Karl Romstad, Chairman, Department of Civil and Environmental Engineering*

*Ben McCoy, Associate Dean of Research, College of Engineering*

8.40-9.00: Status and Background of the MRE Initiative

*James Jirsa, UT Austin*

9.00-9.10: Introduction to the Geotechnical Component of NHPS

*Bruce Kutter, UC Davis*

**Four Lectures on Existing Facilities and NHPS Project Development Plans**

*Session Chaired by J. K. Mitchell, Virginia Tech.*

9.10-9.30: "Existing Tsunami Test Facilities and NHPS Project Development Plans"

*Harry Yeh, University of Washington*

9.30-9.50: "Existing Large-Scale Laboratory Devices and NHPS Project Development Plans"

*Nick Sitar, UC Berkeley*

9.50-10.10: "Existing Field Testing Facilities and NHPS Project Development Plans"

*Ken Stokoe, UT Austin*

10.10-10.25: Break (1065 EU 2)

10.25-10.45: "Existing Centrifuges and Shakers and NHPS Project Development Plans"

*Ricardo Dobry, RPI*

10.45-11.05: Summary comments by session chairman and questions from the floor.

**Three Lectures on Internet Networking and Collaboratories**

*Session Chaired by IM Idriss, UC Davis*

11.05-11.25: Invited Lecture: "An Internet Expert's Vision of NHPS"

*Kyran Mish, CSU Chico*

11.25-1.10: Bus to Lunch at the UC Davis centrifuge and field test facilities

1.10-1.50: Invited Lecture: "Experience of the National Nanofabrication Users Network (NNUN)"

*Noel MacDonald, Cornell University*

1.50-2.10: Invited Lecture: "Collaboratories, Advanced Networking Applications, and Internet2"

*Joan Gargano, UC Davis*

2.10-2.20: Instructions to breakout groups

Within the framework of one of the selected research topics, each break out group will:

- Outline examples of "networked" research program(s)
- Visualize specific examples of how specific facilities and researchers should be networked.
- Summarize the facility needs to address the selected research topic.

2.20-3.30: **Breakout group discussions:**

Topic T1 (Room 1065 EU 2):

Study of response, deformation and failure of soil embankment systems used in dams, dikes, levees, as well as highways and bridge approaches, and of natural slopes, with emphasis on large deformation/failure phenomena. Problems in Topic 1 generally involve large static driving shear stresses.

Topic T2 (Room 3085 EU 2):

Study of response and large deformation in level and gently sloping ground, including effects on structures and facilities such as buildings, bridges, pipelines, and waterfront and retaining structures.

Topic T3 (Room 1066 EU 2):

Evaluation of effectiveness in reducing the earthquake hazards due to ground failure and ground deformation, and new ideas for ground remediation and retrofitting of foundations and structures for new and existing facilities.

Topic T4 (Room 1003 EU 2):

Ground response and soil-foundation-structure interaction due to seismic shaking.

3.30-3.45: Break (Refreshments available in EU 2 courtyard between 3.15 and 4.00)

3.45-5.00: Breakout group discussions, continued.

5.30: Bus departs from EU 2 for Workshop Steak Barbecue

5.40: Bus stops at Aggie Inn in Downtown Davis

5.45: Bus stops at Hallmark Inn in Downtown Davis

6.00 - 8.00: Barbecue at Yolo Land and Cattle Co., Road 25, Woodland, CA (see brochure)

## Friday May 29

8.30 - 9.30: **Plenary Session**

*Chaired by Takaji Kokusho, Chuo University, JAPAN*

**Fifteen minute presentations from breakout groups T1-T4.**

T1: *Ed Kavazanjian, Geosyntech Consultants*

T2: *Tom O'Rourke, Cornell*

T3: *Jim Mitchell, Virginia Tech.*

T4: *Ricardo Dobry, RPI*

9.30 - 10.00: Discussion

10.00 - 10.15: Directions to breakout groups Q1-Q4

The goal of the Friday breakout groups will be to discuss cultural issues associated with the NHPS. All of the breakout groups may discuss the same several topics, but each group will be asked to give priority to providing a definitive answer to the specific question indicated.

10.15-10.30: Break

10.30-12.00: **Breakout group discussions**

Q1 (Room 1065 EU 2):

How do we share facilities and encourage access to them, especially considering the demands of the users including the host institution? How should facilities and researchers be linked via the internet and modern communication technology? Also see questions Q1A and Q1B in pre-workshop writing assignment.

Q2 (Room 2130 Bainer Hall):

How and when do we effectively disseminate data and results to the public and/or share it with others? Implications of sharing on credit, authorship, promotion/tenure. Technical standards of shared data must be considered. Possibility of credit for electronic data "publication". Also see questions Q2A and Q2B in pre-workshop writing assignment.

Q3 (Room 1003 EU 2):

How do we achieve collaboration, remote participation, and/or real time sharing of experiments between two or more groups? How do we solve the related hardware, software, and standards issues? What are the desirable characteristics of the user interfaces of the communication network? Also see questions Q3A and Q3B in pre-workshop writing assignment.

Q4 (Room 1066 EU 2):

How can the network, along with the existing Earthquake Engineering Research Centers, reach out to government research laboratories, private companies, international research facilities, and others interested in geotechnical earthquake engineering to encourage cooperation and collaboration, build partnerships, and make data and results available to all potential users? Also see questions Q4A and Q4B in pre-workshop writing assignment.

12.00 - 1.00: Lunch break (walk to University Club)

1.00-2.30: Q1-Q4 Breakout group discussions continued

2.30-2.45: Break (Room 1065 EU 2)

2.45-3.45: **Fifteen minute presentations from Q1-Q4 breakout groups.**

*Chaired by Les Youd*

Q1: *Jim Jirsa, UT Austin*

Q2: *Steve Kramer, University of Washington*

Q3: *Hon Yim Ko, University of Colorado*

Q4: *Liam Finn, University of British Columbia, CANADA*

3.45-5.00: **Plenary Discussion -**

*Panel of Steering Committee and Q breakout group chairs*

*Discussion from floor*

5.00: Adjourn Plenary Session

5.00 - 5.30: Organizational meetings between breakout group Chairs, Secretaries, and Steering Committee.

6.30: Dinner at a local restaurant: Cafe California, 808 2nd Street (near G Street), Davis.

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## Saturday May 30 (135 Everson Hall)

**Meeting of Steering Committee and Session Chairs**

9.00-10.30 Meeting (135 Everson Hall)

- Discuss Future NHPS Activities
- Plan the Final Workshop Report
- Assign Follow Up Tasks

10.30-12.00: Draft outlines of report sections (each person with a computer).

12.00: Lunch served

12.30-1.00: Discuss draft outlines.

1.00-2.00: Revise and expand draft outlines

2.00: Adjourn.

2.00-5.00: Computers and printers will be available for continued work on final report.

## APPENDIX B. LIST OF WORKSHOP PARTICIPANTS

| | |
|---|---|
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# APPENDIX C. REPORT FROM GROUP T1

Within the framework of the research topics provide the following:
Ta) Outline examples of "networked" research program(s)
Tb) Visualize specific examples of how specific facilities and researchers should be networked.
Tc) Summarize the facility needs to address the research topic.

Breakout Group T1 Research Topic

> Study of response, deformation and failure of soil embankment systems used in dams, dikes, levees, as well as highways and bridge approaches, and of natural slopes, with emphasis on large deformation/failure phenomena. Problems in Topic 1 generally involve large static driving shear stresses.

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**Introduction**

Breakout Group T1 (the group) focused upon the response, deformation, and failure of soil embankment systems used in dams, dikes, levees, and highway systems and of natural slopes, landfills, and other geo-structures. The group identified research sub-topics within this broad topic, discussed facility needs to address these sub-topics, visualized what "networking" would mean within this context, and provided an example of a networked research project that addressed one of these issues.

**Research Sub-Topics**

Research sub-topics encompassed within the scope of Breakout Group T1 were divided into three broad classes:

- Material Behavior;
- "Structural Response"; and
- Validation of Analyses.

Material Behavior addresses fundamental aspects of the response of geo-materials to applied loads. Sub-topics included under the broad class of material behavior included:

- the non-linear stress-strain-pore pressure behavior of gravelly soils, silty soils, residual soils, and solid waste;
- the residual shear strength of all types of geo-materials;
- the effect of the initial stress state, including static shear stress and confining pressure, on the behavior of geo-materials;
- interface behavior, including natural and geosynthetic interfaces; and
- the behavior of brittle materials.

"Structural" Response address the non-linear and sometimes chaotic response of geo-structures. Sub-topics included in this class of issues included:

- soil-geo-structure interaction effects;
- the response of complex, multi-component geo-systems;
- the response of non-homogeneous and discontinuous geo-systems; and
- the response of reinforced soil systems.

Validation of Analyses address validation of engineering methods for evaluation the seismic response of geo-structures. This class of sub-topics included:

- validation of two- and three- dimensional response analyses;
- validation on non-linear response analyses
- validation of analyses for large-deformations (e.g., flow failures);
- validation of simplified (e.g., Newmark-type) seismic deformation analyses; and
- validation of analyses to evaluate the effectiveness of remedial measures.

## Facility Needs

The general consensus of the group was that all of the proposed facilities were useful, either directly or indirectly, in study of the identified research sub-topics. However, some facilities were clearly more important than others for specific topics. Furthermore, data on the behavior of instrumented field sites where large deformations had occur in actual, large magnitude earthquakes was clearly the best source of information on the response, deformation, and failure of geo-systems. However, it is the lack of this information and the physical impossibility of obtaining it in a timely fashion that is the force driving the need for the NHPS. Primary facility needs are summarized for each identified sub-topic on a broad-class specific basis in the following tables.

| ***MATERIAL BEHAVIOR*** | ***Centrifuge*** | ***Large Scale Lab Testing*** | ***Instrumented Field Sites*** | ***Mobile Wave Sources*** | ***Post-Earthquake Laboratory*** | ***1 g Testing (High Explosive)*** |
|---|---|---|---|---|---|---|
| **Residual Strength** | X | X | | | X | X |
| **Gravelly Soils** | | X | X | X | X | X |
| **Silty Soils** | X | | X | X | X | X |
| **Initial Static Shear Stress** | X | X | | | X | X |
| **Residual Soils** | | | X | X | X | |
| **Solid Waste** | | X | X | X | X | |
| **Interfaces** | X | | X | | | X |
| **Cracking/Brittle Behavior** | X | | | | X | X |

| ***STRUCTURAL RESPONSE*** | ***Centrifuge*** | ***Large Scale Lab Testing*** | ***Instrumented Field Sites*** | ***Mobile Wave Sources*** | ***Post-Earthquake Laboratory*** | ***1 g Testing (High Explosive)*** |
|---|---|---|---|---|---|---|
| **Interaction Effects** | X | X | | | X | X |
| **Complex Systems** | X | | | X | X | X |
| **Non-Homogeneous Deposits** | X | | | | X | X |
| **Reinforced Soil** | X | | X | X | | X |

| ***VALIDATION OF ANALYSES*** | ***Centrifuge*** | ***Large Scale Lab Testing*** | ***Instrumented Field Sites*** | ***Mobile Wave Sources*** | ***Post-Earthquake Laboratory*** | ***1 g Testing (High Explosive)*** |
|---|---|---|---|---|---|---|
| **Non-Linear Response** | X | | | | X | X |
| **2-D and 3-D Response** | X | | | | X | X |
| **Flow Failure** | X | | X | | X | X |
| **Newmark Problems** | X | | | | X | X |
| **Remediation** | X | | X | X | X | X |

**Visualization of Networking**

The group envisioned that research using the network facility would involve collaboratively planned experiments employing multiple components of the networked facility. It was recognized that no one facility could address any of the identified research sub-topics in a complete and comprehensive manner. Therefore, an integrated approach using multiple components of the network, each addressing different though inter-related aspects of the problem, was required to address any specific sub-topic. Planning for a particularly experiment would be a group effort, though a single Principal Investigator would be responsible for coordination, execution, and management of the experiment. Planning of an experiment would involve a team of investigators, perhaps one for each component of the NHPS employed in the experiment. Planning should also include input from analysts who would use the results of the experiment and possibly from experts in advanced sensor, technology, instrumentation, robotics and other associated technological areas. The group felt that publication of the preliminary plan to members of the research consortium, and perhaps to the broader geotechnical community, could offer benefits in terms of identifying ancillary measurements that could be made during the experiments to enhance the benefits of the work, particularly for the more costly large-scale types of tests. While there was some concern that this could lead to information overload, with the P.I. being swamped with suggestions on how to "improve" his experiment, the general consensus was that there could be a significant benefit in soliciting input from a broader section of the research community on a proposed experiment before executing the work. The group felt strongly that a detailed plan for rapid dissemination of the results of the experimental work, including a time table for distribution of the details of the experiments and the experimental data, be included in the research plan for each experiment.

**Example of Networked Research**

Evaluation of the residual shear strength of sands was discussed by the group as an example of a networked research project. Key elements of the NSPS that would be involved in the work include a large scale laboratory testing facility, a centrifuge testing facility, and a 1-g blat excitation large scale testing facility. Other components of the NHPS, including instrumented field sites, the mobile wave sources, and the post-earthquake laboratory, and conventional small scale laboratory testing could also play a role in the work. However, the group felt that these three facilities (large scale laboratory testing, centrifuge, and blast-induced loading facilities) could be used to fashion an integrated, distributed experiment to address this important problem. While each facility has limitations, in combination they can be used to develop a comprehensive experiment to address this important problem as follows:

- the large scale laboratory testing would be used to investigate fundamental aspects of the stress-strain-pore pressure behavior of the material at low to moderate strains and to characterize the response of the material to in-situ tests used in practice for site characterization (e.g., penetrometer testing and shear wave velocity measurements);
- the centrifuge testing would be used to evaluate systems response and the large deformation flow phenomenon, taking into account high confining pressures and initial static shear stresses and recognizing limitations with respect to particle size-scaling and pore fluid viscosity may affect the results; in-flight testing of shear wave velocity and cone penetration resistance could also be performed; and
- the 1-g blast facility would be used to evaluate system response at large deformation and flow phenomenon, taking into account initial static shear and not subject to limitations on particle size scaling or pore fluid viscosity but limited to low to moderate confining stresses.

Ancillary measurements made during the centrifuge and 1-g tests could include non-linear site response in the free field and seismic settlement after liquefaction.

# APPENDIX D. REPORT FROM BREAKOUT GROUP T2

Within the framework of the research topics provide the following:
Ta) Outline examples of "networked" research program(s)
Tb) Visualize specific examples of how specific facilities and researchers should be networked.
Tc) Summarize the facility needs to address the research topic.

Breakout Group T2 Research Topic

> Study of response and large deformation in level and gently sloping ground, including effects on structures and facilities such as buildings, bridges, pipelines, and waterfront and retaining structures.

## RESEARCH NEEDS

Research needs are associated with site response and permanent ground deformation. Site response relates to transient ground motion. There are significant uncertainties associated with transient ground motion because the influence of local and regional site conditions and soil property effects are poorly understood. Substantial opportunities exist for clarifying these conditions through the use of networked experimental facilities. Some of the most important site response research needs are summarized under the following subheadings.

### Near Source Effects

The Northridge and Kobe earthquakes have shown that the transient motions within 5 to 10 km of fault rupture have characteristics with severe implications for the built environment. The strong acceleration, velocity, and displacement pulses associated with near source effects generate high lateral forces, large ground strains, and substantial transient deformations that affect surface and underground structures alike. Little is known about how near source motions are modified by and influence local soils and underground conditions.

### Basin Effects

Seismic waves entering large subsurface basins are scattered causing multiple reflections that amplify wave energy at critical locations and result in surface waves with potentially damaging amplitudes and propagation velocities. Seismic waves crossing smaller scale basins can lead to incoherent motions as soft valley or canyon sediments vibrate out of phase with the more rigid rock underlying and adjacent to the valley soils. There is a critical need to understand better the influence of basin geometry, soil properties, and soil stratification on site response within and at the margins of basins.

### Clay/Soft Soil Sites

Clays and other soft sediments transform the natural frequency of incoming seismic waves so that the resulting waveforms can match better the natural period of structures located at these sites. At the same time, the soft sediments themselves may resonate with the incoming seismic waves, thereby amplifying the transient motion affecting surface and underground structures.

### Liquefaction Sites

Soils subject to liquefaction are progressively transformed during seismic shaking into materials with low strength and stiffens. This transformation results in altered material properties that in turn influence the dynamic response of the sediments. As a consequence, seismic waves can be amplified and changed in terms of frequency content. The liquefied, or softened, material can oscillate out of phase with more competent adjacent soils, resulting in damaging concentrations of soil movement within and at the margins of liquefiable deposits.

### Earthquake Duration

The duration of strong shaking has a profound and nonlinear influence of the properties of many soils. Recent experience with the Loma Prieta, Northridge, and Kobe earthquakes has involve strong shaking that lasted only 5 to 10 seconds. Little is known about site response during severe and great magnitude earthquakes when strong shaking may last as long as 30 to 90 seconds. There is an urgent need to improve our understanding and modeling of this phenomenon that can be met only with the appropriate experimental facilities.

**Permanent Ground Deformation**

Permanent ground deformation is caused by soil liquefaction, lurching, and consolidation of loose sediments at level and gently sloping sites. There are critical needs with respect to predicting both the magnitude and spatial distribution of permanent ground deformation . Our current analytical models and empirical relationships from previous earthquake observations are not able to predict either the magnitude or spatial distribution of permanent ground deformation with sufficient reliability. There is substantial need therefore to enhance our modeling and predictive capabilities with improved experimental facilities.

