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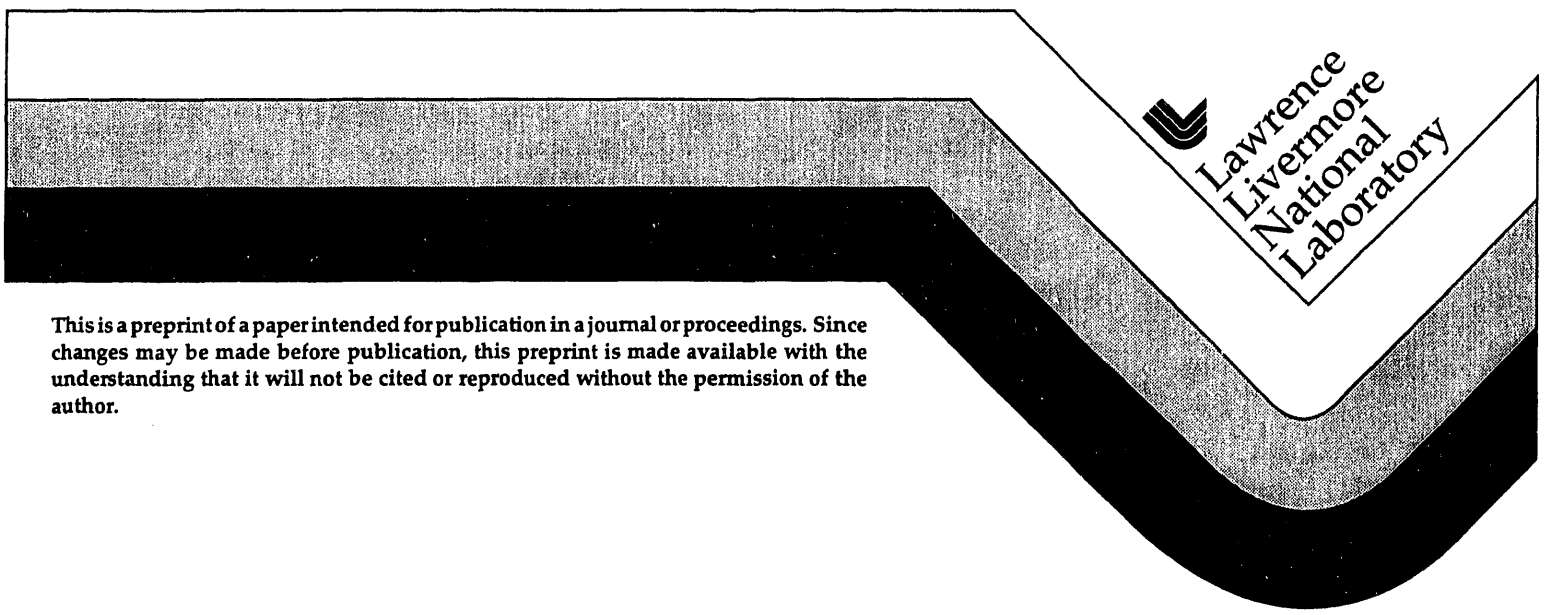

DEPARTMENT OF ENERGY
NATURAL PHENOMENA HAZARDS MITIGATION PROGRAM*

by

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ABSTRACT

This paper will present a summary of past and present accomplishments of the Natural Phenomena Hazards Program that has been ongoing at Lawrence Livermore National Laboratory since 1975.

The Natural Phenomena covered includes earthquake; winds, hurricanes, and tornadoes; flooding and precipitation; lightning; and volcanic events.

The work is organized into four major areas 1) Policy, requirements, standards, and guidance, 2) Technical support, research and development, 3) Technology transfer, and 4) Oversight.

POLICY, REQUIREMENTS, STANDARDS AND GUIDANCE

DEVELOPMENT OF HAZARD ESTIMATES AT DOE SITES

During the early stage of this project, hazard estimates were developed on a probabilistic basis for many DOE sites. Seismic hazards estimates were developed by Tera Corporation for 26 DOE sites. These studies are summarized in reference [1].

