Statement of

Dr. Sivaraj Shyam-Sunder
Acting Deputy Director
Building and Fire Research Laboratory

National Institute of Standards and Technology
Technology Administration
U.S. Department of Commerce

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National Earthquake Hazards Reduction Program

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Mr. Chairman, and members of the Subcommittee, I am pleased to appear today and testify on H.R. 2608, the proposed bill to reauthorize the National Earthquake Hazards Reduction Program (NEHRP).

NEHRP has been an extraordinary, and often exemplary, collaboration between federal agencies, state and local governments, and the private sector.

During its first 26 years, NEHRP has contributed in very significant ways to reduce our nation's vulnerability to the shakes, rattles, and rolls of earthquakes and NIST is proud to have been a part of that record of accomplishment.

While it is difficult to quantify loss prevention through the adoption of improved mitigation practices, there is no doubt that NEHRP products and results have contributed in significant ways to reduce the loss of life and economic losses from earthquakes. In addition, the loss of life from earthquakes in the United States has been small compared with similar earthquakes in other countries.

My testimony today will describe NIST current responsibilities and activities under NEHRP, how they will change if H.R. 2608 is enacted, our comments on those changes, and the extent to which NIST has the resources to carryout the new tasks. I have also provided as an attachment to the testimony a brief description of some of NIST's most significant accomplishments supporting NEHRP research.

NIST Current Responsibilities and Activities

NIST is a natural participant in NEHRP because of its long-time role in providing measurements, standards, and technology to help federal, state, and local government agencies and the private sector protect the nation and its citizens from natural as well as manmade threats.

Currently, we have four major responsibilities:

1. To develop seismic design and construction standards for consideration and subsequent adoption in federal construction;

2. To assist federal, state, and local agencies, research and professional organizations, model code groups and others in developing, testing, and improving seismic design and construction provisions to be incorporated into local codes, standards, and practices;

3. To conduct research on performance criteria and supporting measurement technology for earthquake resistant construction; and

4. To participate in NEHRP post-earthquake investigations and analyze the behavior of structures and lifelines, both those that were damaged and those that were undamaged; and to analyze the effectiveness of the earthquake hazards mitigation programs and how they could be strengthened.

Early in 2001, a NEHRP Strategic Plan was approved by each of the four participating agencies. This plan identified a technology transfer gap that limits the adaptation of basic research knowledge into practice. The plan recommends an expanded problem-focused research and guidelines development effort to facilitate the implementation of new mitigation technologies.

As a first step, NIST requested the Applied Technology Council to convene a workshop of national leaders in earthquake design, practice, regulation, and construction in July of 2002. The purpose of the workshop was to assess the state of knowledge and practice and to suggest an action plan to address the gap between basic research and practice.

The action plan identifies industry priorities in two areas:

(1) support for the *seismic code development process* through technical assistance and development of the technical basis for performance standards; and
(2) improved seismic *design productivity* through the development of tools for the evaluation of advanced technologies and practices.

The action plan, "The Missing Piece: Improving Seismic Design and Construction Practices (ATC-57)," is available from the Applied Technology Council, www.atcouncil.org.

NIST now looks forward to working with the stakeholder community to explore ways to best meet those needs via a public-private partnership. We expect this effort will build on NSF-funded basic academic research, including that conducted as part of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) Consortium.

Our current activities and recent accomplishments are as follows:

National Construction Safety Team

In the aftermath of the World Trade Center Disaster, Congress has given NIST the authority to investigate major building failures in the United States, including those caused by earthquakes.

The National Construction Safety Team (NCST) Act gives NIST the authority to dispatch teams of experts within 48 hours following a major building disaster. Congress anticipated the NCST Act to be applicable to building failures caused by earthquakes. The Act specifies that the NIST Director develop implementing procedures that "provide for coordination with Federal, State, and local entities that may sponsor research or investigation of building failures, including research conducted under the Earthquake Hazards Reduction Act of 1977." In addition, the Committee Report 107-530 published by the House Science Committee on June 25, 2002 states that " The Director should clearly define how earthquake researchers and Teams will carry out their responsibilities in a coordinated fashion in cases where building failures have been caused by an earthquake."

NIST's responsibilities under the NCST Act have been incorporated into the recently completed plan to coordinate post-earthquake investigation issued by the four agencies comprising the National Earthquake Hazards Reduction Program. The plan (USGS Circular #1242) states that, within 48 hours, NIST will examine the relevant factors associated with building failures that occur as a result of the earthquake and will make reasonable efforts to consult with the other NEHRP agencies prior to determining whether to conduct an investigation under the Act. Any NIST investigation conducted under the Authority of the Act will be limited to building failures on one or more buildings or on one class or type of building selected by NIST. NIST recently participated in a series of tabletop exercises with representatives of the other NEHRP agencies. The exercises simulated the response to earthquake scenarios in different parts of the United States to test the plan.

