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ENGINEERING RESEARCH
State University of New York at Buffalo

SECOND-YEAR PROGRAM
In Research, Education and Technology Transfer

September 1, 1987 - August 31, 1988

Technical Memorandum NCEER-87-0028

March 8, 1988

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16. Abstract (Limit: 200 words)

The second-year research plan of the National Center for Earthquake Engineering Research (NCEER) is presented. NCEER's six basic research programs are chiefly described. These are the programs on: 1) Existing structures, 2) Secondary and Protective systems, 3) Lifeline systems, 4) International Cooperative Research, 5) Disaster Research and Planning and, 6) Education and Technology Transfer.

For each program, a brief overview, a summary of research projects or activities, long and short term goals and a list of principal investigators is given. Emphasized is the continuity of the undertakings anticipated for the second year with those of NCEER's first year. Collaborators from industry, consulting firms, government and academia are mentioned.

Seismic hazards and liquefaction potential in the eastern United States, the performance of lightly reinforced concrete buildings, resonance effects for nonstructural secondary systems and the seismic performance of water delivery systems are examples of the engineering research which NCEER will perform. In addition, international cooperative programs which NCEER will support or continue to support are described, as are workshops, lectures, and conferences sponsored by NCEER as part of its Educational and Technology transfer program.

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Introduction

The National Center for Earthquake Engineering Research is primarily concerned with research to improve basic knowledge about earthquakes, engineering practice and the implementation of seismic hazard mitigation procedures to minimize the loss of lives and property. Work is carried out using coordinated and integrated approaches. As stated in the Proposal, attention is primarily focused on structural systems and lifeline systems.

The second-year research plan of the Center as described herein has been developed in keeping with the objectives stated in the original Proposal. It is built upon the base established during the first-year research effort, and is the result of discussions that took place at a number of meetings involving members of the Oversight Committee, members of the Scientific Advisory Committee, Center Investigators, and officials of the National Science Foundation.

The second-year research plan consists both of programs evolved from the first-year activities and new initiatives. The second-year programs are:

Program 1: Existing Structures
Program 2: Secondary and Protective Systems
Program 3: Lifeline Systems
Program 4: International Cooperative Research
Program 5: Disaster Research and Planning
Program 6: Education and Technology Transfer

The relationships between the first- and second-year programs are shown in Figure 1. The second-year thrusts are more focused, with more clearly defined goals and objectives.

Program 1, Existing Structures, incorporates parts of four first year research programs: Seismic Hazard Assessment in the Eastern United States, Ground Motion, Soil and Soil-Structure Interaction, Seismic Performance, Risk and Reliability, and Innovative Computing and Expert Systems. All effort started during the first year has been continued into the second year, however, the emphasis has been shifted from the various broad program area definitions toward the intensive study of existing structures of the type that are prevalent in the eastern United States. Five new projects have been initiated, thus further intensifying studies in this program area.

Program 2, Secondary and Protective Systems, is also a continuation of first-year work. These projects were formerly categorized under the first-year program, Seismic Performance, Risk and Reliability. For the second year, projects such as the study of base isolation devices, active and passive structural control, and secondary system behavior have been grouped together to intensify research into these important areas.

Program 3, Lifeline Systems, is a continuation of research started under two first-year programs: Ground Motion, Soil and Soil-Structure Interaction, and System Performance, Risk and Reliability. The second-year studies are con-

Second Year Programs / First Year Programs	Existing Structures	Secondary and Protective Systems	Lifelines	International Cooperative Research	Disaster Research and Planning	Education and Technology Transfer
Seismic Hazard Assessment in the Eastern United States	X		X			
Ground Motion, Soil and Soil-Structure Interaction	X		X			
Seismic Performance, Risk and Reliability	X	X	X			
Innovative Computing and Expert Systems	X					
International Cooperative Research				X		
Workshops						X
National and International Conferences						X

FIGURE 1 Relationship Between First-Year and Second-Year Research Programs

cerned with mitigating consequences of lifeline system failure. Effort is directed toward two existing lifeline systems: crude oil transmission systems and water delivery systems.

Program 4, International Cooperative Research, encompasses much more broadly based projects than the other program areas. New Agreements are underway with a number of researchers from Japan, Greece and Austria. First-year Agreements exist between NCEER and researchers in Japan, China and Taiwan, and are continuing.

Program 5, Disaster Research and Planning, is a new initiative being started during the second year. This program is designed to expand the Center's research concerns beyond the technical, scientific and engineering areas to include planning, economic, social and political aspects of disaster impact on social systems. Key elements include urban multiple hazard vulnerability, and post-earthquake reconnaissance investigations.

Program 6, Education and Technology Transfer, is an important continuing component of the Center's program. Planned activities in these areas during the second year include two Workshops, a monthly series of Seminars on Earthquakes, continued expansion of the Information Service, publication of Center research, and the publication of an English translation of a significant Japanese research report.

Research Team Organization

NCEER's research activities represent a coordinated and integrated approach to the study of earthquake engineering. As stated above, second year programs focus on the systems aspects of structures and lifelines, with an initial emphasis on earthquake hazard mitigation in the easern United States.

Coordinated research and team efforts are emphasized in all programs. In each area, a team of researchers has been formed to initiate a coordinated effort, define short-term and long-term goals and develop research plans for the second year and beyond. Research teams established for Programs 1, 2 and 3 are shown in Figures 2 through 4.

Interaction with Industry, Consulting Firms and Government Agencies

The major part of the second-year research program is being carried out by researchers at the participating institutions. However, interactions with, and involvement of industry, consulting firms and government agencies are a vital component of these activities.

In addition to their direct participation in the supported research programs, significant contributions have been made by industrial firms to the ongoing activities of the Center in the form of equipment, materials or personnel. Contributing industrial firms and personnel are shown in Figure 5.

Project Area / Institution	Ground Motion	Soil and Soil-Structure Interaction	System Response and Reliability				Risk Assess-ment and Social Impact
			Buildings	Bridges	Dams	Infra-structures	
Brookhaven National Laboratory					X		
Carnegie Mellon University			X				
City University of New York	X	X		X	X	X	
Clarkson University		X					
Columbia University		X	X	X			
Cornell University		X	X			X	X
H.J. Degenkolb Associates			X				
EQE, Inc.							X
Lamont-Doherty Geological Observatory	X	X					
Lehigh University			X			X	
Massachusetts Institute of Technology	X						
Memphis State University			X				X
University of Minnesota			X				
Metropolitan Transportation Authority of New York City						X	
Polytechnic University of New York			X				X
Princeton University	X	X	X	X	X	X	X
Rensselaer Polytechnic University	X	X			X	X	
Rice University		X	X			X	
University of South Carolina			X				
SUNY/Buffalo		X	X	X		X	X
Weidlinger Associates		X	X				X

FIGURE 2 Research Teams in Program 1, Existing Structures

Institution \ Project Area	Secondary Systems	Protective Systems
Clarkson University		X
Cornell University	X	
Florida Atlantic University	X	
George Washington University	X	X
Rice University	X	
Rensselaer Polytechnic Institute		X
SUNY/Buffalo	X	X
Texas A & M	X	X
University of California/Berkeley		X
University of Missouri/Rolla		X

FIGURE 3 Research Teams In Program 2, Secondary and Protective Systems

Project Area / Institution	Water Delivery Systems					Crude Oil Transmission Systems
	Ground Motion, Soil & Soil-Structure Interaction	Analysis of Seismic Hazard	Analysis of System Response and Vulnerability	Serviceability Analysis	Risk Assessment and Social Impact	
City University of New York	X	X				X
Columbia University			X			
Cornell University		X	X	X	X	X
EQE, Inc.			X	X		
Lamont-Doherty Geological Observatory	X					X
Memphis State University	X					
National Automonous University of Mexico			X	X		
Polytechnic University of New York				X	X	X
Princeton University	X	X	X	X	X	X
Rensselaer Polytechnic Institute	X	X	X			X
SUNY/Buffalo					X	X
University of Illinois	X					X
University of Tulsa						X
Weidlinger Associates	X					X

FIGURE 4 Research Teams in Program 3, Lifeline Systems

Project	Industrial Participation and Personnel
Processing of Strong Motion Data From Alaska	• Arco • Chevron • Exxon • Mobil • Shell
Strong Motion Instrumentation	• Kinemetrics, Inc.
Seismic Performance Evaluation	• H.J. Degenkolb Associates C. Poland
Seismic Risk Assessment	• Weidlinger Associates M. Ettouney
Seismic Reliability Analysis of Dams	• Brookhaven National Laboratory A.J. Philippacopoulos
Secondary Systems	• Nalge Company (A Division of Sybron Corporation) R. Mehra, M. McGill, B. Poczatek • Snyder Industries L. Khan, T. Barber
Base Isolation	• M.S. Capse Company M.S. Caspe • Watson Bowman Acme Corporation L. Pietrantoni
Viscoelastic Dampers	• 3M Company P. Mahmoodi
Active Control	• MTS Corporation A.J. Clark, N. Petersen, R. Lund, Y. Gutman • Takenaka Komuten Co. K. Kinoshita, Y. Fukao, H. Abe, N. Yamaguchi • Kayaba Industry Co. N. Haniuda, T. Kubo
Pipeline Field Experiment	• Weidlinger Associates J. Isenberg
System Response and Vulnerability Case Studies	• EQE, Inc. C. Scawthorn • Dames and Moore N.C. Donovan R.T. Eguchi

FIGURE 5 Industrial Participation in Second-Year Research Programs

Project	Industrial Participation and Personnel
Lifeline Systems	• Okumura Corp. S. Kishimoto • Kawasaki Steel Corp. T. Koike • Tokyo Gas T. Harada
Ground Motion Simulation	• Kajima Corporation* M. Miyamura K. Kanda • Central Research Institute of the Electric Power Industry K. Hirata
Spatial Variability	• Kajima Corporation* H. Ukon
Building Response and Reliability	• Shimizu Corporation T. Takada • Takenaka Komuten, Ltd. H. Seya
Soil-Structure Interaction	• Taisei Corporation K. Moriyama • Kajima Corporation* N. Ohbo K. Suzuki

* Supported through the Princeton-Kajima International Cooperative Research Program

FIGURE 5 Industrial Participation in Second-Year Research Programs, (Cont'd)

PROGRAM 1:
Existing Structures

1.1 Overview of Program Area

Existing structures, particularly important buildings and bridges, are designed according to provisions specified in codes and standards. These code provisions are intended to ensure satisfactory performance under loads imposed by users or nature during the lifetime of the structure. Loads imposed by nature include the effects of snow, ice, water, winds and earthquakes. All codes recognize the importance of the first four of these. Some, however, do not include provisions for earthquakes. Others, by reference, suggest the importance of seismic considerations in particular regions of the country, but are not sufficiently prescriptive to ensure compliance. Model codes have been developed in which the United States has been divided into seismic zones, each representing different degrees of seismic hazard, but these have not been implemented. Even if implemented, the model codes only apply to the design of new structures. A basic question still exists with regard to the strength of aging and deteriorating structures such as those prevalent in the eastern and central parts of the United States. Risk assessment for this class of structures is of particular importance, and is the primary thrust of this program.

Existing structures constitute a problem throughout the United States, but are of particular importance in the east for the following reasons: (a) the vast majority of structures are old and deteriorating, (b) with one or two exceptions, the building codes have not and do not contain seismic design provisions, (c) the dynamic performance of certain types of structures and structural details are known to be poor and/or are not well understood, (d) the seismicity and the effects of distant earthquakes are not well known, and (e) parts of the east are susceptible to soil-liquefaction and significant local soil amplification.

The goals of research in the area of Existing Structures are to:

- Estimate seismic hazards and develop applicable response spectra for selected urban areas in the east, such as New York, Boston, etc. Estimate liquefaction and soil instability potential for these sites. Develop practical methods to evaluate the soil-structure interaction effects, that account not only for site soil properties, but also for local geological and topographical conditions.

- Assess the performance of lightly reinforced concrete buildings. In addition, examine other types of structures that were not designed for earthquake forces. Initiate experimental programs to evaluate the safety characteristics of several structural components and configurations that are commonly used, and yet are judged to be seismically vulnerable. Some of these are: lightly reinforced and spliced columns, flexible floor systems, short columns, precast concrete construction, and flat slab buildings.

- Identify significant structural limit states corresponding to differing levels of serviceability and structural damage. Evaluate the consequences of a building response reaching a certain limit state, particularly the state of collapse. More importantly, estimate the consequences of the simultaneous collapse of a number of buildings within a given urban area. Then, with the probability of such a collapse limit state on the one hand, and the consequences of such failures on the other, examine the societal impact.

- Conduct laboratory and field tests to develop techniques for retrofit, repair and rehabilitation of such aging infrastructures. Aging and general deterioration in structural systems is an extremely difficult issue to address, but is an important element of consideration. Particularly, infrastructures in the northeastern United States are aging. This may well mean that any seismic resisting capability of these structures has been significantly reduced.

- Examine the adequacy of the format and specific provisions of codes and standards. Decisions must be made concerning the possibility of requiring different provisions for new structures as opposed to those required for retrofit or repair. Expert systems are helpful in improving the design process, and in establishing code formats.

While emphasis is placed initially on structures that are typically found in the central and eastern parts of the United States, the methodologies to be developed should be applicable to other regions as well.

1.2 Summary of Research Projects

The research studies in Existing Structures can be grouped into four large and several smaller efforts: ground motion, soil and soil-structure interaction, system response and reliability, and risk assessment and social impact. The largest group of projects is concerned with various aspects of risk evaluation of existing buildings, though some of this work also is applicable to new construction. Two groups are concerned with seismicity, ground motion, and soil response. The fourth deals with the response of structures: testing and analysis of various types of buildings or components, damage assessment, and, to a lesser extent, repair and retrofit. These projects and their interrelationships are shown in Figure 6.

Ground Motion

The collection and measurement of ground motion data for regions of moderate seismicity, specifically for the eastern United States is of critical importance. Attenuation relationships, design spectra, spatial variability, and seismic risk maps are being developed at LDGO, MIT, RPI, Princeton, and CUNY in a coordinated manner. Furthermore, the experimental, analytical, and expert systems projects, among others, provide input regarding their needs to this group. Several group meetings, and two specialty conferences (in 1987 and 1988) serve to coordinate the activities and goals of these ground motion projects.

