NIST GCR 13-917-23

Development of NIST Measurement Science R&D Roadmap: Earthquake Risk Reduction in Buildings

The National Institute of Building Sciences
Building Seismic Safety Council
Washington, D.C. 20005

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

Disclaimers

This report was prepared for the Engineering Laboratory of the National Institute of Standards and Technology (NIST) under the National Earthquake Hazards Reduction Program (NEHRP) Contract SB1341-11-SE1183.

NIST policy is to use the International System of Units (metric units) in all its publications. In this report, however, information is presented in U.S. Customary Units (inch-pound), as this is the preferred system of units in the U.S. earthquake engineering industry.

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National Institute of Standards and Technology
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Executive Summary

This report has been prepared by the Building Seismic Safety Council (BSSC) of the National Institute of Building Sciences to assist the National Institute of Standards and Technology (NIST) in planning future research efforts related to seismic safety for new and existing buildings. This report used, as its starting point, research recommendations from the Applied Technology Council (ATC), National Research Council, BSSC and NIST. This report identifies further research activities and funding levels recommended for NIST to pursue for years 0-3, for years 3-5, and for years 5-8.

With the guidance of a Project Technical Committee comprising practitioners and academics, BSSC used the reports and experience from ATC and other sources to develop six lists of potential research topics pertinent to future research. The six topic lists are 1. Design Methodologies; 2. Geotechnical and Ground Motion; 3. Performance-Based Seismic Design; 4. Structural Material and Systems; 5. Nonstructural Systems; and 6. New Systems. Using these six research topics as a basis, BSSC planned and conducted a two-day workshop of the industry's leading academics and practitioners, with the aim of forming a priority list of issues within the six topics along with estimated funding levels. This report summarizes background information and findings from the two-day workshop, and presents the findings in the form of a Measurement Science R&D Roadmap for Earthquake Risk Reduction in Buildings.

Chapter 1

Introduction

The National Earthquake Hazards Reduction Program (NEHRP) Reauthorization Act of 2004 (Public Law 108-360) assigns the National Institute of Standards and Technology (NIST) significant research and development (R&D) responsibilities to improve building codes and standards and advance the state of the practice for buildings, lifelines, and other structures subjected to earthquakes. At the request of NIST, the Applied Technology Council (ATC) developed a research and development roadmap in 2003 to address the research-to-implementation gap. That report was *The Missing Piece: Improving Seismic Design and Construction Practices* (ATC-57, 2003).

ATC-57 laid out broad strategic objectives for earthquake engineering research and further development of codes and standards. The goal of ATC-57 was to create the framework to develop a more efficient, effective, and technically reliable practice for earthquake engineering. It focused on two specific subject areas: systematic support for the seismic code development process, and improving design and construction productivity. Under those two subject areas there are five program elements. They are:

SYSTEMATIC SUPPORT OF THE SEISMIC CODE DEVELOPMENT PROCESS

Program Element 1: Provide technical support for the seismic practice and code development process.

Program Element 2: Develop the technical basis for performance-based seismic engineering by supporting problem-focused, user-directed research and development.

IMPROVING DESIGN AND CONSTRUCTION PRODUCTIVITY

Program Element 3: Support the development of technical resources (e.g., guidelines and manuals) to improve seismic engineering practices.

Program Element 4: Make evaluated technology available to practicing professionals in the design and construction communities.

Program Element 5: Develop tools to enhance the productivity, economy, and effectiveness of earthquake-resistant design and construction process.

Since the publication of ATC-57, NIST has undertaken a considerable amount of R&D toward the five program elements identified in ATC-57. The results of this effort have met the goal of significantly advancing the seismic code development process and improving seismic design and construction productivity. See Appendix C for a detailed list of the projects that NIST has undertaken since publication of ATC-57 in 2003. There are, however, unmet needs in both areas.

To further the recommendations set forth in ATC-57, NIST contracted with the Building Seismic Safety Council (BSSC) of the National Institute of Building Sciences (NIBS) to develop a Measurement Science R&D Roadmap for the NIST Engineering Laboratory's Earthquake Risk Reduction in Buildings and Infrastructure program. The Roadmap was asked to:

- Categorize research activities consistently with the ATC-57 Program Elements 1-5
- Support the NEHRP *Strategic Plan for the National Earthquake Hazards Reduction Program, Fiscal Years 2009-2013*
- Address the relevant recommendations of the 2011 National Research Council (NRC) report *National Earthquake Resilience: Research, Implementation, and Outreach*
- Reflect the broad context of improving building performance to achieve greater national resilience

The BSSC selected a Project Director and formed the Project Technical Committee to oversee the development of the roadmap. The Project Technical Committee analyzed ATC-57 and formulated a broad strategic approach for NIST earthquake risk reduction research for new and existing buildings. They reviewed previously developed research recommendations from various publications, discussed in detail in Chapter 2. As part of those reviews, the Project Technical Committee redefined the Program Elements first proposed in ATC-57 for use in the roadmap:

Program Element 1: Resolve technical issues restricting or slowing progress in the codes and standards development process (e.g., shear for shear wall design, number of records used for design validation, minimum base shear, analysis methods, risk-targets, and site amplification factors).

Program Element 2: Develop the technical basis for performance-based seismic engineering (e.g., fragility specifications and collapse modeling and assessment, as well as items currently excluded, such as losses due to liquefaction and fire-following earthquakes).

Program Element 3: Support problem-focused research to improve seismic engineering (e.g., innovative connections and systems for buildings, rocking foundations, and soil-structure-foundation interaction).

Program Element 4: Make existing knowledge available to practicing engineers (e.g., Technical Briefs, guidelines, design manuals, and research syntheses).

The Project Technical Committee developed an initial list of potential research topics based on previous reports that listed recommended research topics (see list in Chapter 2). Gaps in those reports were also identified, suggesting additional or modified potential research topics necessary to fulfill the broad objectives of the NIST program for Earthquake Risk Reduction in Buildings and Infrastructure. Initially, the research needs list focused on items relating to the following overarching topics: Design Methodology and Analysis; Geotechnical and Ground Motions; Nonstructural; Performance-Based Seismic Design; Structural Materials and Systems – Steel, Concrete, Masonry, Wood; and New Systems. The initial lists excluded topics associated with existing buildings. However, existing building research topics were subsequently included in the roadmap research project.

The Project Technical Committee convened a workshop on behalf of NIST to get broad input on the research recommendations. Thirty-eight experts in the field of earthquake engineering attended the workshop, representing a balance among academics and practitioners, among different geographical regions of the country, and among different disciplines. A list of the workshop attendees and copies of the invitation and workshop materials are provided in Appendix B.

The Project Technical Committee took the recommendations from the workshop, developed and added a list covering the issues of existing buildings, and drafted the NIST Roadmap Recommendations. The next chapter presents a detailed description of the process of how the research topics were chosen, how they were prioritized, and how the costs were estimated for each research topic.

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Chapter 2

NIST Roadmap Recommendations

The goal of the Roadmap is to provide NIST with a prioritized listing of applied (problem-focused) research needs. In its initial charge to the Project Technical Committee, NIST requested that the following resources be used as source material for the research recommendations.

- ATC-57, *The Missing Piece: Improving Seismic Design and Construction Practices*
- Research needs identified during development of the 2009 *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures*
- NIST GCR 09-917-2, *Research Required to Support Full Implementation of Performance-Based Seismic Design*
- NIST Disaster Resilience Workshops, *Resilience Roundtable on Standards for Disaster Resilience for Buildings and Physical Infrastructure System, September 26, 2011 and Standards for Disaster Resilience for Buildings and Physical Infrastructure Systems, November 10, 2011. Both workshops were held in Arlington, Virginia.*
- ATC-73, *Prioritized Research for Reducing the Seismic Hazards of Existing Buildings*
- *Strategic Plan for the National Earthquakes Hazards Reduction Program*
- NIST GCR 10-917-7, *Program Plan for the Development of Collapse Assessment and Mitigation Strategies for Existing Reinforced Concrete Buildings*
- NIST Task Order Summary, presented to the Project Technical Committee on 4-24-12

Based on review of those documents, the Project Technical Committee created six lists of potential research topics:

1. **Design Methods and Analysis**: Topics that could be used to advance how an engineer would design or analyze a structure.
2. **Geotechnical and Ground Motion**: Topics that would be classified under the purview of a geotechnical engineer or seismologist, such as soil-structure interaction, ground motion selection and scaling, and seismic hazard development.
3. **Nonstructural**: Topics related to the design, anchorage, and performance characterization of nonstructural components within a building or other structure.
4. **Performance-Based Seismic Design** Topics related to performance-based seismic design and tools to better assess the earthquake performance of a building or other structure.
5. **Structural Materials and Systems**: Topics specific to the commonly used structural materials (steel, concrete, masonry, and wood).

6. **New Systems**: Topics related to new and developing structural systems that are not commonly used in practice at the time of this report, but show potential to be used if they could be further developed through additional research.

Each item in each list was then assigned one of the four revised program elements below:

Program Element 1	Resolve technical issues restricting or slowing progress in the codes and standards development process.
Program Element 2	Develop the technical basis for performance-based seismic engineering.
Program Element 3	Support problem-focused research to improve seismic engineering.
Program Element 4	Make existing knowledge available to practicing engineers.

These six lists became the basis for discussion at the workshop held on May 15th - 16th, 2012. Workshop participants were first separated into groups based on each of the six lists. To better distribute the material topics, the Structural Materials and New Systems lists were combined and reorganized into (1) Steel, Wood, and New Systems, and (2) Concrete and Masonry.

The groups considered how research on each topic would be carried out and what it would cost to conduct the work. The groups also considered modifications, combinations, or deletions of topics that would improve the overall outcome for the NIST program.

The groups also assigned each topic to one of four types for conducting the research:

- A—Individual investigator
- B—Small technical group
- C—Technical committee including specialized analysis expertise
- D—Technical committee including laboratory testing

Finally, the groups proposed a sequence and priority level for each of the research topics. (Overall priorities were determined by ballot at the end of the workshop.)

The groups considered how research on each topic would best be accomplished and approximately what the cost of that research might be. After the presentations from the six groups, all of the workshop participants were asked to vote on the priorities. The groups also assigned each topic to one of four methods for conducting the research. The priorities were numbered 1 through 3, with one being the highest priority; the priorities were intended to capture the sequential nature of some of the proposed projects. Additionally, participants could indicate if a topic should be excluded from the NIST program. Appendix A provides a detailed summary of the workshop results.

The Project Technical Committee reviewed the workshop results and made adjustments in topic descriptions, costs, research project types, and prioritization based on their experience and overall assessment of the program plan.

The Project Technical Committee modified the research project types to include a review panel component. The review panel was added to help ensure the effectiveness of the research approach and the quality of the findings. The modified recommended research accomplishment methods are:

- A—Individual investigator plus review panel
- B—Small technical group plus review panel
- C—Technical committee including specialized analysis expertise plus review panel
- D—Technical committee including laboratory testing plus review panel

The research topics were then assigned to one of three time frames:

- Time Frame 1 (less than 3 years): Highest Priority
- Time Frame 2 (3-5 years): Higher Priority
- Time Frame 3 (5-8 years): High Priority

Per NIST‘s direction, the research topics at the workshop focused primarily on new buildings. Topics related to existing buildings were developed separately by the Project Technical Committee using the recommendations outlined in ATC-73. The Steering Committee of the ASCE Standards Committee on Seismic Rehabilitation, which oversees ASCE 31: *Seismic Evaluation of Existing Buildings* and ASCE 41: *Seismic Rehabilitation of Existing Buildings* provided a review of the proposed existing buildings research topics. All existing buildings topics were assigned automatically to Time Frame 3, not as a reflection of any perceived lower importance or urgency, but because of NIST programming considerations.

Development of a seismic rating system for buildings that would put a marketplace value on expected seismic performance has been recommended at numerous workshops in the last 10 years. The Structural Engineers Association of Northern California (SEAONC) has been working on this idea for several years. A workshop, funded by FEMA, was held in March, 2011 to better understand the demand for, and uses of, such a rating system. The results of the workshop were mixed with no overwhelming conclusion as to the desirability (or non-desirability) of a rating system. Many public policy issues were identified that would apparently be outside the scope of federal government (NEHRP) resolution and FEMA is not currently funding development efforts. Technical issues were also identified, primarily related to consistently predicting seismic performance for the purpose of establishing a rating. Many of the proposed projects scattered across several of the research categories are crucial to developing this technical basis, and the Project Technical Committee chose to acknowledge the importance of the topic here, without identifying a specific task to develop the rating system.

The final list of research topics was regrouped into the following categories and numbered with an abbreviation for tracking purposes.

Design Methodology and Analysis	DMA
Geotechnical and Ground Motions	GGM
Nonstructural	N
Performance-Based Seismic Design	PBSD
Concrete	C

Masonry	M
New Systems	NS
Steel	S
Wood	W
Existing Buildings	EB

The Project Technical Committee then assigned each project an estimated cost category (based on 2012 dollars).

The following table presents a summary of the final prioritized research topics. This summary table is followed by one-page descriptions for each research topic, prioritized by time frame (1, 2, or 3), and by prioritization within the time frame (1, 2, 3, etc.). For instance, for Time Frame 1, the research topics are denoted 1-1, 1-2, 1-3, and so forth. Because the existing building research topics were assigned to Time Frame 3 and represent a singular set of topics, they are identified using "EB3" to acknowledge Time Frame 3 followed by the priority number.

The resulting estimated costs for research time frames one through three , as well as the total amount, are as follows:

- Time Frame 1 new buildings: $27,050,000
- Time Frame 2 new buildings: $18,750,000
- Time Frame 3 new buildings: $19,050,000
- Time Frame 3 existing buildings: $19,700,000

Total: $84,550,000

Summary of Prioritized Research Topics – New Buildings

Time Frame/ Priority	Workshop ID	Task	Cost Category ($1000)	Project Type
1-1	N2	Develop improved equations for approximating nonstructural design using code-based design procedures, i.e., a new F_p equation	1000	C
1-2	N1	Develop performance criteria for nonstructural components and metrics to assess the reliability of such criteria	1000	C
1-3	DMA20	Continue the development of Technical Briefs for use by practicing engineers and academicians—Specify topics for each time frame	600	B
1-4	DMA1	Evaluate linear analysis procedures, especially for structures with significant higher mode effects	1000	C
1-5	DMA3	Large Post-ATC-84 project (formerly P-delta)	4000	C
1-6	GGM9A	Liquefaction effects on buildings— Phase 1: Survey of liquefaction effects	250	B
1-7	PBSD3	Develop protocol for testing and documentation of results to enable development of consequence functions for both structural and nonstructural systems and components	250	B
1-8	S9	Base plates	1000	D
1-9	C1	Flexural detailing requirements for concrete shear walls	1500	C/D
1-10	W3	Effects of uplift on wood light-frame shear walls	250	A
1-11	DMA21	Suitability of maximum direction ground motions for use in seismic design codes	500	C
1-12	PBSD14	Develop a plan to establish a permanent home for a database of building component fragilities	200	B
1-13	C5	Design requirements for anchoring to concrete	1500	D
1-14	C4	Design shear in concrete shear walls and similar structures	500	C
1-15	DMA9	Provide additional guidance for nonlinear response history analysis and modeling requirements	750	C
1-16	N5	Create a database of recent earthquake performance of nonstructural components	500	B
1-17	PBSD15	Improve analytical models and simulation capabilities for buildings in near-collapse seismic loading	7000	C
1-18	DMA2	Evaluate irregularity (vertical and horizontal) triggers and the associated requirements	1000	C
1-19	GGM6	Continue to augment inventory of ground-motion time histories for use in response history analyses	250	B
1-20	PBSD1	Obtain historical testing data (much may be proprietary) from testing labs for development of nonstructural fragilities	750	B
1-21	M4	Partially grouted masonry walls	1000	B/D
1-22	C2	Slender walls	1000	D
1-23	DMA11	Evaluate strong column-weak beam requirements	500	C
1-24	DMA8	Investigate vertical ground motions and their effect on building performance	500	B
1-25	DMA22	Effect of aftershocks on the design and evaluation of buildings	250	B
2-1	DMA20	Continue the development of Technical Briefs for use by practicing engineers and academicians—Specify topics for each time frame	750	B
2-2	M1	Engineering models for varied masonry shear walls	250	B

Time Frame/ Priority	Workshop ID	Task	Cost Category ($1000)	Project Type
2-3	S7	Attachments to protected zones in steel framing	1000	D
2-4	PBSD7	Develop representative losses for primary categories of code-designed buildings to provide information that can be used to set code performance objectives and to inform the public concerning expected code performance	1000	C
2-5	GGM9B	Liquefaction effects on buildings— Phase 2: Research on both site-specific analysis and liquefaction effects	1500	C
2-6	W1	Requirements for light-frame shear walls	1000	C
2-7	N7	Loss studies using ATC 58 methodology and experience from past earthquakes to determine appropriate cut-off (S_a) for various code requirements	500	C
2-8	GGM2	Develop long-period design ground motions in collaboration with earthquake scientists	500	C
2-9	C10	Design shear in columns in special moment frames	500	C
2-10	PBSD4	Develop consequence functions for structural and nonstructural systems where it's not available	750	C
2-11	C9	Seismic response of Intermediate and Ordinary systems	750	C
2-12	S5	Braced frame (BRBF and EBF) connection ductility design demands	750	C/D
2-13	DMA17	Evaluate diaphragm design equations and methodology	750	C
2-14	GGM8	Benchmark commercial structural dynamic response software	1500	C
2-15	S1	Braced frames without out-of-plane lateral bracing	1000	D
2-16	C11	Shear in deep mat foundations	1750	C/D
2-17	PBSD5	Improve ability to predict damage to structures and contents from soil movements including liquefaction, lateral spread, landslide, and soil failure at foundations	1000	C
2-18	NS5	High-performance, high-rise buildings	750	C
2-19	DMA7	Evaluate the Seismic Design Categories (SDC)	1000	C
2-20	NS2	Rocking systems	750	C
2-21	PBSD13	Improve the characterization of uncertainties in the PBSD process	1000	C
3-1	DMA20	Continue the development of Technical Briefs for use by practicing engineers and academicians—Specify topics for each time frame	300	B
3-2	NS3	High-performance buildings	250	B
3-3	S6	Braced frame (BRBF and EBF) design recommendations for connections and links	250	B
3-4	PBSD18	Catalog information from past earthquakes to attempt to find some correlation with localized earthquake intensity and total downtime	1000	C
3-5	PBSD2	Study structural fragilities that have been developed and make recommendations for developing improvements, including when new testing may be required	1500	C
3-6	DMA22	Effect of aftershocks on the design and evaluation of buildings	500	C
3-7	PBSD16	Develop a systematic comparison of the reparability of various structural materials and systems under various loading intensities	1000	C
3-8	C6	Requirements for tilt-up wall systems	1250	C/D
3-9	NS4	High-performance buildings	1500	C/D

