RECENT AWARDS: APRIL-JUNE 1979

NATIONAL SCIENCE FOUNDATION
DIVISION OF PROBLEM-FOCUSED RESEARCH
DIRECTORATE FOR ENGINEERING AND APPLIED SCIENCE
WASHINGTON, D.C. 20550

PLEASE READ THIS

We are required to update our mailing list every year. If you wish to continue to receive *Recent Awards,* YOU MUST RETURN THE POST CARD ON PAGE 20 OF THIS ISSUE. Indicate the programs of interest to you and attach your white address label (or clearly print your name, address, and mailing list code number). Your name will be deleted from our mailing list if we do not hear from you within thirty days.

ESTABLISHMENT OF THE DIRECTORATE FOR ENGINEERING AND APPLIED SCIENCE (EAS)

Effective July 1, 1979, The National Science Foundation merged the Directorate for Applied Science and Research Applications (ASRA), which had contained the Division of Problem-Focused Research (PFR), and the Division of Engineering. The primary purposes of this reorganization were to:

- Strengthen the engineering programs of NSF by giving engineering a single, more visible place in the NSF organization;
- Enhance NSF's programs of applied and problem-focused research by providing a broader base of science and engineering on which to build; and
- Recognize the key role of engineering in the transfer of science into technology by placing the Foundation's major engineering, industry-related and problem-oriented programs in one organization.

The individual programs of PFR, which are programs whose awards are described in *Recent Awards,* have the same program objectives and levels of funding for FY 1979 as they had before the reorganization.

INTRODUCTION

Recent Awards keeps researchers, research users and policy makers informed about projects being supported by NSF's Division of Problem-Focused Research (PFR).

This brochure describes the awards made by PFR during the period April 1, 1979 through June 1, 1979 (third quarter, Fiscal Year 1979). The data have been reconciled with the NSF's Management Information System. Questions on PFR program objectives, procedures for application, or general information should be addressed to the Professional Assistant for PFR, Room 1134 A, National Science Foundation, Washington, D.C. 20550.

HOW TO OBTAIN PFR RESEARCH FINDINGS AND RESULTS

One of the most important objectives of PFR is the timely and widespread dissemination of the results of PFR-sponsored research to potential users. The name and mailing address of the Principal Investigator and Grantee Institution is contained in each project description in this brochure. Persons wishing to obtain information on project findings including project reports, monographs, journal articles, technical reports, and other such relevant materials should write to the Principal Investigator at the Grantee Institution to determine what information is available and at what, if any, cost it may be obtained. The Grantee Institution may charge a nominal amount for the duplication and mailing of such materials to cover costs. The Principal Investigator may furnish information on how interested persons may acquire reports and other materials as appropriate from the National Technical Information Service (NTIS) of the Department of Commerce in lieu of furnishing the report or other material directly. NTIS is the central point in the United States for the public sale of Government-funded research and development reports and other analyses prepared by Federal agencies, their contractors, and grantees. The Principal Investigator may also cite journals or other publications where project information may be looked up instead of furnishing a copy of the article.

DEFINITIONS AND EXPLANATION OF FORMAT

Formulation and Expression of Seismic Design Provisions;[1] Steven J. Fenves;[2] Carnegie-Mellon University, Department of Civil Engineering, Pittsburgh, PA 15213;[3] **Award #76-19033 A04**

1. **Title of the Specific Grant**

ASRA INFORMATION RESOURCES
NATIONAL SCIENCE FOUNDATION

2. **Principal Investigator:** the chief scientist or administrator who is responsible for the research plan and fiscal expenditures as an NSF awardee. Co-Principal Investigators will also be listed.
3. **Institution Conducting the Research:** any college, university, laboratory, industry, or other organization, whether operating on a profit or nonprofit basis, as well as State governments and Federal organizations.
4. **Award Number:** the award number and amendment number, if applicable.

Alternative Biological Sources of Materials

The Alternative Biological Sources of Materials program deals with selected aspects of the problem of meeting the Nation's future needs for raw materials. This program is directed toward alleviating national dependence on selected scarce resources by making alternative biological sources of materials available in the United States. Three particular topics have been selected for investigation in Fiscal Year 1979: biological conversion of lignocellulosic materials to useful chemicals; biological nitrogen fixation; and production of speciality chemicals from arid land plants (specifically, production of rubber from the guayule plant).

1. Enhancing Plant Productivity With Nitrogen-Fixing Bacteria; Winston J. Brill; University of Wisconsin-Madison, Department of Bacteriology, Madison, WI; **Award #77-00879 A02**

   The objective of this three year research project is to enhance plant productivity by coating the seeds of legumes with specific proteins which bind nitrogen-fixing bacteria to the roots of plants, and to construct and test by field application superior strains of such bacteria, both symbiotic and free-living, for use with legumes and cereals.

   During this project's first two years, it was shown that specific protein-coated clover seeds gave no increased yield under field conditions. Use of superior mutants of *Rhizobium japonicum* led to yield improvement in tests conducted in areas where soybean had not been grown before, but not in areas previously exposed to soybean. This is presumably due to competition of indigenous *Rhizobium* populations. In this, the project's third year, coating of alfalfa and soybean seeds will be studied, and means to overcome the competition of indigenous organisms to super mutants in soybean will be developed and tested.

2. Breeding Improvement of Rubber Yield in Guayule; George P. Hanson; California Arboretum Foundation, 301 N. Baldwin Ave., Arcadia, CA 91006; **Award #76-24472 A03**

   The objective of this project is to develop improved varieties of guayule to a point where guayule can be cultivated as a domestic source of natural rubber.

   During the past two years, guayule seeds from the wild have been collected and germinated, crosses between existing varieties produced and planted, and horticultural procedures for transplanting seedlings developed and evaluated. Hybridization, selection and horticultural studies will continue, and improved varieties from preceding years will be identified and made available for agronomic evaluation.

3. Enhancement of Biological Nitrogen Fixation by Genetic Manipulation of *Rhizobium*; Donald R. Helinski; University of California-San Diego, Department of Biology, La Jolla, CA 92093; **Award #77-24945 A01**

   This award provides incremental funding for the second year of a 4-year continuing grant. The objective of the project is to enhance the nitrogen fixing ability of the bacterium *Rhizobium meliloti*, which forms a symbiotic relationship with alfalfa, by manipulating the genes of the bacterium.

   During the first year of the project a broad host range plasmid suitable for use with *R. meliloti* has been constructed, and conditions for high frequency conjugal mating between *E. coli* and *R. meliloti* were established. In the second year, a gene bank of *R. meliloti* in *E. coli* will be constructed and attempts will be made to clone nitrogen fixing genes. A test system will be set up to evaluate the effect of *R. meliloti* hybrid plasmids on symbiosis with alfalfa.

4. A Multifaceted Approach to Enhancing Biological Nitrogen Fixation; Marvin Lamborg; Chas. F. Kettering Foundation Research Laboratory, 150 E. South College Street, Yellow Springs, OH 45387; **Award #77-27269 A01**

   This award supports the second year of a 3-year continuing project. The goal of the project is to increase the capacity for nitrogen fixation of several living organisms and of the enzyme involved in the process through physiological and chemical manipulations.

   During the first year of the project conditions for optimal growth of five *Azolla* species were identified, the acetylene reduction activity of eleven strains of *Rhizobia* evaluated, and a procedure for isolation of large amounts of the molybdenum-iron cofactor of nitrogenase worked out. In the second year studies on *Azolla* and *Rhizobia* will be continued, and extensive measurements made on the spectral, electro-chemical and catalytic properties of the Fe-Mo cofactor to provide leads to improve the nitrogen fixing activity of these systems.

5. Enhancing Biological Production of Ammonia from Atmospheric Nitrogen and Soil Nitrate; James M. Lyons; University of California-Davis, College of

Agricultural and Environmental Science, Davis, CA 95616; **Award #77-07301 A02**

This award provides incremental funding for the third year of a 5-year continuing grant. The four major objectives of this multidisciplinary project are to enhance nitrogen fixation in bacteria by genetic manipulation, to increase the efficiency of symbiotic nitrogen fixation in legumes, to evaluate the potential for supplying nitrogen to rice crops through the *Azolla/Anabaena* symbiotic system, and to increase the efficiency of conversion of nitrate to ammonia in soil bacteria and in crop plants.

Highlights of the second year's research included the recognition that hydrogen uptake in *Rhizobia* is genetically controlled by a plasmid, the identification of cyclic mononucleotides as regulators of nitrogen fixation by root nodule bacteria, the demonstration that superior mutants of *Rhizobia* can increase total productivity of soy plants, the continued optimization of *Azolla* propagation as a source of nitrogen for rice plants, and the isolation of bacteria which convert nitrate to ammonia under anaerobic conditions. These studies will be continued, expanded and extended to field experiments as appropriate during the third year of the project.

6. New Polymers Based on Industrial Oils From Renewable Resources; John A. Manson; Lehigh University, Materials Research Center, Bethlehem, PA 18015; **Award #78-27336**

   Organic chemicals and polymers, essential to the functioning of the U.S. society, are presently derived largely from petroleum. Alternative sources need to be examined. One possibility is the use of plant-derived materials for the production of the necessary chemicals, polymers, plastics, solvents, and intermediates. The goal of this research project is to investigate and develop prototype new polymers based on renewable agricultural resources, namely, industrial-type oils derived from non-edible oil-seeds. Emphasis be placed on oil-seeds from current or potential cultivars that are adaptable to growth in regions not suitable for other crops.