Extreme wind and tornado hazard estimates were independently developed by McDonald, Metha, and Minor at Texas Tech University and by T. T. Fujita at the University of Chicago. These hazard curves were then combined for the 26 DOE sites. The combined results are summarized in reference [2].

Preliminary flood hazard assessments for screening purposes were developed for 10 DOE sites. This effort was documented in references [3], [4], and [5].

DEVELOPMENT OF SEISMIC SAFETY GUIDE AND STATE-OF-THE PRACTICE MANUALS

Seismic Safety Guide

The Seismic Safety Guide [6], was first published in 1983 by the Lawrence Berkeley Laboratory (LBL), based upon its experience strengthening 34 buildings over a 20-year period. Earthquake safety programs elsewhere were slow to develop. Generally, they were too sophisticated, complex, and expensive to achieve expeditious results. Consequently, the primary purpose of the Seismic Safety Guide was to provide practical advice about earthquake safety to managers of DOE facilities so that they can get the job done without falling into common pitfalls and prolonged diagnosis. Its guidelines include hazard identification and evaluation, site planning, the evaluation and rehabilitation of existing facilities, the design of new facilities, lifelines, operational safety, emergency planning, and the management of risks and liabilities.

Since 1983, great progress has been made in earthquake engineering. Also, a number of damaging earthquakes have taken place in areas where structures were designed to resist them. As a result, many studies, guidelines, and regulations have been published, providing a wealth of new information. This has resulted in the need to revise the original Seismic Safety Guide. An important objective of the 1993 edition is to incorporate and interpret this material so that operators and mangers of DOE sites can achieve a comfortable level of understanding for the decisions they must make relative to seismic risk management.

The format for the Guide will follow that used in the original edition. Each technical section will be written by an experienced professional for an audience composed of

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mar mangers or engineers with little background in earthquake
eng engineering. Comments and advice from the operators-
mar manager's perspective will be provided in the foreword to
eacl each author's section. A draft of the 1993 edition should
be a be available for review by the end of 1993.

Sta State-of-the-Practice Manuals

General guidance for good practice has been developed
in a in a series of state-of-the practice manuals. These are
inte intended to provide the facility manager and designer with
exa examples of details that have been found to work well in
resi resisting the effects of Natural Phenomena.

The following manuals currently exist:

- Suspended Ceiling Bracing Requirements [7]
- Tie-Down and Anchorage Guidelines [8]
- Wind Detailing Requirements [9]
- Seismic Concepts and Detailing Requirements [10]

DE DEVELOPMENT OF DESIGN AND EV EVALUATION GUIDELINES

The second phase of the project was to develop
prac practical natural phenomena design and evaluation
guid guidelines which incorporated the probabilistic seismic,
wind wind, and flood hazard estimates. This was started in 1985
and and has been evolving ever since. A workshop has been
deve developed to accompany the design and evaluation guidance
and and has been conducted nine times since 1989. The latest
versi version of the guidelines is available as reference [11].

During 1992 extensive changes to the guidelines were
impl implemented as a result of ongoing work involving
seisn seismic analysis of high level waste tanks. This led to the
deve development of a document, Reference [12], which
provi provided the theoretical basis for DOE's natural phenomena
haza hazards design and evaluation criteria.