Time Frame/ Priority	Workshop ID	Task	Cost Category ($1000)	Project Type
3-10	N8	Workshop on the integration of BIM modeling with nonstructural component analysis and design	250	B
3-11	C3	Squat walls	500	B
3-12	DMA15	Investigate the use of multi-point spectra for use in design	750	C
3-13	NS1	Design of structural systems with replaceable fuses	750	C
3-14	PBSD10	Improve capability to consider losses from water damage from broken pipes or tanks	500	B
3-15	S2	Steel ordinary braced frames	500	C
3-16	S3	Steel ordinary moment frames	500	C
3-17	S4	Design forces for columns and steel plate shear walls	500	C
3-18	M2	Extend ability to model performance of masonry walls with irregular openings	1500	C/D
3-19	W2	Conventional construction	250	B
3-20	M3	Design and construction guidelines for masonry shear walls confined by reinforced concrete boundary elements	500	C
3-21	C8	Performance of shotcrete walls	1000	D
3-22	GGM11	Time-dependent ground-motion hazard maps	500	B
3-23	S8	Steel and concrete composite systems	2000	C/D
3-24	NS6	Development of smart, innovative, adaptive, sustainable materials and framing systems	1500	A/B/C/D

Total: $64,850,000

Summary of Prioritized Research Topics—Existing Buildings

Time Frame/ Priority	Task	Cost Category ($1000)	Project Type
EB3-1	Calibration of deficiency-based procedures of ASCE 31 and 41 (Tier 1, Tier 2, and simplified rehabilitation) with recent earthquake building performance	1500	C
EB3-2	Study how the variability of existing material properties impacts the whole building performance.	1000	C
EB3-3	Develop tools to identify and inventory existing buildings that are a collapse risk—the "killer buildings"	2000	C
EB3-4	Research program to provide better modeling and acceptance criteria for concrete elements—beams, columns, walls, and slabs—that do not conform with current special detailing provisions, and those that do not even conform to current ACI 318 non-seismic provisions	5000	D
EB3-5	Calibration of ASCE 41 collapse prevention with ASCE 7 risk targets and the 10% conditional probability of collapse in the MCE_R target	4000	C
EB3-6	Technical Briefs on seismic evaluation and retrofit of existing buildings	1200	B
EB3-7	Design examples on seismic evaluation and retrofit of existing buildings	1500	B
EB3-8	Study on concrete-encased steel framing with and without masonry infill	2000	D
EB3-9	Study on reinforced concrete frames with masonry infill	500	B
EB3-10	New tools for non-destructive investigation of building components	1000	D

Total: $19,700,000

Time Frame/Priority	1-1
Title	**Develop improved equations for approximating nonstructural design using code-based design procedures, i.e., a new F_p equation**
Category	Nonstructural
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	The current nonstructural design force equations in ASCE 7 and ASCE 41 have not changed substantially since the 1994 UBC. They are based on an assumed linear increase of the peak ground acceleration up to a capped value; components are delineated as either rigid or flexible, and approximated factors to reduce demands due to ductility of the nonstructural component are applied. Recent studies (Fathali and Lizundia, 2011), have shown that the current equations in ASCE 7 and ASCE 41 for determining design forces for the anchorage of nonstructural components can be overly conservative. This conservatism is very apparent at the higher stories of mid-rise and high-rise buildings. The majority of the R_p factors used in nonstructural component and anchorage design were developed using engineering judgment and have not been validated with testing. If nonstructural design is to become more performance-based, then the R_p factors need to be calibrated to reliability and risk metrics as is currently being done for structural R factors. Additionally, due to issues arising from ACI 318 Appendix D (anchorage to concrete) and the desire to prevent brittle failure, there was a proposal to include an over-strength factor, akin to the omega-zero factor in structural design, for nonstructural anchorage design in ASCE 7-10 Supplement 1. This factor was estimated without much basis, and it was acknowledged that studies were needed to assign different over-strength factors to different nonstructural components. A large study project would review and assess issues related to the design forces for nonstructural components and their anchorage. In addition to the work cited above, there have been many nonstructural research studies carried out. Many of them have been used to develop fragility data for FEMA P-58. Plus, there is a great deal of proprietary testing which has occurred, as described in Topic 1-20. This study would first review the available nonstructural research and proprietary data. Then each facet of the nonstructural force equation would be reviewed and updated based on the research. It is envisioned that the amplification of acceleration up the height of the building will change and the R_p factors and over strength factors would be updated based on the published component testing results. A methodology similar to FEMA P-695 may be devised for determining R_p and over strength factors. No new testing would be carried out during this study; however, recommendations for additional testing would be made that could be carried out in the future. Note: This is a combination of Workshop Tasks N2, N3, and N4.
Cost Category	$1,000,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	N2

Time Frame/Priority	**1-2**
Title	**Develop performance criteria for nonstructural components and metrics to assess the reliability of such criteria**
Category	Nonstructural
Program Element	Support problem-focused research to improve seismic engineering
Description	There has been a major shift toward performance-based design of structures with the move toward classifying performance in terms of conditional and absolute risk of collapse. Reliability-based metrics have been established for structural collapse and an effort is underway to do so for structural function loss. However, very little has been done to classify the performance of nonstructural components in such probabilistic terms. The reliability of current nonstructural design and anchorage requirements is unknown. Significant research, both numerically and physically, is needed to create performance criteria for nonstructural elements. This would include leveraging and expanding on the fragilities that have been developed in FEMA P-58. This study would first ascertain the reliabilities of our current ASCE 7 requirements for functional loss and loss of support/position based on numerical modeling and comparison with published research papers. FEMA P-58 fragilities would be used, augmented with additional testing that is available in the public domain or, if possible, from equipment suppliers' proprietary testing. The results from the ATC-63-2/3 project and similar follow-up studies would also be considered. This task would not include any physical testing and would be based on analysis using FEMA P-58. The effect of the performance of the various nonstructural components and systems on the overall performance of the building will be documented and these data will be used to suggest individual performance criteria. Fragilities of components and systems that are inconsistent with earthquake experience will be identified for further physical or analytical testing. The results of these studies can be directly used to improve and make consistent code requirements for nonstructural elements, although additional studies will probably be needed and will be identified. This study results would be a scoping document where it will be determined what ASCE 7 provides using the FEMA P-58 methodology and using archetype studies to determine which components contribute to the losses and identify the components for which physical testing is necessary. From that information, the study could then propose recommendations to the NEHRP *Recommended Provisions*[1].
Cost Category	$1,000,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	N1

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[1] The relationship between the NEHRP *Recommended Provisions* and national codes and standards is described in the June 2007 *Seismic Waves* newsletter found at http://www.nehrp.gov/pdf/SeismicWavesJune07.pdf.

Time Frame/Priority	1-3
Title	**Continue the development of Technical Briefs for use by practicing engineers and academicians—Specify topics for each time frame**
Category	Design Methodology and Analysis
Program Element	Make existing knowledge available to practicing engineers
Description	Over the past several years, numerous Technical Briefs have been developed that provide guidance for engineers in the design of specific seismic systems. The following issues, among others, should be considered for future Technical Briefs. • Gravity-only Framing Gravity-only framing is subject to the deformation compatibility requirements outlined in ASCE and the referenced material standards. The material standards specify demand levels and detailing requirements that are sometimes difficult to consistently apply and are sometimes overlooked. Providing clarity to these requirements will assist engineers in correctly implementing the intent of these provisions. • Seismically Isolated Buildings Seismically isolated building design requirements have been in building codes and standards for nearly two decades, but the number of buildings designed using this technology is quite low compared to other countries with significant earthquake risk (e.g., Japan). A Technical Brief outlining the benefits of these systems, describing the design process, discussing important constructability issues and providing cost information relative to other seismic solutions would provide engineers with the information they need to include seismically isolated buildings in the list of potential project options. • Loss-estimation Based on FEMA P-58 The information in FEMA P-58 is likely overwhelming for the average engineer to digest at first reading, and it may be some time before implementation products are developed within the project. A Technical Brief on the P-58 methodology and the capabilities of the associated Performance Assessment Calculation Tool (PACT) would be useful and may encourage early adopters • Use of Probability Theory in Structural Engineering Probability theory discussion is available in various resources (certainly in standard probability text books) and is discussed in recent research projects (e.g., in FEMA P-58), but a more complete concentration of this information will be useful to engineers as the profession shifts from deterministic to probabilistic definitions of building performance.
Cost Category	$600,000
Project Type	Small technical group plus review panel
Workshop Identifier	DMA20

Time Frame/Priority	**1-4**
Title	**Evaluate linear analysis procedures, especially for structures with significant higher mode effects**
Category	Design Methodology and Analysis
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	ASCE 7 outlines analysis procedures for use in seismic design. For nearly every structure, the linear analysis procedures outlined in Chapter 12, Equivalent Lateral force (ELF) and Model Response Spectrum Analysis (MRSA), are the two that are used. Recent ATC studies (ATC-63, -76 and -84) have identified that the use of MRSA results in a rate of collapse that exceeds the target value (10% given MCE_R ground shaking) as compared to ELF procedures, especially for buildings with significant higher mode effects. Studies are needed to evaluate the nonlinear response of building archetypes designed using ELF and MRSA procedures, focusing on archetypes with significant higher mode effects (periods in excess of 3 seconds) to determine what changes to these procedures are needed to achieve the intended performance target.
Cost Category	$1,000,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	DMA1

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Time Frame/Priority	**1-5**
Title	**Large Post-ATC-84 project**
Category	Design Methodology and Analysis
Program Element	Support problem-focused research to improve seismic engineering
Description	The recently completed ATC-84 project outlined a series of recommendations for further study. Other recent research efforts outlined several other earthquake analysis and design issues. These recommendations are combined is what is anticipated to be a multi-year research effort that will leverage the modeling and analysis results of the various studies. Details describing the various tasks are outlined in the original workshop descriptions The following is a summary of the issues: • Evaluate P-delta requirements • Further evaluate seismic performance factors (R, C_d, and Ω) for all range of building periods • Evaluate system limitations requirements • Evaluate the dual frame requirements and assess their appropriateness • Evaluate the drift requirements and their effect on building performance • Evaluate the minimum base shear equations for long-period structures and their effect on collapse risk • Evaluate the over-strength requirements This task combines the efforts outlined in DMA3, DMA4, DMA5, DMA10, DMA12, DMA14, and DMA16.
Cost Category	$4,000,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	DMA3

238

Time Frame/Priority	**1-6**
Title	**Liquefaction effects on buildings— Phase 1: Survey of liquefaction effects**
Category	Geotechnical and Ground Motions
Program Element	Support problem-focused research to improve seismic engineering
Description	The problem is how to best compute the seismic response and specify performance criteria for building foundations in liquefiable soil subject to settlement and possible lateral spreading. The problem pertains to both shallow (mats & spread footings) and deep (piles & caissons) foundations. Split the research into two phases. Phase 1, which is this proposal, would consist of gathering relevant information on the design and performance of shallow and deep foundations during seismic induced liquefaction. The information would be obtained from the various ports (e.g., Ports of Los Angeles, Long Beach, and Oakland) and state bridge departments (e.g., Caltrans and WSDOT), and other sources, and use it to prepare a roadmap for future research in Phase 2, which is proposal 2-5.
Cost Category	$250,000
Project Type	Small technical group plus review panel
Workshop Identifier	GGM9A

Time Frame/Priority	**1-7**
Title	**Develop protocol for testing and documentation of results to enable development of consequence functions for both structural and nonstructural systems and components**
Category	Performance-Based Seismic Design
Program Element	Develop the technical basis for performance-based seismic engineering
Description	Currently some testing that may be adequate for development of fragilities is not sufficiently robust or documented to enable development of consequence functions, which are distributions of the likely consequences of a component damage state translated into repair costs, repair time, potential for unsafe placards, casualties and other impacts. Development of consequence functions requires identification of reasonable repair methods and costs for damage states of interest. Guidance is needed both for developing consequence functions from past tests and requirements for documentation of future testing to expand the performance based seismic engineering fragility/consequence function database using essentially all structural laboratory testing. Guidance could be in the form of a technical brief or other short document that includes adequate review. The development of consequence functions using the guidance developed herein would be used by others.
Cost Category	$250,000
Project Type	Small technical group plus review panel
Workshop Identifier	PBSD3

Time Frame/Priority	**1-8**
Title	**Base plates**
Category	Steel
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	The methodologies for design of column base plates and their anchorage to foundations for moment frames and braced frames of steel are not robust. Failure of the plate, the connection to the column, or the anchorage can prematurely compromise the development of assumed yield mechanisms in these structures. A project is needed to consolidate existing research, test viable concepts, and synthesize design provisions. The physical testing is likely to be at the connection level, with analytical extension to capture system behavior. Current research at NIST on deep section columns, the research on anchorage to concrete described at workshop identifier C5 (time frame 1-13), as well as current research being funded by the Pankow Foundation, will influence the scope of this project. Steel base plates for precast concrete columns are not envisioned within this scope, but such a project could be a logical follow-on.
Cost Category	$ 1,000,000
Project Type	Technical committee including laboratory testing plus review panel
Workshop Identifier	S9

241

Time Frame/Priority	**1-9**
Title	**Flexural detailing requirements for concrete shear walls**
Category	Concrete
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	The current design code for concrete buildings contains detailed provisions for the seismic design of shear walls. Earthquakes in Chile (2010) and New Zealand (2011) showed many examples of inadequate performance of walls, including localized concrete crushing, longitudinal reinforcement buckling and fracture, and overall out-of-plane instability of walls. Some ongoing studies are identifying some of the causes for the failures and are suggesting changes in building design practices, but these studies do not provide a sufficient basis for all the changes that may be required. A study should be conducted to synthesize the observations from recent earthquakes and the results of ongoing studies of structural walls, and to develop tentative code revisions. The tentative code revisions should consider the introduction of alternative performance classes for structural walls subject to high seismic demand (Seismic Design Categories D through F). Design and analysis studies should identify the implications for seismic performance and the effects on construction economy associated with the proposed code revisions. If the panel decides that more testing is necessary, that testing would need to be accomplished in a second phase. Additional laboratory tests should be carried out on structural walls to explore the implications of the tentative code revisions.
Cost Category	Phase 1: $500,000 Phase 2: $1,000,000 if additional testing is determined to be necessary
Project Type	Phase 1: Technical committee including specialized analysis expertise plus review panel Phase 2: Technical committee including laboratory testing plus review panel, if additional testing is determined to be necessary
Workshop Identifier	C1

242

Time Frame/Priority	**1-10**
Title	**Effects of uplift on wood light-frame shear walls**
Category	Wood
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	Building code requirements for anchorage of sill plates for wood shear walls were changed significantly following damage observed in the Northridge earthquake. Laboratory tests of wood shear panels, before and after that event, do not demonstrate that the design provisions currently employed make a significant difference in performance. A project is needed to critically review data on performance of wood light-frame shear walls as a function of the uplift deflection permitted at tie-down devices and reconsider the current detailing requirements for steel plate washers as well as to develop criteria for uplift limitations and sill plate connections as required to ensure shear wall performance.
Cost Category	$250,000
Project Type	Individual investigator plus review panel
Workshop Identifier	W3

Time Frame/Priority	**1-11**
Title	**Suitability of maximum direction ground motions for use in seismic design codes**
Category	Design Methodology and Analysis
Program Element	Support problem-focused research to improve seismic engineering
Description	The 2009 NEHRP *Provisions* introduced the use of maximum direction ground motions for use in seismic design. ASCE 7-10 subsequently adopted the same requirements. While research efforts such as FEMA P-695 reinforced the importance of evaluating collapse performance in the direction of maximum response, there is a need to look at the full process regarding the suitability of using maximum direction ground motions. Research studies are needed to investigate the consistency in the design process, including the selection and scaling of ground motions and orthogonal loading requirements, using nonlinear response studies of both unidirectional and bi-directional building archetypes. *Coordinate with GGM5 for evaluating and developing the ground motion parameters*
Cost Category	$500,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	DMA21

244

Time Frame/Priority	**1-12**
Title	**Develop a plan to establish a permanent home for a database of building component fragilities**
Category	Performance-Based Seismic Design
Program Element	Develop the technical basis for performance-based seismic engineering
Description	Procedures to store, improve, and expand the current database of fragilities used in the FEMA P-58 methodology have not been established. Widespread, “common” use of these procedures is dependent on the availability of reliable fragilities and consequence functions. Quality control and maintenance of such a database are major issues. The establishment of this facility as soon as possible will encourage continuous improvement and expansion of the data. A workshop to determine minimum requirements and investigate potential storage locations should be convened.
Cost Category	$200,000
Project Type	Small technical group plus review panel
Workshop Identifier	PBSD14