   This research will evaluate the most appropriate natural oils in terms of versatility for chemical reactions, present and potential availability, and cost. Oils to be considered include drying oils such as tung, linseed and soybean, as well as oils from cultivars such as *Limnanthes* and *Lesquerella*. Emphasis is to be placed on oils that are primarily of industrial rather than nutritional interest. Rubber-like products will be synthesized from the natural oils selected, and their physical and chemical properties characterized. These natural oils will be compared with glassy and brittle polymers such as polystyrene to form interpenetrating polymer networks. The cost-effectiveness of these new materials will be characterized in a preliminary manner.

7. Production of Hydrogen by Marine Blue-Green Algae; Akira Mitsui; University of Miami, School of Marine and Atmospheric Science, Miami, FL 33124; **Award #77-11545 A02**

   The objectives of this research are to characterize promising species of marine blue-green algae which produce hydrogen gas, and to optimize this biological activity in the microbes by environmental (physiological) means. Research for this award period will focus on enhancing and stabilizing hydrogen production and developing small-scale reactor systems.

8. Jojoba Meal As a Livestock Feed; Anthony J. Verbiscar; Anver Bioscience Design, Inc., 160 E. Montecito Ave., Sierra Madre, CA 91024; **Award #76-23895 A03**

   The objective of this research is to develop a practical low-cost procedure to detoxify jojoba meal so that it can be used as an ingredient in livestock feed. The research will complete evaluation of practical processes to detoxify jojoba meal, isolate and identify its two minor toxicants, prepare large quantities of detoxified meal, and demonstrate the efficacy of detoxified meal as feed for cattle, sheep and poultry.

   It is expected that in about five years, as jojoba plantations mature and begin to bear fruit, a practical procedure to detoxify the meal so as to render it suitable for animal feed will become an important factor in determining the economic feasibility of this new agri-industry.

Chemical Threats to Man and the Environment

The Chemical Threats to Man and the Environment Program supports applied research relevant to the prediction, identification, characterization, and control of hazards resulting from chemical compounds in the environment. Emphasis is placed on the development of techniques and methodologies that can be applied to a spectrum of situations, and on research on problems that are not amenable to routine approaches. Proposals in areas that are receiving considerable support from other agencies, such as NIH and EPA, are usually not funded by this program.

The Chemical Threats to Man and the Environment program's allocation for FY 1979 is $3,600,000. All awards that will be made under this program category in FY 1979 will be directed toward completion of prior program objectives. **No funds have been requested for continuation of the Chemical Threats to Man and the Environment program in the FY 1980 budget submitted to the Congress on January 22, 1979.**

1. Investigation of Water-Borne Cancer Hazards Associated With the Buffalo River Environment; John J. Black; Health Research, Inc., 666 Elm Street, Buffalo, NY 14263; **Award #78-22625**

Preliminary studies of the Buffalo River and adjacent Black Rock Ship Canal and the Niagara River have indicated a complex mixture of contaminant organic chemicals in bottom sediments. Several species of bottom feeding fishes collected from these areas exhibit specific neoplasms that appear to result from chronic exposure to the contaminated sediments. The sediments contain carcinogens/mutagens as evidenced by positive Ames test results and high pressure liquid chromatography studies, lending strong support to this hypothesis.

This hypothesis will be directly tested by exposing the appropriate species of fish to a concentrated extract (organic solvent) derived from a composite bottom sediment sample. The objective of these experiments will be to produce tissue lesions identical to those observed in the feral fish populations. Fish to be studied include sheepshead (drum), white sucker, and brown bullhead. In addition to the carcinogenesis testing in fish, data concerning the levels of aromatic hydrocarbon contaminants in fish and bottom sediments collected from this aquatic ecosystem will also be sought.

2. Quantitative Electron Microprobe Analysis of Individual Airborne Particles; Peter R. Buseck; Arizona State University, Department of Chemistry and Geology, Tempe, AZ 85281; **Award #76-17130 A01**

   The goal of the research is to determine the chemical composition of individual submicron airborne particles, and to relate this composition to sources and to the chemical and physical transformation processes these particles undergo. The research is designed to: refine correction procedures developed by this group for the analysis of single particles by X-ray analysis by energy-dispersive and wavelength-dispersive methods using the electron microprobe; characterize by composition, size, and morphology the respirable particles from Phoenix ambient aerosol samples; characterize the aerosols from two major copper smelters; identify area emission sources by comparison of individual particle analysis from ambient and source samples; investigate the nature and extent of particle coating and agglomeration; and explore the capabilities of the scanning transmission electron microscope for submicron particle analysis.

3. Effects of Pollutants on Gills of Freshwater Fishes; Paul O. Fromm; Michigan State University, Department of Physiology, East Lansing, MI 48824; **Award #77-12300 A02**

   Gills represent that tissue or organ of fishes which is maximally exposed to water-borne pollutants. Continuous ventilatory activity insures that the concentration of any toxicant present in the aquatic environment is maintained at the respiratory surface. This study of the action of pollutants on fish gills will provide valuable information relative to the impact of man's activities on the aquatic environment. The project will investigate the isolated perfused gill preparation as a model for the study of the effect of pollutants on fish.

   The overall project will consist of three main divisions: experimental investigation of the permeability properties (flux of water) across isolated perfused gills and the effect of pollutants on same; a study of the salt transport capabilities in gills exposed to pollutants; and biotransformation of pollutants by gills during transit of materials from the ventilate to the blood vascular space.

4. Aerosol Characterization in Real Time; Robert K. Gould; Aerochem Research Labs, Inc., P.O. Box 12, Princeton, NJ 08540; **Award #78-26838**

   This research project is aimed at developing an atmospheric aerosol analysis technique capable of operating in either a continuous mode or as an individual particle analyzer. The instrumentation to be designed will provide information on particle mass and composition. To accomplish these measurements, an aerosol beam will be separated from the gaseous constituents and rapidly vaporized in a high-temperature cell. A pressure sensor will be used to estimate particle mass. Mass spectrometric techniques will be used to measure particle composition. The developed techniques are expected to be capable of measuring several aerosol properties. The research effort to be pursued will include an evaluation of the advantages and limitations of the developed techniques as they apply to specific areas of atmospheric aerosol science.

   One area of expected application is the measurement of particle composition (averaged over all particles) without the need for concentration by integrated collection techniques. Another area of interest concerns the ability to measure concentrations of a given compound (or a few compounds) on a particle-by-particle basis.

5. Oxidation Processes in Soil; Theodore Mill; SRI International, Department of Physical and Organic Chemistry, Menlo Park, CA 94025; **Award #78-27401**

   To understand the behavior of chemicals in the environment, we must understand chemical conversions such as chemical (abiotic) oxidations in soil systems.

   This study has two major objectives: to identify and quantify important oxidants such as peroxy radicals and singlet oxygen formed on sunlight irradiation of soils, and to identify the structural features in soils (clays, humic acids, and metal oxides) that most strongly affect the production of photochemical oxidants. These oxidants will be identified by using the product composition in the oxidation of selected chemical probes. Kinetic analyses of these oxidations should provide a basis for estimating average concentrations. Radical or oxidant traps may also be

used. Model soils made up from known proportions of purified clays and metal oxides will be used to develop an improved understanding of the role of these materials, as well as humic acids, in generating or scavenging oxy radicals, singlet oxygen, and other oxidants.

Community Water Management

The Community Water Management program (CWM) traces its origin to elements within the former Regional Environmental Systems (1971-75) and Regional Environmental Management (1976-78) programs that dealt with water-related issues of land use, urban water resources, residuals and risk management. CWM's goal was to support research focused on management of threats to community water to achieve and maintain acceptable levels of health, safety and environmental quality at reasonable cost. CWM was designed to meet that goal by supporting research to identify and assess alternative and innovative concepts for dealing with community water/wastewater-related problems.

The Community Water Management program's allocation for FY 1978 was $700,000, an amount which is based upon continuation needs for existing grants. It is not likely that awards will be made under this program category in FY 1979 which are not directed toward completion of prior project and program objectives. **No funds were requested for continuation of the Community Water Management Program in the FY 1980 budget submitted to Congress on January 22, 1979.**

1. Stabilization of Community Wastewater Sludges By Soil Invertebrates; Roy C. Hartenstein; S.U.N.Y., College of Environmental Science and Forestry, Environmental and Forest Biology, Syracuse, NY 13210; **Award #78-09331**

   This research will determine the feasibility of utilizing earthworms for stabilization of community wastewater treatment plant sludges prior to their application to agricultural land for use as a soil conditioner. Substances contained in anaerobically digested sludges which exert a toxicity effect on soil invertebrates will be identified. The optimum conditions for amelioration of the toxicity effect are being identified and characterized. The nutritional needs of several earthworm species are being studied as they may be affected by temperature, moisture and oxidation-reduction potential. Caloric and space needs for optimum conversion of sludges into biomass and humus as well as the functional role of minerals in soil on conversion of sludges into castings are being investigated. The effects of chemical precipitants on the conversion process are also being characterized.

2. Wetland Utilization For Management of Community Wastewater; Robert H. Kadlec; University of Michigan, Department of Chemical Engineering, Ann Arbor, MI 48109; **Award #77-23868 A01**

   This research will evaluate the use of a peat marsh wetland in the Houghton Lake Wildlife Area for advanced treatment of domestic wastewater. A 600 acre site designed to accept 180 million gallons per year of effluent data is being monitored to provide for verification and potential readjustment of ecosystem models constructed and validated under a prior NSF grant.