Interagency Committee on Seismic Safety in Construction

NIST chairs and provides the technical secretariat for the Interagency Committee on Seismic Safety in Construction (ICSSC). The ICSSC is composed of representatives from 32 federal agencies and develops uniform standards of seismic safety for federally owned, leased, assisted, and regulated buildings. The ICSSC also provides guidance to the federal agencies on the use of industry standards and codes for design and construction of federal buildings to meet the standard of life safety established for federal buildings.

The ICSSC issued Standards of Seismic Safety for Federally Owned and Leased Buildings (ICSSC RP 6) in January 2002. This reflects the most recent standard for evaluation of seismic risks in existing buildings, Seismic Evaluation of Existing Buildings (ASCE 31), and the most recent guidance for rehabilitation of existing buildings, Prestandard for the Seismic Rehabilitation of Existing Buildings (FEMA 356). It also provides for evaluation and rehabilitation of existing buildings to a higher performance standard of immediate occupancy, where this higher performance level is needed to fulfill an agency's mission.

NIST staff serve on the Provisions Update Committee that drafts proposals for change to the NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures. The ICSSC reviews and responds to ballots on changes to the NEHRP Recommended Provisions. The ICSSC further conducts comparisons of the current model building codes and standards to the NEHRP Recommended Provisions to provide the federal agencies guidance on the use of the model codes and standards. These comparisons coincide with the release by FEMA of the NEHRP Recommended Provisions. The ICSSC released recommendations for the use of the model codes and standards in 2001 and is currently conducting a code comparison study, on which new recommendations will be issued later this year.

Currently the ICSSC is conducting a project to update the NEHRP Handbook for Seismic Rehabilitation of Existing Buildings. The handbook is intended to provide practical guidance to design professionals on the seismic rehabilitation of standard building types. The handbook will facilitate implementation for federal buildings when a policy decision is made to proceed.

Prevention of Progressive Structural Collapse

NIST has initiated a project to develop and implement performance criteria for codes and standards, tools and practical guidance for prevention of progressive structural collapse.

Progressive collapse refers to the spread of a structural failure – by a chain reaction – that is disproportionate to a localized triggering failure, often due to abnormal loads. Such collapse can result in a disproportionate loss of life and injuries. The project is considering four distinct but interrelated strategies to mitigate progressive collapse: (1) system design concepts, (2) retard collapse after triggering event, (3) built-in redundancy via alternate load paths, and (4) retrofit and design to "harden" structure.

A key focus of the project is to develop retrofit and design methods that take advantage of the synergies associated with mitigating progressive collapse under multiple threats (blast, impact, fire, wind, and earthquake). The project depends heavily on the development and use of advanced modeling and simulation tools to evaluate the vulnerability of structural systems to progressive collapse under different threats. The project is reviewing and using knowledge gained from controlled demolition technology and builds on that knowledge to develop effective mitigation strategies for progressive collapse. Finally, the project is developing performance criteria and methods to mitigate progressive structural collapse cost-effectively for both new and existing structures based on a combination of existing knowledge, the results of analytical model sensitivity studies, and laboratory and field measurements.

NIST held a national workshop on Prevention of Progressive Collapse on July 10-12, 2002 in Chicago. Proceedings of the workshop, which include recommendations for a national plan for a problem-focused study, were published in September 2002. NIST has completed a draft of a best practices guideline for retrofit of existing buildings and plans to issue the final guideline later this year.

Fire Safety Design and Retrofit of Structures

NIST is using a multi-hazard approach to facilitate the development of mitigation technologies. In addition, building fires can often result following an earthquake.

The objective of this project is to develop significantly improved standards, tools, and practical guidance for the fire safety design and retrofit of structures. The project is focusing on standards and tools for steel and concrete structures and on verified predictive tools and performance criteria to evaluate structural fire performance in real fires.

Five key factors are being considered in developing performance-based methods:

(1) While the current standard fire endurance test method, which stipulates a prescribed time-temperature exposure, is adequate to compare relative performance of structural components, it does not provide any indication about the actual performance (i.e., load carrying capacity) of a component in a real fire environment (e.g., involving fire of building contents).

(2) The role of structural connections, diaphragms, and redundancy in enabling load transfer and maintaining overall structural integrity during fire is ignored in structural design. Current design methods are based on fire endurance tests of single components and do not account for the behavior of inter-component connections or the complex two- and three-dimensional behavior of the entire structure.