Soil and Soil-Structure Interaction

The many problems remaining in the understanding of dynamic soil behavior receive a concentrated attention by NCEER with special attention being paid to soil types typically found in the East. In particular, emphasis is placed on the potential

Ground Motion

- Ground Motion, Instrumentation and Data Base
  LDGO
- Source Mechanism and Wave Propagation
  LDGO, RPI
- Seismic Hazard Curve
  LDGO, MIT
- Spatial Variability
  Princeton, CUNY

Soil and Soil-Structure Interaction

- Constitutive Modeling and Experiments
  Clarkson, Columbia, Cornell, Princeton, RPI, SUNY/Buffalo
- Dynamic Behavior of Soils
  Cornell, Princeton, RPI, SUNY/Buffalo
- Liquefaction and Large Deformation
  Cornell, CUNY, LDGO, Princeton, RPI, SUNY/Buffalo
- Centrifuge Model and Field Experiments
  Princeton, RPI, Weidlinger
- SSI; Large Basemat, Embedment, Pile Foundation, Secondary Systems
  Columbia, CUNY, Rice, SUNY/Buffalo
- Computer Code Development
  CUNY, Columbia, Princeton

System Response and Reliability

Buildings

- Adequacy of Codes and Standards
  Degenkolb, Weidlinger, Cornell
  Princeton
- Nonlinear Response Analysis
  - Response Modification Factor
    Memphis State, Princeton
  - Damage Models
    Columbia, Cornell, Poly U,
    SUNY/Buffalo, Weidlinger
- Nonlinear Analysis and Design of 3D Building with Interactive Graphics and Supercomputing
  Cornell
- Laboratory Experimentation and Experimental Verification
  Cornell, Lehigh, Minnesota
  SUNY/Buffalo, Rice, So. Carolina

Buildings (cont'd)

- Reliability Analysis
  Cornell, Memphis State,
  Princeton
- Expert Systems
  - Building Damage Evaluation
    Carnegie Mellon
  - Structural Design
    Cornell, Columbia
  - Architectural Design
    Lehigh

Bridges

- Response Modification Factor
  SUNY/Buffalo
- Damage Models
  Columbia, CUNY,
  Princeton

Dams

- Seismic Input Criteria
- System Transfer Function
- Limit States and Fragilities
  BNL, CUNY,
  Princeton, RPI

Infrastructures

- Inspection, Rehabilitation, Retrofitting, Field Experiments
  Cornell, CUNY, Lehigh
  MTA, Princeton, Rice
  SUNY/Buffalo, RPI

Risk Assessment and Social Impact

- Identification of Building Stock
  Cornell, EQE, Poly U, Weidlinger
- Probabilistic Risk Assessment
  - Individual Buildings
    EQE, Memphis State, Poly U, Princeton
  - Regional Risk
    EQE, Memphis State, Poly U, Princeton
  - Common Cause Effect on Buildings and Lifeline Systems
    Cornell, EQE, Memphis State, Poly U
- Social Impact
  SUNY/Buffalo

Working Group Interactions

- Buildings and Bridges groups on Response Modification Factor and Damage Models
- Bridges and Infrastructures groups on Damage Models and Inspection, Retrofitting and Rehabilitation
- Experimental group and Damage Model/Reliability group for verification of analytical models
- Experimental group and Infrastructures group on field tests
- Expert Systems group with Damage Model, Reliability group, Codes and Standard group
- Interactive Graphics and Supercomputing group with Expert Systems group and Experimental group

FIGURE 6 Research Activities in Program 1, Existing Structures

problem of soil-liquefaction and "Mexico City-type" soil amplification. These coordinated projects encompass several joint experimental studies at Clarkston, Cornell, Princeton, RPI, and SUNY/Buffalo. Interaction is achieved through regular meetings and exchange of scientists and students. Other investigations utilize field experiments (Weidlinger Associates and the International Program with Beijing Polytechnic University). Analytical soil-structure interaction methods are being developed at Rice, Columbia, Princeton, SUNY/Buffalo, and CUNY.

System Response and Reliability

The problem of the safety of existing buildings is addressed in several of the projects. The recently published ATC-14 document does not apply to the many older buildings common in the East. Several practicing engineers are cooperating in a project to write a building evaluation manual similar to ATC-14 for zones of moderate seismicity (Degenkolb and Cornell).

About a dozen experimental projects are concerned with the performance of typical building components. Most of the existing information regarding structural behavior is for new construction; these NCEER projects study weak links in existing buildings. One group of projects is concerned with studying reinforced concrete details, such as splices, lightly reinforced columns, and joints (Cornell, Lehigh, SUNY/Buffalo, Rice). Several experienced East Coast design firms are helping with the identification of typical building details used during the past 40 years. Other projects have to do with semi-rigid connections, and flexible floor systems (South Carolina, Minnesota, SUNY/Buffalo, Lehigh).

The dynamic analysis research projects (Cornell) are developing more reliable tools for predicting the nonlinear response of complex structural systems, mainly buildings, with a two-way exchange of information between experimental and risk-analysis projects.

Expert system programs are being developed to aid designers and planners in preliminary architectural design, structural design, building damage evaluation, and structural analysis (Lehigh, Cornell, Carnegie-Mellon, Columbia). The first three of these projects are fully coordinated and will rely on expert input solicited mainly from practicing designers.

Another project is concerned with evaluating the effects of seismic inputs on the existing transit systems of the Metropolitan New York transit agencies (ie., the Metropolitan Transportation Authority (MTA) and the New York City Transit Authority). These agencies operate and maintain an extensive commuter system consisting of surface rail facilities, buried rail tunnels through both soil and rock materials, river tunnels and elevated rail lines. A variety of surface and near surface structures are required to provide support to operate the rail lines. To date, the potentially large impact of seismic loadings has not been considered in their design.

Researchers are evaluating the damage that is likely to occur to the current system from a seismic event with a magnitude reasonable for the New York City area. Then design specifications currently used by City and consultant engineering personnel will be updated to include a seismic loading component (CUNY, MTA).

Researchers are developing a concept and preparing for a mobile unit "INTELAB" equipped with state-of-the-art experimental and computer equipment. This unit would be used to perform field experiments for generating necessary and useful information not only on the state of degradation of the infrastructures, but also on possible retrofitting and rehabilitation (Cornell, Lehigh, Princeton, RPI, SUNY/Buffalo).

System reliability analyses depend upon performance data developed from experimental and analytical research (Princeton, Cornell, Memphis State).

The above projects are concerned primarily with buildings. Several, more modest projects are concerned with the study of dams, bridges, and infrastructure (RPI, Brookhaven, Columbia, CUNY, Princeton, SUNY/Buffalo).

Risk Assessment and Social Impact

The long-term goals of specific and regional risk assessment, as well as social impact, already receive attention within NCEER. Probabilistic risk assessment (PRA) serves multiple purposes. They aid systems response projects by identifying the critical needs. The reduction of risk and the requirements of rational codes for retrofit or new design will be helped greatly by PRA. Finally, the assessment of social and economic impact of risk to classes of building stocks and geographical regions must be largely based on PRA techniques. Therefore, NCEER has a strong effort in this area (Princeton, Cornell, EQE, Polytechnic University, Weidlinger, Memphis State, SUNY/Buffalo).

1.3 Short-Term Goals

It is intended that the study of Existing Structures will result in a more realistic assessment of the seismic risk to existing structures. "Risk" can be interpreted in a number of different ways, and in this context has been defined to include societal impact.

With this goal in mind, researchers are working toward producing analytical and experimental results in a form that can be used to evaluate the probability that a particular structure, subjected to multi-hazard conditions (particularly seismic conditions) will reach an undesirable "limit" state. A limit state can be defined as collapse or serious reduction in functional capability. Structural reliability analysis will then be used to estimate such limit state probabilities. Risk assessment experts, with the aid of social scientists and other appropriate professionals, will utilize this information to analyze "societal impact." This could be measured in terms of loss of human life and value of property, loss of productivity, and personal suffering and economic loss arising therefrom. Risk analysis also could be used to define critical research needs, and to improve design codes. Expert systems can help incorporate the results of these uncertainty analyses into the process of risk assessment.

Short-term activities toward accomplishing these goals include the following:

Ground motion: Fundamental studies continue to determine expected ground motion levels and additional studies are being carried out to determine the site-specific soil amplification effects that are important input to the risk assessment of existing structures in the eastern United States.

Soil and Soil-structure Interaction (SSI): Studies are being performed to develop methodologies to evaluate SSI effects for the global assessment of risk involving the existing structures in the area under consideration. In fact, currently available or upgraded computer programs, which may take into account nonlinear soil properties, will be used to develop relatively simple, practical and yet scientifically acceptable methods for global risk assessment. At the same time, these computer programs are used to investigate dynamic interaction between existing structures, particularly buildings in urban settings. While fundamental soil mechanics research on constitutive modeling and experiments, dynamic behavior of soils, etc. is encouraged, the results must be supportive of more application-oriented research projects involving subject matters such as liquefaction and large ground deformation, issues related to large basemat, embedment, pile foundations, and SSI effects on secondary systems. Centrifuge model and field tests are an integral part of the SSI study on existing structures for the purpose of verifying analytical results.

Structural limit states: Analytical and experimental investigations are aimed at deriving expressions that can be used to estimate the resisting capacity of a building structure corresponding to the limit state under consideration. Such expressions take different analytical forms depending on the structural type and limit state. They must be accompanied by statements indicating the statistical variability and uncertainty involved. If the ultimate failure of a shear-wall type building is considered, for example, then the probability distribution function of the ultimate base shear capacity is needed. The information is then integrated with the probability distribution function of a seismically induced force in order to estimate a limit state probability.

Testing Programs: Critical structural components and subsystem tests are underway at several institutions. These studies are continuing in order to verify analytical predictions of structural damage, and are also being coordinated with other projects involving existing structures.

Engineers experienced in earthquake-resistant design in the east are contributing to the identification of critical structures and in designing the test programs. Some of the experiments are performed on shaking tables, others use large test frames. These tests are coordinated to combine the obvious advantages of large-scale experiments with the convenience and greater versatility of model testing.

Innovative Computing: New knowledge and more realistic nonlinear representation of complex structures are being incorporated in graphics-oriented computer programs so that analytical and experimental studies can go hand-in-hand. These projects will result in better damage models, reliable analysis of limit states, improved experimental programs and probabilistic response prediction.

Repair and Retrofit: Strength deterioration due to aging and wear-out, and possible inadequacy of design provisions for seismic events are mentioned in Section 1.1. While some aspects of these issues require long-term efforts, more immediate attention is paid to the question of whether specific retrofitting or other strengthening measures are needed for some older structures, which are either critically aging or not designed for seismic events. On-site diagnostic tests of infrastructures, typically older bridges, are in progress.

Code Evaluation: As indicated in Section 1.1, one of the important goals is to study the adequacy of design codes and standards for building structures. Some of the issues related to this require immediate attention. For example, are the soil factors appearing in ANSI Standards and other codes adequate measures for SSI effects, particularly in the eastern United States? How well does the response modification factor R that appears in ATC 3-06 or the new SEAOC code account for the nonlinear characteristics of structural dynamics? Methods of evaluation of existing buildings is of special importance but with specific relevance to eastern construction types.

Reliability Analysis: Reliability analysis is being performed taking advantage of the current state-of-the-knowledge of ground motion, SSI effects and system response behavior. Expert systems are being developed for building structures. Risk analysis will then follow with the aid of experts on socio-economic issues.

1.4 Long-Term Goals

Structural Response: Adequate understanding of the inelastic dynamic response of structures in various locations, especially in regions of moderate seismicity, is needed to accomplish the long-term goals of this program. Those goals include: the development of rational building code provisions in various parts of the country, development of methods of upgrade and retrofit, investigation of the societal and economic impact of earthquakes and multi-hazard risks, and the study of aging structures. It is expected that major revisions of building codes will be necessary as a result of the knowledge and understanding obtained from the various projects. For example, certain force reduction factors in the codes depend strongly on local and regional construction practices. Methods for establishing their values must be developed.

Code Evaluation: Some of the issues related to design codes and standards require long-term efforts. For example, to what extent do the particular load combinations specified in codes and standards, together with specified values of load factors, strength reduction factors and design loads, provide uniformly safe designs? What is the socio-economic impact if codes and standards are altered? What should be the differences in performance goals for existing structures and new designs?

Expert System Development: Expert system packages will be created to aid designers, planners, and public officials in improved earthquake-resistant design and safety evaluation of buildings.

Performance and Reliability Studies: The performance and reliability studies will jointly assure that the weakest links are evaluated in their order of importance. Close interaction will be maintained among studies of risk, experimental, and analytical studies, protective systems, soil-structure interaction, and ground motion. Such a cooperation will assure that the most critical problems are tackled first and that information is generated and supplied in a useful manner.

Large-Scale Structural Interaction: Some of the problems described in Section 1.1 are long-term tasks. Interactions among building structures during an earthquake, and the possibility of simultaneous collapse of a large number of buildings are complex issues and must be approached from the point of view of large-scale systems. This becomes even more complex when societal impact is considered.

1.5 Center Investigators in Program 1

The investigators in the area of Existing Structures are:

Name	Affiliation
Abel, J.	Cornell University
Ahmad, S.	SUNY at Buffalo
Armbruster, J.	Lamont-Doherty Geological Observatory
Banerjee, P. K.	SUNY at Buffalo
Bielak, J.	Carnegie-Mellon University
Bradburn, J. H.	University of South Carolina
Budhu, M.	SUNY at Buffalo
Cakmak, A.	Princeton University
Chang, K. C.	SUNY at Buffalo
Conley, C.H.	Cornell University
Constantino, C.	City University of New York
Dasgupta, G.	Columbia University
Dickerson, J.	University of South Carolina
Dobry, R.	Rensselaer Polytechnic Institute
Durrani, A.	Rice University
Elgamal, A.	Rensselaer Polytechnic Institute
Ettouney, M.	Weidlinger Associates
Fenves, S.	Carnegie-Mellon University
Galambos, T.	University of Minnesota
Gergely, P.	Cornell University
Ghosn, M.	City University of New York
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Miller, C.A.	City University of New York
Mueller, P.	Lehigh University
Papageorgiou, A.	Rensselaer Polytechnic Institute
Philippacopoulos, A.	Brookhaven National Laboratory
Poland, C.	Degenkolb Associates
Prevost, J.	Princeton University
Radziminski, J.	University of South Carolina
Reinhorn, A. M.	SUNY at Buffalo
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Simpson, D. W.	Lamont-Doherty Geological Observatory
Stewart, H.	Cornell University
Tallin, A.	Polytechnic Institute of New York
Turkstra, C.	Polytechnic Institute of New York
Tuttle, M.	Lamont-Doherty Geological Observatory
Veletsos, A. S.	Rice University
Veneziano, D.	Massachusetts Institute of Technology
White, R. N.	Cornell University
Wilson, J.	Lehigh University
Zimmie, T. F.	Rensselaer Polytechnic Institute

PROGRAM 2: Secondary And Protective Systems

2.1 Overview of Program Area

Closely related to research on existing and new structures, this program focuses on two specific areas: **secondary** and **protective systems**.