Time Frame/Priority	**1-13**
Title	**Design requirements for anchoring to concrete**
Category	Concrete
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	The current seismic design requirements for anchoring to concrete are not well validated, with ad-hoc, compounding, and sometimes confusing factors (from ACI 318 and ASCE 7) placed upon the basic predictions for anchorage capacity in concrete contained in the provisions of ACI 318 Appendix D. A stronger technical basis in both mechanical performance and system reliability is needed for the seismic adjustments to the basic provisions, and the two standards need to be unified so that lower strength-reduction factors in the ACI standard are not inappropriately combined with the increased load factors in ASCE 7. There are similar problems with the provisions for anchorage to masonry. Research is needed to improve requirements for cast-in-place anchors typical of those used in foundations of building and non-building structures, including use of large diameter anchor bolts (greater than 2 inches in diameter). This research requires coordination with all the affected standards developing organizations, including ACI, ASCE, AISC, AISI, AWC and TMS. The goals of this study include more realistic predictions for capacity under seismic loadings as well as simplified procedures for routine design and more constructible details.
Cost Category	$ 1,500,000
Project Type	Technical committee including laboratory testing plus review panel
Workshop Identifier	C5

246

Time Frame/Priority	1-14
Title	**Design shear in concrete shear walls and similar structures**
Category	Concrete
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	Numerous analytical studies have suggested that design shear forces for shear walls (and similar structures) designed by ASCE 7 are well below forces that may actually develop during strong earthquake shaking. Similar observations have been made by designers of tall buildings using nonlinear analysis as part of performance-based designs. Some building codes (e.g., Eurocode 8) have adopted dynamic amplification factors that result in much higher design shears than are obtained by current ASCE 7 requirements. In some cases, the amplified shears would have significant construction cost implications, and may make construction of shear walls impractical. Studies are needed to synthesize the results from past research on dynamic amplification of wall shear. The studies should analyze applicability to typical U.S. construction, and should conduct additional analytical studies if necessary to obtain data relevant to U.S. construction. Existing data on wall shear strength should be analyzed to understand the relation between nominal shear strength and expected shear strength as function of imposed deformation demands. If revisions to current practice are indicated, preliminary designs should be carried out so that construction cost implications are understood. Finally, the studies should recommend whether similar provisions are required for other systems such as steel braced frames, steel shear walls, etc.
Cost Category	$500,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	C4

247

Time Frame/Priority	**1-15**
Title	**Provide additional guidance for nonlinear response history analysis and modeling requirements**
Category	Design Methodology and Analysis
Program Element	Support problem-focused research to improve seismic engineering
Description	Chapter 16 of ASCE 7-10 is being studied/modified as part of the current BSSC PUC effort (IT-4) in support of the 2014 NEHRP Provisions. Significant progress has been made in this effort, but additional research will likely be needed to validate the technical decisions that were made based on limited studies. Additional studies are needed to verify the recommended changes achieve the intended collapse capacity by evaluating the nonlinear response of building archetypes. Building archetypes developed for recently completed ATC projects (58-2, 63, 76 and 84) could be leveraged in this effort to assess the acceptance criteria and the resulting collapse safety parameters.
Cost Category	$750,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	DMA9

248

Time Frame/Priority	**1-16**
Title	**Create a database of recent earthquake performance of nonstructural components**
Category	Nonstructural
Program Element	Support problem-focused research to improve seismic engineering
Description	There have been a significant number of major earthquakes in populated areas of developed countries in the past two years. Therefore a number of buildings with modern architectural, mechanical, and electrical systems underwent design-level or larger shaking. It is desirable to create a database to collect and compile all of this information. The information can then be correlated with available analytical and laboratory performance data. It is expected that once started, this database would become a central location for both earthquake performance data and testing data. In addition to the study of past earthquakes, this task should create a framework for a systematic collection of nonstructural damage to be included in the disaster and failure events database. This task is related to workshop task PBSD1 (1-20) and may be combined with it.
Cost Category	$500,000
Project Type	Small technical group plus review panel
Workshop Identifier	N5

Time Frame/Priority	1-17
Title	**Improve analytical models and simulation capabilities for buildings in near-collapse seismic loading**
Category	Performance-Based Seismic Design
Program Element	Develop the technical basis for performance-based seismic engineering
Description	In current performance-based assessment approaches, a prevalent performance objective is the avoidance of collapse for some maximum considered seismic loading. In the performance assessment methodology developed in the FEMA P-58 project, the results of collapse prediction are dominant in assessing casualty rates. Typically, a collapse assessment analysis does not directly simulate collapse but monitors other demands (e.g., drift) that can be associated with collapse. Transfer of gravity loads to redundant supports away from the collapse initiation is poorly simulated. These methods are necessarily approximate and usually conservative. Collapse simulation capabilities should be developed to directly simulate the initiation and progression of collapse. Projects are ongoing in this regard for older concrete frame buildings but little has been done for concrete walls and structures of other building materials and types. Analytical technologies from other industries, such as automotive crash simulations, should be reviewed for applicability. The project would leverage the results and recommendations from ATC-96 (Task Order 23, Analysis, Modeling, and Simulation for Performance-Based Seismic Engineering) and would begin with a scoping workshop to identify an overall plan and research needs. The project is projected to take 5-10 years and the estimated cost does not include laboratory testing that may be required.
Cost Category	$7,000,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	PBSD15

Time Frame/Priority	**1-18**
Title	**Evaluate irregularity (vertical and horizontal) triggers and the associated requirements**
Category	Design Methodology and Analysis
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	The torsional irregularity triggers, through a BSSC Simplified Design Project, have been found to have little effect on the collapse risk for Seismic Design Category (SDC) B buildings, resulting in a code change proposal to eliminate the requirement. The other irregularity triggers and requirements in all SDCs have not been systematically evaluated to determine their effectiveness in providing the collapse performance target. Studies are needed to evaluate the nonlinear response of building archetypes that include the listed irregularities to assess their effectiveness. Archetype configurations without irregularities should be developed as a baseline in order to assess the relative change in performance. Where possible, simplified analytical models should in used better interrogate the range of irregularity. This task combines the efforts outlined in DMA2 and DMA6.
Cost Category	$1,000,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	DMA2

251

Time Frame/Priority	1-19
Title	**Continue to augment inventory of ground-motion time histories for use in response history analyses**
Category	Geotechnical and Ground Motions
Program Element	Support problem-focused research to improve seismic engineering
Description	While catalogs such as the COSMOS VDC, PEER, and CESMD are available to select ground-motion time histories for use in analysis, recent events (Chile, Christchurch, and Tohoku) provide a unique opportunity to augment these databases. An effort needs to be made to document these records, and their site characteristics and other relevant metadata, so they can be readily used by the design and research community. Ground-motion simulations should be included. Search capabilities, similar to the PEER DGML, are needed to facilitate record selection for engineering analysis. Although the collection of these ground-motion records and integration of these data into the aforementioned databases would primarily be done by the USGS, CGS, and PEER, funding is still needed to develop tools for searching, identifying, and obtaining representative records for use in earthquake engineering applications, such as the dynamic response analysis of structures per Chapter 16 of ASCE 7. The development of the basic framework for these tools would be the prime focus of the NIST effort.
Cost Category	$250,000
Project Type	Small technical group plus review panel
Workshop Identifier	GGM6

252

Time Frame/Priority	**1-20**
Title	**Obtain historical testing data (much may be proprietary) from testing labs for development of nonstructural fragilities**
Category	Performance-Based Seismic Design
Program Element	Develop the technical basis for performance-based seismic engineering
Description	It is known that many nonstructural components have been tested for seismic performance over the years. It is unclear what data exist and to what extent it may be applied to current systems and components, and whether the data are available for PBSD use. However, given the lack of hard fragility data, a concerted and organized effort should be made to collect information that might be available. Both testing laboratories and manufacturing companies should be contacted to identify data. Requirements for release of such data should be collected. The project technical committee recognizes that much of the data is proprietary and it may be difficult to release. Methods to generalize data sets of similar equipment and systems to protect proprietary interests should be investigated. Once the generalized data has been obtained, the technical group would analyze the data and develop new fragility curves for FEMA P-58 PACT or refine the existing fragility curves.
Cost Category	$750,000
Project Type	Small technical group plus review panel
Workshop Identifier	PBSD1

Time Frame/Priority	**1-21**
Title	**Partially grouted masonry walls**
Category	Masonry
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	Most physical testing of hollow unit masonry has been on completely ungrouted or fully grouted specimens. Code equations for the shear strength of partially grouted masonry were interpolated from such testing. Recent testing has indicated that the actual shear strength of partially grouted hollow unit masonry is lower than the design shear strength calculated by current standards. A panel should be convened to evaluate available test data and develop a consensus on improved procedures that can be incorporated in U.S. standards. If the panel decides that more testing is necessary, that testing would need to be accomplished in a second phase. In either case the final outcome is a set of recommended design provisions consistent with representative test data.
Cost Category	Phase 1: $250,000 for the basic project Phase 2: $750,000 if additional testing is determined to be necessary
Project Type	Phase 1: Small technical group plus review panel Phase 2: Technical committee including laboratory testing plus review panel, if additional testing is determined to be necessary
Workshop Identifier	M4

254

Time Frame/Priority	**1-22**
Title	**Slender walls**
Category	Concrete
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	The current design code for concrete buildings provides detailed provisions for the seismic design of slender shear walls based primarily on flexural performance considerations, with less attention paid to details for shear reinforcement. Some details for shear reinforcement have been questioned, especially including lap splices of horizontal reinforcement in the web and lap splicing of horizontal reinforcement with boundary element transverse reinforcement. A series of laboratory tests should be conducted to identify the effectiveness of lap-spliced shear reinforcement to resist shear in structural walls. The tests should consider walls developing high shear within the flexural hinge zone, as well as walls developing high shear but not with the flexural hinge zone. The test results should be used as a basis for a recommendation on the use of lap-spliced reinforcement in different regions of structural wall buildings.
Cost Category	$1,000,000
Project Type	Technical committee including laboratory testing plus review panel
Workshop Identifier	C2

Time Frame/Priority	1-23
Title	**Evaluate strong column–weak beam requirements**
Category	Design Methodology and Analysis
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	The design philosophy for beam-column moment frames is to achieve a strong-column/weak beam design that results in flexural yielding of beams over a considerable portion of the building height, with more limited yielding occurring in the columns, for the design basis earthquake loading. Several studies (ATC-63, ATC-76 and ATC-84) have suggested that the current design approach (for both concrete and steel buildings) may not be achieving the intended behavior (10 percent chance of collapse conditioned on the Maximum Considered Earthquake occurring at the site), and this may be compromising the collapse resistance of modern buildings. Studies are needed to evaluate the nonlinear response of building archetypes including both steel and concrete construction. The studies should include building designs using current code strong-column/weak beam requirements and alternative formulations and assessing the resulting collapse capacities. The studies should identify the implications for seismic performance and the effects on construction economy associated with different approaches to selecting the column-to-beam strength ratio.
Cost Category	$500,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	DMA11

256

Time Frame/Priority	**1-24**
Title	**Investigate vertical ground motions and their effect on building performance**
Category	Design Methodology and Analysis
Program Element	Support problem-focused research to improve seismic engineering
Description	In many of the recent earthquakes, the extent that vertical accelerations affected building performance has been discussed in depth, with limited consensus. To assist in the seismic design of structures sensitive to vertical ground motions (e.g., flat-bottom, cylindrical, liquid-filled tanks; suspended boiler structures in power plants; and, high bay aircraft assembly plants), vertical acceleration spectra were developed during the 2009 Provisions update, but an in-depth assessment of these spectra has not been performed so the effect of vertical accelerations on collapse performance has not been determined. Studies are needed to evaluate the effect of vertical accelerations. Results from this study could be used to determine both vertical acceleration requirements for the ASCE 7 load combinations (e.g., a critical review of the term $0.2S_{DS}$) and the vertical period appropriate for analysis and design. Given the complexity of this effort and the need to include the ground motion community in particular, USGS, it is recommended that this effort begin with a pilot study and be coordinated with the workshop task GGM4.
Cost Category	$500,000
Project Type	Small technical group plus review panel
Workshop Identifier	DMA8

257

Time Frame/Priority	1-25
Title	**Effect of aftershocks on the design and evaluation of buildings**
Category	Design Methodology and Analysis
Program Element	Support problem-focused research to improve seismic engineering
Description	Recent earthquakes (e.g., Chile, Christchurch, and Japan) re-emphasized the occurrence of large and numerous aftershocks and the associated demands on buildings. The design seismic hazard for new buildings should be evaluated considering the potential of these aftershocks to assess if changes are warranted, and the post-earthquake evaluation of buildings should be critically reviewed to determine if changes are needed. It is recommended that this research effort begin with a pilot study to gather reconnaissance information from the recent earthquakes and to identify the scope for future work. NOTE: This effort involves recovering or collecting data from Chile, Christchurch, Japan, and other recent earthquakes. This is a priority task that must be completed prior to addressing the items above which are also found in Time Frame 3/Priority 3-6.
Cost Category	$250,000
Project Type	Small technical group plus review panel
Workshop Identifier	DMA22

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Time Frame/Priority	**2-1**
Title	**Continue the development of Technical Briefs for use by practicing engineers and academicians—Specify topics for each time frame**
Category	Design Methodology and Analysis
Program Element	Make existing knowledge available to practicing engineers

Description

Over the past several years, numerous Technical Briefs have been developed that provide guidance for engineers in the design of specific seismic systems. The following issues, among others, should be considered for future Technical Briefs.

- Tilt-up Wall Buildings

  The performance of tilt-up wall buildings in previous earthquakes has led to complex detailing requirements in ASCE 7 and ACI 318. In addition, the dynamic behavior of tilt-up wall buildings is typically governed by diaphragm behavior, which is not currently accounted for in the ASCE 7 design process. This Technical Brief would outline the current seismic design requirements for tilt-up wall buildings, discuss the design approach assuming diaphragm-controlling behavior and will outline the various demands and detailing approaches for in-plane and out-of-plane forces.

- Precast Concrete Diaphragms

  Precast concrete diaphragms have exhibited poor performance in previous earthquakes, resulting in design requirements being specifically adopted to account for their behavior. While their design is currently governed by ASCE, ACI and PCI requirements, alternative guidelines have been developed that recommend increased demand levels and specific detailing suggestions. This Technical Brief would outline the current seismic design requirements, describe the alternative design recommendations and provide best-practices detailing approaches.

- Un-topped Steel Deck Diaphragms

  Un-topped steel deck diaphragms performance is governed, in large part, by the manner in which the steel deck is connected to the steel framing and to the adjacent steel deck sheets. The Steel Deck Institute is working on developing updated seismic design requirements. This Technical Brief would outline the current seismic design requirements and provide best-practices detailing approaches.

- Nonstructural Performance for Non-engineers

  The intended performance on nonstructural components is not well understood by the non-engineering community. This Technical Brief would discuss nonstructural performance, consequences of nonstructural earthquake damage, and the different levels of performance from life safety to operational. The intended audience for this Technical Brief is building owners, architects, mechanical/electrical engineers, and contractors.