**Permanent Ground Deformation Effects on Structures**

- Bridges
- Waterfront Structures
- Pile-Supported Buildings
- Pipelines
- Shallow Foundations

| | near source | basin effects | clay soft soil | liquefiable | EQ duration | PGD prediction | | PGD effects on structures |
|---|---|---|---|---|---|---|---|---|
| | | | | | | MAG | Spatial | |
| Centrifuge | | | X | X | X | X | X | X |
| Large-scale lab devices | | | X | X | X | X | | X |
| instrumented field sites | X | X | X | X | X | X | X | X |
| mobile seismic wave source | | | X | X | | | | X |
| Post EQ labs | X | X | X | X | | X | X | X |
| high explosives | | | | X | | X | X | X |

# APPENDIX E. REPORT FROM BREAKOUT GROUP T3

Within the framework of the research topics provide the following:
Ta) Outline examples of "networked" research program(s)
Tb) Visualize specific examples of how specific facilities and researchers should be networked.
Tc) Summarize the facility needs to address the research topic.

Breakout Group T3 Research Topic

> Evaluation of effectiveness in reducing the earthquake hazards due to ground failure and ground deformation. New ideas for ground remediation and retrofitting of foundations and structures for new and existing facilities.

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**Topic T3 Evaluation of effectiveness in reducing the earthquake hazards due to ground failure and ground deformation, and new ideas for ground remediation and retrofitting of foundations and structures for new and existing facilities.**

Ground modification for mitigation of liquefaction risk and consequent settlement and lateral spreading, as well as for prevention of other types of ground failure such as landslides, is now widely used. Experiences in recent earthquakes in Japan and California show that many treatment methods are effective, and that improved ground can withstand earthquake shaking without failure and with significantly less deformation than untreated ground.

Nonetheless, there are a number of unresolved questions that if answered, and developments in technology, that if pursued, can lead to better and more cost-effective construction and increased protection of structures and facilities. Important advances in this area require a better understanding of the seismic response of large, complex, and often “one-of-a-kind” systems. The proper utilization of the several components of the proposed integrated and networked NHPS can provide this needed understanding.

Examples of some of the issues needing resolution include:

1. The liquefaction resistance and residual strength of silty soils.
2. The liquefaction resistance and residual strength of gravelly soils and soils containing cobbles and boulders.
3. Ground improvement at developed sites; i.e., at sites where there are existing structures and facilities.
4. Ground response and ground improvement strategies for sites with stratified soil profiles.
5. Methods for determination of the degree, depth, and lateral dimensions of ground improvement required for safe, economical design.
6. Assessment of the dynamic composite response and strength of improved ground that is variable in density over short distances; i.e., tens of cm.
7. Practical methods for estimating the stability and deformation response of improved ground.
8. Improved understanding of mechanisms of densification using different methods; e.g., vibration, impact, displacement.
9. Reliable methods for quality assurance of ground improvement.
10. Design and construction of improved ground for prevention of slope failures and landslides.
11. Mitigation strategies that include consideration of two level design (serviceability and prevention of loss of life).
12. Evaluation of improved soil-structure interactions, to include the effects of ground improvement on the dynamic response of supported structures and facilities.

Most components of the integrated NHPS facilities and network can be brought to bear on the problems that are listed above. This is illustrated by the accompanying table that matches the problems, listed in the left column, to the system facilities and components, listed across the top. It may be seen that several methods may be used to study each problem. Because more than one technique can be applied, redundant and unique solutions can be obtained as opposed to the uncertain and often indeterminate solutions often result when only one method is used.

Several ground improvement technologies needing further study and development, in addition to those that are now widely used were identified, and they include:

1. Deep soil mixing and other types of in-ground walls and/or reinforcing elements, including size, strength and stiffness, and distribution within the ground to achieve the required level of stability.
2. Explosive compaction for the densification of clean, cohesionless soils.
3. The effectiveness of drainage as a stand-alone technique for liquefaction prevention.
4. The potential for “passive remediation” using slow injection and permeation.
5. Isolation and containment approaches to prevention of liquefaction and lateral spreading.
6. Use of reinforced soil pads for limiting differential settlement.
7. The potential usefulness of deformation-tolerant foundations, to include such possibilities as cushions around piles and isolation using perimeter trenches.

These technologies can be investigated under controlled conditions using several of the NHPS testing components.

| FACILITY OR SYSTEM<br><br>PROBLEM | CENTRIFUGE | PRE-EQ MOBILE LAB | LARGE LAB (SHAKE TABLE LARGE TRIAX TORSIONAL & SIMPLE SHEAR) | INSTRUMENTED SITES | POST EQ MOBILE LAB | BLAST EXCITATION IN FIELD | CASE STUDIES |
|---|---|---|---|---|---|---|---|
| **Silty Soils** | X | X | | X | X | X | X |
| **Soils with boulders and cobbles** | X | X | | X | X | X | X |
| **Developed site** | X | X | X | | X | X | X |
| **Stratified soils** | X | X | X | X | X | | X |
| **Degree and extent of treatment** | X | | X | X | X | | X |
| **Behavior of composite ground** | X | X | X | | X | | X |
| **Treated ground stability and deformation** | X | X | X | X | X | X | X |
| **Densification mechanisms** | X | X | X | X | X | X | X |
| **Quality assurance** | X | X | X | | X | X | |
| **Landslide stabilization** | X | | X | | X | X | X |
| **Mitigation strategies** | | | | | | X | X |
| **Soil-Structure Interaction** | X | X | X | X | X | X | X |

# APPENDIX F. REPORT FROM BREAKOUT GROUP T4

Within the framework of the research topics provide the following:
Ta) Outline examples of "networked" research program(s)
Tb) Visualize specific examples of how specific facilities and researchers should be networked.
Tc) Summarize the facility needs to address the research topic.

Breakout Group T4 Research Topic

Ground response and soil-foundation-structure interaction due to seismic shaking.

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Ground Response and Soil-Foundation-Structure Interaction due to Shaking

<u>Mehmet Celebi-USGS</u>

Mehmet proposed soil-structure interaction array consisting of a variety of pore pressure transducers and accelerometers (both down-hole and within structure). Arrays in horizontal and vertical directions will be used. USGS has already purchased essentially all instrumentation at a cost of $150,000. Instrumentation would be placed prior to construction of new structure. The building must be 5 or 6 stories high, must not be supported on piles, have a reasonable range of Vs for the soil profile, and be located in a seismically active area. He would actually like to build a structure strictly for research purposes.

<u>Research Subtopics (Critical Earthquake Engineering Problems within T4)</u>

<u>Free Field</u>

1. Response of soft soils to strong shaking (both 1-D and 2 or 3D)
2. Response of soils to near-field motions
3. Response of soils to vertical motions. (dry soil, sat. soil, and partially sat. soil)
4. Verification of shear modulus reduction and damping vs. strain characteristics

<u>SSI and SFI</u>

1. Response of structures on shallow foundations (USGS experiment)
2. Response of structures on pile foundations
3. Response of buried facilities to shaking

Footnotes
Near, free and intermediate field soil response
Response of structure on foundation (response of foundation, input to structural engineer)

<u>Facilities</u>

Ground motions with high explosives (Nevada site and Wyoming mine)
Soil island (Explosives and Earthquakes)
Mobile seismic wave sources
Post-earthquake mobile site laboratory
Large cyclic triaxial shear
Cyclic Simple Shear
Laminar shear box/bag
Centrifuge Models
Site Characterization (Port of LA)
Site and SSI Instrumentation (Strong support and add advanced geotechnical sensors)

| Facilities | Struc. on Shallow Fnd | Struc on Deep Fnd | Buried Facilities | Soft Soils | Near Field Motions | G/Gmax and Damping | Vertical Motions | Spatial Variability |
|---|---|---|---|---|---|---|---|---|
| Ground Motion simulation with explosives | X Scale model of USGS | X | X | X | X | X | | |
| Mobile Seismic Sources | X | X | | | | X | | |
| Post-EQ Mobile Site Lab | X | X | X | X | | X | X | X |
| Large Cyclic Triaxial/Torsion Device | | | | | | X | | |
| Cyclic Simple Shear | | | | | | X | | |
| Laminar Shear Box | X Scale model of USGS | X | X | X | X | X | X | |
| Centrifuge Models | X Scale model of USGS | X | X | X | X | X | X | |
| Site Characterization | X | X | X | X | X | X | X | X |
| Permanent Site and SSI Instrumentation | X (USGS exp) | X | X | X | X | X | X | X |

# APPENDIX G. REPORT FROM BREAKOUT GROUP Q1

Members of Q1 breakout groups will respond to the following questions:

Q1A - OTHER NETWORK EXPERIENCES.

> A key aspect of NHPS is to create a different research culture where concepts like cooperation (between facilities, between investigators) and sharing (of facilities, data, and credit) become very important. Other communities have been doing these for many years (the particle physicists doing joint research at large accelerators and publishing papers with dozens of authors come to mind). Do you think we have something to learn from these other experiences? If so, how do we go about it? Do you know of any other relevant examples? Based on your knowledge or perception of these experiences, are there any pitfalls our community should try to avoid?

Q1B - SHARING FACILITIES.

> The sharing of facilities is a very important concept. It implies that, while a facility is installed at a university and is operated by that university group, it does not belong to the group in the usual sense. The group may be authorized to use the facility only part of the time, with the rest of the time being allocated to outside groups by a decision being made by NHPS, that is outside the university. In exchange for appropriate financial support, the facility should provide service to outside users that should be efficient, orderly, on time, that is businesslike. How should this be organized within the university? Will it always require the creation of a separate center with a manager that is not a tenure-track faculty member, who can take responsibility and answer any telephone call or e-mail within 48 hours?

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Discussion Group Q1 Sharing and Linking of Facilities and Information

Chair: Jim Jirsa

Recorder: Glenn Rix

Members: John Diehl, Ricardo Dobry, Gary Norris, Ed Idriss, Xiangwu Zeng, Majid Manzari, James Martin, Joan Gargano

Examples of Sharing Facilities:

Centrifuges are perhaps the best example of sharing of facilities within the geotechnical earthquake engineering community. The group reviewed guidelines that have allowed shared use of centrifuges to work well including the need to plan ahead and have a well-defined system to prioritize use of the facility. In general there must be well-defined standards for the scheduling, access, and measurement/data formats. The latter will assure that the data generated by one researcher will be used with confidence by others. Steps need to be taken to make sure that raw data is documented (which is typically not the case).

John Diehl reviewed the IRIS model in which there is a committee that reviews experimental plans and makes sure the experiment is viable and well planned. One of the most prevalent problems is deciding what to do when a given experiment occupies more facility time than originally planned. The need for the committee to be impartial and representative was recognized. The group also discussed the need for the host institution to be actively involved in the operation and use of the facility rather than being simply another user of a facility managed by a third party.

The group talked about data format standards such as those used in the exploration geophysics and modal testing industries. Apparently, the atmospheric research community is also moving in this direction. The availablity (or lack thereof) of ground motion data following an earthquake was mentioned as an example close to home. It was suggested that the consortium will need to have a committee to develop and enforce data presentation and archival formats ("data etiquette"). Many of the reasons that the Internet has worked well in recent times that Kim Mish and Joan Gargano mentioned on Thursday such as standards, etc. can be applied to sharing of experimental data.

We discussed what criteria will be used to determine membership in the consortium. Should it be limited to universities (however large or small), or should private partners be allowed to join. Many expressed the opinion that membership should be limited to academic institutions and that membership fees or dues should be high enough to be taken seriously but low enough to allow small institutions to join. Access to the facilities should be open to all types of organizations through an "affiliates" program that has a different fee or dues structure.

**Sharing of Facilities**

1 Representative committee that governs facility access and use

- review experimental design
- may suggest or require participation of others
- establish data presentation and archival formats ("data etiquette" - Ricardo Dobry) e.g., exploration geophysics (SEG-Y format)
- modal testing (SDF, Universal file format)
- publication rights/dissemination guidelines/standards

2 Host institution responsibilities and rights

3 Consortium Member and Affiliate Guidelines

- membership limited to academic institutions
- "moderate" fees or dues that encourages smaller institutions toparticipate, but large enough to be taken seriously
- others participate via an "affiliates" program with different fee and dues structure.
- objective is to encourage access
- defines access level to data, online participation, etc.

**Linking of Facilities**

1 Requires staff, hardware, and software for videoconferencing, visualization, and integration.

- includes computer scientists to understand mathematical modeling needs.

2 Need to define various levels of "networking" and "linking"

- non-real-time collaborative experiment design
- real-time observation and monitoring of experiment via video conferencing ("remote observation")
- real-time access to data collection devices ("remote access")
- real-time control of experiments ("remote control")

3 Internet2 should provide the bandwidth, quality of service, resource reservation for GEE applications, but requirements need to be estimated. Two special needs may be high-speed network access from remote locations (e.g. mobile post-earthquake field labs) and satellite- based communications in the event that land-based links are down after an earthquake.

4 "High Performance Seismic Simulation" should include the ability to combine analytical modeling and experimental data.

**Conclusions**

1. We need to agree on procedures and standards for data sharing.
2. We have lots of expertise to draw on for networking and linking facilities.

# APPENDIX H. REPORT FROM BREAKOUT GROUP Q2

Members of Q2 breakout groups will respond to the following questions:

Q2A - INTELLECTUAL PROPERTY

> A key aspect of NHPS is to create a different research culture where concepts like COOPERATION (between facilities, between investigators) and SHARING (of facilities, data , and credit) become very important. How would you solve the contradiction between this and our current academic culture in which people are judged very much individually, in terms of reputation, promotion and tenure? Specifically, how do we credit the contributions to sharing and cooperation of academics so that university bodies and administrators judging them see and appreciate these contributions?

Q2B - DATA DISSEMINATION AND CREDIT

> The advent of the Internet and the Web has made the immediate public availability of experimental data a real possibility. But how soon is soon enough? We certainly don't want to publish the data before we verify its correctness. Also, any publication of data involves an additional effort in describing the experiment, providing calibration constants, answering questions of interested readers, etc. Or perhaps we are not sure of the correctness of the data until we finish a series of experiments, and we publish the series with attached discussions and interpretations. How different is this from a paper? Or is that what we are talking about, publishing experimental papers but will ALL backup data in digital form available in the Net. In any case, shouldn't the people who conceived and did the experiment have "first pick" at the data, without being forced to publish the raw data too soon? If we decide to have a policy of making experimental data publicly available before people producing them would spontaneously do it otherwise, how do we make sure that the experimenters get their share of the credit when other people use the data in papers, reports and presentations? There are here "outside" aspects to be considered (reputation) and "inside" aspects (promotion, tenure, raises).

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**How and when do we effectively disseminate data and results to the public and/or share it with others?**

Dissemination of experimental data generated at NHPS facilities will be an important part of the NHPS network. The Q2 discussion group considered the question of how and when this data should be disseminated to others; implicit in these discussions was the broad issue of intellectual property. The discussion group consisted of:

Steve Kramer, *University of Washington (Chairman)*
J.P. Bardet, *University of Southern California (Secretary)*
Ross Boulanger, *University of California, Davis*
Tom Holzer, *USGS*
Ed Kavazanjian, *GeoSyntec Consultants*
Jim Mitchell, *Virginia Tech*
Kyle Rollins, *Brigham Young University*
Nick Sitar, *University of California, Berkeley*

The Q2 group vigorously discussed the question posed to it, particularly with respect to intellectual property and the proper credit thereof. These discussions revealed different and strongly held opinions on the degree to which experimental designs, procedures, and results belong to those who develop and generate them. These discussions pointed out the disparity between the reward system that currently exists in academia and the advancement of the earthquake engineering profession. While there was general agreement that the current academic system does not reward many of the types of contributions that contribute most to the advancement of the profession, the fact remains that most of earthquake engineering is performed at academic institutions. Thus, while undesirable, the constraints of academia and real and must be addressed.

To balance the dual requirements of rapid dissemination of useful data with the constraints of intellectual credit for their generation, the Q2 group felt that a *Journal of Experimental Results in Earthquake Engineering* (*JEREE*) should be established as an important part of the NHPS. *JEREE* would be a high-quality, peer-reviewed, electronic journal that would be published on the WWW. *JEREE* publications would generally consist of relatively short papers describing the experimental design, instrumentation and data acquisition, facilities and equipment, and test procedures. The experimental results, in the form of both raw and processed data (with description of processing protocol), would be linked to the text. All descriptions and data would be sufficiently complete to allow interpretation by others. Preliminary conclusions, if available, could be included with the text of a *JEREE* publication. JEREE publication would be required for research projects that used NHPS facilities, and would be available for experimental research generated using other facilities. The Q2 group felt that JEREE should have rigorous publication standards that would ensure recognition that a JEREE publication represented very high quality experimental research both within the earthquake engineering profession and within the broader academic community.

The development and management of *JEREE* would require a firm commitment from the NHPS program. Because of the strong potential and desire that the published data be used by others, *JEREE* submissions would require careful peer review of a type that is not performed by existing refereed journals. Review of data and accompanying descriptions will require the development of specific criteria by which the quality and completeness of data and supporting documentation are to be evaluated. The NHPS organization would also need to establish guidelines for the format and content of *JEREE* publications. The Q2 group felt, however, that the strong potential benefits of rapid and wide dissemination of data would justify the investment of time and money that would be required to produce *JEREE*.

Establishment of the NHPS and of *JEREE* as a mechanism for timely dissemination of useful data will require that careful attention be paid to data throughout the process of experimental design, testing, and interpretation. Group Q2 felt that research proposals involving the use of NHPS facilities should be required to explicitly address the control and assurance of data quality, and that such sections of proposals be carefully considered during the proposal review process. Some projects could benefit from the inclusion of validation teams that would provide an independent review of the project from experimental design to quality of experimental results.

By establishing *JEREE*, the question of how NHPS data is to be disseminated is clearly answered. The Q2 group discussed the issue of when data should be disseminated at length. The group generally agreed that data should be disseminated as soon as its completeness and validity had been established, though there was some disagreement about exactly how that should be accomplished and how long the process should take. Different types of projects will undoubtedly produce different types and amounts of experimental data that will take different amounts of time to verify. Some projects, such as those involving instrumentation of sites prior to earthquakes, may be able to release data very soon after installation and checking of instrumentation. Others, such as those that involve complex model testing programs, may require significant interpretation before the quality of the experimental data can be established. The timing of data dissemination will apparently need to be evaluated on a case-by-case basis, and may involve reporting requirements placed upon researchers by funding agencies. Group Q2 felt that this issue should be studied by NHPS management.