In earthquake engineering research, an area of increasing concern is performance of **secondary systems** which are anchored or attached to primary structural systems. Many secondary systems perform vital functions whose failure during an earthquake could be just as catastrophic, if not more so, as the failure of the primary structure itself. These systems can be broadly classified either as non-structural or structural secondary systems.

Computer systems, control systems, machinery, panels, storage tanks and heavy equipment are examples of non-structural secondary systems. Performance integrity of these systems under seismic loads, transmitted through the primary structural system, is important since they serve a vital function and their failure may have far reaching ramifications.

Examples of structural secondary systems include stairways, cladding, structural partitions, suspended ceilings, piping systems and ducts. For these systems, not only is their seismic behavior of practical concern, but their interaction with the primary structural system is also important since their presence is capable of modifying structural behavior of the primary system to which they are attached. Thus, these primary-secondary interactions cannot be ignored in the seismic analysis of either the secondary or the primary system.

While considerable analytical, numerical and experimental work on seismic performance evaluation of secondary systems has been conducted over the last decade, a good understanding of the dynamic behavior of these systems is lacking. The goal of research in this area is to focus on developing a greater understanding of their dynamic behavior under seismic loads. However, this is difficult to ascertain due to several inherent, dynamic characteristics of the combined primary-secondary system. Problems to be investigated include:

- **Large Number of Degrees of Freedom:** Both primary and secondary systems are multi-degree-of-freedom systems and the number of degrees of freedom of the combined system is, in general, prohibitively large. Moreover, the large differences in the stiffness, damping and mass terms between the primary and secondary systems pose serious numerical problems.

- **Tuning:** Resonance effects must be considered since any number of natural frequencies of the secondary system may be arbitrarily close to or coincide with the frequencies of the primary system. The presence of other secondary systems may cause additional tuning problems.

- **Attachment Configuration:** Attachment configurations between the secondary and the primary systems vary and can be quite complex, causing difficulties in modeling of the combined system.

- **Non-classical Damping and Gyroscopic Effects:** Non-classical damping occurs when different damping ratios exist in the primary and secondary systems and its effect is particularly significant at tuning. Moreover, when the secondary system has dynamics of its own, such as a rotating machinery, it gives rise to gyroscopic effects.

- **Nonlinearity:** Structures are generally designed to dissipate some of the energy input during severe earthquake ground motion by means of inelastic deformation. Hence, seismic analysis of the combined primary-secondary system needs to be extended to the inelastic range.

Protective systems are devices or systems which, when incorporated into a structure, help to improve the structure's ability to withstand seismic or other environmental loads. These systems can be passive, such as base isolators or viscoelastic dampers; or active, such as active tendons or active mass dampers; or combined passive-active systems.

Several recent reports and workshops have assessed the current state-of-the-art of protective systems, which in turn has led to recommended priorities for research in this area.

At the request of and with the support of the National Science Foundation, a one-day Applied Technology Council (ATC) workshop was held in March, 1986, to develop a proposed research agenda in the area of base isolation and energy dissipation. Included in the recommendations are: "Emphasize research on simple modifications of working structural systems by means of innovative energy dissipation and base-isolation systems; and emphasize experimental research with substantially more resources than theoretical investigations."

In a 1986 National Research Council (NRC) report on research needs based on lessons learned from the September, 1985, Mexico City earthquake, a research agenda concerning retrofit of buildings calls for the following: "Development and evaluation of systems and devices that might increase damping or modify the natural period of existing buildings."

At the inaugural Forum sponsored by NCEER held in May, 1987, leading experts in the area of protective systems reviewed the state-of-the-art and identified important research issues leading to the implementation of promising passive and active systems concepts. These issues include: "Accelerated development and evaluation of innovative passive and active protective systems for earthquake hazard mitigation, with emphasis on further experimental studies and large-scale testing."

These observations point to the need for research and development of innovative passive, active and hybrid protective systems. Because the use of protective systems is relatively new, a wide range of issues must be considered in assessing their effectiveness and implementability in earthquake hazard mitigation for structures and secondary systems. The following issues are considered important for the purpose of the second-year program:

- **System and Structural Response:** At present, the basis of our knowledge of the response of secondary systems and of the response of structures employing protective systems is largely theoretical with relatively little experimental and actual performance data. A better understanding of their response under seismic loads is needed and the task must be a combined effort involving analysis, simulation and laboratory experiments. In particular, as observed earlier, experimental verification must be considered as one of the most important tasks to be undertaken.

- **Merits and Limitations of Various Protective Systems:** Consider, for example, base isolation systems. At present, several leading isolation systems exist that have been implemented in the construction of medium to large size structures. Evaluation of their performance under a unified performance criterion is timely and important. It is also timely to examine other alternate systems such as the use of viscoelastic dampers, hybrid passive-active systems and active systems.

- **Materials, Quality Control and Reliability:** In addition to response characteristics, criteria for performance evaluation of secondary and protective systems should include development of new and better materials. Longevity and reliability, cost and maintenance, environmental resistance, and the nature and consequences of failure mechanisms must be considered.

- **Design Criteria and Possible Codification:** Design criteria and related design procedures for secondary and protective systems need to be developed, which must take into account issues such as strong ground motion, materials, reliability, cost and system response.

2.2 Summary of Research Projects

Research activities in Program 2 are graphically presented in Figure 7. While they basically consist of three main areas (secondary systems, active systems and passive systems), there is strong interaction among them. For example, an active area of research is that of hybrid systems, in which combined active and passive control principles are examined. The protection of secondary systems by passive means is another area of interaction between secondary and passive systems. Finally, most protective systems are themselves secondary systems. Interactions with primary structures are important for protective systems as well as for other secondary systems.

Research on secondary, active and passive protective systems has strong industrial participation. In most cases, personnel, equipment and other resources are provided to on-going research programs.

Secondary Systems

Consistent with the short-term goals stated in Section 2.3, both analytical and experimental work is being carried out. In analysis, emphasis is placed on the development of a procedure for reliable and accurate prediction of secondary system response in the seismic environment. Work in this area includes sensitivity of secondary system response to primary structural parameter variations, to nonlinearity in primary structural behavior, and to modeling of input excitation. The accuracy and efficiency of different methods to

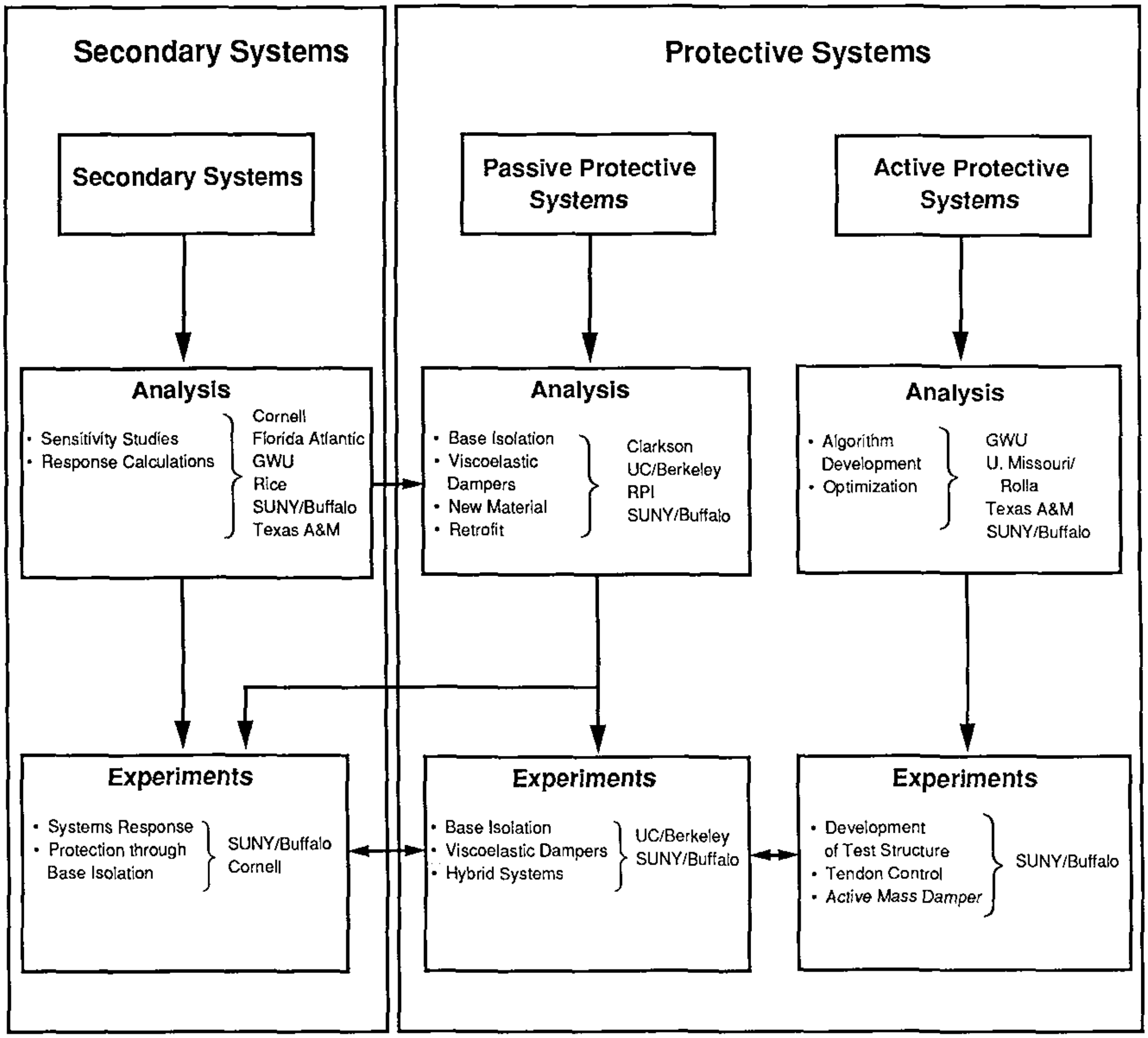

FIGURE 7 Research Activities in Program 2, Secondary and Protective Systems

obtain time histories of response of coupled systems subjected to seismic excitations are also being investigated (Cornell, Florida Atlantic, GWU, Rice, SUNY/Buffalo, Texas A&M).

Experimental work designed to verify the results obtained above is being planned using the SUNY/Buffalo shaking table. In addition, possible protection of secondary systems through base isolation is being investigated in the laboratory (SUNY/Buffalo, Cornell).

Passive Protective Systems

Base isolation and viscoelastic dampers are systems under investigation. Emphasis again is placed on experimental studies. A wide variety of friction and energy dissipating systems for base-isolated structures are being studied. An additional study of application of active control to base-isolated structures is underway, which is directed to determine the efficiency of reducing the power requirements in active control by coupling the control with base isolation (Clarkson, UC/Berkeley, RPI, SUNY/Buffalo).

The experimental study of using viscoelastic dampers as a protective measure was initiated in 1986-87 and is being continued during the second year. Viscoelastic dampers installed in tall structures have been found effective against wind-induced motion. The purpose of this investigation is to assess their effect on structures subjected to seismic excitations. Using models of currently available viscoelastic dampers, preliminary results show that they can be effective as well in the seismic situation (UC/Berkeley, SUNY/Buffalo).

Possible new materials for base isolation bearings are being explored. Initial efforts in this direction are focused on pseudoelastic shape memory materials, since such materials have promising hysteretic damping characteristics for earthquake inputs (SUNY/Buffalo).

Active Protective Systems

The present research is focused on evaluation of implementability of active control algorithms and devices for the protection of structures during earthquakes. A major activity during the second year is the development and fabrication of a new larger steel frame for experimental studies of protective systems. The model, a six-story three-bay frame, is a 1:4 scaled replica of a hypothetical prototype.

The design was done such that the yield strength of the structure is low and the system can be later improved by additions of protective systems. The structure is designed to resist 20 percent of the El Centro earthquake and 10 percent of that record in the longitudinal and transverse directions, respectively. The model structure will be used for the study of active mass dampers and for active tendon control. In addition, it is designed to accommodate synchronized horizontal motion for the possible use of base isolators for studies of hybrid systems (GWU, U. of Missouri at Rolla, SUNY/Buffalo, Texas A&M).

2.3 Short-Term Goals

Secondary Systems

In secondary systems, the need to perform a systematic investigation of their seismic performance involving analysis, simulation and laboratory experiments is clearly indicated. Short-term activities toward accomplishing these objectives include the following:

Analysis: From the point of view of engineering practice and design, improvements on the recently developed methodologies are needed in several problem areas. They include the following:

- *Effect of Nonlinear Primary Structural Behavior:* Under the action of severe earthquakes, engineering structures are expected to dissipate some of the energy input by means of inelastic deformation. The effect on secondary systems of this excursion into the nonlinear range on the part of the primary structure is thus of importance. Some work has been initiated in this area, in which the primary structure (PS) is modeled as a single-degree-of-freedom system and the mass ratio is assumed to be small so that the decoupled analysis can be used. It is shown that the effect of inelastic behavior of the primary structure is a reduction of the secondary system response.

  Better understanding of this nonlinear effect is clearly needed under more general conditions. For example, similar studies must be performed on multi-degree-of-freedom PS-systems and on multiple-supported secondary systems.

- *Effect of Uncertainties in Primary Structural Parameters:* As indicated in Section 2.1, tuning is an important consideration in the analysis of secondary systems, which is characterized by large peak response values. Thus, for design purposes, sensitivity indices relating peak response of a secondary system to primary parameter variations need to be developed. Work is progressing in this area where the use of spectral moments is suggested as peak response sensitivity indices which provide a quantitative measure of relative importance of parameter uncertainties in the design of secondary systems.

  The need of a more comprehensive sensitivity analysis is indicated. These results will be particularly useful to designers in order to evaluate relative importance of parameter uncertainties in the primary structure and to determine the desired dynamic characteristics of secondary systems.

Optimization and Protection: *Mitigation of* potential seismic damage to secondary systems can be achieved in several ways. The most direct route is to consider enhancing their performance through optimization in their dynamic characteristics, in their placement within a primary structure or in innovative design of their supports. Preliminary results show that, for example, judicious placement of a secondary system not only can enhance its own response characteristics but also benefit the overall PS structural system. A systematic study of these possible optimization schemes does not exist now and is clearly needed.