Time Frame/Priority	**2-1** **(continuation)**
	• Nonstructural Design for Engineers The design on nonstructural components is specified in Chapter 13 of ASCE 7 and the referenced standards. The requirements can be difficult to follow, especially for systems that are governed by the referenced standards. This Technical Brief would summarize the nonstructural design requirements and associated performance targets, FEMA E74 material, and will provided design examples for both life safety and operational nonstructural performance. The intended audience of this Technical Brief is practicing structural engineers
Cost Category	$750,000
Project Type	Small technical group plus review panel
Workshop Identifier	DMA20

Time Frame/Priority	**2-2**
Title	**Engineering models for varied masonry shear walls**
Category	Masonry
Program Element	Support problem-focused research to improve seismic engineering
Description	Recent laboratory and analytical studies have expanded knowledge regarding performance and analytical modeling of reinforced masonry shear walls with various aspect ratios, axial loads, and reinforcement configurations. This project is to assemble a small technical group with expertise in reinforced masonry testing and design to synthesize the recent findings along with existing knowledge and present the findings in a form of refined engineering models for reinforced masonry readily usable by engineering practitioners.
Cost Category	$250,000
Project Type	Small technical group plus review panel
Workshop Identifier	M1

261

Time Frame/Priority	**2-3**
Title	**Attachments to protected zones in steel framing**
Category	Steel
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	Testing conducted in the SAC project following the Northridge earthquake demonstrated brittle failures at small discontinuities in flanges of moment frame beams undergoing significant inelastic straining. This led to strong restrictions on any attachments to structural steel of many systems in regions where inelastic strain would be expected. There is a lack of knowledge as to how extensive and universal such restrictions should be. Research is needed to study the effect, if any, of attachments to protected zones such as flanges of shear-governed EBF links, SCBF braces, SPSW web plates, and SMF/IMF webs. The project should include component testing of realistic braces, moment frame and link beam webs, and wall plates with various types of fasteners. The result may be different recommendations for different anchors and connections within different types of yielding zones.
Cost Category	$1,000,000
Project Type	Technical committee including laboratory testing plus review panel
Workshop Identifier	S7

262

Time Frame/Priority	2-4
Title	**Develop representative losses for primary categories of code-designed buildings to provide information that can be used to set code performance objectives and to inform the public concerning expected code performance**
Category	Performance-Based Seismic Design
Program Element	Support problem-focused research to improve seismic engineering
Description	Building performance levels measured by life safety, repair costs and downtime achieved by current code requirements are not sufficiently understood to achieve a broad consensus that would include input from policy makers and stakeholders with economic interests in such performance. FEMA P-58 studies of a wide range of buildings are needed to both test the consistency of code requirements and to identify generalized expected code performance, both considering individual owners and the cumulative effect of code performance in communities. Following reasonable determination and documentation of generalized code performance expectations that follow the work currently being performed by the ATC 63-2/3 projects, a workshop should be convened including representatives of the technical community and a broad range of other stakeholders to discuss the current expected performance and the costs and benefits of changing the code goals. Collaboration with FEMA on this research project is anticipated.
Cost Category	$1,000,000
Project Type	Technical Committee including specialized analysis expertise plus review panel
Workshop Identifier	PBSD7

263

Time Frame/Priority	2-5
Title	**Liquefaction effects on buildings— Phase 2: Research on both site-specific analysis and liquefaction effects**
Category	Geotechnical and Ground Motions
Program Element	Support problem-focused research to improve seismic engineering
Description	The problem is how to best compute the seismic response and specify performance criteria for building foundations in liquefiable soil subject to settlement and possible lateral spreading. The problem pertains to both shallow (mats & spread footings) and deep (piles & caissons) foundations. Key questions to be addressed are: (1) How much total and differential displacements due to lateral spread and settlement can be tolerated before unacceptable failure occurs to the foundation, (2) What analytical methods are suitable to reliably compute the foundation response for liquefiable soils, and (3) how should the research results be translated into improved code design criteria. One possible example research topic is the approach for computing the seismic response of pile-supported buildings, where the piles penetrate through liquefiable soil. Is the present two-step approach adequate? In the first step, the surface ground motion is specified and input to the above-ground above-pile building model, which in turn generates the base shear and overturning moment. Step two consists of applying these forces to the pile foundation and computing the pile response with programs such as LPILE and APILE, which use nonlinear *p-y* and *t-z* curves to model the soil-pile interaction in the soils' liquefied and non-liquefied states. Research is needed to determine whether this procedure, as opposed to a more direct procedure that models the soil-pile-foundation-structure interaction together in one step, is sufficient for design. The specific research would be recommended as the outcome of Phase 1 (1-6) and therefore is difficult to itemize a prioritize list at this time.
Cost Category	$1,500,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	GGM9B

264

Time Frame/Priority	**2-6**
Title	**Requirements for light-frame shear walls**
Category	Wood and Steel
Program Element	Support problem-focused research to improve seismic engineering
Description	By a wide margin, light-frame construction constitutes more building construction than any other structural system. The life safety experience in earthquake ground shaking has been relatively good, but there have been problems in terms of economic loss and disruption from loss of shelter. Innovations in framing materials and methods constantly introduce new aspects for which the seismic performance is not well understood. Design methods grossly simplify the actual performance of such structures. Much of our design methodology is rooted in past performance of systems that are not quite the same as currently constructed and in testing that was essentially static. Detailing rules in building codes have grown by accretion from damage observations following earthquakes, and they do not seem to form a well-integrated and robust design procedure. Issue-focused research is needed to determine analysis, design, and detailing requirements to achieve intended seismic performance of engineered light-frame shear walls. This work needs to include both wood and cold-formed steel framing, single and multi-story, and the configurations currently permitted. Among the conflicts to be resolved: 1) Is detailing for over-strength necessary given the practical observation that much of the testing conducted to date has shown detailing without over-strength provisions to be adequate? 2) The CUREE and NEES wood frame projects showed needs for detailing provisions that are not yet implemented in current standards. 3) The FEMA P-695 project found that nonstructural finishes must be present to justify the current seismic design parameters, yet system detailing rules do not include any such requirements. This discrepancy must be resolved. 4) Current design methods encourage walls with high unit shear capacities and hold-downs to prevent uplift (overturning or rocking), yet the vast majority of structures upon which judgments of past performance have been based did not have such hold-downs devices, and thus developed much lower unit shear resistance. New testing is not envisioned, but a substantial analytical effort is envisioned. The outcome should clarify the currently murky boundaries between design adapted from empirical observations of performance and laboratory tested solutions, between bare structural systems and the integrated system with specific finishes, and between collapse prevention and damage control.
Cost Category	$ 1,000,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	W1

Time Frame/Priority	**2-7**
Title	**Loss studies using ATC 58 methodology and experience from past earthquakes to determine appropriate cut-off (S_a) for various code requirements**
Category	Nonstructural
Program Element	Support problem-focused research to improve seismic engineering
Description	There is a lot of debate as to when engineers should explicitly consider nonstructural elements in their design. Currently, Seismic Design Category (SDC) B is completely exempt from consideration of nonstructural design for non-essential buildings and many nonstructural components in SDC C are exempt. Past earthquakes have shown that various nonstructural elements and systems experience damage at different earthquake intensities. This specific item has been identified by the NEHRP PUC Issue Team 2 as an area where research is needed to make more scientific decisions about when to exempt nonstructural design, rather than the judgment based decisions that have been made and are currently codified. This study would seek to determine a value of either a S_{DS} or floor or roof acceleration which would trigger consideration of seismic effects on specific groups of nonstructural elements. A focused study using FEMA P-58 methods, backed up by past earthquake data when available, would be used for this project. It is assumed that this task would draw upon the work done in task N1 and be checked against the database developed in task N5, and the estimated research costs reflect that. While this is a high priority, it should be completed only after tasks N1 and N5 have been carried out.
Cost Category	$500,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	N7

265

Time Frame/Priority	**2-8**
Title	**Develop long-period design ground motions in collaboration with earthquake scientists**
Category	Geotechnical and Ground Motions
Program Element	Support problem-focused research to improve seismic engineering
Description	Presently, the general procedure in Chapter 11 of ASCE 7 for the determination of design response spectra at long natural periods, $T > 2$ sec, uses the F_v site coefficients. However, these site coefficients were derived for $T \leq 2.0$ sec, and thus their applicability for longer periods is questionable. The reason is that the term "site," as it is normally understood (i.e., as the geology under the building footprint), is generally not relevant for the determination of long-period motions, which are governed more by the regional rather than local geology. For example, 3-D numerical simulations of ground motion and ground motions recorded during past earthquakes have demonstrated that basin effects become increasingly important for these long periods. Research is needed to determine whether (1) the ground-motion prediction equations (GMPEs) used by the USGS to prepare the code ground-motion maps, can be reliably used by themselves to determine a new set of site coefficients, F_d, applicable to most locations within the U.S., and (2), the development long-period ground-motion maps, using 3-D numerical simulations in lieu of the F_d site coefficients, is feasible for selected regions such as Los Angeles, Seattle, and Salt Lake City, where large basins are present. Some 3-D numerical simulations have already been performed by the USGS and SCEC for the Los Angeles and Seattle and more are planned. The research would need to be conducted jointly with the USGS, which is responsible for ultimately preparing the code ground-motion maps.
Cost Category	$500,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	GGM2

266

Time Frame/Priority	**2-9**
Title	**Design shear in columns in special moment frames**
Category	Concrete
Program Element	Support problem-focused research to improve seismic engineering
Description	ACI 318 requires columns to be designed for either (a) the shear corresponding to development of plastic hinges at the top and bottom of the story or (b) the shear corresponding to the development of plastic hinges in the beams framing into the columns, but never less than (c) the shear obtained from code-based analysis of the building. In typical designs, only (b) and (c) are considered. Some research and performance-based designs of buildings has shown that actual column shears may be greater than values obtained by this approach. The implications for building performance are unknown. This study will review existing research and design data, and will conduct nonlinear dynamic analyses on building archetypes to identify the amplitude of column shears relative to typical design values. Alternative shear design provisions will be developed if deemed appropriate.
Cost Category	$500,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	C10

267

Time Frame/Priority	2-10
Title	**Develop consequence functions for structural and nonstructural systems where they are not available**
Category	Performance-Based Seismic Design
Program Element	Develop the technical basis for performance-based seismic engineering
Description	Prior to the formalization of performance based earthquake engineering procedures, much laboratory testing has been done with little regard for the need to collect fragility data and no consideration of the development of PBSD consequence functions. Review currently available research results, identify those that might be useful for PBSD, and identify those with sufficient data to develop consequence functions. Develop the consequence functions where possible and enter them into the P-58 database. This task envisions development of consequence functions in accordance with protocol from workshop identifier PBSD3. Review existing fragilities to identify components with inadequate consequence functions, and research results with insufficient data to develop consequence functions. Develop a listing of systems and components that need improved consequence functions (to be developed by others over time) This project may be a candidate for partnering with FEMA.
Cost Category	$750,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	PBSD4

268

Time Frame/Priority	**2-11**
Title	**Seismic response of intermediate and ordinary systems**
Category	Concrete
Program Element	Support problem-focused research to improve seismic engineering
Description	The ACI 318 seismic subcommittee emphasizes proportioning and detailing of earthquake-resisting concrete construction designed for regions of highest seismicity, with somewhat less attention paid to intermediate and ordinary systems used in regions of lower seismicity. Some recent studies, including observations following the Christchurch, New Zealand earthquakes, suggest that buildings designed using intermediate or ordinary seismic-force-resisting systems may have lower performance capabilities than was previously assumed. These systems are widely used in regions of lower seismicity in the U.S., suggesting potentially large impacts when a future earthquake strikes one of these regions. This study will review existing data to refine models for seismic performance capability of structural concrete frame and wall components detailed in accordance with requirements for ordinary and intermediate systems. Series of archetype buildings will be developed and analyzed to determine overall system performance for representative seismic hazard, for comparison with accepted performance expectations. Deficient procedures for determining seismic forces and for detailing concrete components, as well as improvements in those procedures, will be identified. Construction cost impacts associated with recommended code changes will also be identified. The study will also identify where additional laboratory testing is required, but no specific research was proposed in this plan.
Cost Category	$750,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	C9

269

Time Frame/Priority	**2-12**
Title	**Braced frame (BRBF and EBF) connection ductility design demands**
Category	Steel
Program Element	Support problem-focused research to improve seismic engineering
Description	Buckling restrained braced fames and eccentrically braced frames impose much larger displacement demands on connections and small elements than concentrically braced frames. Design is generally based upon linear analysis with response modification factors, which are not necessarily well calibrated for connection demands in these types of systems. Recent research by Roeder and others has clarified the demands on gusset plates of CBFs, but the knowledge base to establish a method for estimating ductility demands at gusset plates in buckling restrained braced frames and at link beams in eccentrically braced frames is inadequate. The research should study realistically proportioned connections, specifically including gusset plates, to assess the demands at MCE-level ground motions. The research should build upon prior research on gusset plate connections in special concentrically braced frames. Braces that carry significant gravity load need to be included in the study. This research topic could identify additional research, including selective physical laboratory testing, as a second phase.
Cost Category	Phase 1: $ 750,000 Phase 2: Cost to be determined if additional testing is determined to be necessary
Project Type	Phase 1: Technical committee including specialized analysis expertise plus review panel Phase 2: Technical committee including laboratory testing plus review panel, if additional testing is determined to be necessary.
Workshop Identifier	S5

270

Time Frame/Priority	**2-13**
Title	**Evaluate diaphragm design equations and methodology**
Category	Design Methodology and Analysis
Program Element	Support problem-focused research to improve seismic engineering
Description	As part of the current BSSC PUC effort developing the 2014 NEHRP Provisions, an issue team (IT-6) was assigned the task of evaluating diaphragm design. Significant progress has been made in this effort, but additional research will likely be needed to validate the technical decisions that were made on the new formulations and the accompanying acceptance criteria. Studies are needed to verify the recommended changes achieve the intended collapse capacity by evaluating the nonlinear response of building archetypes. Building archetypes were developed as part of the current effort, but additional detailed models will be needed to confirm the new approach.
Cost Category	$750,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	DMA17

Time Frame/Priority	**2-14**
Title	**Benchmark commercial structural dynamic response software**
Category	Geotechnical and Ground Motions
Program Element	Support problem-focused research to improve seismic engineering
Description	There is a need to benchmark the available structural dynamic response methods currently being used by practicing engineers focusing on the following modeling issues: (i) the input motion to the substructure, (ii) the interaction of the substructure with the surrounding soil, and (iii) the nonlinear response of the soil and substructure. Improved methods to specify seismic pressures on walls are needed. An evaluation of the capability to model vertical response due to vertical ground motion is also necessary. With respect to the modeling of the soil-foundation-substructure system, focused research is needed on: (i) rotational stiffness of shallow foundations with non-rigid foundation elements, (ii) stiffness, damping, and ultimate capacity of nonlinear piles in nonlinear soil, particularly soil undergoing lateral spreading, and (iii) quantification of kinematic effects for different types of foundations and embedment. This research project will leverage the results of the recently completed ATC-83 (task order 10) project.
Cost Category	$1,500,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	GGM8

272

Time Frame/Priority	2-15
Title	**Braced frames without out-of-plane lateral bracing**
Category	Steel
Program Element	Support problem-focused research to improve seismic engineering
Description	Current design standards do not include procedures to cover out-of-plane bracing for braced frames with any of the following features: 1) Columns that extend over several beam and brace intersections without out-of-plane braces because there are no intermediate floors, 2) Beams without out-of-plane bracing between columns, and 3) Braces that extend across multiple levels of beams. Common examples include multi-panel braced frames in tall public spaces like theaters and arenas, industrial structures with open framing, and architecturally exposed bracing, such as the John Hancock Building in Chicago or the Bank of China. Research is needed to develop and validate the necessary design provisions. The scope should include concentrically and eccentrically braced frames. Limited component testing combined with analysis is envisioned.
Cost Category	$1,000,000
Project Type	Technical committee including laboratory testing plus review panel
Workshop Identifier	S1

273

Time Frame/Priority	2-16
Title	**Shear in deep mat foundations**
Category	Concrete
Program Element	Support problem-focused research to improve seismic engineering
Description	Shear design of deep mat foundations generally follows the long-accepted methods for shear design of shallow footings, including (a) use the full width as an effective width for one-way shear, and (b) selection of a depth such that shear reinforcement is not required. The validity/safety of this approach for deep mat foundations is unclear. The issue is especially important for tall buildings in which a significant portion (or all) of the seismic resistance is concentrated in a core wall supported by a deep mat. A technical committee should convene a workshop to identify industry practices, collect information on sample designs, and gain insight from reinforced concrete experts with expertise in related fields such as shear and moment transfer in slab-column connections and shear in deep concrete members. Based on the outcomes of the workshop, the technical committee will (a) develop a set of interim recommendations and (b) recommend whether a field testing program would be useful to resolve pending questions and, if so, the schematic details of the testing program. If a testing program is recommended, a second phase should be funded whereby the technical committee works with a testing team to develop and conduct large-scale tests of specimens with representative conditions. Based on the outcomes of the tests, the technical committee will develop a set of final recommendations for design practice.
Cost Category	Phase 1: $250,000 Phase 2: $1,500,000 if testing is determined to be necessary
Project Type	Phase 1: Technical committee including specialized analysis expertise plus review panel Phase 2: Technical committee including laboratory testing plus review panel, if testing is determined to be necessary
Workshop Identifier	C11

274

Time Frame/Priority	**2-17**
Title	**Improve ability to predict damage to structures and contents from soil movements including liquefaction, lateral spread, landslide, and soil failure at foundations**
Category	Performance-Based Seismic Design
Program Element	Develop the technical basis for performance-based seismic engineering
Description	Since it is generally assumed that large soil deformation under structures is not a life safety issue, detailed consequences of soil/foundation failure on the superstructure have not been systematically studied. However, for comprehensive performance assessments, losses from damage to the superstructure must be considered. Damage to the superstructure due to foundation movements from liquefaction, lateral spreading, or soil failure can be analytically simulated and losses estimated for a set of building types with representative materials and configurations. A method to develop fragilities and consequences functions from such analyses can be developed for an initial set of building types. The results from an initial set of building types are not expected to be comprehensive but adequate to add this functionality to FEMA P-58. It is expected that a more complete database of functions will be developed over time using the methodology developed, but the costs of such development are not included here.
Cost Category	$1,000,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	PBSD5

Time Frame/Priority	2-18
Title	**High-performance, high-rise buildings**
Category	New Systems
Program Element	Support problem-focused research to improve seismic engineering
Description	In the past decade, various independent organizations have developed performance-based design guidelines for high-rise buildings in the western U.S. (for example, the PEER TBI Guidelines and the LATBSDC Recommendations). These guidelines are limited in important ways: (1) high-rise buildings; (2) western U.S.; (3) conventional construction forms involving structural steel and/or structural concrete; (4) Occupancy Category II. Also, different jurisdictions continue to follow different approaches, without apparent technical basis. The building industry would be better served if a unified set of design guidelines, with broader applicability, was available for use. A technical committee should be convened to advance the development and consistent use of performance-based seismic design guidelines for new buildings. Revisions to current guidelines should be recommended based on experiences gained from their use in recent years. To the extent practical, existing guidelines should be extended to include protective systems such as seismic isolation and energy dissipation devices; higher Occupancy Categories, especially Occupancy Category III; and building configurations other than high-rise buildings.
Cost Category	$750,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	NS5