   Observations will be made to determine the effect of wastewater effluent application on hydrologic, nutrient, soil, microbial, algal, vegetation and animal compartments of the ecosystem. Water quality parameters are being determined at the treatment plant and in the wetland to assess renovation efficiency. Ecosystem uptake of phosphorus and nitrogen is being investigated to determine mechanisms of nutrient removal. Impacts on public use of wetland, potential benefits from increased wetland productivity, and preservation of the quality of receiving waters are also being determined. Cooperating agencies include the State of Michigan Department of Natural Resources, the U.S. Environmental Protection Agency, the Houghton Lake Sewer Authority and the consulting engineering firm of Williams and Works, Inc. of Grand Rapid, Michigan.

Earthquake Hazards Mitigation

The goals of the Earthquake Hazards Mitigation program are to develop an understanding of earthquakes in relation to constructed facilities, and to reduce casualties, damage and social and economic disruption which are the result of earthquakes. The actions necessary to attain these goals are heavily dependent upon technical capabilities which require development through research.

Primary objectives of EHM-supported research are: to determine the nature of strong ground shaking during earthquakes from instrumental data; to develop analytical procedures to predict the spatial and temporal distribution of strong ground motion at different sites; to understand the dynamic behavior of soil and rock subjected to strong shaking; to determine the nature of the interaction of structures and their supporting soil during earthquakes; to determine the engineering aspects of reservoir-induced seismicity; to develop procedures for performing dynamic analyses of proposed or existing construction under earthquake loadings; to develop an understanding of materials and structural components subjected to damaging dynamic loads; to develop procedures for analysis and design of non-structural and architectural systems for earthquake effects; and to study the influences of architecture and urban planning activities on the earthquake vulnerability of regions.

1. Engineering Monographs on Earthquake Criteria and Structural Design; M. S. Agbabian; Earthquake Engineering Research Institute, 2620 Telegraph Ave., Berkeley, CA 94704; **Award #79-06776**

   One of the most important aspects of earthquake engineering research is the dissemination and application of the results to those individuals and organizations who have the need-to-know in order to make knowledgeable decisions pertaining to the mitigation of the earthquake hazard.

   The objective of this project is to encapsulate the practical knowledge of earthquake engineering into reference volumes for use by engineers, building officials, and governmental agencies interested in the mitigation of earthquake hazards, the safety of citizens, and the protection of property.

   This series of monographs will serve as a ready reference on the major topics of concern in seismic design. The monograph volumes to be developed are: Seismicity and earthquake hazard analysis, dynamics of structures, interpreting strong motion accelerograms, understanding soil behavior, soil-structure interaction, seismic design spectra, design criteria and seismic design procedures. The monographs will be prepared by national experts, each in his own field, and will be reviewed by an advisory committee of equally qualified stature. This project is a natural sequel to the series of lectures presented by authors at regional seminars under the direction of the Earthquake Engineering Research Institute.

2. Analysis of Lifelines Subjected to Earthquakes; Richard E. Barlow; University of California-Berkeley, Operations Research Center, Berkeley, CA 94720; **Award #78-22265**

   This research is addressed to the development of a systematic procedure for assessing the reliability of lifeline systems subjected to strong motion earthquakes. Emphasis will be on a methodology for review of an existing lifeline system. Common features and differences of systems will be mathematically modeled to permit the systematic refinement of details based on experience. The behavior of the elements of the lifeline system will be studied from a structural engineering viewpoint. The resulting methodology will be applied to an actual lifeline system in California.

3. A Longitudinal and Cross Cultural Study of the Post Impact Phases of a Major National Disaster; Frederick L. Bates; University of Georgia, Department of Sociology, Athens, GA 30602; **Award #77-12721 A02**

   This proposal is for the third year of a continuing award to analyze the aftermath of the February 1976 earthquake in Guatemala. The research includes longitudinal analyses of households affected by the earthquake and comparable data from households in unaffected sites; interviews with officials of local and international relief and rehabilitation agencies to determine organizational responses to the event; and interviews with local leaders to determine their perceptions of post-earthquake adjustments.

   Results are intended to provide information useful to Guatemala, other Central and South American nations, and agencies engaged in disaster relief and reconstruction in improving efforts to assist disaster stricken communities in the future.

4. Tall Buildings and Urban Habitat: Impact on the Urban Environment and Planning for Natural Disasters; Lynn S. Beedle; Lehigh University, Department of Civil Engineering, Bethlehem, PA 18015; **Award #78-16324**

   This research will utilize data assembled by the Council on Tall Buildings and Urban Habitat. The Council, representing 1200 voluntary participants from more than 52 countries and a wide variety of professional disciplines, prepared a new and comprehensive collection of information in a five volume monograph.

   This research effort will be concerned with the overall process of incorporating planning for natural disasters into high-rise structures and for assessing the impacts of such planning. This research will have three phases: utilization/implementation research, which will examine mechanisms to get material in the monographs on Tall Buildings into standards, model codes, and specifications; the development of an improved data base on dynamic forces and loads on tall buildings due to natural hazards; and a study to redefine critically needed research topics related to tall building construction.

5. Conference on Stability of Space Frame Structures Under Static and Dynamic Loads; Lynn S. Beedle; Lehigh University, Department of Civil Engineering, Bethlehem, PA 18015; **Award #79-02613**

   Large space frame structures used as a means of covering large unobstructed areas (for example, the Houston Astrodome) have become popular in recent years because of their cost advantage. Such structures are assembled from large numbers of individual elements and present a complex problem for analysis for the variety of static and dynamic loads to which they may be subject. Because of the level of complexity of these structures, the analysis often has to be carried out by lumping many individual elements into equivalent continuous surfaces or sub-units. A serious problem in using such an approach is that the stability of the space frame components may not be correctly addressed.

   It is the purpose of this conference to assemble an international group of research and design experts to exchange the most up-to-date knowledge on the static and dynamic behavior of such structures and to assess the needs and priorities for research in this area. The results will be published as a proceedings

volume to make the information easily available to interested persons.

6. Dynamic Response Analysis of Offshore Platforms; Jack G. Bouwkamp; J. G. Bouwkamp, Inc., 1930 Shattuck Ave., Berkeley, CA 94704; **Award#76-82385 A01**

Oil and gas exploration and production offshore from the U.S. has previously been confined to the Continental Shelf. Recent offshore exploration has been moving into deeper waters and into regions with high seismicity. Under these circumstances the traditional methods of analysis of offshore structures assuming static equivalent load conditions are no longer appropriate.

The purpose of this project is to develop a computer program for the three-dimensional dynamic analysis of tubular framed offshore platforms subjected to the combined loads of earthquakes and wave forces. One unique feature of this program is its ability to take into account the flexibility of the tubular joint regions of the structure. Joint flexibility can have a substantial influence on the behavior of the structure, but in the past this effect has been generally ignored in each of the analytical techniques used in the solution of such problems.

The dynamic response of typical structures in both shallow and deep waters will be analyzed, including the influence of the foundation. Simplified analytical procedures will be developed and the effect of nonlinear joint deformation will also be investigated.

7. The National Program on Strong-Motion Instrumentation; A. G. Brady; U.S. Geological Survey, 12201 Sunrise Valley Drive, Reston, VA 22092; **Award #73-07125 A08**

This project is a continuation of the NSF-supported Seismic Engineering Program on strong-motion instrumentation and data management. The objectives of the program are to maintain and operate the national strong-motion network, to record strong ground motions and the response of representative types of structures during potentially damaging earthquakes, and to disseminate this data and information about the sites and structures to external users in earthquake engineering research and design practice.

The program is organized around two principal projects: data management and network operations, and two secondary projects: network design and data analysis. The data management project is to develop an information retrieval system to provide users with immediate access to all available data and records. The network operation project is to carry out a gradual upgrading of existing instrumentation and a redistribution of those instruments. Under network design, the effort will be to participate in studies of optimum network procedures and to provide assistance to other agencies in the planning of their networks. Under the data analysis project, analytical studies related to the strong-motion and routine processing and analysis of relevant data will be conducted. The results obtained are presented in the publication entitled, "Seismic Engineering Program Reports" which summarizes preliminary data and information obtained each quarter; in strong-motion data reports that present more detailed data processing and analysis; and through technical reports and papers presented or published in appropriate meetings and publications.

8. The Integration of Seismic Design Principles into Preliminary Architectural Design; Kenneth I. Britz, Carnegie Mellon University, Department of Architecture, Pittsburgh, PA 15213; **Award #79-00007**

The utilization of research on building response to seismic events has not been adequately studied. One hypothesis is that seismic provisions are perceived by architects as constraints to architectural design; thus, implementation of seismic codes may affect the visual quality of the environment. A second hypothesis is that architects find it difficult to utilize research because the methodologies are not conducive to ready assimilation of findings.

This project will assess the sensitivity of U.S. architects to seismic design principles to discover problems in assimilating seismic research in architectural practice, and will seek methods for the solution of these problems.

A survey of Eastern U.S. architects will profile the extent to which seismic design research has entered professional practice. The researchers will engage architectural firms in an empirical study of the process of integrating seismic design strategies into actual design projects. Results will be translated into operational strategies addressed to architects.

9. Cyclic Response of Masonry Anchor Bolts; Russell H. Brown; Clemson University, Department of Civil Engineering, Clemson, SC; **Award #78-06095**

Masonry loadbearing structures depend on diaphragm and shear wall action to resist lateral forces from wind or earthquake. The connection between the floor system and the bearing wall is a critical part of the structural system. Many such connections require the use of anchor bolts. This research project will provide information on the cyclic strength and behavior of anchor bolts in masonry.

Anchor bolts will be embedded in masonry walls and subjected to cyclic reversed loading applied axially and transversely simultaneously. Variables will include loading history, bolt size, bolt spacing, bolt position, mortar type, masonry unit type, and wall reinforcing.