From the point of view of protection, another direction which needs to be explored is the potential applicability of passive or active control devices. While considerations of passive and active control have been mainly directed to primary structures, the protection of secondary systems using similar devices at the substructure level merits serious consideration.

Experimental Work: Experimental work on secondary systems has been fragmentary and not as extensive as the analytical work. A better understanding of the various factors entering the design and analysis of secondary systems must be gained through experimental investigation in the laboratory or in the field. Hence, systematic experimental work focusing on the dynamics of secondary systems together with various methods of optimization and protection must be considered as one of the important research tasks in this important area of investigation.

Protective Systems

For protective systems, unified performance criteria need to be developed. Merits and limitations of various protective systems can thus be evaluated on the basis of these criteria. Short-term activities are as follows:

Implementation: From this point of view, research must be more sharply focused on specific system configurations. Consider, for example, active systems. As demanded by reliability, cost and hardware development, applicable active control systems must be simple. Simple control concepts using a minimum number of actuators and sensors may well deserve more attention in the near future. Simple control, of course, does not mean simple problems. Since civil engineering structures are complex systems, this inherent incompatibility gives rise to a number of concerns such as modeling errors and spillover effect, time delay, parameter uncertainties and cost effectiveness.

Experimental Research: Experimental studies carried out to date on protective systems have been severely limited in size and scope. More laboratory tests need to be performed using larger multi-degree-of-freedom structural models. These tests need to be followed by full-scale testing either in the laboratory or in the field.

2.4 Long-Term Goals

Development of Simple Response Calculation Procedures: The ultimate impact of new methodologies and approaches rests with their usage by the design industry. While considerable advances in secondary system analysis have been made, crude guidelines such as the use of amplification factors are still being practiced in various building codes. Similar crude guidelines are being proposed for the revised ASME code related to nuclear power plants. A challenging task for researchers in this area is thus the development of accurate yet simple response calculation procedures which can be incorporated into codes and standards.

Performance and Design Assessments: Reliability, cost, failure mechanisms, maintenance and other important issues must also be considered in the development of performance and design criteria. A synthesis of these issues into a unified concept is needed for a realistic performance and design assessment of protective as well as secondary systems.

Hardware Development, Reliability and Cost-Effectiveness Factors: For new and innovative protective systems, the important questions of hardware development, reliability and cost-effectiveness must be addressed. However, to find answers to these questions are more long-term tasks since they will depend on control strategies, specific structural applications, hardware details and a variety of other issues, many of which need to be better understood and further developed.

Full-Scale Testing: Emphasis in the long term should also be placed on full systems studies, including the effects of ground motion, soil-structure interaction and structural response. The need for full-scale testing is also indicated. In this regard, one or more of our contemplated International Cooperative Research Programs may provide an opportunity for such testing.

Performance Evaluations: Finally, performance evaluation of these systems must be carried out in terms of their societal impact. For example, the societal impact of installing protective systems in critical structures such as hospitals, fire and police stations and key government buildings may considerably outweigh the added cost. Studies in this direction are clearly warranted.

2.5 Center Investigators in Program 2

The investigators in the area of Secondary and Protective Systems are:

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Kelly, J. M.	University of California-Berkeley
Lin, Y. K.	Florida Atlantic University
Lutes, L.	Texas A & M
Manolis, G. D.	SUNY at Buffalo
Prawel, S. P.	SUNY at Buffalo
Reinhorn, A. M.	SUNY at Buffalo
Reismann, H.	SUNY at Buffalo
Sarkani, S.	George Washington University
Soong, T. T.	SUNY at Buffalo
Spanos, P. D.	Rice University
Tadjbakhsh, I.	Rensselaer Polytechnic Institute
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Gutman, Y.	MTS Corporation
Haniuda, N.	Kayaba Industry Co.
Khan, L.	Snyder Industries
Kinoshita, K.	Takenaka Komuten Co.
Kubo, T.	Kayaba Industry Co.
Lund, R.	MTS Corporation
Mahmoodi, P.	3M Company
McGill, M.	Nalge Co.
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Poczatek, B.	Nalge Co.
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PROGRAM 3:
Lifeline Systems

3.1 Overview of Program Area

As in the case of Existing Structures, the second-year program concerning Lifeline Systems emphasizes studies pertinent to the mitigation of serious consequences of system failure which would have a substantial societal impact. From this point of view, Center researchers are concentrating on a few existing systems which are subject to potentially catastrophic seismic hazards and for which owners and regulatory agency cooperation are expected to be forthcoming. The water transmission system in the City of San Francisco, for example, is a typical example of the concern that the City Fire Department has for post-earthquake firefighting capabilities. The second system is a local or nationwide communication system on which modern society has become so critically dependent. The third example involves energy transmission systems. Oil pipeline failures due to large-scale landslides during the recent Ecuador earthquake have inflicted a devastating loss of economy and productivity upon that country. We have been fortunate that no major earthquakes as large in scale as those of the New Madrid, Missouri earthquakes of 1811-1812 and the Charleston, South Carolina, earthquake of 1866 have struck the central United States. Some energy transmission systems including crude oil, petroleum and natural gas pipelines traverse this area from the South and Southwest to the densely populated areas of the North and Northeast. Physical and functional failure of such energy systems due to seismic events and the resulting possible disruptions in energy supply and contamination of the environment could have disasterous consequences to owners, users and the public at large.

Unlike building structures, lifeline systems physically extend over large spatial areas. Therefore, these systems tend to be more susceptible to a greater number of seismically induced events. The following five types of seismic events are considered the major causes of physical damage to lifeline systems, particularly underground pipelines:

- Ground motion associated with wave propagation;
- Fault movement at pipeline crossing locations;
- Liquefaction;
- Landslides;
- Interaction with other under- and above-ground structures.

For ease of identifying specific issues to which the second-year effort is being directed, underground pipeline systems, representing a major component of water transmission, energy transmission and other lifeline systems, are considered in the following as an example. These issues are, for the most part, equally valid when other lifeline systems are considered.

1. Analytical models appropriate for pipeline network analysis must be developed. By combining these models with those for pumping stations and other facilities, representative models for total network systems can be constructed. Methods must then be developed to estimate the vulnerability and serviceability of such networks in probabilistic terms (see item 4, below).

2. Practically meaningful and analytically tractable interrelationships between vulnerability and serviceability must be established for each lifeline system. In this program, "vulnerability" and "serviceability" refer to a system's physical damage and functional performance under seismic conditions, respectively.

3. Analytical methods developed for vulnerability and serviceability must be verified in an appropriate or simulated seismic environment.

4. Vulnerability and serviceability probabilities estimated above must be used by risk experts and social scientists for risk analysis and societal impact assessment. Equally important, however, is the use of these probability values in developing logical strategies for repair and restoration of damaged systems. For example, these strategies must consider, among other issues, the speed of recovery of system serviceability as a function of the rate at which manpower and other resources can be expended; and establishment of institutional and area priorities so that restoration work can proceed. Vulnerability analysis will also help identify those structural components (weaker links) which should be retrofit prior to a seismic event.

5. The interaction between different lifeline systems must be addressed. Attention must be given to the evaluation of specific, cost-effective mitigation measures.

3.2 Summary of Research Projects

The second-year research studies in Lifeline Systems can be grouped into the investigation of two major systems: water delivery systems and crude oil transmission systems. The first group of projects is primarily concerned with the performance of water delivery systems under seismic events, while the second group attempts a first-cut seismic risk assessment of a crude oil transmission system. These projects and the investigators in charge thereof are shown in Figure 8 for the water delivery system study and Figure 9 for the crude oil transmission system study.

Water Delivery Systems

Research on water delivery systems is concerned, among others, with ground motion studies; system performance, vulnerability and serviceability; risk assessment and societal impact; and physical as well as functional interaction among structural and mechanical components within a water delivery system. The majority of researchers involved in this project have significant experience on lifeline studies. The tasks being undertaken involve analytical and other lifeline techniques which represent the forefront of research in terms of detail and sophistication, as well as practicality.

Ground Motion Studies: Much of the research in this area is drawn from the more fundamental studies conducted in Program 1, Existing Structures. For example, the collection and measurement of ground motion data; development of attenuation relationships, design spectra, spatial

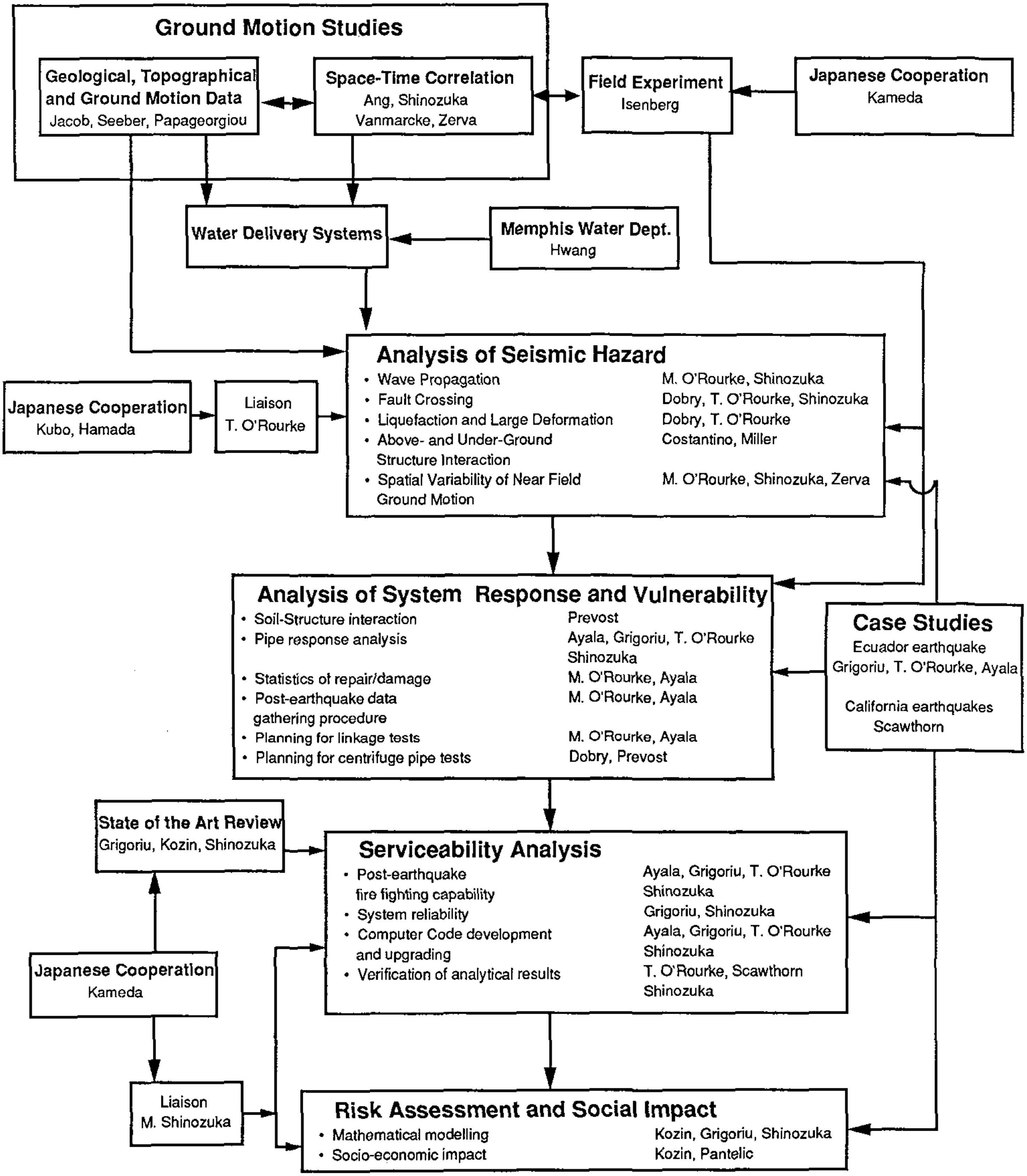


FIGURE 8 Research Activities in Program 3, Lifeline Systems - Water Delivery Systems Study

variability and seismic hazard maps; and investigation of phenomena such as soil liquefaction, soil amplification and large ground deformation is planned to be incorporated into the analysis of water delivery systems (CUNY, Cornell, LDGO, Princeton, RPI, University of Illinois).

An important consideration in the seismic evaluation of lifeline systems is the spatial variation of ground motions including the differential ground motion between supports (e.g., between manholes) which may include significant stresses and strains in the underground pipe structure. Furthermore, since lifelines are spatially extended structures, they cross regions with different material properties. The spatial variations and phase differences introduce additional seismic loadings in the lifelines. An analytical model which takes into account spatial variations such as differing material properties and topographical and geologic changes is being developed. This model will be used to provide input motions in the response analyses of lifeline systems (CUNY, University of Illinois, Princeton).

In addition, a field experiment is in place where an instrumented welded steel and ductile iron pipe with push-on joints was installed in Owens Pasture, near Parkfield, California. It is anticipated that an earthquake can occur at this site at any time. Once this event occurs, the resulting data gathered will be used to calibrate and verify various analytical procedures applied to pipeline fault-crossing situations (Weidlinger Associates and the International Project with the Disaster Prevention Research Institute of Kyoto University).

System Performance, Vulnerability and Serviceability: The study of the behavior of buried pipelines constitutes an important area of research within this program. Analytical models are being developed to predict seismically induced damage/ leakage in segmented and welded buried pipelines. In this respect, statistics on the damage sustained by the Mexico City water system from the 1985 earthquake are being collected and incorporated into the model. Characterization of pipe joint and junction behavior is also investigated since damage often concentrates at these locations (Cornell, Princeton, RPI, UNAM).

Towards the development and refinement of analytical methods for the seismic analysis of segmented pipelines specifically, a research project focuses, in two steps, on the effects of seismic ground waves on pipe joints. First, new analytical methods are being developed for evaluating seismically induced deformation of pipe joints. The methods are being validated primarily from results of laboratory tests. Secondly, existing methods for the seismic analysis of segmented pipelines are being extended to include joint models and to account for uncertainties in pipeline properties, soil conditions, and seismic excitation. The analysis is based on stochastic finite element and/or difference methods (Cornell, RPI, UNAM).