DE DEVELOPMENT OF NATURAL PHENOMENA RUL RULE, ORDER, AND STANDARDS

As part of a coordinated effort to ensure proper
perf performance of DOE facilities subjected to natural
phen phenomena hazards (NPH), a new DOE order in the 5480
serie series has been approved. This order, designated DOE
5480 5480.28 [13], is intended to establish: (1) requirements for
mitig mitigation of NPH at DOE facilities, (2) consistent NPH
requi requirements for all NPHs and for all DOE facilities, and
(3) N (3) NPH requirements appropriate for facility characteristics
and and objectives within a graded approach. The order
embo embodies the principles established by DOE Order
6430 6430.1A and UCRL-15910 [11], which have been in use at
DOE facilities for more than seven years. In addition, it establishes as requirements good practices that have been used at many of the DOE sites. The requirements cover the following:

- Assessment of NPHs for new and existing sites
- Natural phenomena effects to be considered
- Design of new facilities
- Evaluation and upgrade of existing facilities
- Design of additions and modifications
- Target performance goals
- Graded approach and performance categories
- Interactions and common cause effects
- Instrumentation.

The goals of the order are to (1) provide for safe workplaces, (2) protect against property loss or damage, (3) provide for continued operation of essential facilities, and (4) protect public health and the environment against exposure to hazardous materials — all in a cost-effective manner. To assist in implementing the new order, a series of DOE standards is being developed. Four standards are required to implement the order. The first, DOE-STD-1020-XX [14], is familiar to many in the DOE complex as UCRL-15910, "NPH Design and Evaluation Guidelines." DOE-STD-1021-93, "Natural Phenomena Hazards Performance Categorization Criteria for Structures, Systems, and Components," [15] accompanied the order upon its issuance. Standards 1022 [16] and 1023 [17] will provide criteria for site characterization and hazard assessment; they should be available by the end of 1993. The order also draws on other DOE standards as well as national codes and standards. The order uses DOE-STD-1024-92 [18] for guidance in the use of available probabilistic seismic hazard curves.

For new facilities, the order becomes effective on the date of issuance. For existing facilities, implementation is planned over several years because of constraints and programmatic mission considerations. To start the process of evaluating and upgrading existing facilities, the order requires contractors/operators to establish an implementation plan that contains a prioritized evaluation schedule and identifies current and future NPH mitigation actions. DOE-STD-1025-XX [19] which is under development will help conduct this effort in a consistent manner.

This plan is to be submitted to the Cognizant Secretarial Officer (CSO) within one year of the effective date of the order. Over the next few months a workshop will be developed for the CSOs covering the requirements of the order plus guidance on its implementation.

The issuance and implementation of DOE Order 5480.28 provides the framework for meeting Executive Order 12699 for seismic-hazard mitigation of new federal facilities and an Executive Order, under development,

which will require evaluation of existing facilities. In addition, it will form the basis for a new NPH rule under development as part of Title 10, Code of Federal Regulations.

DEVELOPMENT OF A METHODOLOGY FOR EVALUATING EXISTING FACILITIES

Currently a multiyear project is underway to develop NPH guidelines for evaluation of existing DOE facilities by the use of experience data. This project is intended to supplement the guidance provided in DOE-STD-1020-XX in the area of existing facilities. A program plan has been developed [20].

DOE existing facility evaluations can take direct advantage of the experience data base compilations and guidelines developed by SQUG and EPRI. As a first step, through a special agreement between DOE and EPRI, the SQUG and EPRI reference documents for using experience data are available to DOE for facility reviews. LLNL has already conducted two orientation workshops to provide DOE facility personnel with an overview of the SQUG and EPRI reference materials. The workshops are currently a mandatory step for any DOE site wishing to obtain the documents. A training program will be developed to permit use of these documents for safety evaluations.

Because the systems and components in DOE facilities are so diverse, additional experience-based tools are needed for the DOE efforts beyond the 20 SQUG classes of equipment currently included in the EPRI/SQUG data base. Examples include piping systems; heating, ventilation, and air-conditioning equipment; filter compartments; glove boxes; and fire-protection panels. A questionnaire is being used to help determine the types of safety systems and equipment components that will require seismic evaluation at DOE facilities.

In contrast to the SQUG deterministic criteria, DOE facilities are required to demonstrate their ability to achieve probabilistic performance goals. The larger the potential risks are, the stricter the performance requirements become. DOE and its contractors are, therefore, assessing the probabilistic performance goals achieved when seismic experience-based screening evaluation methods are used.