276

Time Frame/Priority	**2-19**
Title	**Evaluate the Seismic Design Categories (SDC)**
Category	Design Methodology and Analysis
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	As part of the current BSSC PUC effort developing the 2014 NEHRP Provisions, an issue team (IT-2 and IT-7) was assigned the task of evaluating the Seismic Design Categories (SDC) to determine whether the current number of categories is needed and whether the current spectral acceleration cut-offs are appropriate. Progress is being made, but the resulting recommendations won't have the benefit of technical studies to assess the impact. Example building studies are needed to assess the impact of the changes being proposed by IT-2 and IT-7, focusing on cost-benefit analyses, using the FEMA P-58 methodology, as well as interrogating the resulting collapse performance, using nonlinear building response.
Cost Category	$1,000,000
Project Type	Technical committee including specialized analysis plus review panel
Workshop Identifier	DMA7

Time Frame/Priority	**2-20**
Title	**Rocking systems**
Category	New Systems
Program Element	Support problem-focused research to improve seismic engineering
Description	Basic concepts on the behavior of rocking systems have been developed and demonstrated through laboratory testing. Efforts are needed to compile the existing research results and to develop the technical means and considerations to move these concepts into building codes, including the impact on non-structural issues, where they will gain more widespread acceptance and use. The concepts should apply, as appropriate, to a range of systems, from low-rise walls rocking on spread footings to un-bonded, post-tensioned systems.
Cost Category	$750,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	NS2

278

Time Frame/Priority	**2-21**
Title	**Improve the characterization of uncertainties in the PBSD process**
Category	Performance-Based Seismic Design
Program Element	Develop the technical basis for performance-based seismic engineering
Description	Uncertainties incorporated in current FEMA P-58 procedures yield large ranges of "believable" loss results. Better understanding of the various sources of uncertainty (including uncertainties associated with ground motion, analytical modeling, fragilities and consequence functions) can guide improvements in the process, possibly reduce uncertainties, and give engineers a better perspective for communicating results. The major sources of uncertainties should be systematically studied to identify steps where they can be reduced. The exclusive use of log normal functions and the combination of uncertainties in different situations should also be studied. Single source documentation of the source and rationalization of uncertainties used in performance based earthquake engineering would be valuable for ongoing use and improvement of the methodology.
Cost Category	$1,000,000
Project Type	Technical committee including specialized analysis expertise with review panel
Workshop Identifier	PBSD13

Time Frame/Priority	**3-1**
Title	**Continue the development of Technical Briefs for use by practicing engineers and academicians—Specify topics for each time frame**
Category	Design Methodology and Analysis
Program Element	Make existing knowledge available to practicing engineers
Description	Over the past several years, numerous Technical Briefs have been developed that provide guidance for engineers in the design of specific seismic systems. The following issues, among others, should be considered for future Technical Briefs. Additional detail for several of the topics can be found in the original workshop descriptions and are noted in the parentheses. • Nonstructural Mechanics-based System Modeling Chapter 13 of ASCE 7 outlines the specific design and detailing requirements for nonstructural components. Alternate approaches to these prescriptive requirements include detailed modeling and analysis of nonstructural systems to predict their performance and to better predict size and bracing requirements. This Technical Brief would provide guidelines outlining the various practices for modeling nonstructural system performance for varying levels of performance. • Masonry Walls with Boundary Elements The design and detailing of masonry walls varies greatly by Seismic Design Category (SDC). In SDC D and higher, masonry walls, depending in the demand levels, require boundary elements. This technical brief would outline the seismic design approach for masonry walls in these high seismic areas and would include practical detailing approach for boundary elements.
Cost Category	$300,000
Project Type	Small technical group plus review panel
Workshop Identifier	DMA20

280

Time Frame/Priority	**3-2**
Title	**High-performance buildings**
Category	New Systems
Program Element	Support problem-focused research to improve seismic engineering
Description	Conventional design of buildings relies on inelastic response of the structural components to control earthquake design forces. Buildings so designed can be expected to be damaged following design-level earthquake shaking. Resilient communities require buildings that will experience lower levels of damage when subjected to strong ground motion. Overall, the development of higher performing structural systems is a major undertaking that requires development of structural materials and systems concepts that deliver higher performance with reduced repair requirements; laboratory tests on components and structural systems to demonstrate performance; and design guidelines, building code provisions, and technology transfer to facilitate their use. This task (NS3) is the first step in a multi-phase effort to support problem-focused research to improve seismic engineering. It will engage a small technical group to convene a workshop to vet ideas in support of the overall program. The major product of this task will be an action plan for NEHRP-wide (NSF, FEMA, NIST, and USGS) follow-on studies to be implemented in task NS4.
Cost Category	$250,000
Project Type	Small technical group plus review panel
Workshop Identifier	NS3

281

Time Frame/Priority	3-3
Title	**Braced frame (BRBF and EBF) design recommendations for connections and links**
Category	Steel
Program Element	Support problem-focused research to improve seismic engineering
Description	Research on connections for Special Concentrically Braced Frames (SCBF) is leading to new design recommendations. Connections in Buckling Restrained Braced Frames and Eccentrically Braced Frames need to follow a similar path. Recommended project 2-12 (S5) will develop the knowledge base. Research synthesis and development is needed to prepare recommendations for design of connections, including gusset plates for BRBFs, and link beams in EBFs. This work should take advantage of existing test and analytical results, including that developed in the related project to study ductility demands on connections within BRBFs and EBFs and the recent and current work on SCBF gusset plates. The goal is to develop methods that give reliable results when applied to structures designed by linear analysis methods making use of seismic response modifications factors.
Cost Category	$250,000
Project Type	Small technical group plus review panel
Workshop Identifier	S6

282

Time Frame/Priority	**3-4**
Title	**Catalog information from past earthquakes to attempt to find some correlation with localized earthquake intensity and total downtime**
Category	Performance-Based Seismic Design
Program Element	Develop the technical basis for performance-based seismic engineering
Description	FEMA P-58 methodology includes a computation of repair time based on damage assessments, but what is more important for building owners is the time from the moment of the earthquake until they can reoccupy their building—commonly called "downtime". Key variables need to be identified and methods developed for estimating total downtime with reasonable uncertainties. Such information is important for communities estimating or improving their resilience. Collect and study past earthquake data, including where possible from insurance companies and federal agencies. Based on this data and typical processes to gain re-occupancy, develop a comprehensive formulation for expected total downtime Identification of key variables in a formulation for expected downtime can encourage communities and individual owners to take steps to increase their resilience. This project is a candidate for partnering with FEMA.
Cost Category	$1,000,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	PBSD18

283

Time Frame/Priority	3-5
Title	**Study structural fragilities that have been developed and make recommendations for developing improvements, including when new testing may be required**
Category	Performance-Based Seismic Design
Program Element	Develop the technical basis for performance-based seismic engineering
Description	FEMA P-58 includes many structural fragilities, but many more need to be developed, particularly to model the existing building inventory. It has been suggested that such fragilities can be developed by individual engineers on an as-needed basis, but this is expected to significantly slow down the acceptance and use of performance-based earthquake engineering. The following are the structural systems that have the highest need for serviceable fragilities: • Steel braced frames • Steel or concrete frames with masonry infill • Concrete shear walls • Reinforced masonry • Light steel stick framing systems • Light wood stick framing systems • Limited ductility steel moment frames Other lateral force components that may have significant effects on losses: • Diaphragm chords and collectors • Wood diaphragms • Precast concrete with and without concrete topping • Steel deck with concrete topping • Steel ribbed deck roof Gravity systems that may have significant effects on losses: • Precast concrete • Concrete gravity frames Fragilities already provided by FEMA P-58 should be reviewed for adequacy and data for the above systems and components should be collected. Fragilities should be improved or developed when possible and comprehensive documentation of new testing and analytical needs to enable maximum use of performance based earthquake engineering should be developed. This task does not include new laboratory testing or systematic analytical development of fragility data, but does require collecting and analyzing available data.
Cost Category	$1,500,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	PBSD2

Time Frame/Priority	**3-6**
Title	**Effect of aftershocks on the design and evaluation of buildings**
Category	Design Methodology and Analysis
Program Element	Support problem-focused research to improve seismic engineering
Description	Recent earthquakes (e.g., Chile, Christchurch, and Japan) re-emphasized the occurrence of large and numerous aftershocks and the associated demands on buildings. The design seismic hazard for new buildings should be evaluated considering the potential of these aftershocks to assess if changes are warranted, and the post-earthquake evaluation of buildings should be critically reviewed to determine if changes are needed. It is recommended that this research effort begin with a pilot study to gather reconnaissance information from the recent earthquakes and to identify the scope for future work.
Cost Category	$500,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	DMA22

284

Time Frame/Priority	**3-7**
Title	**Develop a systematic comparison of the reparability of various structural materials and systems under various loading intensities**
Category	Performance-Based Seismic Design
Program Element	Support problem-focused research to improve seismic engineering
Description	Although collapse prevention will probably be the primary code goal for quite some time, owners may be encouraged to use systems that are easily reparable if this knowledge were available in a credible document. Such systems not only could minimize repair cost, but could limit downtime. Expected damage levels and the time and cost of repair for common structural systems can be estimated from the FEMA P-58 fragility database. This data can be augmented by earthquake experience. Repair methods assumed in FEMA P-58 should be reviewed and discussed. Initial construction cost plus expected cumulative repair costs at sites with standardized hazard curves could be developed and compared. Such data would encourage use of most efficient systems as well as encouraging improvement of existing systems and development of new systems.
Cost Category	$1,000,000
Project Type	Technical committee including specialized analysis plus review panel
Workshop Identifier	PBSD16

Time Frame/Priority	**3-8**
Title	**Requirements for tilt-up wall systems**
Category	Concrete
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	Design requirements for tilt-up wall systems are based primarily on data for box-like systems with plywood and timber roofs. Many modern tilt-up systems use other roofing systems, and many tilt-ups now are more similar to multi-story frames than the single-story, solid walls of past years. Seismic design requirements for the walls of such structures and for wall-to-wall and wall-to-diaphragm connections are needed. This task will review recent developments in the tilt-up industry, the future findings of the current BSSC working group on rigid-wall flexible-diaphragm systems, and conduct a critical review relevant building code provisions and laboratory test data. The principal products will be a summary report of the findings and recommendations for future studies including laboratory and analytical studies.
Cost Category	Phase 1: $250,000 Phase 2: $1,000,000
Project Type	Phase 1: Technical committee including specialized analysis expertise plus review panel Phase 2: Technical committee including laboratory testing plus review panel, if determined to be necessary
Workshop Identifier	C6

286

Time Frame/Priority	3-9
Title	**High-performance buildings**
Category	New Systems
Program Element	Support problem-focused research to improve seismic engineering
Description	Conventional design of buildings relies on inelastic response of the structural components to control earthquake design forces. Buildings so designed can be expected to be damaged following design-level earthquakes. Resilient communities require buildings that will experience lower levels of damage when subjected to strong ground motion. Overall, the development of higher performing structural systems is a major undertaking that requires development of structural materials and systems concepts that deliver higher performance with reduced repair requirements; laboratory tests on components and structural systems to demonstrate performance; and design guidelines, building code provisions, and technology transfer to facilitate their use. This task (NS4) is a first phase follow-on task to task NS3 (3-2), which developed an action plan for studies to support development of high-performance buildings. The budget is set arbitrarily, considering an assumed moderate level of activity in support of the action plan. Additional phased efforts are likely to be required to fully implement the action plan.
Cost Category	Phase 1: $500,000 Phase 2: $1,000,000 if testing is determined to be necessary
Project Type	Phase 1: Technical committee including specialized analysis expertise plus review panel Phase 2: Technical committee including laboratory testing plus review panel, if testing is determined to be necessary
Workshop Identifier	NS4

287

Time Frame/Priority	**3-10**
Title	**Workshop on the Integration of BIM modeling with nonstructural component analysis and design**
Category	Nonstructural
Program Element	Support problem-focused research to improve seismic engineering
Description	Optimum performance-based nonstructural design requires a thorough understanding of all the nonstructural elements and systems in a building. Eventually every system in the building will be part of a Building Information Model (BIM). It would be beneficial to take advantage of this for nonstructural design and performance assessment. A workshop involving software representatives, engineers, and architects to discuss how to leverage BIM for nonstructural design and performance assessment should be convened. The main topic would be to link BIM for nonstructural components to structural analysis models. An associated topic that should be discussed is the coordination of BIM with FEMA P-58 analysis. The anticipated product of the workshop would be a report containing recommendations which software vendors and engineers could begin to implement BIM.
Cost Category	$250,000
Project Type	Small technical group plus review panel
Workshop Identifier	N8

288

Time Frame/Priority	**3-11**
Title	**Squat walls**
Category	Concrete
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	The current design code for concrete buildings provides detailed provisions for the seismic design of shear walls based primarily on flexural performance considerations. In practice, however, many squat shear walls have proportions and loading that result in their performance being governed by shear, rather than flexural, considerations. Studies to simulate collapse of such structures have been problematic. Improved abilities to model such walls and to design structures including them are needed. Requirements for the detailing of “shear-controlled” squat shear walls and the structures supported by them need to be developed. This task is a first phase to define the design space and review the related building code provisions and existing test data. Products of this task will include (a) improved techniques to model the performance of squat walls, (b) interim building code revisions to improve design and detailing of structures with low-rise walls, and (c) recommendations for follow-on laboratory and analytical research required to better understand the performance.
Cost Category	$500,000
Project Type	Small technical group plus review panel
Workshop Identifier	C3

289

Time Frame/Priority	**3-12**
Title	**Investigate the use of multi-point spectra for use in design**
Category	Design Methodology and Analysis
Program Element	Support problem-focused research to improve seismic engineering
Description	USGS is capable of providing multi-point spectra for use in design. Comparison of these more detailed spectra with the current, two-point spectrum used in design suggest the shapes are different in the critical 0.5-1 second period range. Previous studies (such as ATC-63, ATC-76 and ATC-84) indicated a reduced collapse capacity in this period range for a variety of building archetypes. A study is needed to determine how additional spectral accelerations could be implemented in the design process, and whether the resulting design requirements would provide for more consistent collapse capacities. Coordinate this effort with GGM1. It is recommended that this research effort begin with a workshop to vet the ideas and develop a plan for further work.
Cost Category	$750,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	DMA15

Time Frame/Priority	**3-13**
Title	**Design of structural systems with replaceable fuses**
Category	New Systems
Program Element	Support problem-focused research to improve seismic engineering
Description	Basic concepts on the use of energy-dissipating systems including replaceable fuses have been advanced and demonstrated through laboratory testing. Efforts are needed to compile the existing research results and to develop the technical means and considerations to move these concepts into building codes, including the impact on non-structural issues, where they will gain more widespread acceptance and use. This task will review existing technologies that have been developed through laboratory testing or that have demonstrated applications in actual buildings, and will recommend provisions for building code adoption where appropriate.
Cost Category	$750,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	NS1

Time Frame/Priority	3-14
Title	**Improve capability to consider losses from water damage from broken pipes or tanks**
Category	Performance-Based Seismic Design
Program Element	Develop the technical basis for performance-based seismic engineering
Description	The vulnerability of buildings to losses from water damage, particularly downtime, is well known. Fragilities have been developed for a few piping materials and systems but a systematic review is needed to identify systems for which new fragilities are required or for which new testing is required. Such a review should include gravity systems such as rainwater and sanitary waste (a hospital in Chile was shut down for an extended period due to a break in a waste line). However, little data are available from which water flow rates can be related to water spread and damage. Models need to be developed to estimate such damage considering permeability of floor separations and finishes. The project is a good candidate for cooperative work with FEMA.
Cost Category	$500,000
Project Type	Small technical group plus review panel
Workshop Identifier	PBSD10

Time Frame/Priority	**3-15**
Title	**Steel ordinary braced frames**
Category	Steel
Program Element	Support problem-focused research to improve seismic engineering
Description	Current design standards for steel ordinary concentrically braced frames (OCBF) include significant differences in detailing between the OCBF and those braced frames designed with no seismic detailing (the R=3 option). Yet the permitted R factors are essentially the same and the application of the OCBF is severely limited in the higher seismic design categories. A systematic review is needed of the detailing rules, associated capacities, and performance for all types of braced frames (OCBF, SCBF, and R=3) for a variety of configurations commonly used in buildings and industrial (non-building) structures. The objective is to see if the currently permitted design space (Seismic Design Categories, heights, functions) for the OCBF can be expanded. This project will be analytical, based upon existing knowledge for the performance of braced frames. It will likely include FEMA P-695 analyses. This project should follow and extend the recently awarded NEES project on braced frame detailing for use in regions of low seismic hazard, which also will study the R=3 type of frame.
Cost Category	$500,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	S2

Time Frame/Priority	**3-16**
Title	**Steel ordinary moment frames**
Category	Steel
Program Element	Support problem-focused research to improve seismic engineering
Description	Current design standards for steel ordinary moment frames (OMF) include significant differences in detailing between the OMF and those moment frames designed with no seismic detailing (the R=3 option). Yet the permitted R factors are essentially the same and the application of the OMF is severely limited in the higher seismic design categories. A systematic review is needed of the detailing rules, associated capacities, and performance for all types of steel moment frames (OMF, IMF, SMF, and R=3) for a variety of configurations commonly used in buildings and industrial (non-building) structures. The objective is to see if the currently permitted design space (Seismic Design Categories, heights, functions) for the OCBF can be expanded. This project will be analytical, based upon existing knowledge for the performance of braced frames. It will likely include FEMA P-695 analyses.
Cost Category	$500,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	S3