# APPENDIX I. REPORT FROM BREAKOUT GROUP Q3

Members of Q3 breakout groups will respond to the following questions

Q3A - DATA SHARING AND STANDARDS

> Use of the Net to divulge experimental data can be classified in two main aspects: (i) unlimited public availability to anybody interested, and (ii) availability and sharing of data with a limited group (established group within NHPS, inter-university team doing cooperative research, etc.) Both involve important technical questions related to availability and/or development of adequate hardware/software, development of both general and ad hoc technical standards. How do we go about addressing these issues? What do you know about useful tools for this now available "out there"? Should NHPS or our geotechnical/tsunami community form a task force or technical committee to work on these issues?

Q3B - INTERNET TOOLS

> The INTERNET has opened the possibility of real cooperative experimental research throughout the country and the world, including things like remote participation, real time sharing, virtual meetings, experiments being physically done at an institution but controlled from another, very close and "on time" use of experimental data just out of the oven by analysts at other universities, etc. How do we best facilitate these developments? What investments, software/hardware developments, and institutional changes are necessary? What can we learn from other communities who may already be doing some of these things? Any suggestions?

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**1. How do we achieve collaboration, remote participation, and/or real time sharing of experiments between two or more groups?**

<u>Achieve Collaboration</u>

Collaboration cannot be forced on the research community. We should instead set up standards for software, hardware, and cultural issue to facilitate collaborative efforts, and let the community foster such collaboration henceforth. It should be noted that individual researchers that choose not to collaborate will suffer some potential penalties (i.e., being left out of important projects, or having a collaborative contractual precondition on some research funding sources) that will encourage them to join the community as active participants.

<u>Remote Participation</u>

Here, we need examples of using technology in innovative ways. One example involves using the Post-EQ Field Lab to provide continuous video and data telemetry from the site of an earthquake. Remote researchers (i.e., those not at the site of the disaster) could aid those in the field by providing suggestions on what to view, where to go, and what to look for. This case study would be aided considerably by new technology, such as GPS (which would permit remote researchers to learn quickly where the field team is located), or user-interfaces (e.g., windowed displays, which would permit remote researchers to view the field team's results in a small portion of their computer screen, in order to avoid having to waste time when the team was traveling between sites). A demonstration of this technology on a Post-EQ setting would go a long way towards identifying the strengths and weaknesses of this technology, as well as the cultural issues involved (e.g., contention for the lab).

<u>Real-time Sharing of Experimental Data</u>

Technology is not available yet to do the highest-bandwidth real-time sharing, although Internet-2 should take care of this problem with its facility for dedicated real-time high-bandwidth access. At this time, it is feasible to perform some real-time data sharing such as broadcasting results from an experiment over the web. Many issues remain to be resolved that limit access to the data, however, including criteria of public dissemination (e.g., for publicly funded research), classified data (e.g., for commercial partners such as oil companies), recognition of the needs of researchers to be able to protect their data temporarily (e.g., Ph.D. students working to establish a research track record), and quality-control concerns about posting raw data for eventual public use. Thus, the answer for the larger question of "how should the data be disseminated?" is case dependent.

**2. How do we solve the related hardware, software, and standards issues?**

The single most important cultural issue here is to learn to trust the standards that are emerging elsewhere (e.g., the sensor devices discussed by Professor McDonald this morning) as suitable for use within our proposed network environment. We need first to identify our functional needs, seek out cases where similar needs are in existence and have been met, and then leverage those existing results. This will permit us to learn about where our problems are common to other settings, and where they are unique. In the former case, we can learn from others, and then concentrate our more focussed attention on those problems that are unique to our field.

**3. What are the desirable characteristics of the user interfaces of the communications network?**

An intuitive and self-explanatory interface is desirable, because of the wide range of levels of skills and communications experience present in this community. But successful commercial user interfaces are supposed to be intuitive and self-documenting, so following emerging standards from user interface design will be a good first step in addressing this issue. We need to identify our particular interface needs (e.g., for remote control of experiments) so that Internet-2 funding can be sought for these specialized needs.

It is also desirable to include some form of user-interface examples that permit K-12 outreach activities, such as permitting some form of remote viewing (as in the KidCam from UCSD) or broadcast of recent data (such as that from the Mars Rover). Some examples of potential specialized needs:

- Dedicated bandwidth for experimental control
- Dedicated chat rooms for video and telemetry display
- General user-interface issues for controlling testing equipment.

# APPENDIX J. REPORT FROM BREAKOUT GROUP Q4

Members of Q4 breakout groups will respond to the following questions

Q4A - OUTREACH

> How can the network, along with the existing Earthquake Engineering Research Centers, reach out to government research laboratories, private companies, and international research facilities, and others interested in geotechnical earthquake engineering to encourage cooperation and collaboration, build partnerships, and make data and results available to all potential users.

Q4B - ETHICAL CONCERNS

> Publication of experimental data, sharing of facilities, allocation of credit to experimentalists for their work, cooperative research throughout the research and the world, poses clear ethical challenges, especially in the transition period until people get used to the new culture and start abiding more or less automatically by the new rules. How do we address these ethical concerns? Any ideas? Should we have a special task force or committee on ethics within NHPS, ASCE or another professional organization, start developing guidelines on these issues?

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Answers from group discussion: Cooperation with these many groups external to NHPS is essential to the success of the program. The cooperation and linkage with some groups are much more important than others. The most important groups with which close cooperation must be developed are government laboratories that have parallel equipment or facilities that may receive NHPS support to upgrade equipment. For example, some Corps of Engineers facilities at WES, such as the large centrifuge facility and the wave basin, may become part of the NHPS system. In these instances formal written agreements will be required to assure access, needed support facilities and blocked periods of time for NHPS research. The breakout group suggests development of a liaison committee that would meet regularly to develop or schedule facilities and to resolve any conflicts. Principal agencies with which this level of cooperation is needed include the U.S. Army Corps of Engineers, the U.S. Geological survey (instrumented sites and facilities), and Department of Energy (Nevada Test Site).

A second liaison committee would be required to link with federal and state agencies that would either support research at NHPS facilities and/or use test results from research the projects. These agencies might include the agencies noted above plus the Federal Highway Administration, state departments of transportation, the Bureau of Reclamation, the Department of Defense, the Bureau of Mines, the Environmental Protection Agency, and others.

A liaison committed should also be organized to reach out to private industry to assist in developing research programs that will meet the needs of private industry and allow access to the test facilities for both nonproprietary and proprietary research. Such testing will improve the quality of engineering in the U.S., albeit some will be commercial, and improve the competitiveness of U.S. industry in the international arena. Some other nations, such as Japan and the European Economic Community (EEC), have already invested in large-scale testing equipment and are using it to their competitive advantage in the world market. Access to similar facilities could be advantageous to U.S. industry. Industries that could benefit from testing at NHPS facilities include the structural, geotechnical and coastal engineering design firms, gas and oil companies, manufacturing enterprises, and insurance companies.

NHPS should reach out to the international community to establish mutually beneficial working agreements. The advantage to NHPS would be to gain access to international facilities which we may not wish to duplicate and to integrate the expertise of foreign engineers into research conducted in NHPS facilities. In many instances, formal agreements and memorandums of understanding between governments may be required. For example, NSF and other U.S. agencies already have cooperative agreements with Japan, China and other countries that likely could be amended to add NHPS cooperation. Specific countries with which advantageous agreements could be developed include Canada, Mexico, Japan, and the EEC. Again, implementation of an international liaison committee would be a useful vehicle for outreach to the international community.

# APPENDIX K. DISCUSSIONS FROM NEWS.CMP.CSUCHICO.EDU/ENGR.GEO.NHPS

All workshop participants and other interested parties were encouraged to post written responses to a pre-workshop questionnaire on a private newsgroup established specifically for this purpose. This newsgroup was hosted on the news server of the Computational Mechanics Project at CSU Chico (thanks to Kim Mish), and the newsgroup was titled "engr.geo.nhps".

Each participant was asked to address the questions corresponding to their assigned breakout groups, though they were welcome to address any other question. There were two "cultural" questions for each "Q" breakout group and one "research topic" assignment for each "T" breakout group. The list was active from 4/27/98 until 6/3/98.

***Q1A - OTHER NETWORK EXPERIENCES.*** *A key aspect of NHPS is to create a different research culture where concepts like cooperation (between facilities, between investigators) and sharing (of facilities, data, and credit) become very important. Other communities have been doing these for many years (the particle physicists doing joint research at large accelerators and publishing papers with dozens of authors come to mind). Do you think we have something to learn from these other experiences? If so, how do we go about it? Do you know of any other relevant examples? Based on your knowledge or perception of these experiences, are there any pitfalls our community should try to avoid?*

Cooperation between investigators and sharing facilities and experimental data is a major trend in many fields of research. Many of us have the experience of download earthquake record from USGS's earthquake information center. There is no one there who claims to have the ownership of the data. If a project is funded by private industry, the sponsor may claim to have the ownership of the data. But if a project is funded by public money such as NHPS or NSF, the researcher has the obligation to make the relevant information available to other researchers.

In the past, even though experimental data from projects funded by government agencies are supposed to be public information, it is very difficult for other researchers to get access to the data. With the latest network technology, it is quite possible to establish an electronic data archive. To make such an archieve useful and effective, major funding agencies such as NSF could make it mandatory for investigators to post experimental data to the archive within a specific period of time (say one year to allow the principal investigator(s) to check the validity of the data and to have a first crack on it) after the project is finished. In the past, there were many cases where experimental data were not thoroughly investigated while other researchers were desperately seeking such information for their analytical models.

To establish such a data archive, a manager at a hosting institution helped by a network expert can do the job. NSF or some other agency can provide a startup grant and some continuous support for managing the data base. If a standard format about data stored there is established (minimum information required, data format, reference, contacting person, etc.) most of us can manage to send or access information there.

Some years ago, all the data from centrifuge tests conducted at the Cambridge Geotechnical Centrifuge Center was stored in a data archive so that everyone there can use it. It was pretty useful for researchers there. Now with today's technology, it is quite possible to establish a data base which is accessible by anyone who is interested in the data. Several years ago, it was suggested to have all the data from the VELACS project posted on a web site. It is a pity that somehow it was not materialized. **- X. Zeng**

The only networked experience in the geotechnical area that I am familiar with is the establishment of the National Geotechnical Experimentation Sites through cooperation between NSF and FHWA and various local host sites. Even so, there is very little word that I get as to activities that are planned or have been undertaken to date at the various sites. We need a better communication system. ( Furthermore, based on only 11 of 40 respondents to this pre-workshop questionnaire, the web or e-mail alone is not sufficient to accomplish this task; additional word needs to be made available to the geotechnical engineering public through Geotechnical News and/or Civil Engineering magazine.). Similarly, there needs to be much greater cooperation between state DOT's so that research efforts aren't duplicated and within DOT's so that structural and geotechnical groups are aware of each others needs and capabilities. Even within the university there is need for better communication between different research groups (geotechnical and structural). Often times such groups try to "go it alone" and waste a lot of time and money and get the wrong or incomplete answer to their research inquiry. **- Gary Norris**

Actually, I think the reasons for the small fraction of respondents is:

1. Everyone is too busy,
2. People did not know how to conveniently access the newsgroup,
3. People tend to put things off until the last minute.

I doubt if the response would be any better to a magazine article. **- Bruce Kutter** (in response to Gary Norris)

Do you think we have something to learn from these other experiences? Yes, certainly. This would require a shift in the tradition mode of operations. A main concern is how faculty are properly credited considering traditional evaluation and performance standards. This would be of particular concern for younger, non-tenured faculty.

If so, how do we go about it? Not sure. This approach would require joint support of many members of engineering and research community to achieve.

Do you know of any other relevant examples? Engineering groups with some government agencies, such as the Corps of Engineers and U.S. Geological Survey have performed some work using this shared, cooperative approach.

Based on your knowledge or perception of these experiences, are there any pitfalls our community should try to avoid? Again, this relates mainly to creating an environment where credit for original ideas and contribution from each researchers are not clearly accounted for, especially when personnel evaluations are dependent upon tangible, measurable products. **- James Martin**

I think my most useful contribution to the workshop at this stage would be to describe my personal experience with Canadian programs very similar to the program to be discussed at the workshop.

In Canada, the Natural Sciences and Engineering Research Council has a bias towards cooperative research in general, and in particular has two programs which offer significant funding for cooperative research. One program is the Strategic Grant Program, which is designed to meet government research objectives, typically relatively short term (3-5 years) and for quick transfer to the public sector. The second program is the Network of Centres of Excellence which has the objective of advancing Canadian economic competitiveness. It may be useful to explain briefly how these programs work.

I will deal first with an ongoing Strategic Grant Research program in which I am principal investigator. This is entitled "Evaluation of Seismic Risk in Southwestern British Columbia". The program involves the University of British Columbia; Carleton University, Ottawa; Geological Survey of Canada, Terrain Analysis Section; Pacific Geoscience Centre, Vancouver Island; Earth Physics Branch, Ottawa; Tokyo Institute of Technology; BC Geological Survey; Ministry of Transportation & Highways, B.C.; 10 insurance companies and local municipalities.

One factor which has contributed very significantly to the smooth running of our program is that the contributions expected of the different participating groups are well defined. This ensures that responsibilities for effective contribution to the objectives of the research program are clearly attributable. To provide an example of this, I have outlined below the responsibilities of the different groups in the project.

University of British Columbia

Structural Engineering:

- Identification of building classes for British Columbia
- Establish vulnerabilities for these classes

- Establish building inventory
- Conduct risk (loss estimates) for various return periods using different loss estimation procedures
- Nonstructural damage assessment
- Development of GIS system for display and transmission of results
- Consequences of scenario earthquakes

Geotechnical Engineering:

- Spatial distribution of soil amplification factors
- Distribution of probability of liquefaction
- Distribution of site responses to scenario earthquakes
- Mapping of expected levels of soil deformation
- Distributions of peak ground acceleration, peak ground velocity at various probabilities
- Assessment of flood protection dike stability
- Use of microtremors to develop distribution of site periods
- Investigation of whether microtremors can be used to establish relative amplification potential of different sites with respect to rock and firm soil
- 2-D and 3-D ground response analyses

Tokyo Institute of Technology

- Collaborating with UBC on microtremor measurements
- Providing additional equipment, technical staff and advice

Carleton University Geophysics Group:

- Earthquake source modelling
- Stochastic ground motion and spectral modelling
- Distribution of rock motions
- Distribution of MMI's
- Modelling of subduction earthquake ground motions
- Calibration of attenuation relations

Geological Survey of Canada

Developing the architecture of the Fraser Delta by means of

- Shear wave velocity distribution
- Cone penetration data
- Deep boreholes to bedrock (up to 700 m)

BC Geological Survey

- Providing access to and use of their GIS data system
- Providing database on geological and surficial deposits
- Data from detailed liquefaction studies conducted by the Survey in some locations
- Data from ground amplification studies conducted in Victoria

Ministry of Transportation & Highways, B.C.

Soils data from new highway projects and bridge construction and remediation projects also.

Pacific Geoscience Centre

- Interpretation of local small earthquakes
- Ground motions from earthquakes in the M=4 to M=5.5 range from the local strong motion network
- Interpretation of the data in terms of radiation patterns, source mechanism and travel path, and local amplifications
- Providing seismic data for analyses

Earth Physics Branch and Pacific Geoscience Centre

Information and recent data on source zones affecting southwestern British Columbia.

Insurance Companies

> The companies are major financial sponsors of the project. They have an interest in specific risk data at specified return periods. The industries contribute to the scientific or engineering part of the project by allowing access to their loss assessment software, explaining their needs and concerns, and evaluating our methods of data analysis and presentation. An insurance industry liaison committee has now been formed which will work very closely with us as the first data is just becoming available.

Local Municipalities

> Municipalities who have interests that are more local than general have provided supplementary funds to deal with their special problems. The municipalities are strongly interested from Emergency Planning and Emergency Response viewpoints in how the research findings will be presented for maximum effectiveness. Their views are actively solicited and a number of general meetings are planned already with them to ensure that data is presented in a suitable way to meet emergency needs.

How Does The Program Work

All the participants have a significant stake in the final outcome. The universities and the government scientific organizations have specific technical tasks to perform. UBC has the overall responsibility to integrate these contributions to produce a useful final product that will help the insurance companies and the municipalities to cope with seismic risk. Each participating group in the project develops its own contribution with a clear understanding of how and when it is needed, and how it fits into the overall picture. Each group will publish their own research contribution independently.

The findings that result from integrating these different contributions will be joint publications. So far, there has been no disagreements or unhappiness about what has happened on the publication side.

I note in some of the submissions to the workshop web site that there is concern about publication rights. This is a very real problem, and I think the best way to avoid it is to allow independent publication rights to each group who participate as far as their own fundamental research contribution is concerned. But the final product that results from the integration of the individual contributions should be published jointly. This, of course, raises the issue of whose name goes first. I think it is very important in these networked operations to identify a principal investigator, although there can be more than one if the nature of the project lends itself to these distinctions. The principal investigator carries the responsibility for the proper integration of all the information and, provided he does this job well, it seems natural that his name should be first in reporting the integrated findings of the research (my secretary sharply remarked here "how do you know it's a he" - a very apposite remark). Presumably, in any given project some contributions will obviously be more substantial than others, and this should guide the order of publication.

In the case of our grant, it is specified in the grant application what funds the different groups will get as the project develops, but the responsibility for continued distribution lies with the principal investigator. If somebody is not doing the job, then the funding is cut off. Since the principal investigator is responsible for the final product, it is appropriate that he be in a position to recommend whether or not funding continues to flow to any participating group in the project.

Adequate funding for the participating groups is the glue that holds things together. However, it is very important also that the project is structured in such a way that the various groups have a significant professional say in the project, so that a successful conclusion enhances their professional image and reputation.