Existing analytical models for evaluating post-earthquake serviceability are being extended via the development of a more efficient computer-based algorithm. This new algorithm can read geometrical characteristics of networks from utility maps and account for the uncertainty in the characteristics of soil, pipelines, and the earthquake. It involves repeated hydraulic analyses for simulated damage states and statistical evaluations of various serviceability measures, e.g., the water flow and head at critical locations in the system (Cornell, Princeton, RPI, UNAM).

In an effort to assess the reliability of and develop risk analysis for lifeline systems, researchers are developing an analytical and numerical package capable of evaluating the vulnerability and serviceability of water delivery systems. This package will be implemented in a water transmission system in either Los Angeles or San Francisco, and the predictions of its seismic vulnerability and serviceability by field demonstration will be attempted. In a more recent development, Memphis Light, Gas and Water Division of Memphis endorsed a seismic study of their water delivery system to be performed jointly with Memphis State University under NCEER sponsorship (Cornell, Princeton, Memphis State).

Adequate response to fires following earthquakes requires satisfactory post-earthquake performance of several major systems, including water, telecommunications, gas and power, and transportation lifelines. The consequences of damage and reduced functionality of one or more of these major lifeline systems, in terms of conflagration potential, and alternatively, benefits due to enhanced functionality are being quantified. An analytical framework which permits detailed modeling of a jurisdiction's damage and conflagration response and/or more approximate but adequate modeling of a region's damage and losses is being developed. This framework will be applied to examine the impacts on potential post-earthquake fire losses of the reduced and/or enhanced functionality of the following lifelines: water, telecommunications, residential and commercial gas distribution, electricity, highways, liquid fuel pipelines and major petroleum tank farms (EQE, Cornell, Princeton, Poly U).

Finally, conceptual planning for centrifuge testing of an underground pipe subjected to fault motion is being carried out (Princeton, RPI).

Risk Assessment and Social Impact: Because modern society is increasingly dependent on lifeline systems such as pipelines of all kinds, transportation networks, communication and power networks, etc., the functioning of these systems in a post-earthquake environment is critical. Research in this area is focused on understanding the lifeline systems' response to a major earthquake, the interaction among various subsystems, and by so doing, providing knowledge that would be useful in earthquake mitigation and preparedness planning. Toward this goal, researchers are considering the response of the post-earthquake urban lifeline system through a dynamic system model. The model is being constructed to study the transient effects and interactions among the various lifelines of an urban system following a major earthquake. The study is generating simulation tools by which various reconstruction strategies can be tested to determine optimal mitigation policies based upon various restoration goals. These tools also allow the study of the relative effect on the urban system of the various lifelines to determine which among these subsystems are to take priority over others in restoration from the viewpoint of cost effectiveness (Poly U, Cornell, Princeton).

Crude Oil Transmission Systems

Crude oil transmission systems represent the second major area of study. The research involves the development of a first-cut risk assessment for a crude oil pipeline system, possibly a simulated system, which extends from the Gulf of Mexico area and Texas to the northeastern part of the U.S. This system appears particularly vulnerable to earthquakes because it traverses the New Madrid area. The significance of this study lies not only in performing a risk analysis for such a system, including assessment of the societal impact arising from its failure, but also in identifying future research needs to make such an analysis more reliable. Much of the research results from other projects in the Lifeline Systems program area, as well as those from Program 1, Existing Structures, are being incorporated into this study.

As a starting point, researchers have agreed to perform a serviceability analysis on a crude oil transmission system which spans from the New Orleans area to the Chicago area. This analysis is for a postulated recurrence of the 1811-1812 New Madrid, Missouri earthquake. Factors including peak ground acceleration, extent of permanent ground displacement, and the likelihood of such displacements are being incorporated into the model. Maps, reports, geometrical and mechanical characteristics of this geographic area have been obtained, and river crossings for pipelines have been identified as critical points (CUNY, Cornell, EQE, LDGO, Poly U, Princeton, RPI, SUNY/Buffalo, University of Tulsa, Weidlinger Associates).

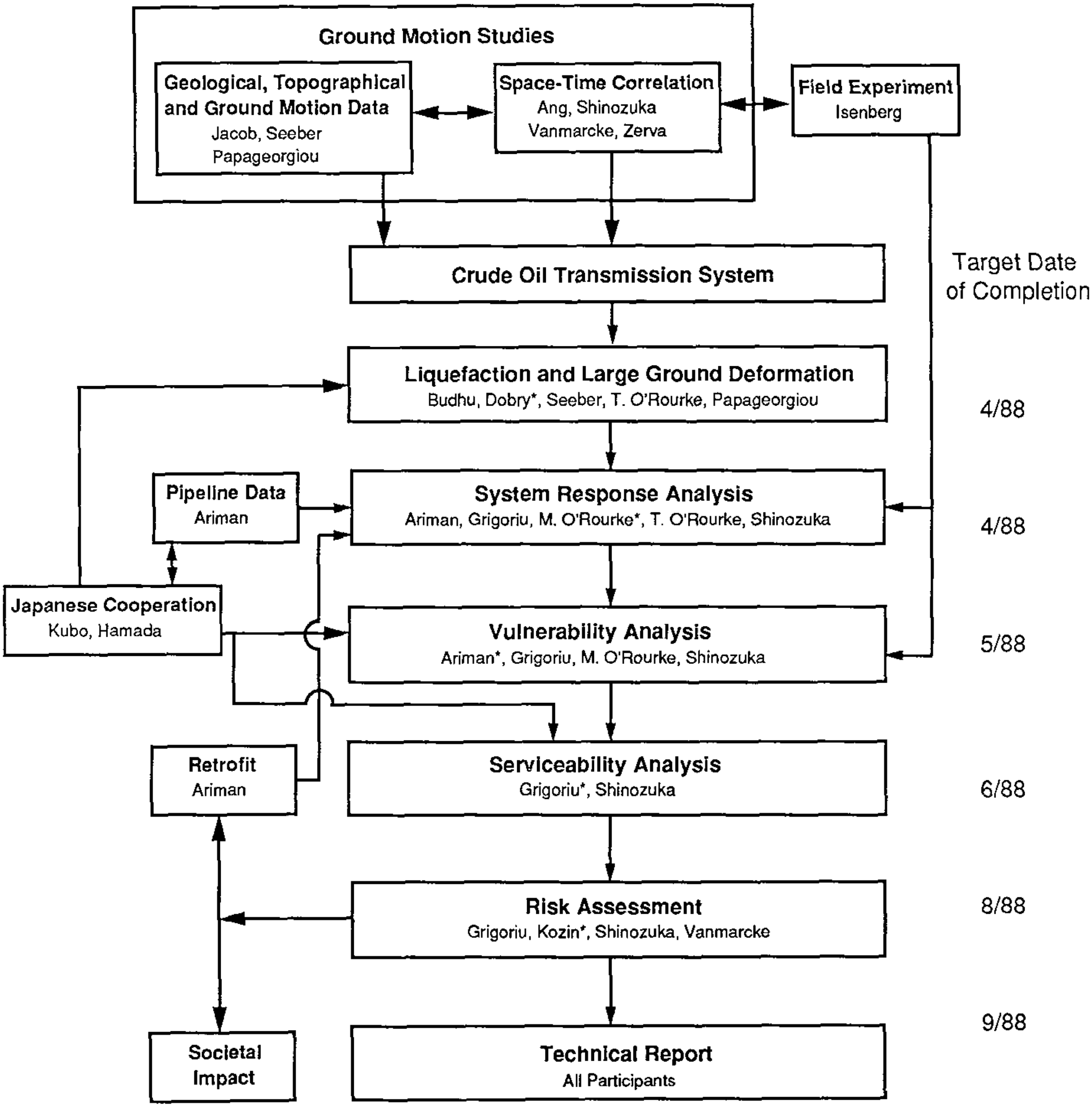
To complete the pilot study before the end of this project year, target dates have been designated (as indicated in Figure 9) for each research item. A coordinator for each research item has also been designated, who is responsible for integrating the work of other investigators and ensuring that the specific target date is met.

3.3 Short-term Goals

It is intended that the study of Lifeline Systems will result in greater understanding of how these systems respond and interact when subjected to seismic events. With this goal in mind, researchers are working together to integrate the many disciplinary areas concerning the study of earthquakes into a comprehensive framework. In this context, Lifeline Systems are viewed as complex, multi-dimensional, stochastic and dynamic systems. Short-term activities are described in the following paragraphs.

Vulnerability and Serviceability Evaluation: The first step towards evaluating the vulnerability and serviceability of a total network system is to identify potential damage modes and assess the probability of such damage occurring at critical locations of the system under certain earthquake intensity levels. The notion of a damage probability matrix or, alternatively, fragility curves, can be used in this context. The seismic "intensity" must also be clearly defined. In this connection, particular combinations of seismic intensity, soil properties, geological conditions, topographical characteristics, etc. must be identified. Adverse combinations of these will tend to produce not only failure at critical locations of the structural system itself, but also such "soil failures" as liquefaction and landslides, which in turn could induce large-scale structural failure. The likelihood and spatial extent of such large-scale failures must be probabilistically estimated. Also, the behavior of pipelines subjected to such soil failures are of major concern.

Vulnerability and Serviceability Estimates for Network Models: Methods are being developed to estimate the vulnerability and serviceability of network models. It appears reasonable to model the total network system as a linear graph consisting of vertices and branches in which the vertices represent, for example, pipe junctions, pumping stations, etc., and branches represent pipelines. Thus, a seismic event could result in physical damage to a network system equivalent to the removal of a subset (or possibly the entire set) of vertices and branches from the original network. The network system may or may not be vulnerable



* Indicates coordinator of task

FIGURE 9 Research Activities in Program 3, Lifeline Systems - Crude Oil Transmission Systems Study

to a seismic event and furthermore does remain or does not remain serviceable after a seismic event, depending on the type of vulnerability and serviceability defined for the system.

Estimation of Risk: The annual likelihood of various extents of physical failures and damage are being estimated taking into consideration the seismic hazard of the area which will influence the lifeline system. The estimation of the annual likelihood of system serviceability then follows. The interrelationship between the extent of the system's physical damage and the degree of its functional performance must be known for this estimation.

Experimental Research: In the area of experimental research, the feasibility of laboratory leakage tests of piping segments under seismic conditions are being investigated. Also, in anticipation of an imminent earthquake, fully-instrumented piping segments are buried across a fault in Owens Pasture, near Parkfield, California. Ultimately, the purpose of such experiments is to verify the damage probability matrices or fragility curves developed for analysis. To verify the results of a system vulnerability and serviceability analysis, future post-earthquake reconnaissance and field studies should be directed to develop a database for the interrelationship between system damage and functional performance.

Development of a Risk Assessment Model for a Crude Oil Transmission System: As shown in Figure 9, researchers are actively developing a first-cut risk assessment for a typical crude oil transmission system. This assessment will use geological, topographical and ground motion data and space-time correlation studies as input parameters, to determine the potential for liquefaction and large ground deformation in the region. From this, a system response analysis will be performed, followed by vulnerability and serviceability analyses. The final risk assessment will address possible retrofit methods for weaker components of the system, as well as the societal impact of its potential failure.

3.4 Long-term Goals

Risk Assessment and Social Impact: Eventually, engineers, scientists, risk experts, economists, insurance experts, system owners and regulatory agencies must work together to evaluate the cost-effectiveness of specific mitigation measures. These measures may be suggested by engineers and scientists when they pertain to technical issues, or by socio-economic experts when they relate to societal issues. In this way, the lifeline systems' response to a major earthquake, and the interactions among various subsystems, can be better understood, thus providing knowledge that could be useful in earthquake mitigation and preparedness planning. Some of these tasks are suitable for incorporation into expert systems for the management of lifelines in emergencies.

Interrelationship and Interaction Between Lifeline Systems: The interrelationship and interaction among different lifeline systems must be investigated from both the technical and societal points of view. For example, the loss of firefighting capability on the one hand and leakage from natural gas pipelines due to severe earthquakes on the other, represents the kind of most unfortunate interrelationship with which we must be concerned.

3.5 Center Investigators in Program 3

The investigators in the area of Lifeline Systems are:

Name	Affiliation
Ang, A.S.	University of Illinois
Ariman, T.	University of Tulsa
Armbruster, J.	Lamont-Doherty Geological Observatory
Ayala, G.	National Automonous University of Mexico
Budhu, M.	SUNY at Buffalo
Costantino, C. J.	City College of New York
Dobry, R.	Rensselaer Polytechnic Institute
Giese, R.	SUNY at Buffalo
Grigoriu, M. D.	Cornell University
Hwang, H.	Memphis State University
Isenberg, J.	Weidlinger Associates
Jacob, K.	Lamont-Doherty Geological Observatory
Khater, M.	Cornell University
Kozin, F.	Polytechnic Institute of New York
Miller, C. A.	City College of New York
O'Rourke, M.	Rensselaer Polytechnic Institute
O'Rourke, T. D.	Cornell University
Pantelic, J.	NCEER
Papageorgiou, A.	Rensselaer Polytechnic Institute
Prevost, J. H.	Princeton University
Scawthorn, C.	EQE, Inc.
Seeber, L.	Lamont-Doherty Geological Observatory
Shinozuka, M.	Princeton University
Tuttle, M.	Lamont-Doherty Geological Observatory
Vanmarcke, E.	Princeton University
Veneziano, D.	Massachusetts Institute of Technology
Zerva, A.	City College of New York

NCEER's Lifeline Systems research effort has strong international cooperative components; indeed, Professor G. Ayala of UNAM, Mexico has been engaged in research projects at Cornell University and RPI working primarily on issues arising from water delivery systems.

Three Japanese groups are actively involved in this research program. The first group is headed by Professors K. Kubo and M. Hamada of Tokai University, Shizuoka, Japan and financially supported by many Japanese corporations and consulting firms. This group is the Japanese counterpart of the U.S. group with M. Shinozuka of Princeton University as general coordinator and with T. O'Rourke of Cornell University as technical coordinator of the U.S.-Japan Cooperative Research on Liquefaction Effects on Buried Lifelines. The second group is also headed by Professors Kubo and Hamada with M. Shinozuka of Princeton University representing the U.S. group working on crude oil transmission systems.

The third group is led by Professor H. Kameda of the Disaster Prevention Research Institute (DPRI), Kyoto University, Kyoto, Japan. Professor Kameda is in charge of DPRI's recently established Urban Earthquake Hazard Research Center and his group will work with M. Shinozuka and other NCEER investigators in pursuing the issue of urban seismic hazard mitigation. This cooperation is of particular importance since work will be initiated on inherent socio-economic problems in seismically induced disaster situations. Furthermore, Professor Kameda's group is jointly working with J. Isenberg's group on the field experiments in Parkfield, California, which involves pipe segements buried across a fault.