The specific objectives of the research are to determine the strength of anchor bolts in masonry

subjected to cyclic axial forces and shear forces acting simultaneously; to develop design recommendations for anchor bolts in masonry structures in high wind and earthquake zones; and to develop mathematical models to predict the behavior of anchor bolts in masonry.

10. Numerical and Experimental Study of Earthquake Strong Motion; James N. Brune; University of California-San Diego, Department of Geophysics and Planetary Physics, La Jolla, CA 92093; **Award #77-23829 A01**

    This project will study the characterization of earthquake ground motion in terms of fault proximity, fault type, and intervening earth structure by numerical computations and laboratory experiments. Results from spontaneous shear ruptures in foam rubber have provided new information on rupture mechanics and the focusing of wave energy in the direction of rupture.

    A three-dimensional finite element method for modeling crack-induced waves has accurately reproduced analytical results for a growing circular crack and simulated surface motions in laboratory experiments. New results obtained using computer methods concerning surface contours of maximum particle velocity during an earthquake, response spectra as a function of distance and direction from a strike-slip earthquake, and seismic amplification curves for a three-dimensional sedimentary deposit will be used in this research.

    The project is intended to further calibrate the computer methods for modeling actual earthquakes, to simulate ground motion under a variety of conditions, and to produce rules for characterizing ground motion which are suited to the needs of design engineers.

11. Seismic Behavior of Structures: Analysis and Design of Structures; Anil K. Chopra; University of California-Berkeley, Earthquake Engineering Research Center, Department of Civil Engineering, Berkeley, CA 94720; **Award #79-08261**

    Considerable effort is needed in analytical research to achieve a better understanding of seismic performance and modes of failure of structures; to increase the reliability of controlling seismic damage; and to develop methods of design based on correlative analytical and experimental studies. These analytical and design capabilities should be applied to ensure a proper balance between the total cost and safety of structures constructed in a seismic environment.

    This project is to conduct comprehensive research aimed at establishing improved analytical and design capabilities for seismic engineering. Based upon present knowledge and future research needs, emphasis on particular studies has been properly adjusted and reflected in the present project. Six complementary and interrelated sub-projects are integrated into this single project in order to maximize the productivity and benefits. These six sub-projects are: (1) Analytical Study of Building Response, (2) Soil-Structure Interaction Effects in Building Response, (3) Dynamics of Rigid Blocks and Foundation Tipping, (4) Development of Nonlinear Structural Analysis Techniques, (5) Probabilistic Studies of Seismic Response, and (6) Analytical Methods for Design.

    For the last three years the investigating team at Berkeley has made significant progress and important contributions to the general research and practicing engineering communities. Many of the analysis and design methods, computer programs, etc. have been extensively applied. This project properly reflects current knowledge and practice, and addresses future research needs in outlining an integrated program of continuing efforts required to upgrade the present capabilities and design practices in earthquake engineering.

12. Seismic Behavior of Complete Structural Systems; Ray W. Clough; University of California-Berkeley, Department of Civil Engineering, Berkeley, CA 94720; **Award #79-08257**

    The ultimate goal of this project is to develop improved computer procedures for predicting the dynamic response of structures to intense earthquake motions. The effort is divided into six technically interrelated sub-projects centered around the earthquake simulator facility toward achieving this goal.

    These sub-projects are: (1) Earthquake Simulator Studies—to perform dynamic test of steel and concrete structures, (2) System Identification—to develop methods of evaluating the mathematical model properties, (3) Computer Program Development—to evaluate the dynamic response of the mathematical model, (4) Energy Absorption Devices—to develop and test special structural components for improving the seismic resistance of structural systems, (5) Field Measurements—to measure the dynamic properties of actual buildings and structures, and (6) Post-Earthquake Damage Studies to conduct reconnaissance surveys and detailed engineering analysis of earthquake damaged structures.

    The earthquake simulator has proven to be a most versatile research tool during its five year existence. Continuing exploitation of its effectiveness and efforts to overcome its limitations are necessary to provide direct evidence of actual structural performance under realistic base excitations and to evaluate the predictive capability of developed computer programs. System Identification studies are required to define physical properties and to incorporate them into mathematical models, which

will be formulated and coded to represent different structural elements and used to develop general purpose non-linear analysis programs. In addition, mechanisms and practical utilization of energy absorbing devices will be investigated to improve the seismic performance of various types of structures. Finally, field measurements and actual earthquake damage investigations will be conducted to supplement the analytical and experimental research to achieve an improved understanding of, and to develop improved predictive capability for, the seismic behavior of structures.

13. Seismic Resistance of Buildings with Reinforced Concrete Structural Walls; W. G. Corley; Portland Cement Association, Old Orchard Road, Skokie, IL 60076; **Award #77-15333 A01**

    The ultimate objective of this investigation is the development of reliable and practical design procedures for earthquake-resistant reinforced concrete structural wall (shear wall) systems. Included under this broad category of structures are isolated walls, coupled walls and frame-wall systems.

    Realistic estimates of the strength and deformation requirements in critical regions of structural wall systems will be obtained through dynamic inelastic analyses. These estimates will correspond to different combinations of the significant structural and ground motion parameters. Laboratory tests on large-size specimens are planned. Results of these tests and correlation with theory will be used to develop methods of predicting the available strength and deformation capacities of properly proportioned and detailed structural walls.

14. Influence of Nonstructural Cladding on Dynamic Properties and Response of High Rise Buildings; Barry J. Goodno; Georgia Institute of Technology, Department of Civil Engineering, Atlanta, GA 30332; **Award #77-04269 A01**

    In the past little attention has been paid to the effect of exterior cladding in multi-story buildings subjected to seismic forces. Recent studies have shown that cladding may actually provide a considerable amount of resistance to low level excitation and thus help control interstory drift and building motion. Reports of cladding failures prompt us to ask whether or not the stiffness and energy absorption capacity of these elements can be used to advantage in modern building designs.

    This project studies the problem of cladding-structure interaction, and is designed to put future follow-on studies on a firm analytical and experimental basis. The findings are expected to be of immediate use to designers in integrating cladding into the structural design, and are directly applicable to the problem of low level response which is largely linear. With experience gained in the linear problem, future studies of cladding-structure interaction which encompass both material and geometric nonlinearities and strong ground motion excitation are anticipated.

15. Analytical Method for Determining Seismic Response of Cooling Towers on Footing Foundations; Phillip L. Gould; Washington University, Department of Civil Engineering, St. Louis, MO 63130; **Award #79-00012**

    This project will investigate the response of large cooling towers founded on circular ring footings to earthquake-induced ground motion. Such structures are generally founded on deep, rigid piles or caissons, and the lower region of the shell and the foundation ring are subjected to large seismic forces. It is believed that a ring footing foundation with appropriate site conditions may mitigate seismic forces by interacting with its surrounding soil to dissipate the energy induced by seismic waves.

    The major analytical component required for this study is a model of the soil-structure system. The shell and foundation components of the soil-structure system are to be modeled using high-precision rotational shell finite elements, while the surrounding soil will be represented by a finite element discretization. The response of the interacting system to earthquake-type dynamic loading will be studied for a variety of soil conditions in order to assess the importance of interaction on the response of large towers. To facilitate the utilization of the results of this research, an existing high precision finite element code (SHORE III) will be extended to include soil-structure interaction effects. Suitable documentation will be prepared in accordance with the specifications of NISEE. NISEE will also make resulting computer programs publicly available.

16. Workshop on Seismic Resistance of Nonengineered Structures; Ajaya K. Gupta; Illinois Institute of Technology, Department of Civil Engineering, Chicago, IL 60616; **Award #79-11668**

    The objective of this project is to organize and hold a two day workshop at the Illinois Institute of Technology on the topic of earthquake resistance of non-engineered structures. Nonengineered structures are defined as those which, due to either their size or the scale of economic investment involved, are not subject to specific engineering analysis to determine their seismic resistance and are constructed according to general codes and/or tradition. It is estimated that up to 80% of the structures built in the U.S. fall into this category.

    It is important to carefully assess the present state-of-the-art related to nonengineered structures, to improve the flow of new information and technology developed through seismic research for use in such structures, and to evaluate present and future research needs in earthquake engineering as related to nonengineered structures. The workshop will

address these objectives by assembling a representative group involved in different aspects of the problem. A workshop report will be prepared which will include state-of-the-art papers and recommendations regarding problem areas and research needs on various aspects of the topic.

17. Cooperative Program in Earthquake Engineering-Repair and Retrofit of Structures; Robert D. Hanson; University of Michigan, Department of Civil Engineering, Ann Arbor, MI 48109; **Award #78-16730**

    This project initiates a new international coordination effort to exchange results of earthquake engineering research on the repair and retrofit of existing buildings. The Cooperative Program serves as the focal point for the U.S.-Japan Panel on Wind and Seismic Effects, which is working to develop a coordinated research plan on this issue. Major tasks which are being undertaken include the coordination of research efforts and personnel, the establishment of priorities for specific projects, and the promotion of the exchange of information between the two countries. eriodic meetings, workshops, conferences and publications are planned.

18. Workshop on Interpretation of Strong-Motion Earthquake Records Obtained In and/or Near Buildings; Gary C. Hart; University of California-Los Angeles, Department of Mechanics and Structures, Los Angeles, CA 90024; **Award #79-08980**

    The objective of this project is to hold a workshop on the interpretation of strong-motion earthquake records obtained in and/or near buildings. The workshop will serve to answer the following questions: What methods can be used to study earthquake records in addition to those methods of analysis currently available? What are the existing building instrumentation programs and can these programs be modified to improve the information obtained? What are the most important response quantities to be measured for different types of buildings? Should there be standard analyses performed on the records? If so, then what should they be, who should do them and how should they be reported?