(3) There is a need to evaluate the effectiveness of alternative retrofit, design, and fire protection strategies to enhance structural fire endurance (including alternate cementitious spray or board systems, intumescent coatings, high-performance fire protective coatings, active suppression systems, and more sensitive sensing and monitoring). No practical, high-level models exist today that couple the fire dynamics to the structural system response, and the resulting transient, multi-dimensional heat transfer through structural components made with multiple materials.

(4) There is a lack of knowledge about the fire behavior of structures built with innovative materials (e.g., high-strength concrete or steel structures).

(5) There is a need to better model and predict the fire hazard to structures from internal and external fires. This includes deterministic and probabilistic models for specifying the magnitude, location, and spatial distribution of fire hazards on structures; determination of reliability-based load factors for combined dead, live, and fire loads and resistance factors for loss in structural strength and stiffness; and methods for load and resistance factor design (LRFD) under fire conditions.

The project will develop performance criteria and methods to assure cost-effective structural performance under fire for both retrofit and design applications based on a combination of existing knowledge from around the world, the results of analytical model sensitivity studies, and laboratory and field measurements.

H.R. 2608 National Earthquake Hazards Reduction Program Reauthorization Act of 2003

If H.R. 2608 is enacted, the roles and responsibilities of NIST in NEHRP will change in the following ways:

(1) NIST will become the lead agency for the program.

(2) The bill creates an Interagency Coordinating Committee (ICC) for NEHRP with the NIST Director as the Chair and the directors of FEMA, USGS, NSF, OSTP and OMB as the other members. It tasks the Committee with oversight, planning, management, and coordination of the program. The legislation also requires the Committee to develop and periodically update a strategic plan for the program that establishes the NEHRP goals and priorities and develop and submit to OMB a coordinated interagency budget that will ensure appropriate balance among activities.

(3) The bill directs the ICC to transmit to Congress an annual report on the program at the time of the President's budget request. The report should include the program budget for the current and upcoming fiscal years for each NEHRP agency and a description of the activities of the program during the previous year. It should also include the

effectiveness of the program in furthering the goals established in the strategic plans and a description of the extent to which the program has incorporated the recommendations of the external NEHRP Advisory.

(4) The bill requires the Director of NIST to establish an Advisory Committee consisting of representatives of research and academic institutions, industry, and State and local government. It tasks the Advisory Committee with assessing trends and developments in earthquake hazards reduction science and engineering and the effectiveness of the Program. The Advisory Committee must report its findings and recommendations to the Director of NIST one year after enactment, and at least once every two years thereafter.

NIST believes that the proposed changes to the Interagency Coordinating Committee, adding representatives from the Office of Science and Technology Policy and the Office of Management and Budget, and the formation of a Federal Advisory Committee will serve to strengthen the NEHRP program. NIST has the experience and expertise to perform the lead agency function for NEHRP

Mr. Chairman, I want to thank you and the Subcommittee again for allowing me to testify today about NIST's activities in support of NEHRP and allowing us to discuss our views on H.R. 2608. I would be happy to answer any questions at this time.

Products and Results of NIST Problem-Focused R&D

Bridge Column Reinforcing Requirements

Immediately following the 1971 San Fernando earthquake, NIST dispatched a team to document and investigate structural damage caused by the earthquake. In particular, many bridge columns suffered either significant damage or failure. As a result, design requirements for bridge columns in seismic zones were modified. However, the adequacy of these design modifications was not verified.

NIST initiated a project in the 1980s to provide the necessary verification, consisting of two full-scale bridge column tests. The challenges arose from the size of the test specimens and the need to apply horizontal seismic loads in addition to vertical gravity loads. The series of column tests was the first of its kind and as such, provided important benchmark data. The tests also verified the adequacy of the revised design specifications.

In addition, NIST tested companion 1/6-scale bridge columns and the results indicated that the behavior of full-scale bridge columns could be extrapolated from small-scale bridge column tests. This finding suggests that high costs associated with full-scale tests are not always necessary and less expensive small-scale tests may be sufficient.

Welded Steel Moment Frame Connections

Steel framed buildings traditionally have been considered to be among the most seismic resistant structural systems. The January 17, 1994, Northridge Earthquake, however, caused unexpected damage to many welded steel moment frame buildings. In general, the damage was confined to beam-to-column connections that suffered brittle fracture in the flange welds.

In response to these failures, NIST initiated a project to study methods to modify existing buildings to improve their seismic performance, in collaboration with the American Institute of Steel Construction, the University of Texas, the University of California at San Diego, and Lehigh University. Eighteen full-scale tests were conducted on three different methods to reduce the stresses at the beam-to-column connections.