DOE is also considering the use of experience data in evaluating other natural phenomena hazards (NPH). This may include screening evaluation guidelines for wind and flood. As with earthquake experience data, considerable information is compiled and available for determining the important performance attributes for systems and components subject to these other NPHs.

DOE facility management and operations personnel will play an important role in the development and review of the guidelines. A Steering Group of selected individuals from the operating contractors will ensure that appropriate priorities are established from the facility-operation perspective. The Steering Group will also charter a team of industry experts for technical review of the implementation guidelines. The Technical Review Team will determine the adequacy of the technical content of the screening evaluation guidelines, including the safety margins that will result from implementation of the criteria.

TECHNICAL SUPPORT, RESEARCH AND DEVELOPMENT

POST EARTHQUAKE INSPECTION TEAM

We maintain a team of engineers knowledgeable in earthquake response and walkdown techniques to respond to earthquakes that effect industrial facilities and DOE sites. The purpose of inspections of industrial facilities is to document both damage caused by the earthquake as well as good performance. The team is available to respond after an earthquake where strong ground motions has occurred and facilities with structures and components similar to those found in DOE facilities exist.

The team has responded to the following earthquakes:

- Greenville Earthquake (1980)
  (Lawrence Livermore National Laboratory)
- Morgan Hill Earthquake (1984)
- Mexico City Earthquake (1985)
- New Zealand Earthquake (1987)
  (Bay of Plenty)
- Whittier Earthquake (1987)
- Loma Prieta Earthquake (1989)
- Costa Rica Earthquake (1991)
- Cape Mendocino Earthquake (1992)
- Landers and Big Bear Earthquakes (1992)

Response to these events is documented with photographs and summary reports. The emphasis is on response of industrial structures and components and lessons learned to reduce seismic risk at DOE facilities.

SURVEY OF SEISMIC INSTRUMENTATION

We are preparing a summary of available seismic instrumentation and its applications at DOE facilities. The summary will include manufactures' information, applications at DOE sites, and recommendations to DOE on seismic instrumentation needs.

This will assist DOE sites planning to install or upgrade their site and facility seismic instrumentation. DOE Order 5480.28 requires seismic instrumentation at DOE sites having facilities in performance categories 2, 3, or 4.

DE' DEVELOPMENT OF EARTHQUAKE-ALERT SYS SYSTEM AND AFTERSHOCK WARNING SYS SYSTEM

This project builds on the recently completed feasi feasibility study [21], examining the use of an earthquake-alert alert system to detect an earthquake occurrence at a very early early stage. We plan to set up a demonstration system at LLN LLNL and use its output (the early detection of a distant earth earthquake) to start emergency generators or raise fire-house door doors. A schematic of the system is shown in Figure 1. If th If the system is successful, we may expand it to cover DOE DOE facilities in the San Francisco Bay area; the New Madi Madrid, Missouri, area; or the Charleston, South Carolina, area. area. Application of this system can enhance safety, prote protect investments in unique equipment, and improve post event event recovery.

A spin-off of this effort is the development of an after aftershock warning system. This is a portable system that can b can be deployed in an area after an earthquake has occurred. The s The system will monitor aftershocks and send out an alarm by ra by radio to warn of impending ground motion. This syste system in shown in Figure 2. Once developed, both syste systems have the potential to be transferred to industry for furthe further use.

APPLICATION OF BASE ISOLATION AND PASSIVE ENERGY DISSIPATION TECHNOLOGY TO DOE

For nearly two decades, the United States Department of Energy (DOE) has substantially increased its efforts to reduce the effects of earthquakes on its facilities. Traditional means within the DOE for designing or retrofitting structures to mitigate earthquake effects include strengthening and anchoring. A nontraditional and increasingly popular concept for mitigating the effects of earthquakes on structures is seismic base isolation, see Figure 3.