Communication

In the case of our grant, many of the participants are widely separated and communication is primarily by the Internet. This is used to exchange interim reports of progress with each other, to transfer data, and to look for help from other participants when some technical or other difficulties are encountered. Participants are comfortable with this type of interaction. Where this type of interaction is not particularly effective is for the discussion of important complex technical ideas, especially when more than two participants are involved in a discussion. The process is too slow and too formal for the vigorous debate that can occur between knowledgeable people trying to explore the dimensions of the problem. This is recognized by the granting agency who fund a number of coordination meetings during the year. In our case, we found that a fairly long initial meeting was necessary to make sure that everybody understood what we were trying to do, what the expectations of the supporters were, and the philosophy and structure of our approach to achieving the objectives of the program. It is necessary to review this structure on an ongoing basis. This type of discussion, in my opinion, cannot be done over the Internet with the same effectiveness.

In the management of the projects, we have found it important also to establish milestones of progress along the way, and to periodically check how progress towards these milestones is proceeding. The various contributions to the final project are all essential and integration time is much too late to find out that some of the individual components have not met their objectives.

One area where difficulties may arise regarding professional recognition is where somebody designs an experimental program which he intends to execute on another facility. If both units involved are academic, then I can seen the potential for some problems regarding recognition and publication. To avoid this, the roles of the different parties must be very clearly defined. If a person who designs a test procedure fully in order to deal with a problem that he has and simply uses the alternate site as a test facility, I don't see why there should be a problem about publication. On the other hand, if he intends to draw substantially on the advice of the researchers at the test institution, and solicits their help in understanding the testing process and results, then I think that the researchers at the test institution may have legitimate expectations of publication rights. If these things are recognized ahead of time and agreement reached, there should not be any problem, but it is very dangerous not to be clear about the relative roles before such a cooperative venture is started.

I have had experience with two previous multi-year multi-university projects. In one of these, the definition of the final product of the cooperative effort was too general to enforce substantial integration of the contributions of the participants. The result of this was that while some good individual contributions to the overall problem were made, the general objectives of the program were not really met. In contrast, the objective of the present research program is such that it absolutely enforces cooperation and integration of individual contributions so that the results may make any sense at all. These are the kinds of projects on which a networking of facilities and qualified people can lead to successful projects. Research projects of this kind are the ones to successfully launch a new network of research facilities and personnel.

Centres of Excellence

There are something like 15 of these centres in Canada ranging from medical research to research on high strength concrete. Each centre is comprised of a number of usually widely distributed nodes, one of which is the administrative node. Funding is available to maintain administrative staff and management personnel at this node. Funding is for 7 years with the possibility of one 7-year renewal. The operation of these centres is very similar to the Strategic Grant projects. The main difference is that the research topics tend to be more pure than applied and there is a more long-term attitude towards reaching objectives. **- Liam Finn**

I am aware of several examples that may be relevant to geotechnical earthquake engineering research. One is the Strategic Highway Research Program (SHRP) in which there were focused efforts on asphalt mix design (SuperPave) and pavement performance (LTPP) among others. I am not sure what lessons can be learned from these efforts, but it would worthwhile to ask program managers at FHWA and various researchers in the pavements area for their views of SHRP.

Let's also not forget about the three recently funded NSF Earthquake Engineering Centers. It seems to me that any discussion of networked research efforts in geotechnical earthquake engineering must include mention of the centers. **- Glenn Rix**

***Q1B - SHARING FACILITIES.*** *The sharing of facilities is a very important concept. It implies that, while a facility is installed at a university and is operated by that university group, it does not belong to the group in the usual sense. The group may be authorized to use the facility only part of the time, with the rest of the time being allocated to outside groups by a decision being made by NHPS, that is outside the university. In exchange for appropriate financial support, the facility should provide service to outside users that should be efficient, orderly, on time, that is businesslike. How should this be organized within the university? Will it always require the creation of a separate center with a manager that is not a tenure-track faculty member, who can take responsibility and answer any telephone call or e-mail within 48 hours?*

I think I would welcome anyone including the NHPS to help recruit users and efficiently schedule the use of the UC Davis centrifuge facilities. If a local Facility Director loses control over scheduling a facility, he/she would also shed some of the responsibilities. This might allow the Director to spend more time conducting his/her own research and act like a normal faculty member.

In addition to a network of facilities, I envision the NHPS as a network of researchers. Desired consequences are more efficient use of, and more convenient access to major facilities.

Each visiting research project would require a different level of assistance of local staff. Experienced visiting researchers will require little training and do most of the work themselves, other visiting researchers may want to pay local researchers to do the test and process the data while they show up on the day of the test or watch it over the internet. Some experiments require significant specialized instrumentation developments while others use existing instrumentation. To handle the broad spectrum of research projects at a large facility a versatile local staff will be required.

The local staff provides very important institutional memory: How to build experiments, how to process data efficiently, how to adjust all of the instrumentation, and safety issues.

The size and composition of required staff will vary from facility to facility. At the UC Davis centrifuge facilities, we have a post doc facility manager and three full time technicians, to support about 4 or 5 ongoing projects. For most MRE facilities, a tenure track faculty member could not manage without a staff. **- Bruce Kutter**

A facility that is funded by public funding agencies remains to be a public property. Therefore it should remain open to other researchers for projects funded by public agencies. For privately sponsored projects, it is up to the hosting university. Geographically, researchers on geotechnical earthquake engineering are spread around the country. It is impossible and unwise for each of them to have the equipment needed for their research installed at their institution. Even relatively well equipped laboratories may need to use facilities at other places. Thus, the sharing of facilities is very important.

My own experience on this has been pleasant and successful. For the last four years I used the centrifuge facility at UC Davis for a number of times for different projects, which was a tremendous help for my research. It seems to me that with some careful planing, the sharing of facilities can become a reality.

My suggestion is: for all federally funded facilities, the hosting institution can allocate a certain portion of the year (say 1/4 to 1/3) for external users. The hosting institution can make it public in advance what period of time is available for outside users, how much will be charged for using the facility, and what kind of help the outside user can get from the hosting institution, making it more businesslike. Considering the difficulty of leaving during normal academic year, it may consist of mainly summer months. However, to help the host planning the schedule, an outside user should contact the host at least 6 month in advance. If no outside user sign up, then the host can arrange for their own tests. In order to encourage collaboration between researchers and effective use of available facilities, the effectiveness of facility sharing can be used as a criterion in determining future support from funding agencies, thus making national laboratories more inclusive.

Managing a national testing facility is not a easy job. It is essential that the funding package of the facility includes at least a half-time manager's position. The other half can come from research projects as in most cases it will not be a pure business manager but a technical one. Whether it is a tenure-track position or not, it is up to the institution. Our opinion does not count much in this kind of situation. **- X. Zeng**

Sharing facilities will be difficult as long as we have competing alliances. The formation of the various earthquake engineering centers likely precludes a truly universal sharing of facilities. Which entity (NSF, FHWA, DOE, etc.) has the power to override such self imposed divisions. In fact, given that this is an NSF sponsored workshop means that our discussions may not be shared with FHWA or other supposedly interested parties. **- Gary Norris**

Many existing experimental facilities that were established through partial funding from the federal government have been built by substantial investment of their hosting institutions and/or matching funds from private industry. It is not clear that these facilities are actually public domain or owned by the hosting institution. To date, there have been numerous examples of successful use of such facilities by the researchers from other institutions. Use of UC-Davis and RPI's centrifuge facilities by other researchers are good example of such sharing of the facilities. In majority of these cases, however, the outside researchers had close ties with the hosting institution and had collaborated with the faculty members in the hosting institution in the past.

Managing a major experimental facility in a university has been an extra burden on the faculty member(s) in charge of the facility and even when a non tenure track person managed the facility, finding the additional support for him/her has been a major concern of the hosting institution.

If the sharing of the facilities, that will be built or upgraded through federal funds in future, implies that an outside entity such as NHPS will allocate the time for using the facilities by the potential users, then the facility should be operated by a manager who is supported by outside funds which can be provided through the overhead charges to the potential users. It is reasonable that the facility should still be under the oversight of a director from the hosting institution and the hosting institution may still have priority in the use of the facility for its educational and research purposes.

Another aspect of the facility sharing is the location of the facility and convenience of its use by potential users. I believe that in funding the new experimental facilities throughout the country, federal funding agencies such as NSF should consider the geographical location of the new facility. A new facility in an area that is not very close to the major experimental facilities can potentially attract the researchers in the neighboring states to use the facility. We are currently building a six-degree of freedom shake table (3m by 3m) in the George Washington University Virginia Campus which is conveniently located from some major research universities in the Washington area. University has committed to provide the necessary funds for a post-doc facility manager. We expect that the facility will attract researchers in the earthquake engineering community from University of Maryland, Johns Hopkins University, Catholic University, NIST, FHWA, etc. We plan to have the facility open to all interested users. **- Majid Manzari**

How should this be organized within the university? Difficult to answer this question, as the most appropriate arrangement for services would probably vary depending upon the research organization.

Will it always require the creation of a separate center with a manager that is not a tenure-track faculty member, who can take responsibility and answer any telephone call or e-mail within 48 hours? Yes, the center would indeed have to have a dedicated manager with full-time responsibility to the proposed. **- James Martin**

Most of the responses thus far seem to agree on the need for a full-time or nearly full-time, non-tenure track manager for any large-scale facility. This makes a great deal of sense, but this seems to be a difficult thing to do within a university environment. One of the problems with a short-term program like NHPS is that it doesn't provide for ongoing costs like technical staff, maintenance, etc. It is up to the host institution to pay for these items using "soft money" from their own research projects and/or by charging other researchers. Thus, the cost eventually falls back on a sponsor like NSF after several markups involving indirect costs, fringe benefits, etc.

Perhaps we should advocate a more direct approach in which NSF (or another sponsor) provides for ongoing costs "up front" using an escrow account or some similar financing mechanism. **- Glenn Rix**

Question 1. In your opinion, what are the major unsolved geotechnical problems or issues that should or could be addressed through experimental research using enhanced seismic simulation facilities?

Problem 1: Near-fault motions including effects of base-rock irregularity and soil nonlinearity. Based on earthquake observations by vertical and horizontal arrays in high seismic areas, data base of near-fault strong motion records should be formed to establish design seismic motions ( deterministic / probabilistic) considering not only the magnitude or distance but also other fault parameters including directivity. Effects of base-rock irregularity such as the basin-edge effect highlighted in Kobe during the 1995 Kobe earthquake should be taken into account with respect to relative locations to an earthquake fault.

Evaluation method of soil nonlinearity effect on the design motion in soft soil sites should also be established for near-fault strong earthquakes based on the records. In the method, reduction in surface acceleration due to soil nonlinearity should be properly evaluated for rational structural design.

Problem 2: Effect of vertical motions on stability of structures.

In near-fault regions, the vertical acceleration sometimes exceeds the horizontal component, although some of the records in Kobe reflected the effect of soil liquefaction in soft soil sites. A reasonable design method for strong vertical motion in near fault regions, exceeding 1G in the extreme, should be explored by analyzing strong motion records and by performing large scale shake table tests.

Problem 3: Dynamic and residual deformation induced in liquefied or softened soils during strong motion earthquakes and its effect on buried structures.

The evaluation of dynamic or residual deformations induced in soft ground during strong earthquakes and its effect on buried structures are very important for seismic safety of urban underground structures.

Earthquake observation systems including not only seismographs but also deformation gages, inclinometers, strain gages, pressure gages, piezometers, etc. in both soils and structures should be established in high seismicity areas. In model tests, by means of 1G / centrifuge shake table tests or field tests using explosives, the mechanism and design method for residual deformations due to lateral spread in liquefied ground should be investigated. Not only a uniform sand layer which has been studied quite often in the past, but also non-homogeneous layered sand should be investigated. If possible, trenching of lateral spreading ground in past earthquakes is worth trying.

Problem 4: Stability/Instability of stiff soils (gravels, soft rocks, etc.) during strong earthquakes.

Stiff soils like gravel and soft rock serve as bearing strata for deep foundations and also directly support important structures like long span bridges, high-rise buildings, energy storage and power facilities, etc. Among them, well-graded gravelly soils are widespread and often encountered in big project although little is known compared with sandy soils. It is of significance to clarify the conditions for stability / instability of such stiff soil layers during strong seismic motions in a near fault zone. Accumulation of world-wide case history data is first needed. Laboratory tests on undisturbed samples as well as insitu investigations like penetration tests and PS-logging in damaged areas are needed. For the magnitude of earthquake motions, observational data or estimated values are used. By forming a large data base a design criteria for assessing seismic stability of stiff layer in near fault zone should be established.

Problem 5: Effect of near-surface fault movements on various structures.

In shallow earthquakes, fault movements sometimes show up at ground surface endangering various civil engineering structures. If the ground is covered with soft soils, the movement will be smoothed by a cushion effect. If a structure is ductile such as soil structures, it may survive the fault movement. The mechanism of near-surface fault movements and its effect on surface soft soils or soil structures should be studied by a large-scale model tests or by centrifuge tests, which are also simulated by numerical analyses. Trenching and surveying near-surface active faults in recent earthquakes are also needed. **- Takaji Kokusho** (in response to Questions 1A and 1B)

***Q2A - INTELLECTUAL PROPERTY.*** *A key aspect of NHPS is to create a different research culture where concepts like COOPERATION (between facilities, between investigators) and SHARING (of facilities, data, and credit) become very important. How would you solve the contradiction between this and our current academic culture in which people are judged very much individually, in terms of reputation, promotion and tenure? Specifically, how do we credit the contributions to sharing and cooperation of academics so that university bodies and administrators judging them see and appreciate these contributions?*

Is this any different than the increasingly common requirement when preparing promotion and tenure cases that the individual's specific contributions to reports and papers be stated? Nonetheless, I agree that university evaluators do like to cling to the idea of "individual scholarly contributions" - even while extolling the great need and virtue of inter-disciplinary, cross-disciplinary, and other forms of collaborative activity. It will be necessary that universities rethink criteria as they relate to this issue as they are now being asked to do in relation to the value of engineering practice by faculty members. Fortunately, the cream does rise to the top, and those who are the pioneers, the innovators, the creative thinkers, and the overall achievers will be easy to identify.

It may be less easy, however, to distribute the credit among the soldiers. **- James K. Mitchell**

This question involves two aspects, pertaining to the issue of 1) intellectual property ownership and 2) credit and acknowledgment of researchers participating in community efforts.

1) Intellectual Property Ownership. This aspect is covered in part by current policy in which NSF allows an individual university to own patents and grant licenses. Compensation and recognition of the researcher for the invention is then a matter of each university's policy. In networked research programs, there is some chance for simultaneous claims by two or more institutions for intellectual property. It seems that networked research doesn't so much increase the chance for disagreements over intellectual property rights as it creates more opportunities for information exchange. Since increased information exchange is a characteristic of a modern research environment, it is unlikely that networked research will add substantially more risk of disagreements than the risk already inherent in a climate of expanding information technologies. The current procedures and safeguards for protecting intellectual property seem to be practical and adequate. I know of no problem with intellectual property disagreements related to NCEER-sponsored activities. No special problems of this type have been brought to my attention with respect to NUNN-related activities.

Sharing and cooperating with respect to facilities and data in networked research brings benefits to the researcher. As a contributing member of the team, a participating networked researcher increases his/her chances for success and continued support from the network. Established, senior faculty need to mentor younger researchers in this process and bring the importance of the networked research effort to the attention of chairs, deans, and university administrators.

NUNN facilities are operated by competent technicians who work with researchers external to the institution where the research facilities are housed. The home institution faculty are not required to operate the facilities for external researchers, but rather a professional staff performs this function. User fees help defray the cost of the technicians. There is no pressure on home institution faculty for day-to-day operations or imposition on their time to make the equipment perform satisfactorily. The key is to separate home institution faculty from the daily chores of operating the research facilities through the use of a competent, funded staff of technicians. Adequate funding for equipment operation and maintenance is essential. **- Tom O'Rourke**

> Tom:
>
> re. your description of NUNN facilities operation, a couple of questions: -Are the operating technicians employees of the host institution?
>
> -Does this model mean that the host institution relinquishes control of scheduling the facility?

> I suppose that the investigator's institution will get its overhead at an "off-campus" rate, but the experimental facility will only get its flat rate? **- Pedro**, in response to Tom

To me, the only straightforward way to facilitate sharing of data and facilities and facilitate cooperation is to separate experimentation from analysis. Part of the criteria for support to an experimenter proposing a large-scale test would be support from analysts who would use the data from his proposed test. Thus, the experimenter would be motivated to collect as much useful data as possible and interest as many outside analysts as possible in his experiment. By not having an responsibility for analysis, and by getting credit simply for performing the experiment and publishing the data, the intellectual property questions and conflicts between rapid dissemination of experimental data and analysis of the data can be significantly reduced.

I get a little annoyed when tenure concerns are cited as barriers to dissemination of knowledge and advancement of the profession. If this is the case, it is the tenure system that must be changed to remove these barriers. We should not be discussing adapting our research system to facilitate a counter-productive tenure system. If tenure is a barrier to cooperative research, what we need to discuss is how to make University bodies and administrators realize that the current tenure system is counterproductive to good science and research, not how our research programs can facilitate a flawed tenure system. **- E. Kavazanjian**

***Q2B - DATA DISSEMINATION AND CREDIT.*** *The advent of the Internet and the Web has made the immediate public availability of experimental data a real possibility. But how soon is soon enough? We certainly don't want to publish the data before we verify its correctness. Also, any publication of data involves an additional effort in describing the experiment, providing calibration constants, answering questions of interested readers, etc. Or perhaps we are not sure of the correctness of the data until we finish a series of experiments, and we publish the series with attached discussions and interpretations. How different is this from a paper? Or is that what we are talking about, publishing experimental papers but will ALL backup data in digital form available in the Net. In any case, shouldn't the people who conceived and did the experiment have "first pick" at the data, without being forced to publish the raw data too soon? If we decide to have a policy of making experimental data publicly available before people producing them would spontaneously do it otherwise, how do we make sure that the experimenters get their share of the credit when other people use the data in papers, reports and presentations? There are here "outside" aspects to be considered (reputation) and "inside" aspects (promotion, tenure, raises).*

My responses to Q2B are intertwined with the questions below.

Q2B - DATA DISSEMINATION AND CREDIT. The advent of the Internet and the Web has made the immediate public availability of experimental data a real possibility. But how soon is soon enough?