PROGRAM 4:
International Cooperative Research

4.1 Overview of Program Area

Cooperative research at the international level has been a major feature of NCEER. Formal, joint research programs initiated with China, Japan and Taiwan during the first research year are continuing into the second year and beyond. As stated in Section 3, Lifeline Systems, researchers from Japan are playing an integral role in the development of a crude oil transmission system model. Other joint research projects with Austria and Greece are being finalized and numerous projects with other countries are currently under negotiation. Further interaction with Chinese and Japanese researchers is expected in the near future.

In addition, mechanisms have been established by which researchers and students in other countries can visit NCEER-affiliated institutions for collaborative work, education and training. During the first research year, NCEER hosted numerous foreign visitors from Central Research Institute of the Electric Power Industry of Japan, Taisei Corporation, Shimizu Construction Company, Kajima Corporation, the China Academy of Building Research, Chinese Ministry of Urban and Rural Construction and Protection, Beijing Polytechnic University and the Russian Central Research Institute of Building Components. These types of visits are continuing into the second year.

4.2 Summary of Research Projects

U.S. - China Earthquake Engineering Program

Two broadly based cooperative research programs in earthquake engineering between U.S. investigators and investigators at the China Academy of Building Research and Beijing Polytechnic University is continuing during the second year. The availability of research personnel and full-scale testing facilities in China continues to represent a unique opportunity to establish a long-term cooperative research program in the broad area of earthquake engineering research and practice.

Researchers at the China Academy of Building Research are involved in the development of expert systems, for eventual application in the design of building structures in seismic zones. Research objectives of that cooperative venture are as follows:

- The China Academy of Building Research will complete a code-based "expert system" for the preliminary design of building structures in seismic zones for use on a personal computer by the end of April, 1988.

- One or two researchers from the United States associated with NCEER projects on expert systems will be invited to visit the China Academy for two or three weeks to examine the preliminary undertakings, and to make suggestions for appropriate modifications to facilitate comparisons with the work currently underway in the United States. Visits to several other universities in China working on expert systems will be scheduled.

- During the fall of 1988, two or three researchers from the China Academy will visit Cornell University to incorporate their findings into the expert systems being developed by NCEER.

A second cooperative research program at the China Academy is underway and deals with a comparative experimental study of a six-story masonry building. A scaled model structure will be constructed in Beijing and tested in a pseudo-dynamic fashion to simulate a known earthquake. An identical structure will be constructed in Buffalo and will be tested on its shaking table. The seismic excitation will be the same as that presumed in Beijing.

Researchers at Beijing Polytechnic Universtiy are involved in the development of earthquake-resistant design and analysis procedures for buildings. This project involves the construction and field testing of a full-scale five-story steel-frame structure at the University, loaded with synchronous vibrators, in an area well-instrumented with strong-motion measuring devices. Various effects on the superstructure and structural components will be gauged during testing.

A scale model of the same structure will be constructed at SUNY/Buffalo for testing on the shaking table. The model will replicate as closely as possible the construction and loading conditions which are associated with the full-scale tests. The scale model will be tested under numerous known seismic excitations. In addition, researchers at SUNY/Buffalo will attempt to make modifications to the shaking table to simulate results observed in the testing of the full-scale model. The goal of this research is to enhance understanding in the areas of structural dynamics, soil-structure interaction, and protective systems, in addition to acquiring measured data on building performance under actual cyclic loading conditions.

A second cooperative research program involves the analysis and testing of large scale space structures of the cable/truss type. Both analytical and experimental works are being conducted at both institutions, and faculty members are being exchanged on a more-or-less regular basis.

U.S. - Taiwan Earthquake Engineering Research Program

A multi-year cooperative study between researchers at the University of Illinois, Columbia University, Princeton University and researchers at the National Taiwan University and the National Central University in Taiwan is focused on the development of improved definitions of seismic ground motions and design procedures for lifelines. This cooperation is based on complimentary expertise between the U.S. and Taiwan investigators. Central to the cooperative research is the availability of recent dense array strong motion data obtained from the SMART-1 array. With the aid of such data, all the investigators have been involved with innovative analytical modeling of seismic ground motions for lifeline purposes.

First year research in this program focused on the development of a three-dimensional wave propagation model. During the second year, the model is being exercised to obtain numerical results of ground motions at specific distances on the ground surface. Some parametric studies are being performed to evaluate the influence of major parameters on the calculated motions.

The calculated results will be used to determine the appropriate transfer functions that represent approximately the ground transmission between the source and the surface stations. The parameters of the transfer function can then be evaluated by a time-domain system identification approach.

Subsequent studies will include examination of the effects of the parameters of the source mechanism, the development of an analytical attenuation relation, and the spatial correlation and variability of earthquake ground motions. Researchers will then be able to estimate transfer functions representing seismic wave transmission between a specific fault rupture and the ground station. The results of the stochastic field theory can then be applied to the SMART-1 array data.

U.S. - Japan Cooperative Research on Earthquake Induced Ground Deformation and Its Effects on Structures

A cooperative study between researchers at Cornell University and Tokai University in Japan has been established to investigate liquefaction effects on buried lifelines. The cooperative research was endorsed at a meeting in June, 1987 at the Public Works Research Institute (PWRI) in Tsukuba City, Japan. The meeting was attended by researchers from PWRI, Tokyo, Kyoto, Tokai, and Kanazawa Universities, Nippon Telegraph and Telephone, and Tokyo Gas. Recently, this cooperative research has been expanded in its scope with the aid of substantial industry support in Japan so that the research now deals with earthquake induced ground deformation and its effects on structures. The U.S. effort in the expanded cooperative research involves Cornell University, Princeton University and Rensselaer Polytechnic Institute.

Permanent ground movements are known to have been the most troublesome source of lifeline damage during previous earthquakes. Both U.S. and Japanese researchers have worked extensively in this subject area, and it is recognized that considerable benefits will result from a cooperative effort to collect case history data and recommend analytical and design methods on the basis of a careful data review. The project concentrates on permanent ground movements caused by soil liquefaction. In addition, landslide and debris flow problems are being evaluated by a case history evaluation of the 1987 Ecuador earthquakes and related ground failures.

The overall objectives of the research are to:

- Develop comprehensive case histories of permanent ground movements and lifeline performance during earthquakes, with emphasis on liquefaction effects. Several U.S. and Japanese case histories are included in the study as well as an in-depth summary of the ground failures and pipeline system response during the 1987 Ecuador earthquakes.

- Evaluate the relationship between ground deformation and damage of subsurface structures. Emphasis is placed on buried pipelines and related facilities, such as subsurface vaults, pumps, and regulating equipment. Emphasis is also placed on the factors which influence ground movement patterns including soil and groundwater conditions, land form type, topography, and geologic structure. A summary of the most important factors affecting lifeline performance will be given in the case histories document.

- Select and test various analytical models for soil-pipe interaction against the case history information, and choose the models best suited for evaluating pipeline performance during earthquakes.

- Perform a parametric study of pipeline response to large differential soil movements to evalute the most critical siting, construction, and pipeline material properties affecting behavior.

- Make recommendations for improved siting and design. Attention is devoted to effective countermeasures against earthquake damage such as the use of ductile materials, flexible joints and connections, and anchoring against buoyancy effects.

The short term goal is to produce a joint U.S. Japan case history volume, documenting permanent ground deformation effects and lifeline response. The target date for completion of the case history and data base summary is December, 1988. The long term goal, targeted for completion in December, 1989, is the issuing of recommendations for improved design, siting, and risk assessment for buried lifeline facilities. These recommendations will be proposed jointly by U.S. and Japanese investigators, and discussed and adopted at a special workshop convened in the U.S.

U.S. - Japan Cooperative Research on Urban Earthquake Hazard Mitigation

A cooperative research program is underway between the Urban Earthquake Hazard Research Center at Disaster Prevention Research Institute, Kyoto University and Princeton University. Researchers are jointly working on a number of urban-related earthquake issues. In particular, the research focuses on how urban lifeline systems perform under seismic conditions and what societal impact their functional failure might entail. In this respect, a state-of-the-art review on the performance of lifeline systems under earthquake conditions is being completed with respect to water, gas and electricity delivery systems, and highway and telecommunications network systems. Other joint efforts include development of methodology for evaluation of the societal impact of seismic events.

U.S. - Japan Cooperative Research on Buried Lifeline Field Experiments

The necessity and importance of field experiments on buried lifeline systems subjected to actual earthquakes have long been recognized by engineers designing systems and researchers. In spite of this recognition, not much work has been done, presumably due to the fact that such experiments are expensive in terms of burying pipes of various types, instrumenting them and performing data analysis. Furthermore, earthquakes of meaningful intensity must occur at the buried pipeline sites.

In anticipation of a magnitude 6.0 earthquake on the San Andreas Fault in the very near future, Weidlinger Associates, mainly with support from NCEER, instrumented welded steel pipes and ductile iron segmented pipes buried across the fault at Owen's Pasture near Parkfield, California. This was done to investigate the effect of the expected strike-slip at the fault on pipe behavior and verify whether or not current design and analysis practice is acceptable. The instrumentation is currently set up to measure pipe strain and displacement by means of strain gauges and displacement transducers, as appropriate, and also to measure the amount of strike-slip fault motion.

It is highly desirable, however, that the near-field ground motion at the time of the aniticipated fault slip also be monitored. In this connection, Weidlinger Associates, and the Urban Earthquake Hazard Research Center (UEHRC) at the Disaster Prevention Research Institute (DPRI), Kyoto University, agrees to perform the following cooperative research: UEHRC will purchase three of the most advanced strong motion seismometers and allow Weidlinger Associates to use them without charge at buried pipe locations for the sole purpose of this particular field experiment and for a period of time necessary for the experiment's completion. It is also agreed that researchers from Kyoto University will visit the site at the time of installation to assist and ensure their proper installation. Further cooperative research will ensue in data analysis and evaluation of the current state of design and analysis of buried pipelines based on experimental results upon the occurrence of at least one significant earthquake at the site.

U.S. - Kajima Corp. Cooperative Research

A two-year joint research program between researchers at Princeton University and Kajima Corporation in Tokyo, Japan began June 1, 1987. The joint research program is supported by Kajima Corporation. The primary areas of research are soils and soil-structure interaction, and seismic reliability analysis and risk assessment.

In the area of soil and soil-structure interaction, researchers are developing a general purpose computer code for the analysis of static and transient phenomena (wave propagation) in both dry and saturated soils. This code will also be used for the analysis of soil and soil-structure interacting systems, and to devise simplified procedures to provide engineering practice with state-of-the-art analysis capabilities for design.

Concerning seismic reliability and risk assessment, the following tasks are being performed:

- Stochastic and statistical assessment of earthquake ground motions based on the available data from Japan and the United States.

- Probabilistic assessment of the nonlinear behavior of buildings subjected to the maximum credible (design basis) earthquakes.

Under this program, Kajima Corporation sends four to five engineers to Princeton University each year to carry out the tasks indicated above, and to interact with Princeton researchers. At the same time, Princeton University is sending three researchers[1] (graduate students and post-doctoral researchers) for an extended period of time to work with engineers and researchers at Kajima Corporation in Japan. The most advanced experimental studies relevant to this joint research program are underway in Kajima's facilities. A second review meeting for this joint research program is scheduled sometime in November, 1988.

U.S. - Greece Cooperative Research on Reinforced Concrete Structures

A cooperative research program is in the final stages of negotiations between NCEER and National Technical University of Athens (NTUA).

[1]The following students will visit Kajima Corporation this summer: John Cunniff, Binod Bhartia and Edmondo DiPasquale.

Researchers are jointly working on the development of deterministic and stochastic methods in order to determine the performance, risk and reliability of reinforced concrete structures under earthquake excitation.

U.S. - Austria Cooperative Research on Stochastic Methods as Applied to Earthquake Engineering

The Center for Structural Dynamics Research of Austria (consisting of IfM and BVK of University of Innsbruck, IfAM and ILFB of TU Vienna, and IfM of MU Leoben), headquartered at the University of Innsbruck, agreed to work jointly with NCEER researchers on a number of issues arising from the stochastic nature of seismic ground motion and structural response. Specifically, the cooperative research focuses on stochastic characterization of seismic ground motion, and reliability analysis and risk assessment of structures under such stochastic ground motion.

In addition, seminars and workshops are planned to be held in Austria as well as in the United States on timely subject matters. Short- and long-term visits by senior and junior Austrian and U.S. researchers are planned to provide for closer interaction. Proposals will be written to secure the travel funds for the seminars, workshops and exchange of personnel from the U.S.-Austria Cooperative Science Program (NSF-FWF). More specific cooperative research programs are currently under consideration.

4.3 Center Investigators in Program 4

The investigators in the area of International Cooperative Research are:

Name	Affiliation
Ang, A.H-S.	University of Illinois
Cakmak, A.	Princeton University
Canhuang, S.	Beijing Polytechnic University
Dobry, R.	Rensselaer Polytechnic Institute
Guangqian, H.	China Academy of Building Research
Hamada, M.	Tokai University
Isenberg, J.	Weidlinger Associates
Kameda, H.	Kyoto University
Katayama, T.	University of Tokyo
Kawashima, K.	Public Works Research Institute of Japan
Ketter, R.L.	SUNY at Buffalo
Kobori, T.	Kajima Corporation
Kubo, K.	Tokai University
Lee, G.C.	SUNY at Buffalo
Loh, C-H.	National Central University of Taiwan
O'Rourke, T.D.	Cornell University
Peifu, X.	China Academy of Building Research
Prevost, J.	Princeton University
Schueller, G.I.	University of Innsbruck
Shinozuka, M.	Princeton University
Sugito, M.	Kyoto University
Takada, S.	Kobe University
Tan, R.Y.	National Taiwan University
Tassios, T.P.	National Technical University of Athens
Vanmarcke, E.	Princeton University
Yeh, C-S.	National Taiwan University
Yeh, Y-C.	Beijing Polytechnic University

List of Long-term Visitors From Foreign Countries

Name	Affiliation
Abe, H.	Takenaka Komuten, Ltd.
Cao, Zi 7/87 - 10/87	Beijing Polytechnic University
Chen, Dan 11/87 - 12/87	Tsinghua University
Fan, Jashen 4/88 - 4/89	Yunnan Institute of Technology
Fukao, Y. 6/88-1/89	Takenaka Komuten, Ltd.
Hirata, K. 9/86-12/87	Central Research Institute of the Electric Power Industry Abiko, Chiba, Japan.
Kanda, K. 8/87 - 7/88	Kajima Corporation Tokyo, Japan
Kinoshita, K.	Takenaka Komuten, Ltd.
Li, Jun-Zhi 10/87 - 8/88	Beijing Polytechnic University
Miyamura, M. 8/87 - 11/87	Kajima Corporation Tokyo, Japan
Moriyama, K. 11/86 - 3/88	Taisei Corporation Tokyo, Japan
Ohbo, N. 8/87 - 11/87	Kajima Corporation Tokyo, Japan
Seya, H. 3/20/88 - 3/19/90	Takenaka Komuten, Ltd. Tokyo, Japan
Shen, Zhuang 10/87 - 8/88	Beijing Polytechnic University
Suzuki, K. 11/87 - 3/88	Kajima Corporation Tokyo, Japan
Takada, T. 7/86 - 7/88	Shimizu Construction Company, Tokyo, Japan
Ukon, H. 11/87 - 3/88	Kajima Corporation Tokyo, Japan
Yamaguchi, N.	Takenaka Komuten, Ltd.