    A comprehensive report will be published based on the workshop. Topics will include the Present State of Instrumentation, Current Signal Processing Techniques, State of Building Analysis, Information Derivable about Building's Dynamic Response Parameters (e.g. natural frequencies, mode shapes, etc.), Inference of Damage from Instrument Records, Relationship, if any, between Low Level versus High Level Records, and Future Directions.

19. Connections in Concrete Masonry Buildings under Seismic Forces; Gilbert A. Hegemier; University of California-San Diego, Department of Applied Mechanics and Engineering Sciences, La Jolla, CA 92093; **Award #78-16581**

    Concrete masonry systems account for approximately one-half billion dollars worth of buildings in seismically active areas of the United States. There has been very little research conducted on the basic properties of masonry or the connections of various components comprising a building structure. This project will investigate the behavior of connections between floors and walls, between walls, and between roofs and walls subjected to seismic excitations. This research project will investigate the out-of-plane forces in conjunction with in-plane loads on various types of connections subjected to seismic excitations.

    Experimental investigations will be supplemented by mathematical models in order to develop design criteria techniques to evaluate existing buildings and to predict the behavior of newly constructed buildings.

    The systems to be investigated are precast reinforced concrete slabs supported by interior walls, a cast-in-place slab on an interior wall, and a hollow core prestressed concrete plank on an interior masonry wall. Various oscillatory, horizontal loadings will be applied to the connections while a constant force vertical load will be maintained. Future studies will investigate oscillatory, vertical forces in conjunction with oscillatory, horizontal forces.

20. Seismic Response of Structures and Strong-Motion Instrumentation; George W. Housner; California Institute of Technology, Department of Engineering and Applied Science, Pasadena, CA 91104; **Award #77-23687 A01**

    A three-year program of research in earthquake engineering at the California Institute of Technology will be undertaken. The program includes the analysis of recorded earthquake motions of structures; dynamic testing of structures; the analysis of vibrations in the strongly nonlinear range where damage is occurring; the development of a portable digital accelerograph network; operation and upgrading of existing strong-motion instrument networks of the program; and analysis of earthquake data to improve seismic design criteria.

21. Liquid Storage Tank Failure due to Earthquake Excitation; Thomas J. R. Hughes; California Institute of Technology, Department of Engineering and Applied Science, Pasadena, CA 91104; **Award #79-00712**

    This award supports an integrated experimental and analytical research program directed towards developing improved understanding and design methodology for the strong-motion excitation of cylindrical liquid storage tanks.

    The goal of the experimental work is to understand the nonlinear physical phenomena occurring during earthquake excitation of a fluid filled storage

tank. This understanding will hopefully lead to simplified analytical/numerical analysis techniques useful in improving tank design. The experimental work is designed to study aspects such as flexible tank/fluid interaction, nonlinear fluid behavior (swirling, wave cresting) and tank uplifting.

The object of the analytical work is to develop a finite element method for the dynamic, three-dimensional, nonlinear, inelastic analysis of ground-supported, cylindrical liquid storage tanks, which treats the effects of fluid-structure interaction, free-surface sloshing, and contact-release effects associated with uplifting. The method will be coded and used to analyze tank configurations subjected to earthquake excitations. The computer program will be made freely available to the engineering community.

22. *In Situ* Soil Dynamic Testing and Analysis to Determine Soil Constitutive Properties; Paul Ibanez; ANCO Engineers, Inc., 1700 Colorado Ave., Santa Monica, CA 90404; **Award #79-00001**

    The purpose of this research is to develop a coupled *in situ* dynamic testing/nonlinear modeling technique for determining the *in situ* dynamic properties of soils. Such an approach to site soils modeling and earthquake engineering could supplement and possibly supplant laboratory test techniques which of necessity involve disturbed soil samples, and which require substantial engineering judgment to interpret.

    A major component of this research is the experimentally validated transfer of technology in nonlinear soil modeling and multi-dimensional nonlinear wave propagation computer methods from the defense community into the civilian sector. The research consists of execution of a series of in-situ dynamic tests at a previously studied site; use of advanced numerical techniques and nonlinear constitutive laws to model the experiments; sensitivity studies to establish a sensitivity matrix; and the use of this sensitivity matrix in parameter identification studies to establish the optimal nonlinear constitutive soil model, taking into consideration both model and experimental uncertainties. A better knowledge of subsurface *in situ* properties will lead to greater confidence in the seismic safety of such structures as dams and power plants.

23. Finite Element Analysis of Reinforced Concrete for Cyclic Loading; Anthony R. Ingraffea; Cornell University, Department of Structural Engineering, Ithaca, NY 14850; **Award #79-00711**

    An analytical formulation will be sought for bond slip in reinforced concrete structures subjected to seismic forces. Experiments have shown that up to half of the inelastic deformation in common reinforced concrete structures subjected to high-level cyclic loading is caused by bond slip. The accompanying stiffness degradation must be known in order to predict the deformations and forces in seismically loaded structures.

    The problem will be approached by using sophisticated finite element techniques of nonlinear and fracture analysis to an isolated region focused on the steel-concrete interface. Experiments will also be conducted to determine the nonlinear stress-strain relationships for the crushed concrete immediately in front of the deformations on reinforcing bars that are subjected to axial forces.

    An axisymmetric concrete section reinforced with a single bar will be utilized in the first phase of the analysis. This model will include concrete crushing at the reinforcement ribs, transverse crack initiation and propagation in the concrete, and yielding of the reinforcement. A three-dimensional analytical model will follow to incorporate the influence of concrete cover, bar spacing, and transverse reinforcement, plus the occurrence of axial cracking. Fracture mechanics techniques will be used to model all cracking phenomena. The end result will be a new bond finite element for nonlinear, cyclic load-slip behavior in reinforced concrete subjected to high intensity repeated and reversed loadings.

24. Inelastic Dynamic Building Response-Correlation with Full Scale Shaking Tests; Lindsay R. Jones; Computech, Inc., 2150 Shattuck Ave., Berkeley, CA 94704; **Award #79-00181**

    A twelve month research study will be carried out in which a number of correlation studies will be performed using results obtained from full-scale large amplitude shaking tests performed on an eleven story reinforced concrete building. It is proposed that state-of-the-art nonlinear dynamic analysis procedures be used to determine the extent to which they adequately model the behavior of a real building subjected to damaging force levels. The building will be further analyzed to determine its behavior when subjected to real earthquake motions as distinct from mechanical shaker-induced motions. It is important to determine whether the building will be able to withstand earthquake-induced base shear levels as high as those it withstood during testing.

    Computer programs developed in the course of this study will be available through NISEE.

25. Multi-Design Approach to Seismic Safety; Earle W. Kennett; American Institute of Architects Research Corp., 1735 New York Ave., N.W., Washington, DC 20006; **Award #78-25163**

    This project will examine the problem of integrating design responses for a range of hazards to which buildings may be subjected. The design concerns to be addressed in this project are Earthquake, Fire, Flood, Extreme Winds, and Energy Conservation. The AIA Research Corporation proposes to identify

those design issues responding to the four latter hazards which conflict with or reinforce aseismic design.

A workshop will be held for organizational representatives and representative professionals and researchers to review the interrelationships of design provisions directed mitigating the five mentioned hazards. Research staff, assisted by the workshop, will develop guidelines and strategies for harmonization of design approaches to hazard mitigation. This multi-hazard design approach will include both seismic and aseismic design principles. Conceptual solutions to problems of design conflict or incompatibility will be developed to test the practical applicability and cost effectiveness of the developed guidelines and the multi-hazard approach.

26. Vibration Testing of an Epoxy-Repaired 4-Story Concrete Structure; Donald M. Kerr, Jr.; Department of Energy, P.O. Box 14100, Las Vegas, NV 89114; **Award #78-12714**

Epoxy-injection methods have been used to repair buildings, bridges and other structures which have been damaged by earthquakes. Experiments have indicated that this method is quite effective in repairing laboratory test specimens whose strength has been improved by the repair. Tests on a shaking table have indicated that epoxy-repaired structures have only a small fraction of the stiffness of the undamaged structure. At this time there is no information available concerning the effectiveness of epoxy repaired structures subjected to high amplitude destructive level vibrations. This project will develop data on this specific consideration of epoxy-repaired structures.

The project consists of several phases: a comparison of dynamic response of an epoxy-repaired structure with the original structure; an evaluation of the effect of the epoxy repair on the stiffness and natural frequencies of the structure; the effect of damping and energy absorption of the system; a comparison of damage patterns; and development of guidelines for the epoxy repair of damaged buildings.

27. Dynamic Properties of Clays under General Three-Dimensional Stresses; Hon-Yim Ko; University of Colorado, Department of Civil Engineering, Boulder, CO 80309; **Award #79-00718**

This research addresses the problems of designing submerged structures such as oil storage tanks to resist the combined loadings of earthquake and wave forces. Studies include the dynamic responses of submerged tanks subjected to seismic action. A general finite element solution procedure has been formulated and a general computer program for use in tank response analysis will be developed. Also included will be studies of wave sloshing effects inside submerged tanks under horizontal and vertical ground excitations; studies of the coupling between interior and exterior fluids; and the formulation of tank-coupled system solution procedures.

28. Conference on Urban Design and Seismic Safety at a Cooperative International Level; Henry J. Lagorio; University of Hawaii-Manoa, Department of Architecture, Honolulu, HI 96822; **Award #78-26166**

Both the United States and Japan have major urban concentrations in severely seismic areas. The urban environment is composed of many interdependent activities, services, and functions. Assessment of the physical growth of cities indicates that many fundamental urban design principles in hazards mitigation may not have been considered, nor were the critical consequences of many design decisions foreseen. Despite many technological advances in earthquake engineering and earthquake prediction, major metropolitan centers remain extremely vulnerable to major seismic events. Because of rapid urbanization and continued development in existing, well-established urban concentrations, a major earthquake impacting a city center would result in much greater damage and life loss than ever before.