"Soon enough" should not be any sooner than it has been. In most cases, the data in past studies have been evaluated and written up in papers when the investigators have been confident that the results are valid and the conclusions tenable. What the Net can do for us is speed the process from that point on, without the interminable (and sometimes biased) review process before publication in a journal. In the new order, anybody and everybody can be a reviewer if they so choose.

We certainly don't want to publish the data before we verify its correctness. Also, any publication of data involves an additional effort in describing the experiment, providing calibration constants, answering questions of interested readers, etc. Or perhaps we are not sure of the correctness of the data until we finish a series of experiments, and we publish the series with attached discussions and interpretations. How different is this from a paper? Or is that what we are talking about, publishing experimental papers but will ALL backup data in digital form available in the Net. In any case, shouldn't the people who conceived and did the experiment have "first pick" at the data, without being forced to publish the raw data too soon?

Certainly they should.

If we decide to have a policy of making experimental data publicly available before people producing them would spontaneously do it otherwise, how do we make sure that the experimenters get their share of the credit when other people use the data in papers, reports and presentations? There are here "outside" aspects to be considered (reputation) and "inside" aspects (promotion, tenure, raises).

What are some arguments for "making experimental data publicly available before people producing them would spontaneously do it otherwise?" I don't know any compelling reasons. The Net offers rapid dissemination when it is time; there is no reason that we should junk all the traditional ways of evaluating our results just because we have the ability to cast our seeds further faster.

The concepts of COOPERATION and SHARING within the NHPS do not and should not, in my opinion, require that the individuals give up all their identity and intellectual property rights. **- James K. Mitchell**

The fundamental issue here is ethical: analysis and publication of research data by non-collecting scientists before the collector of the data has had adequate opportunity to perform these same functions. If the collector of the data is not allowed fair opportunity to analyze it after devoting time and energy to processing the data, it will discourage not only posting of the data but its collection as well. This problem can be partially solved by guidelines as to the length of "ownership" of the collector of the data. It might also be helpful to state clearly on a web site what the ethics of using someone else's data are. My own experience has been that some investigators are just naive about the hard work expended to collect data. A few have been downright unethical, but they are a minority. Guidelines for offering co-authorship including senior authorship might stymie some of the abuse and encourage credit where credit is due.

Having said this, the publicly funded collector of data is under an obligation to ultimately make the data available. Guidelines for timeliness and format would be helpful. **- Thomas Holzer**

What if there was an Electronic Journal of Seismic Simulation Experimental Data? Perhaps it could be published by the NHPS. The publications could be carefully peer reviewed so that proper credit could be given to the experimentalist. The electronic data would be properly archived, maintained, and could be referenced. The criteria for acceptance for publication would require:

- A complete description of the experiment.
- A demonstration that the data is consistent.
- Proper comparisons and references to related work.
- An honest evaluation of experimental errors and uncertainties.
- A complete set of data files in a standard format.

Problems with publication of data in existing journals include: long review processes and page limits which preclude publication of complete data sets. Another perception is that reviewers for existing journals will require "new" methods of interpretation, "new" methods of analysis, or at least a positive comparison between the data and an existing method of analysis. Difficulties in developing methods of interpretation or implementing existing methods of analysis often delay data publication, and in some cases the data becomes obsolete before it is published. **- Bruce Kutter**

A governing principle of data dissemination should be that data are made available only after the data set has been reasonably checked for accuracy and consistency. There is no efficiency in disseminating incorrect information and data. Not only is it counterproductive, but it may propagate errors through the system that take years to get out. We need a system with appropriate safeguards on the quality of the disseminated data. The real issue is what is meant by appropriate. Databases should be made available by Internet as soon as possible, but the data should be checked at least once to assure reasonable accuracy. Caveats must accompany the data, and a description of how the data were developed must be part of their release.

In all cases the party providing the data set must be acknowledged and referenced by other researchers when they publish results predicated on the data set. There should be a strict protocol for this. A good example of rapidly shared data are the vertical array strong motion data on Port Island for the Kobe earthquake through the Geo-Research Institute in Osaka and the auspices of Yoshinori Iwasaki. This very important data set was used by several researchers, some of whom (e.g., Elgamal, et al., 1996) published papers in the ASCE Geotechnical Journal within one year after the Kobe earthquake. Explicit reference was made to Dr. Iwasaki and the Geo-Research Institute in the publication. This example could serve as a model for rapid dissemination, turnaround publications, and appropriate acknowledgement of those originating the data.

Other models for data dissemination include Professor Masanori Hamada's rapid publication of air photo measurements of lateral and vertical ground deformation after the Kobe earthquake. Professor Hamada also made data available in CD format. Similar information could be placed on the Internet, with the statement that the data and appropriate discussion were in press. Researchers using such data could reference the originating researcher either through the Internet version or the later hard copy format.

It seems that different protocols are needed for different data. Strong motion data, vertical arrays, air photo measurements, etc. are earthquake specific. Every attempt should be made to place data of this type with appropriate checks and caveats on the Internet rapidly. Data pertaining to lab and field experiments, GIS representations of spatially distributed systems, and complex numerical simulations need time for interpretation and checking. The appropriate protocol for them is perhaps journal publication with backup data in digital form available on the net. Experiments performed with research facilities network equipment may be required to adopt this approach as a minimum.

We should be pragmatic about data introduced to the Internet. We can create ways to properly acknowledge the use of such data, but we cannot ensure collaboration between the data originator and all users. It should be the prerogative of the originator to chose who he or she wishes to respond to when unsolicited inquiries arrive by e mail. All users, however, should be required to acknowledge the data originator whether or not the originator chooses to respond to inquiries about the data. **- Tom O'Rourke**

I see no reason why the people who conceived and performed an experiment have the *first crack* at the data, unless they also paid for the experiment. In our capitalist society, whoever paid for the experiment is the one who has the right to control how the data gets disseminated. Generally, he will (and should) do so in the manner that best serves his interests. If the experiment is paid for by the National Science Foundation, it seems to me that their best interest is the rapid dissemination of the data to any interested party and not the proprietary guarding of the data by the experimenter. Once again, it seems to me that this is best accomplished by separating the experimenter from the analyst. By recognizing the experimenter for performing the experiment and disseminating the data, we can best facilitate rapid dissemination and sharing of the results of his experiment.

Again, I have little sympathy for concerns such as promotion, tenure, and raises with respect to this issue. We should be performing these experiments to further our knowledge of earthquake engineering and advance the state of the art, not to get a raise or a promotion. While these human motivations undoubtedly figure in our own personal motivations, they should not be a consideration in how best to develop a national research program, except to the extent that we try to prevent them from interfering with the advancement of knowledge. **- E. Kavazanjian**

Question 2. What changes are needed to create a research culture that would encourage and reward cooperation and collaboration between investigators, encourage sharing of facilities, and make the data widely and quickly available to all users?

1. More frequent joint seminars or workshops.

As far as international cooperation and collaboration are concerned, opportunities have been too few for research engineers especially in Japan to get acquainted with American counterparts seeking the same technical topics. Only a limited group of people have close ties to each other between the two countries, but other research engineers mostly in industry who may have large amount of data do not have many chance to attend such meeting. One of a solution is to have more frequent joint seminars or workshops in Japan in which many engineers from industries are invited to give presentations.

2. More participation in national society conferences.

More practical and easier means to have better cooperation with Japanese research engineers are to participate in conferences and symposia sponsored by national societies in Japan. Numerous data on field observations and large scale demonstration data are reported by quite many researchers belonging to public or private research organizations. Foreign people are always welcome to attend and also to present their work in English. Unfortunately, most presentations are in Japanese and also the announcement for national conferences are mostly only in Japanese with some exceptions like the Japan Earthquake Engineering Symposium to be held Nov. 25-27, 1998, in the Shin-Yokohama Prince Hotel in Yokohama. Another International Symposium held this year is Second International Symposium on the Effects of Surface Geology on Seismic Motion-Recent Progress and New Horizon on ESG Study-December 1-3, 1998 Yokohama. Other major national conferences are the Conference of the Japan Geotechnical Society in the Yamaguchi University on July 14-16 and the Annual Convention of Japan Civil Engineers Society in the Kobe University on October 4-6. But once you attend there, you will be able to find Japanese friends who will gladly help you understand presentations and join in discussions. In these occasions you will have a lot of chance to communicate with Japanese engineers in industries who are less well-known internationally but have an access to large scale test data, earthquake data etc. and lots of practical expertise. Thus it may provide a good opportunity to develop intimate relationships for joint researches between researchers in two countries.

3. Simultaneous test programs.

Simultaneous research programs like VELACS are worth while to try again internationally in which experimental or observational aspects should be more pronounced. In Japan simultaneous test programs are very often undertaken, for standardization of soil tests. Simultaneous test programs to establish international standardization for essential test methods which should be simple enough to invite as many organizations as possible may be worthwhile to try.

4. More efforts to publicize earthquake records with sufficient geotechnical data.

In the Kobe earthquake, some of the earthquake data were exceptionally fast to be publicized thanks to great efforts of some outstanding persons. One of their opinions was that the data publication itself was no problem but responding to quite a few questions on the data later days including geotechnical conditions was not an easy job. More reasonable system of data publication has to be discussed internationally for future earthquakes. **- Takeji Kokusho** (in reply to Questions 2A and 2B)

I am assuming that the creation of the NHPS does not signal the end of all other experimental research. Rather, I view it as providing opportunities for significant experimental investigations that are intended from the outset to provide high-quality, validated data to be used by a potentially large number of people (something like the experimental portion of VELACS). Those seeking support for such experimental research would be well aware of this in advance. That said, I expect that such funding would be quite competitive and that those who are successful in obtaining support would be recognized by their peers as having exceptionally strong experimental skills, a fact that would likely be conveyed to promotion and tenure committees through reference letters. Not all research, however, is amenable to the division of experiments and analyses that would be associated with projects of this type.

I would also expect that the NHPS facilities could also be used for more conventional projects in which a single investigator, or team of investigators, conducts experiments and then analyzes the results of those experiments. This is often the best way to attack problems, anyway, with an integrated program of experiments and analysis that allows the course and details of the experimental program to be modified based on analytical interpretation of the results. Such projects should then be required to post the experimental data in a timely manner (likely to be specified by the funding agency). This would allow the developers of the data to analyze, interpret, and publish the results of their experiments, but would also allow others to analyze and re-interpret the results of the experiments in a timely manner. At this point, we are rarely able to obtain the experimental data of others, even after their work has been completed. The ability to gain convenient access to such data would represent a major step forward from current practice.

Those who are not interested or willing to make their experimental data available to others would certainly not be forced to use NHPS facilities, or could use them under terms negotiated between their sponsor and the facility. Projects that did disseminate data should have priority for use of the facilities. **- Steven Kramer** (in response to Questions 2A and 2B)

Our current academic environment is not necessarily in contradiction to concepts like sharing and cooperation, although it may offer little direct incentive for it. Sharing and cooperation have indirect benefits that any faculty member should recognize as being crucial to their long-term success. I think most university administrators already see the value of collaborative multi-author contributions, and that any problems (perceived or real) more often stem from the faculty on the personnel action committees. Those features of the academic environment that might be considered detrimental will change slowly in time, and are not enough of a problem to impact the NHPS effort.

As noted by others, data should only be widely disseminated after it has been scrutinized closely enough to ensure that obvious deficiencies/errors/limitations have been identified and documented. Such close scrutiny of the data requires synthesis of the results, which also sets the stage for presentation to others in publications or reports. Additional scrutiny can come from numerical analyses of the experiments (possibly by a collaborator) that can identify apparent anomalies that warrant closer inspection of both the data and analysis method.

If public dissemination of the data occurs after it has been fully scrutinized, then the experimenters and collaborators should have had enough time to prepare their results for publication in some forum. The dissemination of the data then only leads to better recognition of their work, and it would be short-sighted to hold it back any longer. If another researcher actually gets "ahead" of the experimenter in terms of being able to present findings, then there are plenty of ethical guidelines to make sure that the original source is properly credited. It also seems appropriate to recognize that truly valuable data sets often warrant more than one independent analysis. For example, how many papers have been written about the San Fernando Dams, the Wildlife array, Treasure Island, etc. An experimentalist should consider it a complement when other researchers analyze their data. In fact, such situations should help with issues of academic evaluations (via reputation and external letters), and is an incentive for sharing and cooperation.

Standards for detailed documentation of test data are needed to ensure that every aspect can be followed by researchers years from now. Peer reviewed documentation would help in this regard. Bruce Kutter suggested a journal for such a purpose. Perhaps one of the existing journals (e.g., EERI Spectra) would be willing to serve that role. The cost of this service could be charged to the authors (like page charges in some journals), who charge it to the grantee (e.g., NHPS). A paper describing the results could be published in the journal, and a peer reviewed set of the data (on CD) could be available upon order. **- Ross Boulanger** (in response to Questions 2A & 2B)

***Q3A - DATA SHARING AND STANDARDS.*** *Use of the Net to divulge experimental data can be classified in two main aspects: (i) unlimited public availability to anybody interested, and (ii) availability and sharing of data with a limited group (established group within NHPS, inter-university team doing cooperative research, etc.) Both involve important technical questions related to availability and/or development of adequate hardware/software, development of both general and ad hoc technical standards. How do we go about addressing these issues? What do you know about useful tools for this now available "out there"? Should NHPS or our geotechnical/tsunami community form a task force or technical committee to work on these issues?*

In response to the Cultural Question Q3A:

I personally think that the data should be made available in public domain for downloading. However, postings to the data-bank should be controlled by NHPS. Postings should be checked for their quality. There can be a main panel and several sub-panels. The main panel would send submissions to an appropriate sub-panel assigned for a specific research topic. Within each sub-panel, there can be a chairperson who selects two or three sub-panel members as reviewers for every submission. The proposed "technical support" personnel can be made educated in Internet operations in order to format and post the articles, data, pictures, and tapes of the experiments. This process could become time consuming and would then defeat the purpose of making the data available "out there" ASAP.

I think it is better to compromise on the faster availability of the data and focus on assuring the quality of the data.

"Out there" can be as simple as a web page created by the NHPS group. The data-bank can be stored there for downloading. The laboratory, shake table, and numerical data from VELACS are available at: http://ceor.princeton.edu/~radu/soil/velacs/index.html. We can create NHPS data-bank along the same lines. I think NHPS should form a technical committee to work on these issues.

It might be worthwhile to consider conducting literature reviews of the topics T1 to T4, and any other important topic that would interest the geotechnical earthquake engineering community. Under the same data-bank, results from previously conducted seismic centrifuge tests, field measurements, laboratory tests, and 1g shaking table tests can be compiled. It would involve a lot of work and also some of the old data might not be available in suitable formats. However, at least those references can be provided. This information will be very useful for practicing engineers and researchers to calibrate their analytical and numerical methods and for design purposes. **- Mandar Dewoolkar**

The data should be open to anyone. The reason for this is that there may be researcher, say in France but due to logistics, he/she may not have been included in the group but wishes to use data to conduct research. There is no reason why he/she should be denied access. In addition, competition in using data can produce unique and alternative solutions and provide basis for comparison of results. My only concern is that the data should be made available in a prescribed format that anyone can easily follow. There are many tools for this (EXCEL etc) but the best thing would be to discuss these in a suitable meeting. I am not sure that it is necessary to form a task force or technical committee for this but enforcement of the standardized format can be done by inclusion in the funding and awards by appropriate institutions. **- M. Celebi**

I believe that we will have to have 2 levels of "data availability:" open and limited access. The first level, open to the general public would include:

1. Details and schedules of all upcoming tests.
2. Data from regularly scheduled "open" tests, that is, tests announced well in advance that will be completely open to the public. These could also include specific requests for data collection from K12 and undergraduate students, similar to UCSD's Earthkam program: http://www.kidsat.ucsd.edu, where undergraduates from around the country direct a camera mounted on the Space Shuttle.
3. Selected data from limited access tests. Requests for specific data, unrelated to the objective of the limited access test, could possibly be made ahead of the scheduled limited access tests. This data could then be

made open to the public. I think that in general, most researchers will have some reluctance to making all of the data from a funded research program open to the general public (unless forced to by the funding agency).

The second level of data availability would be limited access, and would be limited to the research group working on the project.

Though I am reluctant to suggest forming another committee, other collaboratories must be connected to find out their experiences, and clear guidelines must be prepared for what would constitute a "limited access" test. Certainly, some pressure must be applied to make as much data open to the public as possible. **- Scott Ashford**

***Q3B - INTERNET TOOLS.*** *The INTERNET has opened the possibility of real cooperative experimental research throughout the country and the world, including things like remote participation, real time sharing, virtual meetings, experiments being physically done at an institution but controlled from another, very close and "on time" use of experimental data just out of the oven by analysts at other universities, etc. How do we best facilitate these developments? What investments, software/hardware developments, and institutional changes are necessary? What can we learn from other communities who may already be doing some of these things? Any suggestion?*

In response to the Cultural Question Q3B:

Although the idea of using the Internet for active remote participation in the actual experiment is interesting, scheduling the events could become difficult because of uncontrollable problems which generally come up due to electronics malfunctioning and other mechanical and electrical breakdowns. Whenever the experimenters are ready, the procedures and the actual experiment can still be shown live on the Internet hoping that the interested people are still patiently waiting. Once the technology is established, this would be lot less expensive than the costs involved with physical presence.

However, is remote participation really necessary and even effective because of the above mentioned problems? Is it worth investing our resources and efforts in establishing the necessary technology? These issues need to be discussed first. **- Mandar Dewoolkar**

Other communities have bulletin boards where they share ideas and data. For example, there is a TSUNAMI bulletin board. As far as I know, the tools are there but it needs a LEADER INSTITUTION TO ESTABLISH the media and MAINTAIN it. As far as I know, investments for these are minimal except for the salaries of the personnel and operational costs for maintenance. **- M. Celebi**

We looked at controlling tests from off-campus for UCSD. Certainly, setting up the test (planning , instrument placement, etc) can be made off-site, but real-time control is difficult because of potential Internets delays. Data could be posted near real-time, and the test could be shown on a "live" camera. The hardware to accomplish this is relatively straight forward, but the software can be a challenging and constant undertaking.