Because base isolation is emerging as a promising technology for mitigating seismic effects, its potential role in the DOE is being evaluated. In order to use the technology within the DOE, criteria and guidance need to be developed. This task is studying the fundamentals of seismic base isolation, applications of the technology, and how the technology might be applied within the DOE.

An additional technology to reduce seismic risk at a facility is the use of passive energy dissipation devices. These can be installed in new designs or used as an option for retrofitting. The applications of these devices to DOE is being examined.

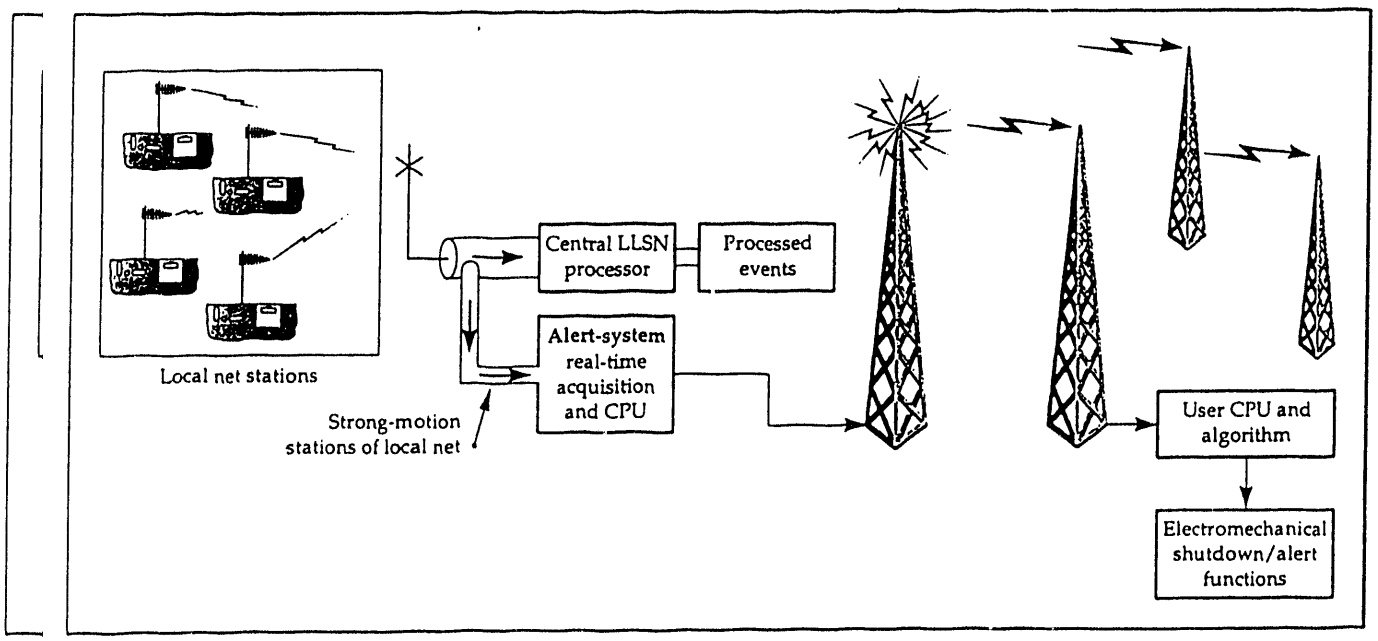

Figure 1. Earthquake Alert System (EAS)