Supported by NCEER

Name	Affiliation
Furuta, H. 2/25/88 - 4/20/88	Kyoto University
Koike, T. 12/7/87 - 1/9/88	Kawasaki Steel Corporation
Kishimoto, S. 2/15/88 - 4/20/88	Okumura Corporation
Yun, C-B. 7/1/88-1/31/88	Korean Advanced Institute of Science and Technology

PROGRAM 5:
Disaster Research And Planning

5.1 Overview of Program Area

The destructive forces of earthquakes cause a great deal of physical damage and human suffering. Dead, injured and homeless, as well as heavy dollar losses, leave permanent marks on the earthquake-affected communities. How do they recover from these events, and how do they undertake earthquake-mitigation measures to minimize the losses in prospective seismic events? These, and similar questions have gained prominence both on the research and policy-making levels. Although many sophisticated earthquake engineering solutions have become available, the process of their application in practice is lagging. A large stock of seismically hazardous existing buildings in the United States presents a constant threat to their occupants and communities at large. Awareness of earthquake threat is still considered to be generally low across the nation, and only infrequently do the communities engage in comprehensive earthquake preparedness planning and implementation of other mitigation measures. Furthermore, many regions in the United States are exposed to the effects of multiple natural hazards. In addition to earthquakes, they may be prone to landslides, flooding or high winds, all of which multiplies their vulnerability.

To intensify the implementation of earthquake hazard reduction measures and to improve the overall seismic safety policy-making process, it is necessary to devote equal attention to developing technical solutions, and to understanding the social implications of earthquake events. That is why in the first year of its operation, NCEER's research plan was expanded beyond the strictly technical areas, to include planning, economic, social and political aspects of disaster impact on social systems. The rationale was to focus on earthquake events, but to keep them in the perspective of other natural hazards, and to view jointly the causes of urban multiple hazard vulnerability. In order to establish its work plan for this new program, NCEER convened a panel of experts to seek advice.

The NCEER Expert Panel on Disaster Research and Planning met in Buffalo on August 17 and 18, 1987. It consisted of leading national and international experts in their fields: **William Anderson,** National Science Foundation; **Frederick Cuny,** Intertect; **Ian Davis,** Oxford Polytechnic; **Professor Russell Dynes,** University of Delaware; **Richard Eisner,** Bay Area Regional Earthquake Preparedness Project; **Professor Barclay Jones,** Cornell University; **Alcira Kreimer,** The World Bank; **Frederick Krimgold,** Virginia Polytechnic Institute; **Professor Henry Lagorio,** University of California at Berkeley; **Professor Dennis Mileti,** Colorado State University; **Professor William Petak,** University of Southern California; **William Riebsame,** Natural Hazards Research and Applications Information Center. Frederick Krimgold was invited to chair the Panel.

The following program description is a summary of the Panel's recommendations.

5.2 Summary of Recommendations

Research

Since earthquakes disrupt both physical structure and social systems, it is necessary to devote attention to investigation of earthquake effects in both of these areas. While research into the physical aspects of earthquake effects has already produced very sophisticated earthquake hazard reduction technologies, research into social, economic, and political implications of earthquakes needs to be increased. The social science research community needs to enlarge, in a systematic way, the overall understanding of human behavior related to earthquakes, their effects, and earthquake mitigation measures, as well as to provide a knowledge base necessary for undertaking scientifically sound and effective earthquake education and implementation efforts.

Priorities in the Area of Research

State-of-the-Art Research Assessments: One of the most important research priorities in the area of social impact of earthquakes is to produce a series of the state-of-the-art research assessments. The benefits of this endeavor would be threefold: first, a series of such assessments will be especially appropriate for NCEER's programmatic research philosophy, providing a good orientation for future disaster research in the critical areas; second, it will clarify the areas that need more concerted research efforts, or which are not investigated at all; and third, the whole earthquake research community will benefit from the results of this effort.

The following substantive areas would be especially beneficial topics for research assessments:

- *Seismic Safety Measures:* The principal goal of this research assessment is to establish the current status among available earthquake hazard reduction measures. Some key questions that ought to be asked include: What are the seismic safety measures that are available today? Which ones deal with the physical structure, and which ones with planning and preparedness?

- *Disaster Planning:* The objective of this research assessment topic would be to identify the status of disaster planning in this country and abroad, especially of emergency response, and of long-term earthquake hazard reduction planning. Some of the questions this research assessment will have to ask are: Which are the organizations that are responsible for emergency response and earthquake preparedness planning? What is the status of natural hazard-specific planning effort *vs.* general community emergency planning? What are the processes of adoption and implementation of earthquake-related planning documents?

- *Risk Communication:* The importance of risk communication has been recently emphasized by experts from many fields of earthquake research. This research assessment would assemble and integrate existing knowledge about how to communicate earthquake risk information, and the findings of earthquake engineering and social science research in such a fashion as to maximize their use by the vulnerable communities.

This research assessment would be directed toward relevant audiences, such as technical and non-technical professionals, elected and appointed public officials, members of the private sector, public at large, and so forth.

- *Other suggested topics:* Adoption and implementation of earthquake hazard reduction measures; mitigation of secondary hazards related to earthquakes; safety of building occupants in earthquakes; and business and industry earthquake mitigation, preparedness, and recovery.

Natural Disaster Impact on Urban Systems: This is a major research area which comprises a number of topics which ought to be studied, such as community and organizational response, decision-making, community change, reconstruction and recovery. Several research questions show the breadth of this area: How do the urban systems perform in a disaster? Which are the factors that contribute to urban vulnerability to natural disasters? What are the appropriate methodologies for search and rescue? What is the role of volunteer emergency response?

Education

General complacency about earthquakes and their destructive consequences have long been attributed to the general lack of knowledge of earthquake threat, and a widespread ignorance that effective action to abate seismic risk can be taken. Adequate earthquake education is considered to be a potent tool in increasing earthquake awareness of principal decision-makers, members of the public and private sector, as well as the public at large, and in motivating them to undertake earthquake hazard reduction activities.

Nevertheless, very little information is available on how to create adequate and effective earthquake education programs, which raise earthquake awareness and motivate targeted audiences to actually change behavior. Little is known about the education measures that are effective and those that are not, even in regions of the U.S. where earthquake education is most advanced. There is no credible information on whether the right audiences are being reached at all.

Undertaking comprehensive earthquake education across the section of audiences is one of the most important actions in contributing to earthquake hazard mitigation throughout the country.

Priorities in the Area of Education

Databases: The most pertinent task in the area of earthquake education is to assemble a series of relevant education materials, some of which are discussed below:

- *Catalog of earthquake education programs* in this country and abroad should be compiled including all the audiences that are being addressed, message delivery mechanisms, "packaging" and marketing strategies, published and other materials used in earthquake education process.

- *Database on regional seismicity* ought to collect regional geological and seismological variables that account for difference in seismicity in the United States. This database and the aforementioned *Catalog of earthquake education programs* are meant to be used jointly as a tool for developing new earthquake education programs for the communities at risk.

- *Survey of earthquake education of professionals* should also be prepared, either as an independent database, or as a part of the *Catalog of earthquake education programs*. The survey will collect information on education of such professional groups as architects, engineers and planners; it would list professional associations involved in program planning, speakers, types of courses, course materials, feedback from course participants, and other pertinent information.

Conferences: Conferences, workshops and seminars are excellent medium for natural hazard education of a variety of audiences. International and national education conferences on a variety of natural hazard topics would convene representatives from a cross-section of disciplines. These events would benefit all the members of the natural disaster community, since they would allow for examination, comparison and transfer of relevant educational experiences between the hazards. Publication of conference and workshop proceedings, and their distribution, would make the findings available to a wide audience.

Implementation

Knowledge about and technologies for abating earthquake hazards have dramatically increased in the last twenty years: earthquake engineering design and retrofit solutions have become more sophisticated; urban planners have learned about land-use techniques; architects know more about the relation of architectural design to building performance in earthquakes; planners have improved their strategies of emergency response, preparedness and long-term recovery planning. In contrast to this, however, the level of practical application of available seismic mitigation measures is low in the United States and throughout the world.

Implementation of earthquake hazard reduction measures requires further investigation. Particular emphasis should be placed on understanding the relevant issues of the implementation process, and developing innovative, active and comprehensive implementation strategies. In order for NCEER to contribute effectively to earthquake hazard reduction in the United States, it is necessary for it to focus on the activities which will motivate a change in the behavior of relevant individuals and organizations.

Earthquake-related program implementation is an issue of no, or very small, constituencies. Furthermore, low probability/high consequence issues must exploit powerful "windows of opportunity" in order to be followed by successful policy implementation. The occurrence of earthquake events in the vulnerable regions create the best policy windows; however, they are the most painful and socially costly. Flurries of seismic regulatory activity which usually occur following notable earthquakes (such as the Long Beach 1933, or the San Fernando 1971 events) are frequently quoted in support of this observation.

Although local earthquakes may be the most persuasive events to open the windows for earthquake mitigation policy implementation in vulnerable areas, innovative planning for implementation process may yield successful strategies for creating policy windows in the absence of local earthquakes. For example:

- *Capitalization on non-local earthquakes:* The Mexico City 1985 earthquake and its effects were successfully used as a policy window to intensify the implementation process of the Los Angeles seismically hazardous buildings' ordinance, and for introducing SB-547, the California state-wide law addressing inventory of seismically hazardous unreinforced masonry buildings.

- *Creation of "artificial" policy windows:* Major seismic-related conferences or workshops may be utilized as appropriate media events for creating the climate necessary for promoting the seismic safety policy adoption and initiating program implementation.

- *Introduction of policies that feature incentives* to motivate change in behavior of individuals and organizations is a strategy that requires local-, state- and federal-level political decision-making. An example would be tax incentives for retrofitting of earthquake hazardous buildings.

Priorities in the Area of Implementation

Implementation Case Studies: One of the urgent priorities for NCEER in this area is to support case study research dealing with the characteristic phases of seismic safety policy implementation process. Detailed adoption and implementation analysis of cases of successful and unsuccessful applications of earthquake hazard reduction measures would illuminate this process and point to its problem areas, and help develop an implementation methodology.

Some of the areas that need to be addressed include:

- *Evaluation of Model Projects:* Evaluation research should be undertaken into the performance of model projects in the United States which deal with promoting seismic safety mitigation. It is anticipated that prospective evaluations would point to the areas in the policy that need to be enhanced or modified. Furthermore, evaluation of either one of the two major projects would yield fresh incentives and state-of-the-art information for establishing new programs to deal with earthquake education and planning in the seismically vulnerable areas of the country.

- *Private sector earthquake hazard mitigation:* In connection with the limitations of the regulatory process mandating implementation of measures to reduce earthquake risks, a comprehensive research effort into unregulated, independent private sector decision-making and action ought to be undertaken. An analysis of the motives leading to successful self-interest implementation of earthquake hazard mitigation measures could reveal patterns to be used for enhancement of seismic safety in this sector.

Identification of Population at Risk: In order to facilitate implementation processes throughout the United States it is necessary to identify the population facing seismic risk, not only regionally, but also across social strata, taking into account income, age, ethnicity, and other variables.

User Councils: It is a widespread feeling that the users of earthquake research are a neglected group, and their input is insufficiently being sought or used. However, if users had a readily available vehicle for communicating their needs and problems, the research agendas would better reflect actual problems and seismic safety policy would be easier to define. Organization of user councils is another priority activity.

Seismic Hazard Reduction and Low Probability/High Consequence Earthquake Events: Because of the long recurrence period of earthquakes in many parts of the United States, seismic issues in this country do not generate constituencies. Yet, even moderate earthquake events have been known to create serious disruption in increasingly complex, sophisticated, and thus vulnerable urban systems. The development of effective strategies to motivate audiences to recognize the costs of low probability/high consequence earthquake events would considerably increase seismic safety in this country.

Seismic Safety Problem Definition: Perceived disparity between the desired and actual state of affairs identifies problems. Yet, different audiences have different perceptions of the same phenomenon. Furthermore, their respective evaluations of the problem on their own priority lists differ to a great degree. Coupled with the low probability/high consequence nature of earthquake risk, earthquake issues seldom generate consensus on action among the affected audiences. An inquiry into developing new, innovative ways for identifying, defining and elaborating on the seismic safety problem would help deal with this issue.

5.3 Post-Earthquake Reconnaissance Investigations

Learning from earthquakes in order to minimize loss of human life and reduce material damage in future seismic events has become a necessary part of earthquake research and effective seismic hazard mitigation. Post-earthquake reconnaissance investigations are the principal and timely way of capturing important and perishable data from the field - gathering information on ground motion, damaged and collapsed buildings and structures, rescue efforts, and societal response. Responding immediately after a damaging earthquake in an organized fashion provides the greatest insurance for a successful reconnaissance investigation. Information which is collected and reports which result from initial investigations are used by the larger research community as a guidance for further, more in-depth studies in the critical areas.

According to its initial proposal and its mandate from the National Science Foundation, the National Center for Earthquake Engineering Research has been, and will be taking a more active role in reconnaissance investigations following earthquake events in this country and abroad.