One consideration is complete separation of the WWW server and local laboratory network for control and data acquisition for security reasons. This can be accomplished by a router (computer switching station) at the WWW server (gateway to the lab).

A successful example of public interaction is the Earthkam program : http://www.kidsat.ucsd.edu **- Scott Ashford**

I am for complete openness, allowing unlimited public availability to anyone who can justify access. I am not familiar with the technology of doing it to offer constructive comments. Let a technical committee be formed to study the issue and keep up with the rapidly changing technology.

However, the timing of posting results on the internet must be controlled by such concerns as quality assurance, legal implications, intellectual ownership and plagiarism. **- Hon-Yim Ko**

***Q4A - OUTREACH.*** *How can the network, along with the existing Earthquake Engineering Research Centers, reach out to government research laboratories, private companies, and international research facilities, and others interested in geotechnical earthquake engineering to encourage cooperation and collaboration, build partnerships, and make data and results available to all potential users.*

There is no question that much of our nation's top geotechnical talent is employed at organizations such as government research laboratories, private companies, and international research facilities. Collaboration with these groups can be facilitated by the Earthquake Engineering Research Centers through programs which bring in these groups as sponsors or collaborators in research. The existing PG&E/PEER program is an excellent example of the positive results obtained by interaction between top industry consultants and university researchers. Not only are research results implemented rapidly, but industry has the opportunity to communicate its needs directly to the researchers, leading to useful results. The centers should reach out to the government agencies, private firms, etc. to involve the relevant experts as advisors or full participants in the research. Obviously, this would most easily facilitated if the organizations contribute to the research funding, and thereby have a stake in the results.

With regard to data dissemination to those not directly involved in the research, as the old saying goes, "you can lead a horse to water, but you can't make it drink." Our focus in reaching out to government agencies, private companies, etc. should focus on two issues:

1. Use the web to disseminate the date, and make the web pages user friendly.
2. Publicize the web address and the types of information available on the web page.

If we have organized web pages that are well publicized, then the burden shifts to the user to make use of the information. Assuming competent staff are hired to prepare web pages, then the outreach issue boils down to the second focus area above. Several thoughts on how to "get the word out" on web pages and the data available on them:

1. Quarterly or semi-annual emails to a user list summarizing what is new on the web page.
2. Newsletters from the research centers with brief articles on the research and data dissemination programs, and of course the relevant web page addresses.
3. Provide information to existing newsletters like EERI for publishing of web addresses. Again, brief one paragraph summaries of what is available would be useful along with the address. **- Jonathan Stewart**

It seems that much of this outreach would depend on the nature of the partnerships between specific groups of researchers and industry participants that could be established. As the data collected and new knowledge is ready (including some form of peer-review) for general distribution outside the group conducting a particular project, then the "network" will provide an excellent means to speed and, in some cases, make possible that dissemination. **- Jose Pires**

In discussing this question, I assume "NHPS" will take the form of some permanent body which will oversee and encourage the development of major networked facilities.

- A user-friendly web site is essential for outreach. This, in turn, requires long-term funding for a permanent staff which will maintain and upgrade the site.

- It is also essential that there be agreed-upon formats for data input, and for the minimum amount of information contained in data sets placed on the web. For field test sites, the National Geotechnical Experimentation Sites project has already developed such formats for conventional laboratory and field tests (http://www.unh.edu/nges/). Further development is required, however, because the NGES database is currently not compatible with all platforms. Further, there is currently very limited funding available for adding new data, and there is a continual problem with training students to input data and maintain the site. This same problem would be faced by a potential NHPS site, and would need constant-long term attention; thus the desirability of a permanent staff.

- An important outcome of this workshop should be a list of major unresolved problems in geotechnical earthquake engineering which can only be addressed through large facilities, permanently instrumented sites and/or large field experiments. The NHPS could then take the initiative of forming research groups to look at these problems which would deliberately include a mix of people from government labs/agencies, universities and, one hopes, industry.
- This approach may alleviate the problems of sharing experimental data, as opposed to data which reside in a single research group or institution; a condition of funding may be that corrected instrumental data sets (although not necessarily their interpretation) must be released after a period which is negotiated with NHPS. **- Pedro de Alba**

***Q4B - ETHICAL CONCERNS.*** *Publication of experimental data, sharing of facilities, allocation of credit to experimentalists for their work, cooperative research throughout the research and the world, poses clear ethical challenges, especially in the transition period until people get used to the new culture and start abiding more or less automatically by the new rules. How do we address these ethical concerns? Any ideas? Should we have a special task force or committee on ethics within NHPS, ASCE or another professional organization, start developing guidelines on these issues?*

It seems that how some of the ethical concerns associated with "networked" research consortia should be addressed depends strongly on the community of researchers involved. Researchers in some communities that, for example, can be encountered in the fields of high-energy physics, astrophysics, astronomy and atmospheric sciences, appear to be used to work in highly-integrated research projects with a large number of participants from several institutions and different countries. In fact, the needs of the high-energy physics community have, in great part, been responsible for the development of the www itself. According to the article by Ross-Flanigan (1998) referred to us, it seems that those communities of researchers have long developed guidelines to address those ethical concerns and are very comfortable with them. On the other hand, this does not seem to be the case among the community of researchers in earthquake engineering where small groups of researchers and or individual researchers seem to be the norm.

Ethical concerns should not only be associated with publication issues and allocation of credit but also with patents, copyrights and commercial gain, particularly in the field of engineering where a goal of the research is the development of tools to be used for commercial purposes. An additional issue that was referred to by others in the newsgroup is the accuracy and validity of the data. How can the data be reviewed? If there are undesirable consequences from the use of "unverified" data can some of the responsibility be allocated to those who made the data available? The article by Ross-Flanigan (1998) implies that before "networked" collaborations are established by groups without a strong tradition of large collaborative research efforts, that the participants should agree on guidelines to be developed through a very thorough and open process. Some of the "networked" programs referred to above appear to have agreements or guidelines that address some of these issues. These guidelines and their consequences can be investigated to ascertain whether they have fostered adequate research and technology transfer environments. Judging by the recommendations of those investigating "networked" research programs and the fact that other consortia have found it useful to establish guidelines on ethical issues, it seems that the establishment of a task force to ascertain the impact of such guidelines on other "networked" programs and to initiate the development of such guidelines is well-warranted. Reference: Ross-Flanigan, N., "The virtues (and vices) of virtual colleagues," MIT Technology Review, April 1998. **- Jose Pires**

As we move into an age in which the sharing of information between researchers is greatly facilitated by the network, the opportunity for unethical behavior is certainly greater than ever before. I question, however, if the "old" rules of conduct are not still applicable. Clearly, credit should still be given to the producer of data when it is used in subsequent work. Also clear is that in a collaborative effort all parties involved should be credited with their contributions. The question is, how is this any different than in the past? The ethical rules haven't changed. What has changed is the ease with which the unscrupulous can break the rules. I fail to see how a task force or committee is going to make a difference in this regard. **- Jonathan Stewart**

I support the idea of an ethics committee within NHPS. A number of issues may arise in multi-investigator, multi-institution, projects in which some form of ombudsman/ethics committee for NHPS might be useful. Geotechnical earthquake researchers form a relatively small village, and the committee's decisions could prove quite persuasive to those who wish to use NHPS facilities again.

Some issues which the committee might consider:

- Premature publication without acknowledgment of other members of the research team, or other misuse of data.
- Honest disagreement over the validity/interpretation of the data.

- Assignment of credit, f.ex. in order of authors on publications. In this case the panel's role would be more towards educating the academic "bean counters" and changing the current culture than in solving individual cases. In experimental physics, for example, large research groups are identified basically by acronyms, and participants are listed alphabetically. As Adams* (1991) puts it: "Publications in experimental physics may list dozens of authors, a fair testimonial to the impossibility of separating personal contributions from the common goal."

A radical solution would be for NHPS to require alphabetical listing of collaborators in publications directly resulting from research at NHPS facilities.

A less radical solution would be for NHPS to require that this problem be resolved internally by the principal and co-principal investigators as part of the proposal. **- Pedro de Alba**

(*) Adams, J.L (1991) " Flying Buttresses, Entropy and O-Rings: The World of an Engineer," Harvard University Press.

If the NHPS network is conducting research with good results that are applicable to government agency needs and can be applied to specific current problems, the government agencies and research laboratories will be interested in cooperation and collaboration. They will be interested in leveraging research dollars.

I do see a problem with private companies and industry. They will be interested in conducting proprietary research and creating and maintaining an edge on competition nationally and internationally. Private companies and industry will probably not want to make data and results available publicly. **- Ledbetter**

***T1 Research Topic.*** *Study of response, deformation and failure of soil embankment systems used in dams, dikes, levees, as well as highways and bridge approaches, and of natural slopes, with emphasis on large deformation/failure phenomena. Problems in Topic 1 generally involve large static driving shear stresses.*

*T1a) Outline examples of "networked" research program(s)*
*T1b) Visualize specific examples of how specific facilities and researchers should be networked.*
*T1c) Summarize the facility needs to address the research topic.*

It is obvious that not every type of structure can be studied in the "networked" effort. Therefore, within the research topic, a couple of centrifuge model configurations can be selected to demonstrate repeatability and "calibrate" the sample preparation procedures, new or enhanced equipment, transducers, and data acquisition techniques. Practicing engineers can offer their input on the situations which have the least seismic design methodologies available. Also, it would be appropriate to select the model configurations in order to simulate the proposed instrumented field sites (Section 2.3 of NHPS/UCD#1) and the earth structures that might be subjected to earthquake-like motions using Mobile Seismic Wave Sources (Section 2.4 of NHPS/UCD#1). The proposed large-scale 1g laminar box (Section 2.2 of NHPS/UCD#1) might not be necessary and also large enough to accommodate realistic earth structures such as dams, landfills, and bridge abutments. It might prove to be useful for conducting 1g tests on natural slopes and landfills.

For the centrifuge tests, depending on the model configurations finally selected, special containers such as laminar or hinged-plate boxes may or may not be necessary. Embankment alone would not require a laminar container. On the other hand, if the foundation soil or loose sand backfill behind a dike have to be modeled, a laminar container would be more appropriate. Depending on the soil type, discrepancy in dynamic and diffusion time scales, and strain rate effects may or may not be an important issue to be considered.

It would be very helpful to take decisions on various centrifuge modeling techniques in the initial stages of the project before even the experiments are conducted, so that all the participants would follow the same procedures. There are no established criteria for issues such as substitute pore fluids, reduction of particle size, strain rate effects, sample preparation technique such as raining versus compaction, the most effective saturation technique, treatment of boundaries for stress wave reflections and plane strain simulation, specific transducers, and so on. Although various suggestions have been made by different individuals, some research is still necessary to fill in the blanks. It may be worthwhile to assign some funding from the total budget for studying such fundamental issues. Centrifuge researchers can use the proposed NHPS project as a platform to finally get together, brainstorm, and select the best available techniques to overcome some of the above mentioned issues which always haunt back at the end in the analysis stages in what-if situations. The same can be by the experts in laboratory and field testing.

Some model configurations could require large sized models tested at high g-levels in centrifuge. Models of typically smaller structures such as small embankments and levees can be tested in smaller centrifuges. Some of the problems such as highways and bridge approaches may require 3D models; however, structures such as dams, dikes, and levees could be plane-strain. 2D or 3D shaking motions will be a tremendous advancement. However, it may be necessary to first conduct 1D shaking tests to understand their basic behavior before proceeding with more complicated 2D and 3D shaking. Since the focus of the project is to simulate realistic situations and not so much to validate FE programs, it is the time to take a step forward from VELACS and use a suitable substitute pore fluid or any other valid approach to take care of the discrepancy in time scales. The tests can still be used for validating design or numerical procedures and at the same time they will provide more realistic simulations. Availability of multiple sets of instrumentation can increase the productivity. Several models can then be prepared simultaneously without wasting time in waiting for the transducers that are already being used in a model in centrifuge.

After the model configurations are selected, the centrifuge experiments can be conducted at two or three different centrifuge facilities. These facilities can be selected after considering their capacity in terms of the maximum g-level at which the shake table can be operated and the corresponding maximum payload, and physical permissible size of the model in order to incorporate simulation of realistic prototype sizes. Each participant can conduct experiments at different g-levels in order to incorporate twofold purpose of performing modeling of models of the instrumented or artificially shaken prototypes and calibration of the facilities as discussed above. One facility can be made in-charge for each model configuration. That facility can then be responsible for productive organization of the collaborative effort for that particular model.

Two or three configurations will not provide all the information needed for a breakthrough advancement in the state-of-the-art of the seismic design procedures for those problems. Once confidence is established by repeating experiments at different facilities, conducting modeling of models, and validating with 1g measurements, various possibilities for further research in centrifuge, laboratories and field for better understanding of the phenomena can be discussed among all the participants of NHPS. Participating universities can then select specific areas for further research. The graduate and doctoral students involved in the main testing program can pursue their dissertations in the topics that are most important as determined by the entire NHPS community. **- Mandar Dewoolkar**

I envision "Networked Research" as encompassing two distinct approaches: (i) multiple experiments/measurements for a large scale field or laboratory test and (ii) sharing of experimental data from a large scale field or laboratory test. With respect to the first approach, the Principal Investigator setting up a large-scale test generally has a specific, often narrowly focused problem he is interested in investigating, e.g., lateral spreading of an embankment on liquefied soil. However, ancillary measurements or experiments may provide valuable data on other problems at minimal additional cost. For example, the lateral spreading test could also be used to validate time-domain effective stress site response models if appropriate measurements of pore pressure and acceleration are made in the free field away from the spreading embankment. Similarly, in a large-scale field test of the stiffness of a pile-supported foundation using explosives to generate earthquake-like ground motions, one may be able to set up a simple sliding block on a plane experiment using rigid and flexible masses to validate Newmark seismic displacement analyses.

To take advantage of this type of "piggy-backing," a large-scale test must be publicized well in advance to allow other investigators to develop ancillary experiments. Furthermore, the Principal Investigator must be amenable to facilitating outside participation, including providing technical and logistical support and perhaps even slightly modifying his primary experiment. Considering the large expense typically associated with generating earthquake-like motions for a large-scale test, there is little doubt in my mind that this can be an extremely cost-effective approach to large-scale experimentation. Performing large-scale tests in this manner would require a cultural change in the way geotechnical earthquake engineering is usually performed in this country, as alluded to in the second set of questions posed to workshop participants. One way this could be accomplished would be to perform large-scale geotechnical engineering experimentation in a manner similar to the way the space shuttle missions are organized. The large-scale test could be advertised in advance and experiment packages could be developed by different investigators and submitted for consideration. A panel of experts could then select experiments for the particular *mission* (large-scale test) under consideration.

The cultural barriers associated with the second approach to networking, sharing data from a single experiment, are more difficult to overcome. Principal Investigators tend to guard data from their experiments relatively closely, at least until they have had the initial opportunity to evaluate, analyze, and interpret this. This is an understandable tendency, given the professional pressures and human desire to gain recognition as the *first on the block* to recognize a phenomenon or develop a method of analysis. However, it can also be counter-productive to rapid advancement in a particular field, as the person performing an experiment may not necessarily be the best person to analyze the data and as it stifles new and creative approached to data analysis from investigators not in the mainstream. Perhaps the only way to accomplish rapid dissemination and sharing of data from large-scale testing for geotechnical earthquake engineering is to separate the experimentation from the analyst. Performing the large-scale test and disseminating the details of the test and the data to the profession would then be the only objective of the experimenter. His reward, or recognition, would come from performing the test itself, and not analyzing the data. This would remove the primary barrier to rapid dissemination and sharing of the data.

Examples of projects where data sharing has been used to some extent, both intentionally and unintentionally, include the Wildlife field instrumentation site in the Imperial Valley and the OII landfill. At Wildlife, site characterization data had been published before the earthquake generated field pore pressure records. As soon as the field data was published, several different groups of analysts, all of whom had access to the same site characterization data, analyzed the recovered pore pressure records. At OII, strong motion records were recovered by the USEPA and thus became public domain relatively quickly after the Northridge earthquake.

Papers on valuation of the properties of municipal solid waste by back analysis of these records were published simultaneously by three independent groups of investigators in a recent ASCE journal issue. It is also worth noting that the California Strong Motion Instrumentation Program is set up along similar lines. Recovered strong motion records are in the public domain and are available to all investigators for the cost of reproduction and postage.

With respect to facility needs for topic T1, because the focus is on large deformation, centrifuge testing is probably the most cost-effective means of large-scale experimentation. Large shakers and blast-induced vibration tests for the specific purpose of generating large deformations in a geotechnical structure are unlikely to be cost-effective means of generating large deformations in field experiments. The difficulty in generating the high amplitude ground motions required to induce large deformations and the *one-time* nature of such field experiments makes such testing costly. However, if a large-scale test using explosives is going to be performed for other reasons, cost effective large deformation experiments may be feasible. Instrumented test sites, while invaluable, are *long-return* propositions * you have to instrument an appropriate site and then wait. Therefore, to me, centrifuge testing offers the most promise for large-scale geotechnical earthquake engineering testing focusing on large deformation problems, despite the problems associated with such tests (scaling and similitude, end effects, inability to reproduce common liquefaction phenomenon, like sand boils, observed in the field, etc.). **- E. Kavazanjian**

Ta) Outline examples of "networked" research program(s)

Physics, medicine, etc. Perhaps the best examples of "networked" research programs in the engineering field are those associated with university consortiums. Consortia formed to address many different field of study have been formed; including those associated with traditional engineering research and that of engineering education. These consortia appear to provide a reasonable framework to emulate for the proposed effort.

Tb) Visualize specific examples of how specific facilities and researchers should be networked. Good knowledge of goals of each.

Ideally each researcher should be fully aware of the work of others. It appears that the internet is a powerful medium by which current updates, status reports, and research findings can be quickly disseminated.

Tc) Summarize the facility needs to address the research topic.