294

Time Frame/Priority	**3-17**
Title	**Design forces for columns and steel plate shear walls**
Category	Steel
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	Research is needed to establish a method for determining appropriate design forces for columns of multi-story steel braced frames and steel plate shear walls. Design based on linear analysis with response modification parameters, such as the R factor, have recently been using a system over-strength factor on the axial force alone to arrive at design requirements for such columns. The method is relatively crude and is due for a critical review and potential improvement. This project is essentially an analytical effort and should take advantage of a similar project (1-9, C1 at the workshop) to study the flexural demands on reinforced concrete shear walls. All types of braced frames, special and ordinary concentric, eccentric, and buckling restrained bracing, should be studied, as well as steel plate shear wall systems. One focus should be to see if the differences between relatively flexible (BRBF and some EBF) and stiff systems should lead to different rules for the columns.
Cost Category	$500,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	S4

Time Frame/Priority	**3-18**
Title	**Extend ability to model performance of masonry walls with irregular openings**
Category	Masonry
Program Element	Support problem-focused research to improve seismic engineering
Description	Most structural masonry walls include openings in a staggering variety of configurations. Although some research studies on masonry walls with irregular openings have been conducted or are underway, additional laboratory study is required to leverage ongoing work and more fully advance our understanding of the key behavior and design issues. Although much of this project is laboratory testing and analytical modeling, the study would include a panel of designers to validate the geometric variations included for study and a technology transfer activity to bring the information together in a form readily usable by engineering practitioners. The latter effort would be an update of project 2-2.
Cost Category	Phase 1: $500,000 Phase 2: $1,000,000 if additional testing is determined to be necessary
Project Type	Phase 1: Technical committee including specialized analysis expertise and laboratory testing plus review panel Phase 2: Technical committee including laboratory testing plus review panel if additional testing is determined to be necessary
Workshop Identifier	M2

Time Frame/Priority	**3-19**
Title	**Conventional construction**
Category	Wood
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	The attention given in building codes to non-engineered lateral force systems in wood light-frame construction has consistently increased over the past few decades, and the use of these provisions is extremely widespread. Many engineers find the provisions are controversial and not well-justified; in other words, many buildings so proportioned simply cannot be shown to work by conventional engineering design analyses. A review based upon both accepted engineering mechanics for wood light frame construction and historical damage records is needed to put the conventional construction provisions on a rational basis. This may well include recommended modifications to the code provisions. Project W1 (2-6) will provide tools for a systematic examination of the limits on applicability of prescriptive rules for non-engineered lateral force systems of light-frame construction.
Cost Category	$ 250,000
Project Type	Small technical group plus review panel
Workshop Identifier	W2

297

Time Frame/Priority	**3-20**
Title	**Design and construction guidelines for masonry shear walls confined by reinforced concrete boundary elements**
Category	Masonry
Program Element	Support problem-focused research to improve seismic engineering
Description	The difficulty of providing any compression ductility at the ends of masonry walls as they are currently constructed in the US has led to a revival of interest in the use of reinforced concrete elements to confine masonry shear panels. Old research on infilled frames is not adequate to provide a model for modern design. Research is needed to further develop the results of recent and planned experimental and analytical research into guidelines for realistic and reliable design of masonry shear walls confined by reinforced concrete boundary elements. This project is intended to build upon the old and new research, but it does not include physical testing itself. The technical committee will synthesize the current knowledge to a pre-standard level. One outcome may be that needs for more physical testing and analytical modeling will be identified.
Cost Category	$500,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	M3

298

Time Frame/Priority	3-21
Title	**Performance of shotcrete walls**
Category	Concrete
Program Element	Support problem-focused research to improve seismic engineering
Description	Shotcrete walls are sometimes used to place concrete in shear walls, yet few, if any, studies have been reported on performance of such walls, including response in flexure, shear, and bond/splicing. Laboratory research is required to explore performance requirements for shotcrete walls. This task will identify most common applications of shotcrete walls in new buildings and develop an action plan for a series of problem-focused tests to explore whether existing code provisions for shear walls (based on experience with cast-in-place walls) can be applied safely to shotcrete walls. A first series of exploratory tests will be conducted as part of this task. The task will propose code revisions if deemed appropriate, and may lay out an action plan for additional tests.
Cost Category	$1,000,000
Project Type	Technical committee including laboratory testing plus review panel.
Workshop Identifier	C8

299

Time Frame/Priority	**3-22**
Title	**Time-dependent ground-motion hazard maps**
Category	Geotechnical and Ground Motions
Program Element	Support problem-focused research to improve seismic engineering
Description	Research on time-dependent earthquakes and ground motions has been conducted during the last several decades, and the USGS has prepared time-dependent ground-motion maps for areas such as New Madrid and Charleston. These maps were based on the concept that the likelihood of a large earthquake on a particular fault zone depended on the time elapsed since the previous large earthquake in that zone. More recently, the USGS has been investigating the role of aftershocks in the ground-motion hazard. This issue is particularly important for certain urban areas where large earthquakes have occurred in the past and are expected to occur in the future. For example, the occurrence of a great magnitude earthquake of M~9 on the Cascadia Subduction Zone (CSZ), or an M~8 event on the San Andreas fault, would likely be followed by large magnitude aftershocks that could cause additional damage, which is not currently considered in the development of code ground-motion maps. Additional research is needed to (1) investigate the time-dependent nature of the earthquake hazard – a primarily USGS and academic activity, (2) determine how it impacts the design response spectrum associated with the Risk-targeted Maximum Considered Earthquake (MCE_R) in the ASCE 7 standard, which has been computed using time-independent recurrence models with aftershocks excluded from consideration, and (3) determine the best procedure for implementing the results into code ground-motion maps. This technical aspect of the research would be coordinated with the USGS. The policy implications associated with including time-dependent ground motions in ASCE 7 would be the prime focus of the NIST effort.
Cost Category	$500,000
Project Type	Small technical group plus review panel
Workshop Identifier	GGM11

Time Frame/Priority	**3-23**
Title	**Steel and concrete composite systems**
Category	Steel and concrete
Program Element	Support problem-focused research to improve seismic engineering
Description	A more robust basis for system design and detailing procedures is needed for composite steel and concrete structures. Early focus should be on: • More detailed design provisions are needed for both braced and unbraced frames to facilitate the design of such systems; for this time frame this task is primarily based upon analytical modeling of system performance and should build upon projects 2-12 and 3-3. • Column splices requirements in all types of systems; for this time frame this task is primarily based on analytical modeling of system performance and should build upon project 3-17. • Concrete-filled steel tube beam-columns need more accurate axial, flexural, and interaction formulas, particularly with respect to the use of high-strength concrete and high-performance steel materials; this task will require laboratory testing. • Data are needed on the behavior of long encased composite columns under cyclic loads, particularly when high-strength steel or concrete is used. Moreover, data on the importance of the detailing of the transverse reinforcement on the performance of these columns are lacking; this task will require laboratory testing. • Should the R=3 option exist for composite systems? This task is primarily analytical modeling of system performance. Composite systems offer potential economies for many types of construction, such as partially restrained moment frames in low-rise buildings and improved stiffness in drift sensitive tall buildings. Lack of interest on the part of individual industries and the small stock of engineers and builders with experience have hampered rapid progress in the development of reliable design provisions. Yet engineers knowledgeable about composite systems believe that the potential is worth pursuing. BSSC introduced the concepts and AISC has carried forward, both borrowing from various sources in the development of the current provisions. This project could easily be divided into several smaller projects; if so, a steering committee will be required.
Cost Category	Phase 1: $1,000,000 Phase 2: $1,000,000 if additional testing is determined to be necessary
Project Type	Phase 1: Technical committee including specialized analysis expertise and laboratory testing plus review panel Phase 2: Technical committee including laboratory testing plus review panel if additional testing is determined to be necessary
Workshop Identifier	S8

Time Frame/Priority	3-24
Title	**Development of smart, innovative, adaptive, and sustainable materials and framing systems**
Category	New Systems
Program Element	Support problem-focused research to improve seismic engineering
Description	Construction materials and framing systems are by-and-large unchanged from those used 50 years ago. Smart/innovative/adaptive/sustainable structural materials and framing systems provide new opportunities for construction and warrant speedy development. Needed are complete structural system detailing and specifications; verification tests on components and structural systems; design tools, standards, and technology transfer materials; consequence functions; and measurement systems to gauge the performance of new materials and systems. Some of the research on new systems has already been performed by NSF. The NIST effort will focus on the applied aspect of the completed research work described above and on the framework for the future development of additional new systems. This task is the first among several tasks required to accomplish this goal over multiple years.
Cost Category	$1,500,000
Project Type	Individual investigator Small technical group Technical committee including specialized analysis expertise Technical committee including laboratory testing All project types include a review panel
Workshop Identifier	NS6

301

Time Frame/Priority	EB3-1
Title	**Calibration of deficiency-based procedures of ASCE 31 and 41 (Tier 1, Tier 2, and simplified rehabilitation) with recent earthquake building performance**
Category	Existing Buildings
Program Element	Support problem-focused research to improve seismic engineering
Description	The Tier 1 Checklist and Tier 2 Deficiency-Only evaluation procedures are rooted in experiences and observations from past earthquakes. If the deficiency-based procedures do not provide results consistent with actual earthquake observations, then credibility in the ASCE 41 standard is lost. The 2010 Chile and the 2010 and 2011 Christchurch earthquakes provide a substantial number of case studies to assess the adequacy of these deficiency-based methods. Many modern buildings that experienced strong ground shaking were located near strong motion recorders and have drawings available. This study would take a subset of buildings from each of the three earthquakes and carry out ASCE 41-13 (since it will be the standard when these studies occur) Tier 1 and Tier 2 (and possibly Tier 3) evaluations of each building, and then correlate the results of the ASCE 41 evaluation with what actually occurred. This would provide real-world examples to assess the adequacy of the provisions and identify needed improvements. This effort should be coordinated with Research Topic 1-25 and 3-6.
Cost Category	$1,500,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	EB1

302

Time Frame/Priority	EB3-2
Title	**Study how the variability of existing material properties impacts the whole building performance**
Category	Existing Buildings
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	ASCE 41 currently requires a substantial amount of material testing. Many engineers have remarked that the amount of testing required is excessive, particularly on material that does not have much variability, like structural steel. Because of this, the material testing requirements are often ignored. When material variability has a significant effect on a structural action, such as concrete shear, there should be enough testing to provide confidence in the material or a significant penalty for no testing. On the other hand, some actions are not affected as much by variations in the material strength and therefore do not require as much testing or as large a penalty when there is no testing. This study would provide guidance as to how the ASCE 41 testing requirements and knowledge-factor penalty for no testing should be revised. This study could lead to a refinement of the knowledge-factor provisions in ASCE 41 based on the specific action instead of one blanket factor, or a completely new approach to dealing with the variability and uncertainties of material properties in existing buildings.
Cost Category	$1,000,000
Project Type	Technical committee including specialized analysis plus review panel.
Workshop Identifier	EB2

303

Time Frame/Priority	**EB3-3**
Title	**Develop tools to identify and inventory existing buildings that are a collapse risk—the “killer buildings”**
Category	Existing Buildings
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	Engineers have a general sense of which types of buildings are the “worst of the worst,” such as non-ductile concrete, older tilt-up concrete wall and wood roof, unreinforced masonry, and wood soft-story multi-family or commercial buildings. However, there are not sufficient procedures to classify which buildings within those overarching types are the true “killer buildings,” or what other buildings could be “killer buildings.” There are currently on-going research efforts on non-ductile concrete buildings and wood soft-story multi-family buildings, and there has also been considerable research in the past on unreinforced masonry. The issues with concrete tilt-up are somewhat known. The engineering community now considers “killer buildings” as those with a substantial risk of collapse, rather than those that merely do not comply with modern standards and may suffer significant damage. The focus of this study would be to first survey all material that has been produced about these types of buildings and develop the framework for an overarching method to screen a building within each class to determine if it is a substantial collapse risk. The study would be focused on high-seismic regions, but would be adaptable to moderate seismic regions as well. The desired product would be a guide for each type of building or possibly a revised ASCE 41-type checklist for each type of building that allows engineers or building jurisdictions to quickly flag what buildings are the “worst of the worst.”
Cost Category	$2,000,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	EB3

304

Time Frame/Priority	EB3-4
Title	**Research program to provide better modeling and acceptance criteria for concrete elements—beams, columns, walls, and slabs—that do not conform with current special detailing provisions, and those that do not even conform to current ACI 318 non-seismic provisions**
Category	Existing Buildings
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	Non-ductile concrete buildings are known to pose some of the greatest risks to the public in major earthquakes. However, current provisions within ASCE 41 are not sufficiently accurate to model these buildings. As nonlinear modeling is used more for assessing existing buildings, the need for better modeling criteria becomes more critical. Additionally, there is considerable disagreement among practitioners who deal with existing concrete buildings as to whether the linear acceptance criteria of ASCE 41 are too conservative or not conservative enough. The program would be based on NIST GCR 10-917-7 and take the recommendations from ATC-95 to create a multi-year research project that includes physical testing of elements and subassemblies of concrete elements commonly encountered in existing concrete buildings designed before modern special detailing was implemented. The goal of this project would be to provide guidance to engineers on the collapse indicators, the proper modeling parameters, and different acceptance criteria so that they can more accurately classify the behavior of non-ductile concrete buildings. Priority would be given to physically testing configurations that are identified by the project technical committee as those most commonly encountered in non-ductile concrete buildings.
Cost Category	$5,000,000
Project Type	Technical committee including laboratory testing plus review panel
Workshop Identifier	EB4

305

Time Frame/Priority	EB3-5
Title	**Calibration of ASCE 41 collapse prevention with ASCE 7 risk targets and the 10% conditional probability of collapse in the MCE_R target**
Category	Existing Buildings
Program Element	Support problem-focused research to improve seismic engineering
Description	ASCE 7 states that buildings designed in accordance with their procedures will have a 10% probability of collapse in the risk-adjusted MCE (MCE_R). ASCE 41's Collapse Prevention Performance Level is intended to have a similar reliability, but that has never been verified. Therefore it is uncertain if one satisfies all the requirements for Collapse Prevention in ASCE 41 using the ASCE 7 MCE_R as the seismic hazard if the resulting building will have the same 10% probability of collapse in the MCE_R as ASCE 7 indents to provide. It is a desire of the profession to have the two standards coordinated such that they give similar results for the same Performance Objective, i.e. Collapse Prevention in the MCE_R. This study would assess the reliability of ASCE 41 Collapse Prevention acceptance criteria using a FEMA P-695 approach. Buildings would be evaluated or designed to just meet the ASCE 41 Collapse Prevention Criteria at the MCE_R, then incremental dynamic analyses would be run to determine the fragility curve for the Collapse Prevention Performance Level. The probability of collapse at the MCE_R and the lognormal standard deviation, beta value, would be determined and compared to the generic fragility curve used to develop the ASCE 7 MCE_R. To limit the work performed, four systems will be studies initially – a 1970's Steel Moment Frame, a 1980's Steel Braced Frame, a 1960's Concrete Moment Frame and 1960's Concrete Shear Wall. The study will determine if the Collapse Prevention acceptance criteria are providing similar 10% conditional probability of collapse. If not, then recommendations to the criteria would be proposed. This study could be on-going and address every major structural system covered in ASCE 41.
Cost Category	$4,000,000
Project Type	Technical committee including specialized analysis expertise plus review panel
Workshop Identifier	EB5

306

Time Frame/Priority **EB3-6**

Title **Technical Briefs on seismic evaluation and retrofit of existing buildings**

Category Existing Buildings

Program Element Make existing knowledge available to practicing engineers

Description

One of the most frequent comments about ASCE 41 is that it is too complicated. Between the SEAOC Design Manuals and the Technical Briefs that have been published, there is a significant amount of material to assist an engineer in the use of ASCE 7 and the material design standards for new construction. Comparable supporting technical guidance for the application of ASCE 41 is not available. Accordingly, the following Technical Briefs are proposed to assist the engineer in understanding ASCE 41.

Seismic evaluation and retrofit of:

- Reinforced concrete moment frames
- Reinforce concrete shear walls
- Concrete tilt-ups
- Wood soft-stories
- Wood industrial buildings
- Unreinforced masonry buildings
- Steel moment frames
- Steel braced frames

The Technical Briefs would need to use real buildings, similar to the case studies done as part of the ATC-33 project.