Post-earthquake sites are excellent full-scale 'laboratories' for gaining first-hand knowledge on a variety of seismic phenomena -- ranging from structural damage assessment to integrated societal impact. For example, a particularly powerful method to assess the effect of site conditions on ground motions and, in turn, on damage potential offers itself during aftershock sequences of major damaging earthquakes. While engineering reconnaissance teams may canvas or document the structural damage to a variety of structures and lifelines after a major earthquake, ground-motion experts equipped with portable ground motion recorders could record after-shock ground motions near the damaged sites in a variety of different soil and rock conditions. This would allow one to carry micro-intensity studies into the quantitative realm by relating the damage level not only to the design and performance characteristics of the structures, but also take into account whether particular ground motion characteristics influenced by site conditions contributed to the observed damage. Similarly, post-earthquake social phenomena are important to be captured early after the event, because they perish equally easily as do the data on the structural performance of engineered damaged buildings. Social scientists and planners are capable to capture information which includes rapidly changing processes of emergency response, search and rescue, relief, community recovery, individual psychological trauma, and relative performance of pre-earthquake plans.

The need has been demonstrated for geoscientists, engineers, architects, planners and social scientists to jointly participate in well coordinated post-earthquake reconnaissance investigation teams. NCEER can significantly contribute to the rapid post-earthquake data collection by helping coordinate team effort to capture valuable earthquake-generated data for future analysis.

Since there appears to be a lack of uniform processes in conducting post-earthquake reconnaissance visits, as a first step, the Center plans to, without supplanting, but in conjunction and cooperation with organizations and institutions already involved in this process, establish guidelines for reconnaissance trip planning, data gathering and information dissemination. Each post-earthquake situation is different in many aspects from another, and it is impossible to produce a stringent checklist, which will be applicable to all situations. Thus, the Center will produce a framework for post-earthquake reconnaissance investigations, including such areas as background information, geoscience data, engineering data, secondary earthquake effects, social impact data, and other relevant information.

In developing this framework, extensive use of existing reconnaissance reports will be made. On the basis of a preliminary review, meetings will be organized to seek advice from experienced participants in previous post-earthquake reconnaissance teams. Also, opinion will be sought from users of published reconnaissance reports.

PROGRAM 6:
Education and Technology Transfer

6.1 Overview of Program Area

The major goal of NCEER is to contribute to earthquake hazard reduction in the United States. In order to achieve it, NCEER must communicate the growing earthquake-related knowledge to audiences ultimately responsible for earthquake hazard reduction decision-making and policy implementation. The Education and Technology Transfer Program addresses this issue by focusing on the need to integrate academic research with industrial applications; to facilitate the exchange of ideas and information among researchers from a variety of disciplines related to earthquake engineering; to integrate research results into programs of study at various universities across the country; to educate future professionals and researchers in engineering, architecture, planning and social science and to offer continuing educational opportunities for the practicing experts; and to offer a comprehensive collection of earthquake-related literature to the research community and the public at large.

To foster this objective, workshops and conferences have been planned during the second year. The workshops and conferences feature topics concerning the assessment of seismic hazards in the eastern United States and the development of knowledge-based systems in earthquake engineering.

In May, 1986, a monthly forum entitled *Seminars on Earthquakes* was established. The purpose of the seminars is to educate the audience about earthquakes, to facilitate cooperation between NCEER and visiting researchers, and to enable visiting speakers to learn more about NCEER.

An Information Service was established at the Center's administrative headquarters in Buffalo to provide a comprehensive library of current research and publications, and a Publications Department was established to publish research findings, resulting from Center-sponsored research programs.

6.2 Workshops and Conferences

Symposium on Seismic Hazards, Ground Motions, Soil-Liquefaction and Engineering Practice in Eastern North America (October 20-22, 1987)

The Symposium on "Seismic Hazards, Ground Motions, Soil-Liquefaction and Engineering Practice in Eastern North America" was held for researchers from the earth sciences and the geotechnical and earthquake engineering disciplines. Participants assessed the present state of theoretical knowledge of earthquake hazards in eastern North America, and discussed the impact (or lack of impact) of this knowledge on engineering practice in Eastern North America. Particular emphasis was placed on how to narrow the gap between theoretical knowledge and engineering practice.

The Symposium was limited to about 60 participants, most of which were invited contributors. The Symposium served in part as a preparation for a major public conference planned jointly by NCEER and the New York Academy of Sciences, scheduled for February 24-26, 1988, in New York City. This later conference addresses related scientific topics, but will also cover public policy issues. Proceedings from the Symposium have been published and are available through NCEER.

Conference on Earthquake Hazards and the Design of Constructed Facilities in the Eastern United States (February 24-26, 1988)

A benchmark conference on "Earthquake Hazards and the Design of Constructed Facilities in the Eastern United States" was held at the Sheraton Centre, New York City, February 24-26, 1988. The conference was jointly sponsored by the New York Academy of Sciences and the National Center for Earthquake Engineering Research and co-sponsored by several organizations including the Earthquake Engineering Research Institute, the Metropolitan Section of the American Society of Civil Engineers and others.

The conference objectives were to review, before the engineering community and decision makers, the state-of-the-art of assessing the earthquake hazards in the eastern United States, to convey a realistic estimate of the severity of such hazards especially for urban centers, and to present alternative methods and strategies for the engineering design community and related regulatory agencies to respond cost-effectively to the earthquake risks.

Design engineers, seismologists, geotechnical engineers and representatives of various private and public organizations from the United States and Canada participated. Speakers and panelists presented the relevant data, discussed scientific and engineering issues and their solutions, and considered alternative policies.

Workshop on Expert Systems in Earthquake Resistant Design (August 17-19, 1988)

The Workshop on Expert Systems in Earthquake Resistant Design will serve as an information dissemination meeting between about 45 researchers and engineers or architects who are actively engaged in earthquake resistant design of buildings. It will provide an opportunity for practicing structural engineers and architects to try several knowledge-based systems developed in NCEER projects, and to offer suggestions for their improvements. At the same time, researchers can exchange ideas about their work and explore avenues and opportunities for cooperation and advancements of the state-of-the-art. The Workshop will rely on hands-on experience and round-table discussions, therefore attendance is limited and is by invitation only.

The knowledge-based systems presented at this Workshop are based on the earlier versions discussed and evaluated by researchers at the August, 1987 Workshop on Knowledge-based Systems in Earthquake Engineering. Several knowledge-based prototype programs will be developed and will be ready to demonstrate at this Workshop. They include ARCHQUAKE for preliminary architectural design, STRAKE for preliminary structural design of buildings, and programs for the safety evaluation of existing or damaged buildings.

International Workshop on the Spatial Variation of Earthquake Ground Motion (September 15-17, 1988)

The Workshop on "Spatial Variation of Earthquake Ground Motion" will be held for a small group of specialists who are actively researching topics in this area. The workshop will be informal, but in-depth. Participants will make brief presentations, followed by lengthy discussion sessions. The main themes and topics of the workshop include:

- Ground motion models that incoporate spatial variation: empirical analyses; geophysical models; engineering models.
- Soil effects; foundation inputs.
- Inputs for lifeline system analysis.
- Design seismic inputs that account for spatial variation.
- Array configurations and data processing from seismological and engineering points of view.

The workshop is limited to about 25 invited participants. It will be held at Dunwalke, an estate owned by Princeton University located in Somerset County, New Jersey, and is co-sponsored by the ASCE Council on Lifeline Earthquake Engineering. Proceedings of the Workshop will be published by NCEER.

6.3 Seminars on Earthquakes

In May of 1986, the National Center for Earthquake Engineering Research established a monthly forum, entitled ***Seminars on Earthquakes***. The purpose of initiating the seminars was to educate the audience about earthquakes, to facilitate cooperation between NCEER and visiting researchers, and to enable visiting speakers to learn more about NCEER.

1987 Program

The first ***Seminar on Earthquakes*** was held in May 1987. It consisted of post-earthquake reconnaissance reports on earthquakes that struck New Zealand and Ecuador in early March. The speakers were Esteban Crespo, Thomas O'Rourke and Peter Yanev. The June seminar speaker, Dr. Charles Scawthorn focused on the hazard of fires following earthquakes. In July, Marjorie Greene, a project planner with the Bay Area Regional Earthquake Preparedness Project (BAREPP) in Oakland, California, discussed the promotion of seismic safety in the ten San Francisco Bay Area counties. The August seminar involved a panel discussion on research applications in earthquake hazard mitigation. The panel participants were Ian Davis, Edward Fratto, Robert Ketter, Frederick Krimgold, Ugo Morelli and William Petak.

The September event was organized to coincide with the anniversary of the 1985 Mexico City earthquakes. NCEER felt that the most appropriate way to commemorate this disaster was by discussing what lessons have been learned from the earthquake and its aftermath. Ten speakers from both the United States and Mexico discussed various dimensions of that disaster.

In October, Dr. Anne Stevens of the Geological Survey of Canada gave a presentation on the peculiarities of Canadian seismicity. The month of November brought "Art Collections: A Discussion of Earthquake Mitigation", by Barbara Roberts, a conservator of the Decorative Arts and Sculpture, of the J. Paul Getty Museum, Santa Monica, California. In December 1987, NCEER held two seminars: the first was Kathleen Tierney's presentation on "Coalinga 1983 and Whittier 1987: A Comparison of Earthquakes". Dr. Dan Chen, a Professor from the Tsinghua University at Beijing, China, gave a presentation on "The 1976 Tangshan Earthquake and the Performance of Structures".

1988 Program

For 1988, the following seminars have been scheduled:

1/11/88 **Professor Vitelmo Bertero**
University of California, Berkeley
"Earthquake Resistant Building Design and Construction"

2/29/88 **Deane Evans**
Steven Winter Associates
"Architectural Issues of Seismic Design"

3/23/88 **Dr. Douglas A. Foutch**
University of Illinois at Urbana-Champaign
"Seismic Design Implications for Steel Buildings"

4/6/88 **Dr. James O. Jirsa**
Ferguson Structural Engineering Lab
"Repair and Strengthening of Reinforced-Concrete Buildings"

5/2/88 **Professor Emilio Rosenblueth**
Institute of Engineering, UNAM
"Seismic Risk Assessment"

6/1/88 **Dr. David E. Alexander**
University of Massachusetts
"Southern Italy, 1980 Earthquake: Some Social Concerns"

7/25/88 **Paul Flores**
Southern California Earthquake Preparedness Project, Los Angeles
Dr. Charles Thiel, Consultant
Piedmont, California
"The Whittier-Narrows Earthquake"

8/23/88 **Richard Roth, Jr.**
Assistant Insurance Commissioner
State of California Dept. of Insurance
"Issues on Earthquake Insurance"

9/16/88 **Professor H. Bolton Seed**
University of California, Berkeley
"Connecting Research and Practice in Geotechnical Engineering: The Case of the Aswan Dam"

10/17/88 **Robert K. Reitherman**
The Reitherman Company
"Non-structural Aspects of Earthquake Effects"

11/14/88 **Dr. Robert Schuster**
United States Geological Survey
"Earthquake-induced Landslides"

12/5/88 **Dr. Patricia A. Bolton**
Battelle Human Affairs Research Center
"Residential Damage Following Earthquakes in the Third World"

6.4 Information Service

A comprehensive Information Service has been established during the first year. The Information Service is a permanent and on-going facility which provides a broad range of services for the staff of the Center and also for the community, industry, and research interests throughout the country. The features of the Information Service include:

- A comprehensive collection in earthquake engineering.
- A computer-based literature database that is accessible to local, regional and national users.
- An information system which provides reference assistance, photocopies, computer and manual searches, individual and inter-library loans, electronic request service, telefacsimile document delivery, individually tailored current awareness service, and regular accessions lists.

During the past year, the collections of the SUNY/Buffalo Libraries have been surveyed and needs for NCEER research have been identified. A large number of items were purchased to establish a comprehensive collection in earthquake engineering and related topics.

A computerized database of the literature in the field has been initiated and developed, using the services of BRS Technologies, Inc. Center staff have, through a series of activities, designed and refined the record structure and inputting procedures. The database is operational, with over 2,000 online records as of February 1988.

Information services, including reference assistance, document delivery, computer and manual index searches, acquisition of materials, photocopy and microform duplication, and the publication of subject literature lists, have been heavily used by NCEER staff and researchers, and by various agencies and professionals throughout the country.

A monthly newsletter, listing new acquisitions and highlighting developments in information science and research related to earthquake engineering, has circulated to about 130 professionals both in and outside the United States.

Cooperative activities involving other libraries and information sources have been initiated and promoted by Information Service staff.

Second-year actvities include:

- Continue to provide comprehensive information support services for staff, investigators, and the public.
- Add approximately 400 new records per month to the existing NCEER database.
- Promote the use of the database by staff, investigators and other interested parties.
- Examine the feasibility of expanding the database to a searchable, full-text database using some form of optical technology.
- Develop remote information stations in Red Jacket and Ketter Hall, that permit Center staff to access the Information Service database, request needed materials, perform searches on national databases, and receive documents via telefacsimile.

6.5 Publications Department

A major goal of the National Center for Earthquake Engineering Research is to communicate the findings and results of research being conducted to the scientific community and the public at large. During the first year of operation, NCEER established a Publications Department to handle the editing, production and distribution of all printed material generated by the Center.

The Department edits and publishes a quarterly newsletter, the *NCEER Bulletin*. The newsletter contains pertinent information regarding timely research in earthquake engineering; NCEER-sponsored events such as workshops, seminars, conferences etc.; administrative and/or Center management activitites; reports from the Information Service; and lists available NCEER publications. The *NCEER Bulletin* is an on-going publication of NCEER which is published in January, April, July and October of each year.

A computerized data base has been developed, initially for distribution purposes, of many professionals involved in earthquake engineering, including academicians, industrial practitioners and government officials. The data base contains over 2,400 names and will continue to be expanded as membership rosters from professional organizations are received.

Over twenty-five technical reports have been published and more reports are in progress. The cover design and layout, cover and title page information, report format and submittal guidelines have been established and applied to these reports. Published reports are distributed to the National Technical Information Service as well as to various libraries throughout the United States and abroad. Over 800 reports have been distributed to various organizations and individuals on an as requested basis.

In addition, the English translation of a significant Japanese research report will be published during the second year. The report, entitled "Manual for Repair Methods of Civil Engineering Structures Damaged by Earthquakes," was prepared in December, 1986, under the auspices of the Japanese Ministry of Construction. It is a major work on inspection, rehabilitation, and repair methods of various earthquake-damaged engineered structures.

6.6 Center Investigators in Program 6

The investigators in the area of Education and Technology Transfer are:

Name	Affiliation
Gergely, P.	Cornell University
Jacob, K.	Lamont-Doherty Geological Observatory
Ketter, R.L.	SUNY at Buffalo
Pantelic, J.	NCEER
Soong, T.T.	SUNY at Buffalo
Vanmarcke, E.	Princeton University
Wilson, J.L.	Lehigh University