The result of this multi-year effort was the publication of comprehensive guidelines for seismic rehabilitation of existing welded steel frame buildings as an AISC Design Guide. The guidelines provided experimentally-validated response prediction models and design equations for the three connection modification concepts that shift loading from the welded joints into the beams, thus enabling the structure to absorb the earthquake's energy in a non-brittle manner.

Test Methods for Structural Control Devices

Structural control devices, such as seismic isolation and passive energy dissipaters, have been installed in numerous structures throughout the world and have proven to be effective in reducing both motions and forces during earthquakes and strong winds. Still these devices are generally produced in small quantities, specifically for each application.

To guarantee that the devices will perform as the designer expected, many building codes and guidelines recommend that the devices be tested before installation. While some of these standards describe a limited number of specific tests, widely accepted test methods did not yet exist at the time of this project. Such standards are useful to designers, manufacturers, and contractors, since they will make the process of validating these devices consistent.

To address the issue NIST has developed two sets of testing guidelines. The *Guidelines for Pre-Qualification, Prototype, and Quality Control Testing of Seismic Isolation Systems* was issued in 1996. ASCE has developed and is currently balloting a national consensus standard based on the NIST-developed isolation device testing guidelines.

While seismic isolation is generally accepted in earthquake engineering practice and recognized in the building codes in high-seismic areas, passive structural dampers are still gaining acceptance and semi-active devices are still in the development phase. NIST has just issued *Guidelines for Testing Passive Energy Dissipation Devices.*

S. SHYAM SUNDER
Acting Deputy Director
Building and Fire Research Laboratory

Dr. Shyam Sunder is Acting Deputy Director of the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST).

BFRL's mission is to meet the measurements and standards needs of the building and fire safety communities by serving as *the* source of critical tools – metrics, models, and knowledge – used to increase productivity, facilitate trade and enhance public safety through technical innovations and improved codes, standards, and practices. New construction and renovation amount to over one trillion dollars annually – about 12 percent of U.S. GDP – and unwanted fires cost the economy over $100 billion annually. Everyone's safety and quality of life and the productivity of all industries depend on the quality of constructed facilities.

BFRL has an annual operating budget of about $39 million and its staff includes about 180 federal employees and 100 research associates and guest researchers from industry, universities, and foreign laboratories.

In his current position, Dr. Sunder also:

- serves as the lead investigator for the federal building and fire safety investigation into the World Trade Center disaster;
- oversees NIST activities related to the National Construction Safety Team Act;
- leads NIST activities related to the National Earthquake Hazards Reduction Program (NEHRP);
- guides effective implementation of the NIST strategic plan within BFRL and the four BFRL goals: Homeland Security, Fire Loss Reduction, Enhanced Building Performance, and High-Performance Construction Materials and Systems;
- chairs, as designated by the NIST Director, the Interagency Committee on Seismic Safety in Construction (ICSSC) – a group that recommends policies and practices to its 32 member-agencies on improving the seismic safety of federal buildings nationwide; and
- serves as the U.S.-side chair of the Wind and Seismic Effects Panel established under the U.S.-Japan Cooperative Program on Natural Resources (UJNR).

Dr. Sunder was chief of the Structures Division from January 1998 until June 2002 and chief of the Materials and Construction Research Division from June 2002, when the Building Materials Division was merged with the Structures Division and renamed, until March 2004. From June 1996 to December 1997, Dr. Sunder was on assignment to the Program Office, the principal staff office of the NIST Director, first as a Program Analyst and later as the Senior Program Analyst for NIST. In 1994, Dr. Sunder joined NIST's Building Materials Division as Manager of BFRL's newly created High-Performance Construction Materials and Systems Program and served in that position until June 1996.

Prior to joining NIST, Dr. Sunder held a succession of positions at the Massachusetts Institute of Technology (MIT) beginning in 1980: instructor, assistant professor, associate professor, principal research scientist, and senior research scientist.

Dr. Sunder's awards include the Gilbert W. Winslow Career Development Chair (1985-87) and the Doherty Professorship in Ocean Utilization (1987-89) from MIT, the Walter L. Huber Civil Engineering Research Prize (1991) from the American Society of Civil Engineers, and the Equal Employment Opportunity Award (1997) from NIST.

Dr. Sunder holds a Bachelor of Technology (Honors) degree in civil engineering from the Indian Institute of Technology, Delhi (1977), a Master of Science degree in civil engineering from MIT (1979), and a Doctor of Science degree in structural engineering from MIT (1981).