Cost Category $1,200,000

Project Type Small technical group plus review panel

Workshop Identifier EB6

307

Time Frame/Priority	**EB3-7**
Title	**Design examples on seismic evaluation and retrofit of existing buildings**
Category	Existing Buildings
Program Element	Make existing knowledge available to practicing engineers
Description	One of the most frequent comments about ASCE 41 is that it is too complicated, with no example problems to reference. Between the SEAOC Design Manuals and the Technical Briefs that have been published, there is a significant amount of material to assist an engineer in the use of ASCE 7 and the material design standards for new construction. The following design examples are proposed: Seismic evaluation and retrofit of: • Reinforced concrete moment frames • Reinforce concrete shear walls • Concrete tilt-ups • Wood soft-stories • Wood industrial buildings • Unreinforced masonry buildings • Steel moment frames • Steel braced frames The design examples would need to use real buildings, similar to the case studies done as with the FEMA 4517/751 publications that FEMA puts out for the NEHRP Provisions.
Cost Category	$1,500,000
Project Type	Small technical group plus review panel
Workshop Identifier	EB7

308

Time Frame/Priority	**EB3-8**
Title	**Study on concrete-encased steel framing with and without masonry infill**
Category	Existing Buildings
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	Most steel buildings built before the 1970s contained steel frames encased in concrete. Those built before the 1940s also commonly had masonry infill. These buildings have traditionally performed much better in earthquakes than analysis of them would predict. Because of the prevalence of these types of buildings in cities like San Francisco, San Diego, Seattle, Portland, Memphis, and Charleston and the numerous adaptive re-use projects that are undertaken on buildings such as these, there is a need for better analytical tools. Therefore, the analysis provisions, modeling, and acceptance criteria need to be updated. This will require a problem focused study with physical testing of common configurations of concrete encased beam-column specimens and testing of bays with concrete encased steel beams and columns with brick infill. The results of the study would be a report and recommendations on modeling, analysis, and performance limit state parameters for concrete encased steel frame components. Also, there would be recommendations related to how to model the contribution of the brick infill and performance limit states for it. The work that is currently ongoing at UCSD regarding brick infill would be used as a starting point for this effort.
Cost Category	$2,000,000
Project Type	Technical committee including laboratory testing plus review panel
Workshop Identifier	EB8

309

Time Frame/Priority	**EB3-9**
Title	**Study on reinforced concrete frames with masonry infill**
Category	Existing Buildings
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	Many non-ductile reinforced concrete frames with masonry infill were used in construction before 1950. The benefits or performance degradation that may come from the masonry infill is not well understood. Modeling methods are somewhat crude, and some engineers have indicated they do not correlate well with testing. The UCSD NEES project, "Seismic Performance Assessment and Retrofit of Non-Ductile RC Frames with Infill Walls" will develop significant new knowledge of this issue. However, NEES projects are underfunded for complete implementation and a separate project is needed to consider the results of this research, combine these results with other data, and improve standards (ASCE 41) for analysis and retrofit of these buildings. The study would also identify additional research needs.
Cost Category	$500,000
Project Type	Small technical group plus review panel
Workshop Identifier	EB9

310

Time Frame/Priority	**EB3-10**
Title	**New tools for non-destructive investigation of building components**
Category	Existing Buildings
Program Element	Resolve technical issues restricting or slowing progress in the codes and standards development process
Description	It is not uncommon to encounter existing buildings that do not have construction documents. Additionally, construction quality control was not as stringent as it is today, leaving questions as to whether the material in the existing building is what was specified on the drawings. Currently the most common way to ascertain this, and the way dictated in ASCE 41, is to perform destructive testing. However, there is significant cost and disruption associated with destructive testing. Better nondestructive testing methods that could be shown to reliably ascertain existing material mechanical properties would be of great help. This project would be an initial study in the viability of using non-destructive methods in lieu of destructive testing for existing building condition surveys. The study would convene a workshop of various structural engineers and material testing experts to determine the most applicable current technologies. Following the workshop, the project team would undertake several focused studies on some of the technologies to determine if they were sufficient or not. The end result of the study would be a report which details recommendations which could be enacted with current technologies and a detailed outline of future research needs.
Cost Category	$1,000,000
Project Type	Technical committee including laboratory testing plus review panel
Workshop Identifier	EB10

Appendix A—Research Topics Tables and Ballot Summaries

The following table summarizes the results of the workshop ballots in detail. Each of the research topics could be voted into one of Time Frames 1, 2, or 3, or could be voted "X" if the voter didn't think the topic was important enough to include. In all, 26 ballots were cast and did not include votes from the Project Technical Committee.

To help identify the "Weighted Total," the following weights were assigned for each ballot vote:

- 1—15 points
- 2—10 points
- 3— 5 points
- X— 0 points

On several ballots, no vote was cast and was recorded as "No Vote Cast" in the summary below.

Several research topics were combined into one and are shown below highlighted in grey and include a brief description in the "Notes" column. "Cost Category" and "Project Type" were assigned by the breakout groups and followed the definitions outlined for the workshop.

Workshop Ballot Summary

					Ballots				**Ballots Cast: 26**		
No.	**Task**	**Notes**	**Cost Category**	**Project Type**	**1**	**2**	**3**	**X**	**Total Votes**	**No Vote Cast**	**Weighted Total**
DMA1	Evaluate Linear Analysis Procedures, especially for structures with significant higher mode effects		250	C	18	6		2	26		330
DMA2	Evaluate irregularity (vertical and horizontal) triggers and the associated requirements	Combine DMA2 and DMA6	500	C	13	11			24	2	305
DMA6	Evaluate the redundancy factor provisions										

					Ballots				Ballots Cast:	26	
No.	**Task**	**Notes**	**Cost Category**	**Project Type**	**1**	**2**	**3**	**X**	**Total Votes**	**No Vote Cast**	**Weighted Total**
DMA3	Evaluate P-delta requirements	Large post-ATC-84 project. Combine DMA3, DMA4, DMA5, DMA10, DMA12, DMA14, DMA16	3000	C	17	7	1		25	1	330
DMA4	Further evaluate seismic performance factors (R, Cd and Ω) for all range of building periods										
DMA5	Evaluate system limitations requirements										
DMA10	Evaluate the dual frame requirements and assess their appropriateness										
DMA12	Evaluate the drift requirements and their effect on building performance										
DMA14	Evaluate the minimum base shear equations for long-period structures and their effect on collapse risk										
DMA16	Evaluate the over-strength requirements										
DMA7	Evaluate the Seismic Design Categories (SDC)		500	C	5	16	5		26		260
DMA8	Investigate vertical ground motions and their effect on building performance	Pilot Study. Include GGM4, but not in initial pilot study	250	B	6	14	6		26		260
DMA9	Provide additional guidance for nonlinear response history analysis and modeling requirements		500	C	12	12	2		26		310

						Ballots			Ballots Cast:	26	
No.	**Task**	**Notes**	**Cost Category**	**Project Type**	**1**	**2**	**3**	**X**	**Total Votes**	**No Vote Cast**	**Weighted Total**
DMA11	Evaluate strong column-weak beam requirements		250	C	8	12	4		24	2	260
DMA13	Evaluate the effectiveness of the earthquake importance factors (I_E) on the performance of Risk Category III and IV buildings	Pilot Study	250	C	7	6	8		21	5	205
DMA18	Further evaluate risk-targeted approach to defining performance										
DMA15	Investigate the use of multi-point spectra for use in design	Workshop	100	B	6	5	15		26		215
DMA17	Evaluate diaphragm design equations and methodology	Wait for IT-6 Report	X		2	6	9	9	26		135
DMA19	Benchmark currently available 3-D nonlinear analysis software	Being studied in ATC-96	X		1		1	24	26		20
DMA20	Continue the development of Technical Briefs for use by practicing engineers and academicians	5 Total	500	B	21	3		1	25	1	345
DMA21	Suitability of maximum direction ground motions for use in seismic design codes	Include GGM5	250	C	7	5	11	2	25	1	210
DMA22	Effect of aftershocks on the design and evaluation of buildings	Pilot Study	100	C	5	12	9		26		240

					Ballots				Ballots Cast:	26	
No.	**Task**	**Notes**	**Cost Category**	**Project Type**	**1**	**2**	**3**	**X**	**Total Votes**	**No Vote Cast**	**Weighted Total**
GGM2	Develop long-period design ground motions in collaboration with earthquake scientists	In a pilot study, update TL and develop an F_d Site Coefficient Table, for the constant displacement portion of spectrum extended to 10-second period.	250	C	8	13	5		26		275
GGM3	Region-specific site factors	Not included in this roadmap. Currently basic research under the purview of PEER	X				1	25	26		5
GGM4	Vertical ground-motion maps	Not included in this roadmap. See also DMA8, which is being developed by PEER; mapping is under the purview of USGS.	X				1	25	26		5
GGM5	Maximum direction ground motions	Not included in this roadmap. See DMA21, which is being developed by PEER; mapping is under the purview of USGS.	X			1	1	24	26		15
GGM6	Continue to augment inventory of ground-motion time histories for use in response history analyses	Provide guidance on options and needs for inventories of ground-motion time histories for use in response history analyses; combine with GGM7	250	B	16	6		1	23	3	300
GGM7	Include accelerograms from subduction zones and stable continental regions in database software used to select time histories for response history analysis	Linked with GGM6									

					Ballots				Ballots Cast:	26	
No.	**Task**	**Notes**	**Cost Category**	**Project Type**	**1**	**2**	**3**	**X**	**Total Votes**	**No Vote Cast**	**Weighted Total**
GGM8	Benchmark commercial structural dynamic response software	Benchmark currently-available soil-foundation-substructure dynamic analysis methodologies	750	C	10	8	7	1	26		265
GGM9A	Liquefaction effects on buildings–Survey of Liquefaction Effects	Compared to liquefaction hazard itself, the effects of liquefaction on buildings and their analysis are under-researched. The proposed needs include (A) a survey of liquefaction effects for non-building structures such as ports and bridges, leading to a research plan for buildings	100	B	16	8	2		26		330
GGM9B	Liquefaction effects on buildings–Research on both site-specific analysis and liquefaction effects	Compared to liquefaction hazard itself, the effects of liquefaction on buildings and their analysis are under-researched. The proposed needs include (B) research on both site-specific analysis of liquefaction effects and development of generic building fragilities for liquefaction that could be used to derive risk-targeted design maps for liquefaction.	750	C	9	12	5		26		280
GGM10	Topographic and other regional geologic effects on ground motion	Not included in this roadmap. Currently basic research under the purview of NSF/USGS.	X			1	1	24	26		15

No.	Task	Notes	Cost Category	Project Type	Ballots 1	2	3	X	Ballots Cast: 26 Total Votes	No Vote Cast	Weighted Total
GGM11	Time-dependent ground-motion hazard maps	Workshop on time-dependent ground-motion hazard maps	100	B	1	5	16	4	26		145
PBSD1	Obtain historical testing data (much may be proprietary) from testing labs for development of nonstructural fragilities		500	B	9	16	1		26		300
PBSD2	Study structural fragilities that have been developed and make recommendations for developing improvements, including when new testing may be required		500	B	5	13	8		26		245
PBSD3	Develop protocol for testing and documentation of results to enable development of consequence functions for both structural and nonstructural systems and components	Workshop	100	B	16	8	2		26		330
PBSD4	Develop consequence functions for structural and nonstructural systems where it's are not available		750		11	8	5		24	2	270

					Ballots				Ballots Cast:	26	
No.	**Task**	**Notes**	**Cost Category**	**Project Type**	**1**	**2**	**3**	**X**	**Total Votes**	**No Vote Cast**	**Weighted Total**
PBSD5	Improve ability to predict damage to structures and contents from soil movements including liquefaction, lateral spread, landslide, and soil failure at foundations		500	C	7	13	5		25	1	260
PBSD7	Develop representative losses for primary categories of code-designed buildings to provide information that can be used to set code performance objectives and to inform the public concerning expected code performance		250	B	10	11	4	1	26		280
PBSD8	Identify new ground motion characteristics or parameters that will improve correlation with nonlinear structural response and damage	Breakout group didn't think this is necessary	X		1	1	6	18	26		55
PBSD9	Develop capability to consider post-earthquake fire damage from sources internal to the building	Suggest N/A as is, but okay as a techbrief	100	B	7	4	11	3	25	1	200
PBSD10	Improve capability to consider losses from water damage from broken pipes or tanks		250	B	3	13	7	2	25	1	210

					Ballots				Ballots Cast:	26	
No.	Task	Notes	Cost Category	Project Type	1	2	3	X	Total Votes	No Vote Cast	Weighted Total
PBSD11	Develop capability to consider losses from internal releases of hazardous materials	Breakout group didn't think this is necessary	X		2	1	5	18	26		65
PBSD12	Develop a Technical Brief on "Use of Probability Theory in Structural Engineering"		100	B	16	4	4	2	26		300
PBSD13	Improve the characterization of uncertainties in the PBSD process		500	C	8	11	5	2	26		255
PBSD14	Develop a plan to establish a permanent home for a database of building component fragilities	Workshop	100	B	16	6	4		26		320
PBSD15	Improve analytical models and simulation capabilities for buildings in near-collapse seismic loading		1500	C	15	6	4	1	26		305
PBSD16	Develop a systematic comparison of the reparability of various structural materials and systems under various loading intensities		500	C	6	9	11		26		235
PBSD17	Develop a Technical Brief on "Loss Estimation based on ATC-58"		100	B	20	2	1	3	26		325

					Ballots				Ballots Cast:	26	
No.	**Task**	**Notes**	**Cost Category**	**Project Type**	**1**	**2**	**3**	**X**	**Total Votes**	**No Vote Cast**	**Weighted Total**
PBSD18	Catalog information from past earthquakes to attempt to find some correlation with localized earthquake intensity and total downtime		500	C	7	10	9		26		250
CMN1	Flexural detailing requirements for concrete shear walls		750	C/D	12	11	2	1	26		300
CMN2	Shear detailing requirements for concrete shear walls	Separate into the two projects below:	X								
CMN2A	Slender Walls		500	C/D	10	10	3	1	24	2	265
CMN2B	Squat Walls		250	B	6	11	5	1	23	3	225
CMN3	Design shear in concrete shear walls and similar structures		250	C	13	12	1		26		320
CMN4	Design requirements for anchoring to concrete		750	D	16	8		2	26		320
CMN5	Requirements for tilt-up wall systems		500	D	2	17	6		25	1	230
CMN6	Lightweight concrete strength limits		X				1	25	26		5
CMN8A	Masonry shear wall variations	Technology transfer to address different aspect ratios, axial loads, and configurations of reinforcement	100	B	13	9	1	1	24	2	290
CMN8B	Masonry shear wall variations	Follow-on research and development for walls with irregular openings	500	C/D		16	7	1	24	2	195
CMN9	Masonry walls with boundary members	Technical Brief	100	B	2	7	15	2	26		175

No.	Task	Notes	Cost Category	Project Type	Ballots 1	2	3	X	Ballots Cast: 26 Total Votes	No Vote Cast	Weighted Total
CMN10	Partially grouted masonry walls	Quality control and shear response. Research project recently funded through NEES. Tech transfer.	250	B	13	5	8		26		285
CMN11	Design of structural systems with replaceable fuses	Move implementation forward. Provide a path for incorporation in building codes.	250	B	3	11	12		26		215
CMN12	Rocking systems		250	B	6	12	6	1	25	1	240
CMN13A	High-performance buildings	Workshop	100	B	14	5	4	1	24	2	280
CMN13B	High-performance buildings	Follow-on research and development	1000	C/D	9	9	5	1	24	2	250
CMN14	High-performance, high-rise buildings	Similar to Tall Buildings Initiative. Develop manual for peer review. Provide mechanism for approving systems	500	C	7	13	5	1	26		260
CMN15	Development of smart, innovative, adaptive, sustainable materials and framing systems	Interdisciplinary research	1500	A/B/C/D	2	2	12	7	23	3	110
CMN16 (new)	Performance of shotcrete walls	Develop comparisons between the response of cast-in-place concrete and shotcrete walls. (Applies more to rehabilitation than to new construction.)	500	D	2	7	15	2	26		175

					Ballots				Ballots Cast:	26	
No.	**Task**	**Notes**	**Cost Category**	**Project Type**	**1**	**2**	**3**	**X**	**Total Votes**	**No Vote Cast**	**Weighted Total**
CMN17 (new)	Seismic response of intermediate and ordinary systems	In Christchurch, several buildings were designed using intermediate or ordinary seismic-force-resisting systems. Establish performance boundaries between different systems.	750	C/D	10	9	6	1	26		270
CMN18 (new)	Design shear in columns in special moment frames	Columns are typically not designed to resist shear corresponding to the development of plastic hinges at the top and bottom of each column. Develop methods for determining appropriate design shear.	250	C	2	11	10	3	26		190
CMN19 (new)	Shear in deep mat foundations	Validity of using simple approximations in the design of deep mat foundations supporting cores. (Importance of reinforcement, effective width.)	1500	C/D	9	9	7	1	26		260

SW1	Braced frames without out-of-plane lateral bracing		500	D	13	7	4	2	26		285
SW2	Steel ordinary braced frames and ordinary moment frames	Divide this research topic into two. SW2A: OCBF and SW2B: OMF	500	C	1	17	4		22	4	205
SW3	Design forces for columns and steel plate shear walls	Essentially an analytical effort	250	C	3	8	14		25	1	195

					Ballots				Ballots Cast:	26	
No.	**Task**	**Notes**	**Cost Category**	**Project Type**	**1**	**2**	**3**	**X**	**Total Votes**	**No Vote Cast**	**Weighted Total**
SW4	Braced frame seismic design demands	Divide this research topic into the topics below:	X								
SW4A	Braced frame seismic design demands	Research involving testing of realistically proportioned BRBF gusset connection to assess impact of higher level of drift demands	250	C	3	19	3		25	1	250
SW4B	Braced frame seismic design demands	Development of design recommendations for SCBF and BRBF gusset plate connections	100	B	6	17	2		25	1	270
SW5	Attachments to protected zones in steel framing		250	D	15	2	7	2	26		280
SW6	Steel and concrete composite systems		2000	D	1	2	20	1	24	2	135
SW7	Requirements for light-frame shear walls		750	C	16	7	3		26		325
SW8	Conventional construction	Small project. Can’t be pursued until SW7 complete	100	B	3	6	17		26		190
SW9	Effects of uplift on light-frame shear walls		100	A	4	16	4	1	25	1	240
SW10	Seismic design of structural glued laminated timber arches and their connections	Should be supported by industry and not NIST	X				2	24	26		10
SW11 (new)	Base plates	Need for design methodology for moment frame and base frame base plates in terms of frame hinging mechanisms and brace frame anchorage	500	D	17	6	2	1	26		325

					Ballots				Ballots Cast:	26	
No.	**Task**	**Notes**	**Cost Category**	**Project Type**	**1**	**2**	**3**	**X**	**Total Votes**	**No Vote Cast**	**Weighted Total**
N1	Develop performance criteria for nonstructural components and metrics to assess the reliability of such criteria	Coordinate with ATC-84/Improve ATC-58	500	C	20	4	2		26		350
N2	Develop improved equations for approximating nonstructural design using code-based design procedures, i.e., a new F_p equation	Combine N2, N3 and N4	500	C	22	3			25	1	360
N3	Review and potentially revise the R_p factors										
N4	Evaluate the need for a nonstructural "over-strength" factor										
N5	Create a database of recent earthquake performance of nonstructural components	Related to PBSD1	250	B	9	11	6		26		275
N6	Technical Brief on nonstructural protection in new buildings	Suggested 3 specific Technical Briefs	X								
N6A	Engineering Technical Brief		100	B	11	10	3	1	25	1	280
N6B	Non-engineering Technical Brief		100	B	14	7	1	3	25	1	285
N6C	Mechanics-based modeling Technical Brief		100	B	2	4	15	4	25	1	145

					Ballots				Ballots Cast:	26	
No.	**Task**	**Notes**	**Cost Category**	**Project Type**	**1**	**2**	**3**	**X**	**Total Votes**	**No Vote Cast**	**Weighted Total**
N7	Loss studies using ATC 58 methodology and experience from past earthquakes to determine appropriate cut-off (S_a) for various code requirements		250	C	9	11	6		26		275
N8 (new)	Workshop on the Integration of BIM modeling with nonstructural component analysis and design		100	B	9	3	12	2	26		225

Total Research Costs: **$32,650,000**

The following tables show the updated research topics list as modified during the workshop. Several items were combined, others eliminated, and numerous new topics were added. The following list also indicates the recommended project type:

- A—Individual investigator
- B—Small technical group
- C—Technical committee including specialized analysis expertise
- D—Technical committee including laboratory testing and the associated cost category:

The following list indicates the cost category that each topic should be assigned:

- 100—Projects expected to cost about $100k
- 250—Projects expected to cost about $250k
- 500—Projects expected to cost about $500k
- 750—Projects expected to cost about $750k
- >750—Projects expected to cost substantially more than $750k ($1M or more)

While not a specific requirement, many of the breakout sessions identified priorities for the research topics which helped inform the remainder of the attendees as they cast their final ballot.