The primary facility needs to investigate this research topic would probably laboratory devices such as large-scale shear boxes and/or shake tables, and centrifuge testing equipment, as well as field measurement devices (pore pressures, movements). It shoud be noted however, that this question would ideally be best answered following the proposed workshop. **- James Martin**

A prime example of a "networked" research program is the VELACS project which coordinated the testing of centrifuge models to produce a data base which was used for the verification of numerical analysis schemes of liquefaction phenomena. Another example, which dealt with static loading of reinforced earth retaining walls, involved experiments carried out by a single laboratory (University of Colorado at Denver) from which results were used as the basis for Class A predictions by about 15 research teams around the world.

It is envisioned that research can be coordinated among research teams with expertise in various aspects of earthquake geotechnical engineering, such as site characterization, constitutive models, numerical analysis, and centrifuge model testing, to examine problems of large deformation and failure of earth structures. Attention must be placed on the selection of sites where access is available to existing data and where there is assurance of future cooperation. The national test sites would be prime examples of such locations.

Facilities that are needed to address such research topics would include drilling equipment, ground motion generators for field testing, dynamic testing equipment for material characterization using large samples, and centrifuges with suitable shaking equipment. It goes without saying that these facilities must be suitably equipped with modern instrumentation capabilities for them to be useful for the research to be conducted. **- Hon-Yim Ko**

I ask the groups pardon in my not being able to attend. I have tried to make the following discussion concise and hope that it is not distorted.

The current state-of-practice in earthquake engineering concerned with large deformation and failure in soil embankment systems of large dams, dikes, levees, bridge approaches, and high natural slopes can be forcing us to make possibly unnecessary excessive and costly seismic remediations or unsafe conclusions. We do not have enough information for the sites that form the earthquake response data base and the empirical basis for analysis and reality-checks. Improved definition and physical evidence is needed of the processes and mechanisms involved as soil progresses to liquefaction and residual strength in order to allow refined analyses for dam safety and soil embankment systems and more cost-effective and safe remediation design and analysis. Because we can make various assumptions coupled with methodologies and numerical analyses which can give solutions or answers to most anything, reliable physical evidence and the reality-checks of analyses must come from both field and equivalent-field data of behavior form well known and defined conditions under dynamic loading such as from centrifuge model experiments.

In application of the state-of-practice, we inherently make some or all of the following assumptions: (1) the soil is always undrained, (2) liquefaction occurs instantaneously and the soil shear strength jumps to residual state, (3) residual strength is constant with monotonic loading, (4) liquefaction is independent of soil zone thickness, permeability, or boundary conditions, (5) liquefaction is independent of when the earthquake peak energy arrives, (6) behavior of the liquefied soil and its resultant effects on a soil embankment system are independent of the soil zone thickness, permeability, and boundary conditions, (7) soil embankment system stability and deformation are controlled by slip-planes independent of the liquefied soil zone thickness and behavior, and (8) non-liquefied soil at a site is unaffected by the earthquake.

Significant progress is being made in the development of numerical methods for analyses of liquefaction and the consequences. However, the engineering profession will most likely always use empirical correlations of in-situ measurements vs potential liquefaction, pore water pressure generation and earthquake response. Every time a site is evaluated for a seismic design and a soil embankment system remediated, in-situ measurements will be made. A value/range of in-situ measurement to achieve will be specified for a construction/remediation contractor. Some in-situ measure will be used to judge soil conditions/improvement and seismic safety of a soil embankment or site. Therefore, improvement in our current state-of-practice and the empirical correlations between in-situ measures and performance of soil deposits has to be made.

I think that the problems in the current state-of-practice stem mainly from the fact that we do not know for the sites which have liquefied and constitute the empirical basis for analysis: (1) the exact and complete soil conditions and profiles, including complex profiles, (2) the real behavior that occurred in the soils during and after the earthquakes or the various influences on the behavior, (3) that the assumed non-liquefied soils (used in comparison to liquefied soils) did not develop pore pressures or stains, change state during the earthquakes or how, and (4) whether artificial and possibly incorrect conditions in laboratory testing may have led to conclusions not totally applicable to the field behavior.

Our earthquake response database needs to be expanded with more complete data in order to provide: (1) for advance in the state-of-practice, (2) a basis for modification and improvement of current methodology and assumptions, and (3) definition of the physical processes and mechanisms involved in the liquefaction process and resultant effects on soil embankment behavior. This would also provide the fundamentals and basis for development of new methodology and analyses. New methodologies have to be based on correct mechanisms and processes.

Current specific needs for more complete earthquake engineering analyses can be identified from examination of the last two decades of experience in seismic evaluation of soil embankment systems and the serious limitations that arise when remediation design is attempted. Due to the lack of knowledge and experience involving the behavior of liquefiable soils under field conditions, we are forced to make, for the critical safety of soil embankment systems, simplifying assumptions concerning behavior.

Some specific needs are: (1) well defined and complete shear stress-strain response curves for earthquake loading including the residual strength portion, (2) strains within a problem soil mass, (3) effects of soil zone thickness, permeability, and boundary conditions, (4) influence of adjacent soil materials and of their permeabilities, (5) dissipation and movement of excess residual pore pressure both during and after an earthquake, (6) redistribution of stresses as a soil is loosing strength, (7) interaction of remediation materials and adjacent soil, (8) dynamic response of remediation materials and of remediated zones, (9) improved Ks and Ka factors for the field evaluation of remediation achievement and for improved first estimates of liquefaction potential, (10) effects of strong aftershocks and (11) soil embankment system internal behavior and failure mechanisms in response to earthquake loading and strength degradation.

We will continue to gather better and better information from real earthquakes over the next decades. However, the state-of-practice and safety needs to be improved now to prevent the increasing loss of lives and property as our world population increases and to provide more economical remediation thus saving possible hundreds of millions of dollars. This can be started presently and achieved by reseach with model experiments and dynamic shaking on both shake-tables and, primarily, centrifuges. We can start conducting complementary and integrated research and experiments (not multi duplicates) on both national and international scale. There are enough needs in earthquake engineering that both small and large experiment facilities can purposely share and complement each other in the research and accomplishments under the NHPS. Large centrifuges can and should be used to extend modeling-of-models for verification. Large centrifuges should be used where research is required for deep foundations, high soil embankments, wide base embankments, adequate response free field, and wave propagation from base rock through soil foundations (simple and complex). The integration, sharing and complementing of research should be orchestrated by the management of the NHPS. Timely and specific working-meetings by integrated researches would be necessary; not general meetings where everyone in the program attends.

U.S. centrifuge facility and upgrade needs for accomplishment of the NHPS needs in earthquake engineering, in my opinion, include: (1) developments and improvements in miniature instrumentation, (2) better data acquisition systems such as optical slip rings, (3) 3-D dynamic shaking systems, (3) electrical and mechanical engineering expertise in centrifuge technology applied to soils and soil systems, and (4) miniature geophysical techniques for use in flight. **- Ledbetter**

***T2 Research Topic.*** *Study of response and large deformation in level and gently sloping ground, including effects on structures and facilities such as buildings, bridges, pipelines, and waterfront and retaining structures.*

*Ta) Outline examples of "networked" research program(s)*
*Tb) Visualize specific examples of how specific facilities and researchers should be networked.*
*Tc) Summarize the facility needs to address the research topic.*

To start with the obvious, the ultimate test of any design method is how it can model actual field behavior. Consequently, instrumented field sites are an indispensable part of verification. In the organization and selection of such test sites for geotechnical earthquake engineering, our experience with the National Geotechnical Experimentation Sites (NGES) program, and specifically with the Treasure Island site in San Francisco Bay, is relevant.

What we have found to be absolutely indispensable is to have a permanent, active, group of researchers associated with the site, who are interested in maximizing its use during what may be a long waiting period (e.g. microtremor studies, prediction exercises, etc.) and are willing to deal with the inevitable problems which will arise during the years which may pass before a strong motion event occurs. We have found (rather to our surprise) that many academic researchers do not choose to make this type of long-term commitment, which is not perceived as a rewarding effort in the current academic culture.

For any field site, the major problems which have to be dealt with are:

- Site ownership: who owns the structure or piece of ground where the instrumentation will be installed? Is long-term ownership assured? Treasure Island belonged to the Navy when the site was developed (1992), but is currently being transferred to the City of San Francisco. We are currently in contact with the City to make sure the site is taken into account in the master plan for future development of the island.

- Site characterization: at Treasure Island, an extensive site characterization study was carried out when the instruments were installed; however, as new field techniques are developed, it may be necessary to critically re-examine the available geotechnical data, and to revisit the site periodically to make new measurements. At any given site, who will decide which measurements to make, and find funds to carry out the work?

At Treasure Island, because a great deal of geotechnical data is available, an important use of the site is to check new exploration techniques against the existing database. In the case of an investigator who wishes to use a new characterization technique at the site, s/he must agree to release the full raw data set (if not its interpretation) within an agreed-upon period. This period is negotiated on a case-by-case basis with the site manager.

- Instrumentation maintenance and upgrades: Who will periodically check the instruments, carry out repairs and upgrade the instrumentation over a period of years? At Treasure Island, routine maintenance is carried out by the California Strong Motion Instrumentation Program (SMIP), which has incorporated the instruments into its network. However, SMIP does not consider it part of its obligation to make major repairs or to upgrade the installation with new instruments, or to incorporate instruments of other types.

- Data dissemination: In the case of Treasure Island, SMIP's charter requires timely publication of all accelerometer data acquired. Geotechnical data for the site is available to everyone at the NGES website. A similar model should be considered for other instrumented sites, i.e. prompt dissemination of the basic measurements, with instrumental data and geotechnical data available on the world wide web. In the current academic culture, this might be a problem at sites which are owned and operated by a particular institution/research group. It would be up to the funding agencies to make it very clear that funding is conditional on prompt dissemination.

Recommendations:

- Field sites are an essential part of model verification. Appropriate sites and structures should be identified and instrumented, both in the U.S. and abroad.

- "Top-down" pressure must be exerted by funding agencies to make sure that all data is shared in a timely fashion.

- Any proposal for establishing an instrumented site should include a plausible long-range funding plan. Long-term funding to support a small, dedicated, control group for each site is essential. This control group would be charged with critically re-examining the state of site instrumentation and characterization on a regular basis, and insuring that the site www database is updated in a timely fashion.

It should be noted that some sites have been installed by state or federal agencies; these have not been uniformly successful, as funding crises, changes in personnel or shifts in research interests by the people involved have resulted in the abandonment of the instrumentation. Ideally, a mix of university, industry and government researchers would form the oversight committee for a site, and insure its long-term survival.

- A general oversight committee, charged with networking all instrumented locations is also essential. A world wide web site should be established for this purpose. This committee would insure that earthquake records are made available promptly, and that all available geotechnical data for all sites is accessible, and updated as new studies are carried out. Another major function of this committee would be to identify potential sites for instrumentation, and to encourage local groups to take on the task of overseeing these sites.

-It is highly desirable to have a specialized state or federal agency in actual charge of routinely checking and maintaining the instrumentation itself. These organizations have the technical expertise to do this efficiently. An annual fee may be required for this purpose, and should be incorporated into the long-range plan of each site. **- Pedro de Alba**

***T3 Research Topic.*** *Evaluation of effectiveness in reducing the earthquake hazards due to ground failure and ground deformation. New ideas for ground remediation and retrofitting of foundations and structures for new and existing facilities.*

*T3a) Outline examples of "networked" research program(s)*
*T3b) Visualize specific examples of how specific facilities and researchers should be networked.*
*T3c) Summarize the facility needs to address the research topic.*

This response addresses the T3 Research Topic. I don't see how we can deal with T3a, T3b, and T3c until there is some idea and agreement about what the research topics should be. I see the T3a, T3b, and T3c responses as being workshop outputs.

Ground remediation has now been shown to be effective in preventing or reducing earthquake-induced ground failure. Just as liquefaction potential depends on the input motions and the in-situ strength of the ground; the resistance of treated ground depends on the improved strength in relation to input motions. Essentially no failures were recorded in improved ground in the Loma Prieta earthquake; however, some settlements and lateral displacements were observed in Kobe. There is some evidence that the SPT (N1)60 and CPT (qc)1 values provide a good measure of the resistance of improved ground (same liquefaction potential curves as untreated ground. Some forms of remediation can eliminate liquefaction potential altogether.

New and Improved Treatment Technologies that deserve further evaluation and potential application include:

1. Deep soil mixing
2. Explosive compaction
3. Drainage as a stand-alone method
4. "Passive site remediation" using slow permeation grouting.

Problem situations of special importance and requiring more research include:

1. Liquefiable silts
2. Liquefiable soils containing cobbles and boulders
3. Ground improvement in and around existing foundations.

Design and performance evaluations are needed relative to the following:

1. Relative effectiveness of different improvement methods, dynamic response of treated ground, required areas and depths of treatment, and deformations adjacent to treated ground.
2. Further validation of the suitability of SPT, CPT and shear wave velocity measurements as indicators of the liquefaction resistance of treated ground.
3. Methods for estimation of time-dependent post-treatment increases of stiffness and strength.
4. Applicability of "two-level" mitigation strategies - (1) avoid significant damage under design earthquake, (2) prevent catastrophic failure under the MCE.
5. Consistent and practical design methods for lateral spreading barriers.
6. Methods for prediction of pore water pressure generation and deformations within densified ground.
7. Better understanding of the consequences of failing to meet densification specifications at every point in a treated volume.
8. Potential usefulness of energy-based methods (e.g., Arias intensity) for design of ground improvement and for assessing the liquefaction resistance of treated ground. **- James K. Mitchell**

With respect to soil improvement research, it seems that two general types of experimental projects can be envisioned - large-scale, field-based investigations of the effectiveness of existing and new techniques, and smaller-scale laboratory-based investigations of the mechanics of existing and new techniques.

The first type would require instrumented field test sites which must be thoroughly characterized - perhaps the NGES sites (Treasure Island, specifically) would be involved.  Other sites being developed or improved by public agencies such as state transportation departments could also be utilized, IF the research community is made aware of potential opportunities in a timely manner.  Any such project would require the participation of the types of specialty contractors who have been responsible for innovations in this field.  Given the low margins on which such contractors operate, some incentive would be required to attract their participation. Perhaps something analogous to the SBIR program would be possible.

The second type of project would likely involve model testing and/or small-scale field testing under carefully controlled conditions. Such projects might benefit from the formation of two teams, both of which would be funded. The first would be the primary experimental team which would design and conduct the experiments. The second would be a validation team which would review and comment on the experimental design prior to testing, and validate the experimental results after testing. Those desiring to receive funding to perform experimental research would be expected to serve on validation teams for other projects. The validation team's activities would require considerable effort and add to the cost of the research and the time required to post the results, but would likely improve the quality and reliability of the results.

Regarding specific topics in this general area, I have little to add to the list of potential topics proposed by Prof. Mitchell. Remediation of pile foundations in soils susceptible to lateral spreading, using both geotechnical and structural means, is worthy of attention. For all specific topics, however, I believe that research should be directed toward the development of performance-based design procedures. This will require improved understanding of the mechanisms responsible for improvement with many existing techniques. As the earthquake engineering profession moves toward performance-based design, mitigation of hazards by soil improvement should not lag behind. **- Steven Kramer**

The 1995 Kobe earthquake was the real-scale natural destructive experiment which sacrificed lives of more than 6000 people. Why not make the best use of the precious experiences gained during the earthquake not only for negative aspects but also for positive aspects where seismic countermeasures worked successfully. Nature tells us much more eloquently than model tests and also gives us a clear image on what type of model test should be chosen.

Soils and Foundations did and will accommodate research papers on case studies of ground, soil structures, buried structures and foundations during the Kobe earthquake in the two special issues in January 1996 and in September 1998. In these volumes, the degree of effectiveness of soil improvements against liquefaction settlements is fully demonstrated for various types of improvement scheme (e.g. Yasuda et al. 1996). The effect of rigidity of deep foundations on foundation damages due to lateral flow in liquefied soil is also shown very clearly (e.g. Matsui et al. 1996) based on a number of actual performance data of piles and caisson foundations along the coastal highways in the Kobe area. The raw data for geotechnical conditions for the highway foundations have already been made available by the Hanshin Express Way Corporation. The effect of soil reinforcement in railway embankments is also quantitatively shown (Tatsuoka et al. 1996).

There has been a joint research group making use of the case histories of the Kobe earthquake chaired by Prof. K. Ishihara with secretary, Y. Goto, where the seismic stability performance in reclaimed land in the Port Island during the earthquake is intensively studied. This Masa soil site is located just next to the liquefied site (only 100m far) where the famous vertical array records were obtained. Thanks to soil improvement by rod compaction scheme no trace of liquefaction was witnessed in the earthquake. Twenty companies from industries joined the group with the research fund and members from universities also participated in the research. The main aim of the research was to quantify in-situ liquefaction strength of the improved Masa soil, decomposed granite containing about 50% of gravel, by in-situ tests and lab tests based on undisturbed samples taken by in-situ freezing sampling technique. Empirical relationships correlating the undrained cyclic strength by the laboratory test and the in-situ test values were developed for this site. Because the recorded seismic motions are available in the neighboring site, dynamic response analyses were carried out based on the in-situ and laboratory test data. The detailed data are available in a report (in Japanese) to be published soon, and there will be a small symposium on the research results this year in Tokyo.

Some new ideas for ground remediation and retrofitting of foundations and structures for new and existing facilities may evolve from close scrutiny of these case studies for the Kobe earthquake. For new facilities, one can have a variety of choice from different type of remedial or retrofitting measures in view of economy. For existing facilities or in highly developed urban area, engineers have to choose remedial measures against liquefaction from only a few options; excess pore-water drainage, cement mixing, grouting etc. The scaled model tests on 1G/centrifuge shake table tests have been and will be carried out to examine the effects of these measures, but in many cases models are too small to reproduce every detail of the geotechnical and remedial conditions. Therefore it is of utmost importance to focus the interest of the experimenter on essential aspects of the phenomena. To do this a close study on case histories on destructive earthquakes like the Kobe earthquake goes a long way. **- Takaji Kokusho**

I would like to share the following thoughts which may be of relevance to topics T1, T2 and T4 as well (some have been mentioned already in other messages):

1. Integration of earthquake case histories and/or in-situ experiments with: a) laboratory studies and modeling, and b) subsequent design/computational analyses.
2. Use of site-specific soil materials (as opposed to clean sands or silts for instance) in our experimental laboratory investigations (including centrifuge models).
3. Greatly increase the deployment of in-situ sensors, and the use of WWW communications for real-time monitoring and condition assessment (essentially make it a routine process).
4. Increase our exposure to the role of robotics in civil engineering construction, sub-surface guided exploration (e.g., directional drilling and sampling, sub-surface ground modification, and condition assessment of underground facilities and foundations), in-flight centrifuge model testing, and other applications.
5. Increase the exposure of our undergraduate students to sensor technologies (measurements), electronic data acquisition systems, and signal processing techniques (long-term educational objective).
   **- Ahmed-W. Elgamal**

I would like to add/reinforce the following few comments to those already posted.