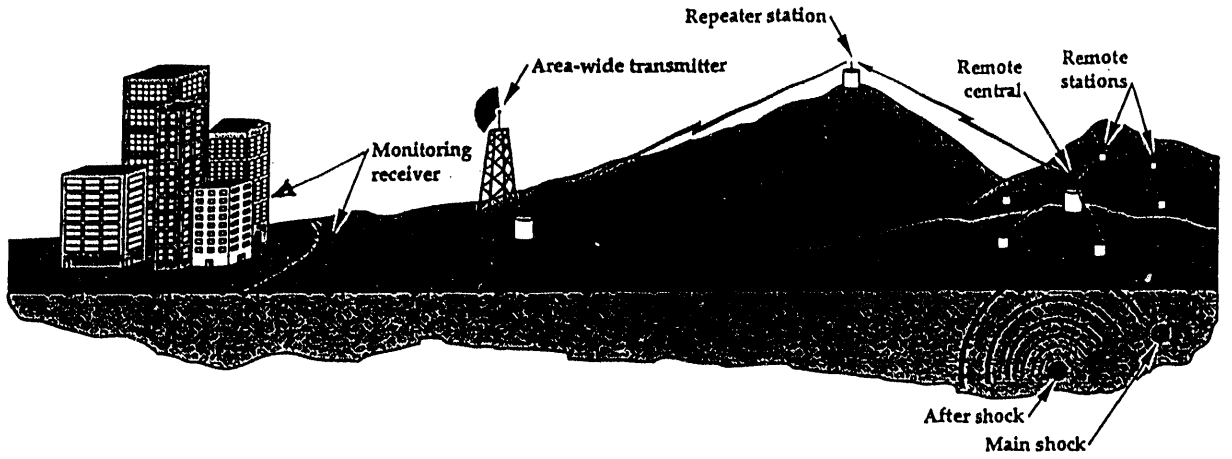

Figure 2. Aftershock Warning System (AWS)

Fixed Base
(Wrestling with nature)

Seismic Base Isolation
("Rigid body" behavior of superstructure)

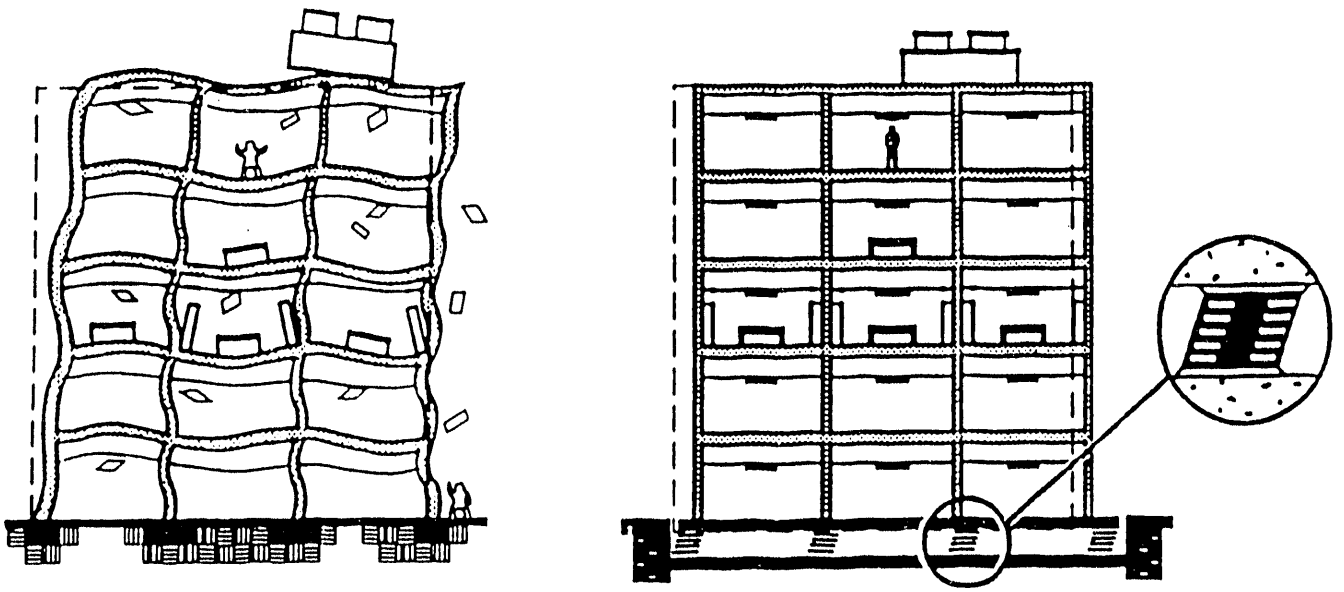

Figure 3. Seismic base isolation is a nontraditional way to mitigate the effects of earthquake motion.