The United States-Japan Joint Seminar on Urban Design and Seismic Safety to be held in Tokyo in May 1979 will be of mutual benefit to both countries in the exchange of information and establishment of cooperative research priorities. Members of the design professions of both countries who are responsible for the planning and design of cities will attend. Earthquake hazards mitigation measures which can be achieved at the scale of urban design will significantly expand our range of approaches to limiting earthquake losses.

29. Structural Response under Random Wind Loading; Y. K. Lin; University of Illinois-Urbana, Department of Aeronautical, Astronautical Engineering, Urbana, IL 61801; **Award #76-84171 A02**

Strong-motion earthquake and strong gusty winds are dynamic natural hazards to man-made structures. Large deflections, over-stresses, and structural instability can take place under certain unfavorable loading conditions. The conventional treatment of such problems is often based on simple equivalent static forces and on deterministic modeling of complex dynamic loading and response processes. More sophisticated analysis is required to improve our understanding of the behavior of structures subjected to the random forces generated by winds or earthquakes.

In the project which this award supplements, analytical studies established the mathematical theory for structural response to random gusty winds and applied stochastic stability concepts to solve the

wind-induced structural instability problems. This amendment will provide additional staff time and support to investigate the feasibility of modifying the methodology developed for wind conditions in earthquake applications. The emphasis of the study will be on the treatment of nonstationary parametric excitations and on the effects of interaction of vertical and horizontal ground motions to the response of structures.

30. Response of Three-Dimensional Structures to Non-Vertically Incident Seismic Waves; Juan E. Luco; University of California-San Diego, Department of Applied Mechanics and Engineering Science, La Jolla, CA 92093; **Award #79-00006**

As part of a continuing study of the dynamic interaction between structures and the soil, a systematic analysis of the dynamic response of structures subjected to non-vertically incident seismic waves will be undertaken. In this study, a structure will be represented by an elastic three-dimensional model (symmetric or non-symmetric), the foundation will be modelled as a rigid mat (flat or embedded), and the soil will be represented by a viscoelastic half-space (uniform or layered). The seismic excitation will be modelled as plane non-vertically incident P, SV, Rayleigh, SH and Love waves. Particular emphasis will be given to the evaluation of additional torsional and rocking components of motion induced by non-vertically incident waves.

This work is motivated by recent studies that tend to invalidate conventional assumptions with regard to vertically incident seismic waves, and by our need to incorporate the additional rocking and torsional components of motion in the earthquake-resistant design of structures. To solve the complete soil-structure interaction problem with non-vertically incident seismic excitation, a sub-structuring procedure is proposed. The procedure is based on the use of carefully developed solutions for simpler sub-problems.

31. Site and Source Effects on Design Earthquake Motions; Ajit K. Mal; University of California-Los Angeles, Department of Mechanics and Structures, Los Angeles, CA 90024; **Award #78-20899**

The objective of the research is to investigate the effects of source and site on design earthground ground motions. A representation theorem which relates the Fourier Transform of the ground motion directly to the displacement discontinuity across a fault will be used to study the effect of the source on the ground motions. A semi-empirical linear system theory and an improved version of the Haskell-Thomson Algorithm will be used to study the effect of the site on ground motion. Field modeling of sites and field experiments will be conducted to verify the analytical procedures that are developed.

32. Seismic Behavior of Masonry Structures; Hugh D. McNiven; University of California-Berkeley, Department of Civil Engineering, Berkeley, CA 94720; **Award #79-08251**

Masonry construction is used extensively throughout the world for housing and office buildings. Due to lack of adequate shear strength and moment resistance as compared with steel and reinforced concrete structures, masonry structures are particularly vulnerable to strong earthquake ground shaking and pose the threat of great life and economic losses if not properly designed. Because of this, research on the earthquake behavior, and consequently the improved methods of design, of masonry structures is urgently needed.

This proposal presents an integrated experimental and analytical program for continuing research on the seismic behavior of masonry structures. Extensive shaking table tests of masonry piers and spandrel girders will be conducted to provide an adequate data base for parametric study, correlative analysis, and for development of mathematical models and analysis procedures. The methodology used is essentially a structural engineering approach in contrast with the structural mechanics approach used in a complementary project on-going at the University of California, San Diego, under Gilbert Hegemier.

Work during the project period will aim at exploratory studies of mathematical models relating loading and deformation, investigation of hysteretic behavior of masonry piers, prediction of ultimate strength of the shear, flexural and sliding modes of failures, and evaluation of the adequacy of the existing building codes. The project will be conducted with close coordination with American Masonry Institute, user's groups, and other current projects on the same subject research should provide much needed information on the use of masonry construction in earthquake areas.

33. Development of a Unified Approach to the Design of Window Glass Subjected to Dynamic Forces; Joseph E. Minor; Texas Tech University, Institute for Disaster Research, Lubbock, TX 79409; **Award #77-24063 A01**

This research will utilize current knowledge and techniques in a critical review of the process by which glass panels are selected for use in engineered structures. It is anticipated that this review can reduce uncertainties inherent in current processes thus enabling practitioners to effect safe, economical designs for glass windows.

This research will develop a tractable approach to the design of glass windows by utilizing current knowledge in wind engineering, glass material properties, and structural response of thin rectangular panels. A utilization plan will be implemented to

relate this new approach to current professional practice and to expose the architectural and engineering professions to the new approach.

34. The United States-Japan Cooperative Research Program on Large-Scale Structural Systems: A Planning Study; Joseph Penzien; University of California-Berkeley, Department of Civil Engineering, Richmond, CA 94720; **Award #76-80835 A02**

Traditionally, concepts for design of structures to resist earthquake forces have evolved from post-inspections of earthquake damage and laboratory simulations. As beneficial as these concepts are, many factors cannot be evaluated by inspection or small scale tests.

The results of small-scale tests could be verified by full-size structural tests to evaluate the time behavior in a structural system. A program to extend the tests to full size structures to determine the parameters which can not be evaluated otherwise would be desirable and beneficial to the engineering profession.

This project will undertake a planning study for development of an effective research program of maximum benefit to both the United States and Japan on large-scale tests of structural systems. A task committee to be established under the U.S.-Japan Panel on Wind and Seismic Effects, U.S.-Japan Natural Resources Program, will be responsible for making detailed plans and recommendations on such a program.

35. National Information Service for Earthquake Engineering; Joseph Penzien; University of California-Berkeley, Earthquake Engineering Research Center, Berkeley, CA 94720; **Award #77-20667**

The National Information Service in Earthquake Engineering (NISEE) has become the national focus for information on earthquake engineering data, projects and research reports. NISEE provides for the transfer of earthquake and other hazards information generated through research to the public users. This award will enable NISEE to collect and assess information from many different sources in order to provide a single, efficient source for researchers in the field who wish to obtain information from a comprehensive collection. The project will be geared to meet the needs of both academic researchers and design engineers at the national level. NISEE's computer program distribution service now has many programs, each fully developed and suitable for use in professional engineering offices. New programs will be added to the library and made available for distribution as they are developed. The Earthquake Engineering Research Library will maintain collections of reports (both published and unpublished), site visit records, data acquired from various seismic regions, and provide an abstracting service and a technical journal directed to the needs of earthquake engineers.

36. Seismic Behavior of Precast Curtain Walls in High Rise Buildings; Dale C. Perry; University of Idaho, Department of Civil Engineering, Moscow, ID 83843; **Award #77-20884 A01**

This research consists of a broad program of full-scale laboratory studies and companion analytical investigations to explore the nature of curtain wall participation in the total structural response characteristics of high-rise buildings subjected to seismic excitation. Primary emphasis of this effort will be placed on the generation of full-scale test data for specific curtain wall assemblages in order to quantify the constitutive relationships for precast concrete cladding systems commonly employed in contemporary structures. The experimental data thus obtained will be utilized in the development of analytical models suitable for predicting the contribution of exterior, normally "non-structural", fascia panels to total building stiffness and energy dissipation. Comparisons will be made of reported full-scale building response measurements with the mathematical model predictions based on the results of this program.

37. Seismic Behavior of Structural Components; Egor P. Popov; University of California-Berkeley, Department of Civil Engineering, Berkeley, CA 94720; **Award #79-08984**

This project represents a major, continuing experimental effort in studying the complex inelastic seismic behavior of essential structural components commonly used in practice. One emphasis is to make use of the sophisticated laboratory testing and data recording and analysis facilities for detailed, slow-motion observations of structural deformations under simulated intensive earthquake excitation. Another emphasis is to conduct correlative experimental and analytical studies in order to establish improved mathematical models and develop general purpose computer programs.

The research is divided into five inter-related sub-projects. These are: 1) Braced steel frames, 2) Reinforced concrete (R/C) walls and infilled frames, 3) R/C ductile frames, 4) R/C beam column components, and 5) Correlative general computer programs. All five sub-projects are extensions of current work concerning both steel and reinforced concrete structures. In the experiments, large-scale components of structural systems will be designed, fabricated and tested in the laboratory by subjecting them to slowly applied loadings in a quasi-static manner simulating earthquake motions. The results of the experimental work will be used as the basis for the construction and verification of mathematical models of structural components. The analytical work and experimental efforts are complementary

so that the capabilities for analyzing the inelastic behavior of structural components can be broadened. The research findings of the project will lead to a better understanding of structural behavior and improved methods of analysis and design of earthquake-resistant steel and reinforced concrete structures.