Other issues in ground improvement include:

- extent (lateral and vertical) degree of treatment to meet performance criteria, including the interaction of a treated zone with surrounding liquefied soils.
- composite behavior of treated ground (e.g., stone columns within the surrounding soil), which is closely related to the issue of uniformity of treatment (effect of loose pockets)
- treatment, and evaluation of treatment, in highly interlayered soils (e.g., silty sands and low-plasticity silts interlayered with sands)
- plus all the issues relevant to predicting the triggering or consequences of liquefaction.

Other treatment methods that warrant further study include:

- in-ground walls (e.g., deep soil mixed walls)
- reinforced soil pads that limit differential settlements due to liquefaction of underlying soils

Facilities for ground improvement studies would need to address construction methods and seismic behavior. Construction methods can be studied in the field, where natural complexities are properly reflected, and in large-scale testing bins, where the conditions are controlled. The latter facility may enable certain construction mechanisms or issues to be studied in ways that aren't possible in the field. Of course, seismic behavior of treated ground can be studied through case histories and laboratory simulations. A large enough shaking table could enable the testing of models that are treated by some full-scale (or near-full scale) construction methods and evaluated with full-scale in-situ testing methods (e.g., a CPT), both of which have significant merits. Further development of centrifuge facilities should include in-flight penetration (mini-CPT) tests, in-flight shear wave velocity measurements, improved measurements of specimen density, etc.

Regarding networked research programs, I would echo the need for an oversight organization with professional staff and detailed archiving of data. **- Ross Boulanger**

Let me first address the research needs in remediation and retrofitting and then offer a few suggestions of how to initiate a networked research effort. Let me also preface my suggestions by saying that I have not been that active in ground remediation, so please forgive my ignorance...

It appears to me that our efforts to date have been consistent with a "brute force" approach in which we densify or grout a large percentage of the volume of soil requiring treatment and use empirical or semi-empirical tests to judge the effectiveness of the improvement. Have we adopted this "macroscopic" approach because we have a poor understanding of the "microscopic" material behavior that must be modified to reduce the liquefaction susceptibility? I think it's interesting that both very small strain (i.e. seismic) and very large strain (i.e. SPT and CPT) tests are used to assess the extent of the soil improvement. That indicates to me that we don't know (or can't agree on) what aspects of material behavior are most significant in reducing liquefaction susceptibility.

Thus, I would argue that research efforts in this area should also focus on microscopic material behavior with the aim of making our macroscopic remediation efforts as efficient as possible. I think this approach is consistent with Dr. Kramer's suggestion that we use performance-based measures to judge the effectiveness of a particular approach if we include efficiency in the definition of performance. I also agree with suggestions from Professors Mitchell and Boulanger that we should examine the behavior of composite systems composed of untreated and treated soil to gain a better understanding of what minimum percentage of the soil must be treated to have the desired result.

This multi-scale approach also lends itself to networked research efforts. I liked Dr Kavazanjian's suggestion in response to Question T1; he suggested that we adopt the approach that NASA has used for shuttle-based research of having "packages" that complement one another. For example, in a large scale simulation designed to study remediation, one researcher or team could focus on the macroscopic aspects of the test while another could focus on microscopic behavior. There could be other "packages" involved such as construction techniques, material characterization, pore pressure response, etc. **- Glenn Rix**

With respect to soil improvement research, it seems that two general types of experimental projects can be envisioned - large-scale, field-based investigations of the effectiveness of existing and new techniques, and smaller-scale laboratory-based investigations of the mechanics of existing and new techniques.

The first type would require instrumented field test sites which must be thoroughly characterized - perhaps the NGES sites (Treasure Island, specifically) would be involved. Other sites being developed or improved by public agencies such as state transportation departments could also be utilized, IF the research community is made aware of potential opportunities in a timely manner. Any such project would require the participation of the types of specialty contractors who have been responsible for innovations in this field. Given the low margins on which such contractors operate, some incentive would be required to attract their participation. Perhaps something analogous to the SBIR program would be possible.

The second type of project would likely involve model testing and/or small-scale field testing under carefully controlled conditions. Such projects might benefit from the formation of two teams, both of which would be funded. The first would be the primary experimental team which would design and conduct the experiments. The second would be a validation team which would review and comment on the experimental design prior to testing, and validate the experimental results after testing. Those desiring to receive funding to perform experimental research would be expected to serve on validation teams for other projects. The validation team's activities would require considerable effort and add to the cost of the research and the time required to post the results, but would likely improve the quality and reliability of the results.

Regarding specific topics in this general area, I have little to add to the list of potential topics proposed by Prof. Mitchell. Remediation of pile foundations in soils susceptible to lateral spreading, using both geotechnical and structural means, is worthy of attention. For all specific topics, however, I believe that research should be directed toward the development of performance-based design procedures. This will require improved understanding of the mechanisms responsible for improvement with many existing techniques. As the earthquake engineering profession moves toward performance-based design, mitigation of hazards by soil improvement should not lag behind. **- Steve Kramer**

***T4 Research Topic.*** *Ground response and soil-foundation-structure interaction due to seismic shaking.*

*T4a) Outline examples of "networked" research program(s)*
*T4b) Visualize specific examples of how specific facilities and researchers should be networked.*
*T4c) Summarize the facility needs to address the research topic.*

(A)

I am not aware of "networked" research programs in this area. I know of ground motion databases that can be accessed through the internet. A link to most of these databases can be found in the web page for the geotechnical engineering server at the University of Southern California.

http://rccg01.usc.edu/GEES/links.html

This is, in fact a very informative server. I should also say that these ground databases follow different formats and, for most of them, it is very difficult to identify what you may need. Detailed and quantitative information on the site conditions, details of the instrument and its installation, etc., are also not available for most of them.

I am aware of "networked" research programs in other disciplines which may be investigated to know if something of interest can be learnt from them. These "networked" research programs are very varied in scope and objectives and something may be learnt from them.

Within ARA there is a intranet which can be used to disseminated information through the company but it has not yet advanced to a stage that it may be considered a integrated "networked" tool for the solution of complex projects. We have conducted a project that required measurement of ground motions from mine blasts in Wyoming, retrieval of the data at the site, and then transmitting of the digitized office to my office in Albuquerque where I analyzed and processed the data. Internet resources were used but this was a relatively small project.

(B & C)

As an example (undeveloped example) I will refer to the simulation of ground motions with explosives. It is expected that the simulation of ground motions with explosives would have to take place in the filed at a relatively remote location with difficult work conditions (including limited access to electric power and even limited vehicular access). This is a situation that would call for remote activation of the instrumentation, storage of the data near the transducers and, if possible, telemetric data transmission to an office site where the data could be processed, analyzed, archived and distributed to those authorized or participating in the experiment.

Although not explicitly requested in items (a) (b) and (c), I would like to refer to some experimental facilities that may be needed under this topic (T4) and some of their possible uses.

1. STRONG MOTION INSTRUMENTATION - selection of sites and instruments, and fielding and maintenance of the instrumentation. (examples of issues: basin and site effects, spatial variation of strong motion, variation of strong motion with depth, identification of site properties and soil properties from recorded ground accelerations, large-scale soil-structure interaction experiments such as pile-soil-structure interaction.)

2. POST-EARTHQUAKE MOBILE LABORATORY - (examples of issues: site characterization for large-scale SSI experiments, aftershock data, damage assessment)

3. CENTRIFUGE WITH SHAKERS - (examples of issues: soil-structure interaction including liquefaction, e.g., pile foundations for bridges, waterfront structures)

4. GROUND MOTIONS WITH EXPLOSIVES - (examples of issues: large scale soil-pile-structure interaction including liquefaction, earth-retaining structures; wave path effects, system identification techniques based on recorded ground motions, large scale structural testing, testing of heavy equipment like 500 kV circuit-breakers and transformers)

5. SHAKING TABLES - (examples of issues: small-scale SSI for pile foundations on soft soils) **- Jose Pires**

a) Example of a "networked" research program: None that I know of

b) Envisioned networked program

UNS/NeTI Facility - The University of Nevada, Reno (UNR) and UNLV of the University of Nevada System (UNS) in Cooperation with the Nevada Testing Institute (NeTI) located at the Nevada Test Site would provide a combined 100-Ton Shake Table (on the UNR campus) and Full Scale Explosively Excited Soil Island test facility. A 10 ft x 10 ft x 6 ft high laminated soil box (currently being built with FEMA money) will provide shake table tests on soil and model pile and pipe structures that can also be tested in model and large to full scale size in the field at the NeTI facilities. The NeTI test will involve as much as a 50m x 50m x 25m deep soil island (a slurry filled trench along three sides and a layered neoprene explosive soil bag along the fourth side). Geotechnical, structural and seismological faculty from UNR and UNLV in conjunction with other project specific faculty will co-operate on various projects. Groups that could pool funds to support tests of common interest might be Caltrans/NDOT/FHWA Region 9 or NSF/FHWA or EPRI/NSF.

The soils to be tested would be sands and silty sands. The NeTI site is a silty sand site with tremendous soil suction. The strength and stiffness of such material can be varied by appropriate injection of water up to the case of liquefaction in smaller saturated areas within the soil island.

Alternatively, NeTI will network with other groups willing to propose and support tests. See the attached NeTI document.

c) Facility needs.

The UNR shake table with laminar soil box will require funds for instrumentation (accelerometers, pore pressure transducers, LVDT's, pressure cells) as well as sample preparation equipment (hopper, scaffolding) and sample characterization equipment (miniature cone). The data acquisition system already exists.

The NeTI Facility will require CPT, SPT and soil sampling which may be available from different cooperating agencies (e.g. Caltrans and NDOT) in the form of services in kind. Various sensors will be required in both the free field and then for project specific data on the structure or in the near-field soil. It is also envisioned that geophysical data should be obtained during testing (e.g. cross trench shear wave assessment during shaking). UNLV and/or Texas Austin has capability for the latter. **- Gary Norris**

These comments are similar to those of the other groups. One of the keys in running a networked research program, particularly one that is experimentally based, is going to be sharing of information and exchange of ideas PRIOR to conducting any experiments. For the group of researchers collaborating on a specific test series, a newsgroup to discuss test design and instrumentation would be an efficient way to exchange ideas. Particularly for expensive large scale tests, it is vital that instrumentation be openly discussed so that no potential vital data is overlooked or improperly obtained.

As far as facilities needed for soil-structure interaction, I think most agree that there must be a balance between relatively expensive full-scale tests (including field-testing of foundation and large/full-scale laboratory testing) and relatively inexpensive centrifuge tests. Ideally, we will be able to validate centrifuge tests using limited full-scale tests, and then expand the results using centrifuge.

Any networked research program should involve some component of each (or at least several) of the testing facilities. The newsgroups could then plan testing at each facility such that the same test conditions are addressed in order to facilitate the comparison between the tests (e.g. between centrifuge, large-laminar box, and field testing). **- Scott Ashford**

Answer to Q1B, Q2B, Q3A

I have worked with a government-operated research laboratory for several years in the past, and I still have close contact with the laboratory and the people working there. I hope my experience will be of some interest and value to this workshop.

The research laboratory was established in 1970 to operate the large-scale shaking table facility in Tsukuba, Japan. The facility was the largest in the world of its kind at that time, and it's the second largest at present. From the beginning, the facility was intended to be shared with researchers in other government research centers and in universities. Also, with private companies. Therefore, they had three types of research projects:

1. Internal research projects managed and executed by the researchers employed by the laboratory (NIED).
2. Joint research projects managed and executed jointly by the researchers at NIED and the organizations engaged in the projects. The researchers involved in the projects shared experimental results.
3. Experimental research projects contracted from private companies.

The operational expenses of the facility (including the maintenance costs) were funded 100 % by the government. For the first two types of projects, no operational fees were collected by NIED. But, NIED had a fee schedule set up for the third type projects. The fee was to recover partially the NIED's expenses due to huge electric bills.

The laboratory had four research engineers including a Chief; two civil engineers, one electrical engineer and one mechanical engineer. All had their own research interests. However, the electrical and mechanical engineers were there mainly because the facility needed highly educated engineers to take care of its electro-hydraulic shaking system. Two locally employed technicians had to be trained for a long period of time so that they could operate the facility by them. So, although the electrical and mechanical engineers had their own research interests, they had to attend almost all experiments and they were not very happy. Their publications and research productivity were interrupted significantly.

Operation of the facility became easy and systematic, as the technician gained enough experience. I recall that more than three years were needed to reach this stage. All the engineers except the Chief of the laboratory can now focus their efforts on their research projects of their interest.

Based on my experience, the operation of a large-scale facility could be done reasonably well by the scheme outlined below.

1. The facility designated as NHPS facility should be funded fully by the NHPS budget. Namely, the operational/maintenance and upgrading expenses should be funded fully. The level of funding to a specific NHPS facility should be reviewed and updated on a regular basis depending mainly on the level of utilization of the facility.

2. Non-commercial projects will not be charged for the operational expenses of the facility. Typical non-commercial projects are responsible for the expenses required for preparation-uninstallation of test models and for attending their experiments.

3. The facility should be operated under the supervision of a steering committee organized under the NHPS project. Each facility would have its own steering committee. The steering committee would consist of the manager of the facility, experts solicited by the NHPS project and representatives of the users of the facility. The major tasks of the steering committee would include at least: 1) Review of utilization of the facility. 2) Determination of the needs for maintenance and upgrading of the facility. 3) Organization and arrangement of a yearly schedule for experiments.

4. The facility would need a manager and technicians. The manager should not be a tenure-track position; its term may be limited to, say, three years. However, the technicians should be very much stationary. The salaries of these people should be funded from the NHPS budget. The major tasks of the manager include at least: 1) promotion of effective operation of the facility, 2) answering questions from the users of the facility, 3) promotion of usage of the facility and 4) dissemination of experimental results produced by the facility. The technicians should be able to operate the facility (including the data acquisition systems and transducers equipped in the facility) to meet experimenter's needs, to make test results available to the

Internet on a real-time basis and to do, at least, simple maintenance works. The experimenters or their employees should do model construction and instrumentation of test models.

5. All projects that utilize the facility should submit to the manager of the facility data reports that contain the details of test models and of experimental data produced within, say, six months (?) after the completion of the experiments. Major funding agencies should support funding for this purpose. The manager of the facility should announce the availability of data reports to the public through established means. Any revisions or comments/remarks that should be reported to the facility and should be appended to the data reports should be announced as updates from the facility manager at a later date within, say, one year from the completion of the experiments. Once a data report becomes available from a NHPS facility, anybody interested should be allowed to use the data. The data may be distributed at cost. However, all publications generated using the experimental data should clearly mention the source of data.

6. The facility should be equipped with a high-performance data acquisition system and most general-purpose transducers commonly used by experimenters.

7. The facility should be equipped with advanced video systems and Internet connections/tools to enable real-time test monitoring and supervision of testing. **- Kagawa** (in reply to Questions 1B, 2B, and 3A)

The following was submitted by Pete Mote at the request of Gary Norris

The Nevada Testing Institute

The NeTI Strong Ground Motion Testing Facility

In January of 1996, Bechtel Nevada (BN); a partnership between Bechtel Nevada Corporation, Johnson Controls Nevada Corporation, and Lockheed Martin Nevada Technologies Corporation, began managing and operating the NTS. BN's management and operations strategy for NTS is to make available the broad scientific and testing capability of the NTS to public and science communities. In keeping this strategy, BN, SRI International and the National Advanced Drilling and Excavation Technologies Institute (NADET) at MIT, established the non-profit Nevada Testing Institute, Inc. (NeTI), an international institute for applied research, technology development, testing, and demonstration of advanced underground, civil, structural, and seismic engineering, and mining. NeTI is incorporated in Nevada, has its headquarters in Las Vegas.

One of NeTI's primary missions is to develop a seismic testing facility for full-scale structures by capitalizing on the unique explosive technologies capabilities and experience that exist within the NeTI design team and the NTS complex. The facility will excited test structures through the application of strong ground motion using recent advancements in the RESCUE technique. NeTI intends integrate the testing facility into the national network of testing facilities through its adoption by one or more of the universities engaged in engineering research and testing.

The RESCUE, Repeatable Earth Shaking by Controlled Underground Expansion, Technique was developed by SRI International starting in the early 1980's through a grant from the National Science Foundation. RESCUE makes it possible to study the response of full-scale structures under simulated seismic loading that includes significant realistic soil-structure interaction. The technique consists of specially designed buried ground motion sources that expand and contract to produce oscillations in a soil cantilever or island, which result in realistic seismic response spectra. With this technique, dynamic loads can be applied to large-scale structures through the surrounding soil.

The capability of RESCUE has been shown through many numerical simulations and scaled tests. RESCUE, combined with a tailored soil island test bed, can provide realistic seismic response spectra for testing structures. The NeTI Strong Ground Motion Testing Facility applies its dynamic loads to the structure through the surrounding soil, thus, allowing for the study of the response of large-scale structures with the inclusion of soil-structure interaction.

The RESCUE technique produces ground motion by simultaneously expanding a planar array of buried vertical sources. Because the sources do minimal damage to the surrounding soil (applied pressure is less than 1 MPa), sequential pulses of ground motion can be applied, and follow-on tests can be conducted at the same location and on the same structure. Recent scaled tests have the capability of creating a very broad response spectrum and indicate that the full-scale facility, 150 to 200 feet on a side, will reliably and repeatably generate displacements approaching 20 inches and accelerations of nearly 4gs.