DEVELOPMENT OF EVALUATION GUIDANCE FOR LIFELINES

A national lifeline standard development program is being conducted by FEMA and NIST. DOE is following these developments and supplementing them to meet life safety and mission requirements for all DOE facilities. The DOE lifelines earthquakes engineering task is planned to begin in fiscal year 1994, as part of the national phenomena hazards mitigation program. The task will be overseen by a DOE management team with technical guidance provided by a Steering Group of management and operating contractor representatives. During Fiscal Year 1994 we expect to follow and participate in the federal program, conduct a workshop, develop an overall plan, organize a Steering Group, and conduct a pilot study at a DOE facility.

TORNADO MISSILE TESTING

The effect of wind borne missiles on various wall configurations has been studied to determine the wall thickness needed to resist penetration, perforation and spall. Available test data is being complimented with additional missile tests conducted at the Texas Tech University Missile Test Facility.

A report documenting the study is under preparation. This work will lead to guidance to protect DOE facilities as a function of various tornado wind speeds.

TECHNOLOGY TRANSFER

PHENOMENAL NEWS

We prepare and issue a quarterly newsletter-Phenomenal News - to the DOE community. This newsletter provides background on various Natural Phenomena and their effects with emphasis on reducing risk at DOE facilities. Lessons learned from past natural phenomena are presented, progress on various programs underway by DOE and other federal agencies are summarized, and upcoming workshops and conferences related to natural phenomena are highlighted.

The intent of the newsletter is to increase awareness of natural phenomena hazards mitigation to DOE management and staff.

NATURAL PHENOMENA HAZARDS WORKSHOPS

A series of workshops have been organized to transfer developments and evolving technology and lessons learned to the DOE community. The following workshops have been held:

- Seismic Safety Seminars
  Berkeley (1980)
  Discussing impacts of the Greenville Earthquake on San Francisco Bay Area DOE Facilities.

  Stanford (1990)
  Discussing impacts of the Loma Prieta Earthquake on DOE facilities.

- Workshops on the philosophy and use of DOE Natural Phenomena Design and Evaluation Guidelines with examples. The workshop covers an overview of the DOE policy and applications to seismic, extreme winds, and floods. Workshop notes are available to participants [22]. Workshops have been held at the following locations:
  Albuquerque, NM (1989)
  Seattle, WA (1989)
  Charleston, SC (1990)
  Boston Area (1990)
  Denver, CO (1990)
  Chicago Area (1991)
  Salt Lake City (1992)
  San Diego, CA (1992)
  Washington, DC 1993)

- Seismic Base Isolation Technology Workshop—Los Angeles Area (1992), [23].
  Discussing Concept and Worldwide Applications of Base Isolation Technology.

  Short Course—Berkeley, CA (1992), [24].
  Providing detail on how to design base isolation systems for use in new or existing facilities.

- Volcanic Hazards Workshop—Portland, OR (1992), [25].
  Explored the hazards and issues associated with volcanic hazards and their effect on DOE facilities. Developed a plan for further work needed to mitigate volcanic hazards. A field trip to Mt. St. Helens was conducted as part of this workshop.

- Lightning Hazards Workshop—Cocoa Beach, FL (1993), [26].
  Explored the nature and effects of lightning and approaches to mitigation. A field trip to the Kennedy Space Center and Cape Canaveral was conducted as part of this workshop to inspect Lightning Mitigation Technology used by the Space Program.