38. Development of an *In Situ* Liquefaction Evaluation System; Dwight A. Sangrey; Cornell University, School of Civil and Environmental Engineering, Ithaca, NY 14850; **Award #78-26815**

An *in situ* liquefaction evaluation system based on effective stress methods and the prediction of excess pore pressure due to cyclic loading will be developed. Previous research has shown that excess pore pressure resulting from undrained cyclic loading of various soils can be related to several fundamental soil properties, including volumetric compressibility. Emphasis will be on measuring these properties in situ so that strength reduction or liquefaction potential of soils can be predicted for cyclic loading.

The research is divided into three phases. The first phase will be a theoretical analysis of the existing effective stress model to obtain a practical design for an *in situ* testing device. The equipment will be built and tested to confirm that it does measure the desired soil properties. Finally, appropriate user oriented manuals will be prepared.

39. Connections of Precast Prestressed Concrete Construction to Withstand Earthquakes; Norman L. Scott; The Consulting Engineers Group, 1701 E. Lake Avenue, Glenview, IL 60025; **Award #78-20900**

Precast prestressed concrete, an important method of construction, has the unique advantages of long spans with shallow depths, fire resistance, durability and minimum maintenance, attractive appearance, reduced construction time and competitive costs. Connections between members have been a major problem in design and performance of precast prestressed construction. Perhaps the most difficult requirements occur in structures designed to withstand the consequences of earthquakes and high winds.

The objective of this project is to document and evaluate the precast prestressed concrete connections used in structures to withstand earthquakes and high winds. This comprehensive state-of-the-art study will result in the classification of connection methods presently employed with respect to their performance history. The research plan is to conduct a literature study of precast connections for structures in earthquake areas, a survey of precast concrete manufacturers, engineers and architects and, most importantly, a classification of connection methods currently employed with respect to performance. Prestressed Concrete Institute will publish and distribute results from this study and will conduct seminars for designers and precast prestressed concrete manufacturers on connections for earthquake resistance.

40. Earthquake Induced Soil-Structure-Water Interaction for Gravity-Type Ocean Structures; Lars Skjelbreia; Science Engineering Associates, 2111 West Crescent Ave., Suite A, Anaheim, CA 92801; **Award #78-25822**

Ocean structures present special problems for engineers because of the loading conditions associated with wave forces and earthquake excitations. This research addresses two important problems for such ocean structures: the soil-structure interaction problem and the earthquake-induced hydrodynamic response problem.

Research is undertaken in this project to evaluate the potential of foundation failure for a gravity-type structure under seismic action by investigating permanent ground deformation due to cyclic loadings, and determine the hydrodynamic forces acting on the structures as a result of seismic action and evaluate the potential of structural damage. A computer program will be developed to determine the response and to assess the safety of the foundation. Small-scale laboratory experiments will be conducted by California State University, Fullerton, to complement the analytic work.

41. Predicting Response Spectra in Eastern United States From Known Displacement Spectra Densities; Ronald L. Street; University of Kentucky, Department of Geology, Lexington, KY 40506; **Award #78-19675**

A serious problem exists in the establishment of proper earthquake design criteria for structures in the Eastern United States (EUS) because of the lack of strong-motion records of EUS earthquakes. Current methods, based on gross assumptions about earthquake intensity, peak acceleration, and about the attenuation characteristics of ground motions in EUS appear insufficient and need improvement. To remedy this situation, researchers must enhance the strong-motion instrument program in EUS to capture future data; they must conduct research to improve physical and geological understanding of the EUS earthquakes; and they must develop improved methods for characterizing the EUS earthquake motions and for defining the EUS design earthquake parameters.

This project is to conduct a comprehensive study to improve the characterization and the modeling of ground motions due to EUS earthquakes.

This project will develop alternative methods for predicting peak ground-motion parameters in EUS by using existing instrument records of EUS earthquakes to characterize the spectral content and duration of the motion, and define the design earthquake motions. A broad sample of EUS

earthquake records will be analyzed and their magnitudes, seismic moments, and spectral characteristics will be determined. The duration of strong-motion due to EUS earthquakes as a function of magnitude, corner frequency, and epicentral distance will be determined. An EUS ground-motion model will be developed.

42. Risk Methodologies in Geotechnical Design of Offshore Structures; Wilson H. Tang; University of Illinois-Urbana, Department of Civil Engineering, Urbana, IL 61801; **Award #78-19680**

The design and construction of offshore structures must take into account the complex problems of interaction of wave forces, earthquake loads, and soil-structure response. Since failures are costly because of large investments and possible environmental losses, the reliability of offshore structures is of concern not only to producers but to regulatory agencies.

This research will identify failure events associated with foundation performance of offshore structures; construct risk event trees; and develop a procedure to evaluate failure probabilities. Because there are few case histories available on the performance of offshore structures, those case histories which do exist will play a large role in the design of future structures. (See also Wu, T. H.)

43. Earthquake Engineering Investigation of Strong Ground Motion; Mihajlo D. Trifunac; University of Southern California, Department of Civil Engineering, Los Angeles, CA 90007; **Award #78-18740** The

The research includes comprehensive theoretical and observational studies of strong earthquake ground motion. The purpose of these studies is to develop more detailed, more realistic, and less uncertain methods for characterization and prediction of strong earthquake ground motion for use in the design of earthquake-resistant structures.

Comprehensive studies will be conducted on earthquake generation, wave propagation and empirical description of the resulting motions in the following six subject areas: 1) Detailed studies of source mechanism, 2) Studies of propagation effects on strong ground motion, 3) Deterministic prediction of strong shaking, 4) Estimation of torsional and strain components of ground motion, 5) Empirical scaling studies of recorded strong ground motion, and 6) Sensitivity studies of scaling parameters and the uncertainties associated with deterministic and empirical estimation of strong shaking.

The thrust of this research is to expand and enrich the usefulness of available data by carrying out studies which clarify, augment and refine existing data; by comparing and/or combining different theoretical models, techniques and methods to establish the most useful physical bases for engineering characterization of strong earthquake ground motion; and by selecting those scaling laws and parameters which significantly contribute to the design spectra for engineering scaling of strong ground motion and also suggest aspects of the problem which are useful areas for additional research.

44. Analysis of Optimal Strong Motion Instrument Location in Building Structures; F. E. Udwadia; University of Southern California, Department of Civil Engineering, Los Angeles, CA 90007; **Award #77-07903 A01**

This research is to develop and test methodologies for locating strong-motion instruments in buildings so that records obtained during earthquake excitations provide as much information as possible. Both the number of recording instruments and their locations will be studied to determine the information that can be obtained and to estimate the cost of alternative arrangements.

Optimized instrumentation is an important factor in the quality of the information recorded under earthquake excitation. Such data can be used to improve our understanding of structural responses during strong ground motions and could lead to improved designs and safety standards.

45. Experimental Investigation of Reinforced Concrete Beam-Connections Subjected to Earthquake Type Loading; James K. Wight; University of Michigan, Department of Civil Engineering, Ann Arbor, MI 48109; **Award #78-24556**

Twenty-four internal and external beam-to-column connections will be constructed and subjected to laboratory simulations of earthquake-type loadings. In order to more closely simulate real beam-to-column subassemblages, half of the specimens will have a floor slab and transverse beams in addition to the main beam and column. The other half of the specimens will be "bare" connections and are intended to serve as benchmarks for comparison with existing experimental data. Other primary variables will be the ratio of the column moment capacity to that of the beam, and the percentage of tranverse reinforcement in the connection. The ratio of the column-to-beam moment capacity was shown to be very important in a recent investigation.

An analytical investigation will parallel these experimental studies. Its first phase will be to develop a mathematical model capable of reproducing the experimental results. The second phase will be to incorporate this model into an inelastic structural analysis program and to study its effect on the seismic response of various buildings.

The need for the information to be derived from this project was pointed out by the design recommendations of Joint Committee 352 of the

American Concrete Institute and the American Society of Civil Engineers. It was found that current practices are too conservative and that construction of beam column connections are difficult to build in actual buildings and as a result that the costs are very expensive. The experimental program will study several variables in order to determine the most efficient amount of steel reinforcement required at the connections of beams to columns.

46. Earthquake Strong Motion Instrumentation and Array Design; Francis T. Wu; S.U.N.Y. State University at Binghamton, Department of Geological Sciences, Binghamton, NY 13901; **Award #76-23897 A02**

Up to now the gathering of strong motion data has been performed by the fixed station technique. Only in rare cases is there an array suitably located to record strong motions systematically around a fault. Also, until recently the timing on records has not been tied to real time. It has been difficult to decipher the precise nature of the waves recorded and to generalize the obtained results for future earthquakes, since the contribution of the source and that of the path could not be easily separated.

The technology of seismic recording has advanced recently. It is now possible to record data digitally using a self-contained portable system, use a "pre-trigger" digital loop to retain the complete strong motion data, including the triggering signal, to use a low-drain accurate crystal clock for coordinated time, and to use a non-linear amplifier to increase dynamic range of the recording system. In this project two such new systems will be studied to increase the efficiency of ground motion data recordings. Optimum design of local and regional instrument arrays will also be investigated to minimize the total cost and maximize the return. The objective of this project is threefold: to develop more efficient strong-motion instruments with wider dynamic range and versatility, to develop criteria for reliable and cost-effective network design, and to study the dynamic seismic source, mechanism by using near field data.

47. Risk Methodologies in Geotechnical Design of Offshore Structures; T. H. Wu; Ohio State University, Department of Civil Engineering, Columbus, OH 43210; **Award #78-19222**

The design and construction of offshore structures must take into account the complex problems of interaction of wave forces, earthquake loads, and soil-structure response. Since failures are costly because of large investments and possible environmental losses, the reliability of offshore structures is of concern not only to producers but to regulatory agencies.

This research will identify failure events associated with foundation performance of offshore structures; construct risk event trees; and develop a procedure to evaluate failure probabilities. Because there are few case histories available on the performance of offshore structures, those case histories which do exist will play a large role in the design of future structures. (See also Tang, Wilson)

48. Response of Nonlinear Saturated Soils to Seismic Disturbances; E. B. Wylie; University of Michigan, Department of Civil Engineering, Ann Arbor, MI 48109; **Award #77-22219 A01**

The objective of this research is the development of analytical procedures for the prediction of potential liquefaction of soil masses. A recently developed model, based upon the application of the method of characteristics to handle the equations for transient motion in saturated soils will be modified to incorporate a more realistic description of material properties. Parametric studies will be used to qualitatively evaluate results from the model, while comparisons with large-scale laboratory results will be utilized to demonstrate the quantitative behavior. The concepts developed in the one-dimensional model will be extended to a two-dimensional spatial domain.

Nonlinear material behavior is utilized both in the shearing stress-shearing strain and in the volumetric deformation portions of the model. These two subsets of the total model are interactively coupled so that the shearing strength of the material varies with transient pore pressure. As the pore pressure develops, the effective stress, the shear modulus and shear strength reduce, thereby permitting larger shearing strains for the same transient shear-excitation. Leakage of excess pore water in response to transient pressure gradients is permitted. The one-dimensional distributed parameter model can handle layered soils with variable soil properties. Various surface and base boundary conditions can be used. The two-dimensional model will provide the opportunity to incorporate lateral variations in material properties for *in situ* studies, in addition to the vertical layering treated by the one-dimensional model.

49. Reliability of Existing Buildings in Earthquake Zones; James T. Yao; Purdue University, Department of Civil Engineering, Lafayette, IN 47907; **Award #77-05290 A02**

One important research task in Earthquake Engineering is to develop means by which existing buildings in earthquake zones can be appraised in terms of how they might respond during an earthquake. This project is a joint effort by the University of California, Berkeley and Purdue University. Berkeley will develop mathematical model by the system identification approach, and will test physical frame models on the shaking table. Purdue will formulate reliability criteria and analyze

test results in terms of damage probability and other probabilistic response measures. This research will provide the basis for formulating effective and realistic counter measures to mitigate damage and losses associated with non-engineered existing buildings in seismic areas.

50. Hydraulic Transients in Liquid-Filled Pipelines during Earthquakes; Fred M. Young; Portland State University, Department of Engineering and Applied Science, Portland, OR 97207; **Award #78-19678**

The earthquake-resistant design of lifeline systems that provide various public services has received considerable research attention recently. One such system, liquid-filled pipelines, transports fuel and water. Current research on pipeline systems has focused upon damage assessment, dynamic response analysis and design criteria. One controversial question remaining is whether overpressures caused by hydraulic transients in a fluid-filled pipeline have any significant effect on the earthquake response of the pipeline.

This research analyzes the effects of hydraulic transients on the failure potential of liquid-filled pipelines during earthquakes. The effects of hydraulic over-pressures caused by differential velocities between pipe wall and ground motions and by vaporization and water-column separation will be investigated. An analytical tool involving the modification of a one-dimensional computer program will be developed and will be used to examine the potential for hydraulic transient-induced damage to water pipeline systems due to earthquakes.

Human Nutrition

The Human Nutrition program will address some important nutritional concerns. An estimated 70 percent of the food consumed in the United States is derived from highly refined ingredients and is processed during manufacture with various additives and supplements. However, effects on human health and performance of the life-long consumption of such processed foods have not been determined. PFR will support research on the assessment of the nutrient value of processed foods through investigations of the physical, chemical and biochemical changes which occur in these foods during cooking, processing, packaging and storage.

1. Assessment of Chloro-Organics Formed in Foods; James R. Kirk; University of Florida, Department of Food Science and Human Nutrition, Gainesville, FL 32611; **Award #78-27067**

Chlorine is used in water treatment processes and food processing to control microbial growth. Chloro-organic compounds some of which may be carcinogens, may be formed during water treatment and food processing procedures. This study proposes to determine the effect of reactant species, reactant concentration, pH, temperature, and light on the rate of chlorine incorporation by bio-organic compounds in foods. The incorporation of chlorine into proteins, lipids, carbohydrates, vitamins, and selected food additives will be studied by determining the identity and concentration of chlorinated reaction products.

Initial studies will be carried out in model systems containing a single substrate in a buffered solution or suspension to which various concentrations of hypochlorous acid will be added. Chlorine incorporation will be determined by scintillation counting of labeled chlorine in organic reaction products. Identification of chlorinated organic compounds will be carried out using chromatography and mass spectrometry.

Real food systems will be investigated to determine the effect of these complex systems on chlorine incorporation. The rate of diffusion of hypochlorous acid and chlorinated reaction products will be determined as a function of pH, temperature, and basic physiological structure of the food system. The stability of chloro-organics will be studied. Collection and interpretation of these data will be used to establish guidelines for the safe use of aqueous chlorine with foods.

Science and Technology to Aid the Physically Handicapped

Science and Technology to Aid the Physically Handicapped will support research on the use of the best available scientific and engineering developments to improve defective speech, visual, tactile, and hearing systems in those persons afflicted with these impairments, and also to find ways to overcome locomotion and manipulatory limitations. The program will involve researchers from many disciplines including biomedical engineering, medicine, law, and the social sciences working with the active participation of handicapped persons on these problems.

1. Children's Auditory Discrimination and Perception of Monosyllabic Words; Lois L. Elliott; Northwestern University, Department of Communicative Disorders, 2299 Sheridan Road, Evanston, IL 60201; **Award #79-06496**

Research has shown that auditory perceptual "thresholds" for monosyllabic nouns that are within the receptive vocabularies of inner-city, three-year-old children decrease as a function of chronologic age and do not asymptote until the age of ten years. This project will determine whether this occurs because of differences between abilities of children and adults in detecting acoustic stimuli, in discriminating acoustic changes that are associated with

speech sounds; in identifying phonemes of speech; or in achieving an organized and integrated percept of a word. Synthesized speech stimuli and pure tones will be used in detection, discrimination and identification procedures that require the subject to select a response from among alternatives; reaction times will also be measured. Although normal children will be studied, project results may have potential applicability to handicapped populations such as hearing-impaired (moderate loss) and language-delayed children.

2. Electronic Information Exchange in Research on Devices For the Disabled; Jane McCarroll; Innovative Systems Research, Inc., 103 Cooper River Plaza East, Pennsauken, NJ 08109; **Award #77-17924 A02**

   This project is to conduct a planning meeting and pilot test of the use of electronic information exchange in the development of an improved nationwide delivery system for rehabilitation technology products, services, and information. The project will be jointly supported by NSF's Division of Information Science and Technology and EAS's Science and Technology to Aid the Physically Handicapped program.

3. An Engineering Foundation Conference on "Biomechanics of Movement"; William R. Rymer; United Engineering Trustees, 345 E. 47 Street, New York, NY 10017; **Award #79-08816**

The control of movement in man requires that neural signals, both afferent and efferent, interface with physical structures (such as muscles and limbs) which possess a range of inertial, elastic frictional and viscous properties. Motor systems neurophysiologists, for the most part preoccupied with electrophysiological aspects of movement control, have devoted less attention to the properties of the mechanical systems which must necessarily be controlled for movement to be executed. On the other hand, engineers interested in movement have been oriented towards precise descriptions of "plant" characteristics and behavior, and have attempted to use the methodology of control theory to formulate (largely unsuccessful) models of the control of movement.

The objective of this meeting is to attempt some synthesis of these disparate approaches by addressing aspects of biomechanics which are relevant to neural control strategies and highlighting recent developments in neurophysiology which may shed light on the neural-mechanical interaction. Thus, neuroscientist may better appreciate the nature of the control problem, while the bioengineer may be influenced by the techniques used by the nervous system to deal with these control problems in life.

NATIONAL SCIENCE FOUNDATION
Professional Assistant
Division of Problem-Focused Research
Room 1134 A
1800 G Street NW
Washington, D.C. 20550

National Science Foundation
Washington, D.C. 20550

Official Business

PENALTY FOR PRIVATE USE. $300

RETURN THIS COVER SHEET TO ROOM 233, IF YOU DO NOT WISH TO RECEIVE THIS MATERIAL ☐, OR IF CHANGE OF ADDRESS IS NEEDED ☐ (INDICATE CHANGE, INCLUDING ZIP CODE).

Postage and Fees Paid
National Science Foundation

THIRD CLASS
Bulk Rate

REQUEST FOR INFORMATION

☐ I WOULD LIKE TO CONTINUE TO RECEIVE *RECENT AWARDS*

☐ I WOULD LIKE TO RECEIVE ADDITIONAL INFORMATION, INCLUDING NOTIFICATION OF WORKSHOPS/SEMINARS, FOR THE FOLLOWING PFR PROGRAMS:

☐ Alternative Biological Sources of Materials

☐ Earthquake Hazards Mitigation

☐ Human Nutrition

☐ Science and Technology to Aid the Handicapped

☐ Check here if your firm is a Small Business

Mailing List Code # _____

NAME _____
(Title) (First) (MI) (Last)

ADDRESS: _____

_____

_____

_____
(Zip Code)

(OR ATTACH YOUR MAILING LABEL HERE)

(NSF 79-44)