- Facility Walkthrough Orientation - St.. Louis, MO, (1991), [27].
  A workshop was organized to discuss facility

walkthrough techniques for wind and earthquakes. The techniques were demonstrated with a field trip to the nearby AB Industries facility.

- Orientation Workshops on the use of the EPRI/SQUG Seismic Evaluation Material Licensed for use at DOE facilities, [28].

  This material was developed by the commercial nuclear industry over the last ten years and made available to DOE through a license agreement with the Electric Power Research Institute. Seven volumes of Seismic Evaluation Material were distributed to staff at DOE sites.

  The material provides a practical approach to seismic evaluation of DOE systems and components based on performance of similar items in past earthquakes.

  The first workshop was held in San Francisco, CA in 1992 and the second workshop in Golden, Colorado in 1993. The second workshop was followed by a walkthrough field exercise at the Rocky Flats Plant.

The workshop series has been useful in transferring Natural Phenomena Technology to the DOE sites and identifying site needs for future work.

The following workshops are tentatively planned for FY94:

Lifelines Workshop
To explore DOE needs in lifeline earthquake engineering and summarize ongoing Federal Standards being developed in this area.

Flood Protection Workshop
Provide details of flood protection technology currently available for use at DOE sites.

Flood Hazards Assessment Workshop
Explore methodologies available for determining flood hazards at DOE sites.

Orientation Workshop on DOE Natural Phenomena Hazards Order and implementing Standards.
Explain the requirements of the order and standards and discuss site implementation procedures.

Natural Phenomena Design and Evaluation Guidelines Workshop.
The tenth workshop on the philosophy and use of the DOE Guidance.

NATURAL PHENOMENA HAZARDS MITIGATION CONFERENCES

The First Natural Phenomena Hazards Mitigation Conference was organized and held at Las Vegas, NV in 1985 [29]. This conference brought together, for the first time, managers, engineers, and scientists from around the DOE complex with the goal of sharing information about ongoing projects in natural phenomena hazards mitigation. The conference was followed by six three-hour mini courses conducted by international experts in each area.

The areas covered were:
Seismic Analysis [32]
Seismic Design [33]
Wind and Tornado Overview [34]
Wind and Tornado Design and Evaluation [35]
Flood Overview [36]
Emergency Preparedness [37].

The second conference was held in Knoxville, Tennessee in 1989 [30]. There was growing interest among DOE sites to continue with this effort, share technology and mitigation strategies, and discuss projects with others around the DOE complex.

The third conference was held in St. Louis, Missouri in 1991 [31] and a two year cycle was established. The number of papers and posters presented continued to grow. A natural phenomena walkthrough workshop was held at the conclusion of the conference.

This summary paper has been prepared for the fourth conference to be held in Atlanta, Georgia in October 1993. This conference is the largest to date with over 125 abstracts submitted indicating both widespread interest and activity at DOE sites.

NATURAL PHENOMENA HAZARDS TECHNOLOGY CENTER

The Natural Phenomena Hazards Technology Center has been established at LLNL during 1992. This center will provide the following services:

- Centralized source of information and reference material with computerized access by the DOE complex.
- Provide resources in developing and reviewing hazard definitions, criteria development, and facility reviews.
- Evaluate lessons learned from observation of natural phenomena events.
- Provide training and technology transfer.
- Keep current on state-of-the-art.

OVERSIGHT

DESIGN REVIEWS AND TECHNICAL SAFETY APPRAISALS

Walkdowns and design reviews have been conducted in the natural phenomena area for several DOE facilities. This work has provided input for design reviews, restart reviews, and technical safety appraisals. This work has also led to the development of the Walkdown Field Guide.

Reviews have been conducted at the following locations:

Design Reviews

Hanford/N-Reactor
Savannah River/K-Reactor
Oak Ridge/HFIR - Design Review and Restart Review

Natural Phenomena Hazards Walkthrough

Paducah Gaseous Diffusion Plant
Rocky Flats Plant

Technical Safety Appraisals

INEL/ANL-West
LANL

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