Modified Research Topics based on Input from Workshop Participants

DESIGN METHODOLOGY AND ANALYSIS CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
1	**DMA1**	**Evaluate linear analysis procedures, especially for structures with significant higher mode effects**	**250C**	**1**
		Recent ATC studies (ATC-63, -76 and -84) have identified that the use of Modal Response Spectrum Analysis (MRSA) results in a rate of collapse that exceeds the target value (10% given MCE_R ground shaking) as compared to Equivalent Lateral Force (ELF) procedures, especially for buildings with significant higher mode effects.		
1	**DMA2**	**Evaluate irregularity (vertical and horizontal) triggers and the associated requirements**	**500C for DMA2 and DMA6**	**1**
		Combine DMA2 and DMA6 into a coordinated research effort. The torsional irregularity triggers, through a BSSC Simplified Design Project (SDC), have been found to be not important to the collapse risk for SDC B buildings. Similar studies of the other irregularity triggers and requirements in all SDCs should be evaluated and the extent that they are needed determined. Use P-695 plus added reliability methods in the assessment of the requirements.		
3	**DMA3**	**Post ATC-84 Project (originally "Evaluated P-Delta Requirements:)**	**>750C for DMA3, DMA4, DMA5, DMA10, DMA12, DMA14 and DMA116**	**1**
		Combine DMA3, DMA4, DMA5, DMA10, DMA12, DMA14, and DMA16 into a coordinated research effort. It is anticipated that this will be multi-year effort that will be able to leverage the modeling and analysis results of the various studies. See each specific research topic for additional detail. P-delta checks are evaluated using an elastic analysis but at amplified drifts. Since it is more important to evaluate P-delta during nonlinear response, the current requirements should be evaluated in order to determine their influence on collapse capacity.		
3	**DMA4**	**Further evaluate seismic performance factors (R, C_d and Ω) for all range of building periods**	**See DMA3**	**See DMA3**
		Combine DMA3, DMA4, DMA5, DMA10, DMA12, DMA14, and DMA16 into a coordinated research effort. ATC-63 evaluated the current seismic performance factors to determine whether the resulting values produced acceptable collapse capacities. ATC-84 further evaluated seismic performance factors, focusing on short- and long-period building behavior. The results of these studies indicated additional investigation is needed to determine whether the current seismic performance factors and associated earthquake demands result in acceptable collapse capacities.		

DESIGN METHODOLOGY AND ANALYSIS CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
3	**DMA5**	**Evaluate system limitations requirements**	**See DMA3**	**See DMA3**
		Combine DMA3, DMA4, DMA5, DMA10, DMA12, DMA14, and DMA16 into a coordinated research effort. As part of the current BSSC PUC effort developing the 2014 NEHRP Provisions, an issue team (IT-7) was assigned the task of evaluating the systems limitation requirements (height limits and system exclusions shown on ASCE 7-10 Table 12.2-1) and suggesting changes to the current list. Additional technical studies are likely needed to support suggested changes to the current requirements.		
3	**DMA6**	**Evaluate the redundancy factor provisions**	**See DMA3**	**See DMA3**
		Combine with DMA2 and DMA6 into a coordinated research effort. The redundancy factor has been in the building code since 1997, although the form of the requirement has changed. A detailed study is needed to determine whether the current requirements affect the collapse capacity or whether such an evaluation is needed.		
1	**DMA7**	**Evaluate the Seismic Design Categories (SDC)**	**500C**	**2**
		As part of the current BSSC PUC effort developing the 2014 NEHRP Provisions, an issue team (IT-2 and IT-7) was assigned the task of evaluating the SDC and whether the current number of categories are needed and whether the current spectral acceleration cut-offs are appropriate. Additional technical studies will be needed to support suggested changes to the current requirements.		
3	**DMA8**	**Investigate vertical ground motions and their effect on building performance**	**250B**	**2**
		Vertical acceleration spectra were developed during the 2009 *Provisions* update, but an in-depth assessment of these spectra should be conducted. Results from this study could be used to determine both vertical acceleration requirements for the ASCE 7 load combinations (e.g., a critical review of the term 0.2*SDS*) and the vertical period appropriate for analysis and design. Begin with a pilot study and coordinate research effort with GGM4.		
3	**DMA9**	**Provide additional guidance for nonlinear response history analysis and modeling requirements**	**500C**	**2**
		Chapter 16 of ASCE 7-10 is being studied/modified as part of the current BSSC PUC effort (IT-4) in support of the 2014 NEHRP Provisions. Additional research is likely needed to verify the recommended changes achieve the intended collapse capacity. Specifically, the research needs to assess acceptance criteria and what collapse safety results. Use ATC-63/76/84 and DMA4 models.		

DESIGN METHODOLOGY AND ANALYSIS CATEGORY				
PEN[1]	No.	Task	Cost Category/ Project Type	Priority
1	**DMA10**	**Evaluate the dual frame requirements and assess their appropriateness**	**See DMA3**	**See DMA3**
		Combine DMA3, DMA4, DMA5, DMA10, DMA12, DMA14, and DMA16 into a coordinated research effort. Needed is a review and potential modification to the dual frame system requirements and associated design coefficients. This is notably relevant to dual systems with both special and intermediate moment frame back-up systems. It is not clear whether the design requirements currently prescribed will provide the desired low probability of collapse given MCER ground shaking at the site. The methodology outlined in FEMA P-695 could be used to assess these requirements.		
1	**DMA11**	**Evaluate strong column-weak beam requirements**	**250**	**2**
		Research and testing is needed to evaluate a proposed change (Proposal 2-1) not adopted for the 2009 *Provisions*. This generic (i.e., not material specific) proposal focused on the minimum flexural strength of columns in special and intermediate steel and concrete moment frames (strong-column/weak-beam). The intent of the proposal was to encourage researchers to evaluate the nonlinear response and seismic performance associated with the proposed requirements as well as their effects on the economy of the resulting design.		
1	**DMA12**	**Evaluate the drift requirements and their effect on building performance**	**See DMA3**	**See DMA3**
		Combine DMA3, DMA4, DMA5, DMA10, DMA12, DMA14, and DMA16 into a coordinated research effort. Research is needed to determine whether any changes to the drift analysis requirements are warranted given the adoption of the MCER ground motions associated with a 10% probability of collapse given their occurrence. Additionally, the drift requirements are thought to ensure appropriate response of non-structure components at the Design Earthquake Level, which also needs to be evaluated. A critical evaluation of the C_d value, and whether it should be set equal to R, is also needed.		
3	**DMA13**	**Evaluate the effectiveness of the earthquake importance factors (I_E) on the performance of Risk Category III and IV buildings**	**250C for DMA13 and DMA18**	**2**
		Combine DMA13 and DMA18 into a coordinated research effort. Risk Category III and IV Buildings require the use of importance factors of 1.25 and 1.5, respectively. It's not clear to what extent the performance for these buildings is enhanced over ordinary buildings when using these factors. Research is needed to assess building performance using I_E and to make recommendations, if necessary, to adjust the values.		

DESIGN METHODOLOGY AND ANALYSIS CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
3	**DMA14**	**Evaluate the minimum base shear equations for long-period structures and their effect on collapse risk**	**See DMA3**	**See DMA3**
		Combine DMA3, DMA4, DMA5, DMA10, DMA12, DMA14, and DMA16 into a coordinated research effort. As part of the ATC-63, ATC-76 and ATC-84 projects, a minimum base shear was found necessary to achieve the intended collapse risk. Additional investigations are needed to fully develop an acceptable approach.		
3	**DMA15**	**Investigate the use of multi-point spectra for use in design**		
		USGS is capable of providing multi-point spectra for use in design. A study is needed to determine whether additional spectral accelerations would support the design process and further provide for more consistent collapse capacities. Coordinate this effort with GGM1. Begin with a workshop.	**100B**	**2**
3	**DMA16**	**Evaluate the over-strength requirements**	**See DMA3**	**See DMA3**
		Combine DMA3, DMA4, DMA5, DMA10, DMA12, DMA14, and DMA16 into a coordinated research effort. ATC-63 indicated that the system-based over-strength factors can vary widely. This was further studied as part of ATC-84, and it was concluded that additional analysis is needed to develop a consistent set of requirements that will result in acceptable and consistent collapse performance.		
3	**DMA17**	**Evaluate diaphragm design equations and methodology**	**Wait for IT-6 Report**	**X**
		As part of the current BSSC PUC effort developing the 2014 NEHRP Provisions, an issue team (IT-6) was assigned the task of evaluating diaphragm design. Additional research is needed to fully develop any necessary changes to diaphragm design as it relates to acceptable collapse performance.		
3	**DMA18**	**Further evaluate risk-targeted approach to defining performance**	**See DMA13**	**See DMA13**
		Combine DMA13 and DMA18 into a coordinated research effort. As part of the 2009 NEHRP Provisions Update, a risk-targeted methodology was adopted to determine the spectral accelerations that are needed to achieve acceptable collapse performance and other performance levels. As part of ATC-84 and BSSC IT-2/-7, this risk-targeted methodology is being developed for other performance levels (serviceability and functionality). Additional research will be needed to fully develop the approach.		

DESIGN METHODOLOGY AND ANALYSIS CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
3	**DMA19**	**Benchmark currently available 3-D nonlinear analysis software**	**Being studied by ATC-96**	**X**
		There is a need to benchmark the available 3-D nonlinear dynamic analysis software currently being used by practicing engineers to compute gravity and seismic response simultaneously. Not only is there potential issues regarding the detailed component modeling, but also the modeling of: (1) nonlinear soil-structural interaction, and (2) vertical input motions. Benchmarking of currently available commercial software is needed to assess their capabilities.		
4	**DMA20**	**Continue the development of Technical Briefs for use by practicing engineers and academicians**	**100B Each**	**1**
		Over the past several years, numerous Technical Briefs have been developed that provide guidance for engineers in the design of specific seismic systems. The following issues, among others, should be considered for future Technical Briefs: • Gravity-only Framing • Tilt-up Wall Buildings • Precast Concrete Diaphragms • Seismically Isolated Buildings • Untopped Steel Deck Diaphragms		
3	**DMA21**	**Suitability of maximum direction ground motions for use in seismic design codes**	**250C**	**3**
		There is a need to look at the full process regarding the suitability of using maximum direction ground motions for use in seismic design codes. Research studies should investigate consistency in the design process and associated results for both uni-directional and bi-directional structures. Coordinate with GGM5		
3	**DMA22**	**Effect of aftershocks on the design and evaluation of buildings**	**100C**	**2**
		Recent earthquakes (e.g., Chile, Christchurch, and Japan) re-emphasized the occurrence of large and numerous aftershocks and the associated demands on buildings. The design seismic hazard for new buildings should be evaluated considering the potential of these aftershocks to assess if changes are warranted, and the post-earthquake evaluation of buildings should be critically reviewed to determine if changes are needed. Begin with a pilot study and use models from DMA4		

347 [1]PEN is the abbreviation for Program Element Number

GEOTECHNICAL AND GROUND MOTION CATEGORY				
PEN[1]	No.	Task	Cost Category	Priority
3	**GGM1**	**Design response spectrum construction and update seismic hazard maps with NGA-east and NGA subduction equations**		
		ASCE 7-05 & 7-10 still employ the TL parameter to obtain the long-period constant-spectral displacement segment of the design spectrum. This approach is inconsistent with the approach to construct the constant acceleration and constant velocity segments, which are derived using PSHA and DSHA procedures. The long period portion can be derived using the same PSHA and DSHA approach, but presently, it can only be done for the western U.S. region outside the PNW. The NGA-east and NGA-subduction equations must be developed to 10-second period in order to develop long-period ground-motion maps for the rest of the U.S. The NGA-east effort has been progressing over the last 2 years while the NGA-subduction effort has just started. Equations from these two research programs will hopefully be available in the next code cycle. However, one or both may need extra funding (from NIST?) to finish. With all three equations (NGA-east, NGA-west, and NGA-subduction) a smooth continuous design response spectrum can be constructed from 0 to 10-second period for any region in the U.S. This spectrum could replace the standard Design Response spectrum in Ch. 11.4 of ASCE 7-10. Investigations on the feasibility of a smooth spectrum, versus the standard spectrum from the general procedure, are suggested by comparing both spectra at a number of U.S. locations.	Not considered for this Roadmap	This research is mainly in the purview of USGS
3	**GGM2**	**Develop site amplification factors and/or ground-motion maps that specifically account for local/regional geology**	**250C**	**2**
		The approach to determine the F_d site coefficients also needs investigation because the term "site", as it is normally understood (i.e., as the geology under the building footprint), is generally not relevant for determining long-period motions, which are governed more by the regional, rather than local geology. Basin effects become increasingly important for these long periods, and the question is whether the NGA-west equations will produce F_d values that adequately account for basin effects, regardless of location within the U.S. Thus, the feasibility of region-specific maps should be investigated, and the possibility of using 3-D seismological simulations to develop these maps should be considered. Some 3-D numerical simulations have already been done and 2475-yr maps for 3-second period spectral accelerations have been prepared for the Los Angeles and Seattle regions. The work would need to be coordinated with the USGS		
3	**GGM3**	**Region-specific site factors**	**N/A**	**N/A**
		This topic is not in NIST's purview.		
3	**GGM4**	**Vertical ground-motion maps**	**See DMA8**	**See DMA8**
		As part of its NGA-West2 project, PEER is currently developing ground-motion prediction equations (GMPEs) for the vertical component. Similar efforts should be undertaken for NGA-east and NGA-subduction GMPEs. Once these equations are developed, then research will be required to determine the best way to generate the vertical ground-motion maps, either with vertical GMPEs in separate PSHA and DSHA for this component, or though V/H ratios applied to horizontal-component maps. Tables of F_a and F_v (and F_d) values, and equations for F_a and F_v in terms of V_s30, would also need to be developed for the vertical component.		

GEOTECHNICAL AND GROUND MOTION CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category**	**Priority**
3	**GGM5**	**Maximum direction ground motions**	**See DMA21**	**See DMA21**
		As part of the NGA-West2 project, PEER is examining the sensitivity of the maximum direction component with respect to independent variables such as magnitude and distance. GMPEs should be developed for the maximum direction component, and a study should be done to determine whether these equations will lead to significantly different design response spectra than the current approach of applying period-dependent scale factors to the ground-motion maps derived from NGA equations based on geometric mean values.		
3	**GGM6**	**Continue to augment inventory of ground-motion time histories for use in response history analyses**	**250B**	**1**
		While catalogs, such as the COSMOS VDC, PEER, and CESMD, are available to select ground-motion time histories for use in analysis, recent events (Chile, Christchurch, and Tohoku) provide a unique opportunity to augment these databases. An effort needs to be made to document these records, and their site characteristics and other relevant metadata so they can be readily used by the design and research community. Ground-motion simulations should be included. Search capabilities, similar to the PEER DGML, are needed to facilitate record selection for engineering analysis.		
3	**GGM7**	**Include accelerograms from subduction zones and stable continental regions in database software used to select time histories for response history analysis**	**See GGM6**	**See GGM6**
		Within the current framework for selecting time histories, many practitioners use the PEER DGML software for selecting accelerograms from shallow crustal earthquakes. However, this software needs to be enhanced to include subduction-zone accelerograms and the relatively small number of accelerograms from stable continental regions. This task is subset of GGM6.		
	GGM8	**Benchmark currently available structural dynamic response software**	**750C**	**1**
		There is a need to benchmark the available structural dynamic response methods currently being used by practicing engineers focusing on the following modeling issues: (i) the input motion to the substructure, (ii) the interaction of the substructure with the surrounding soil, and (iii) the nonlinear response of the soil and substructure. Improved methods to specify seismic pressures on walls are needed. Also, evaluation of the capability to model vertical response due to vertical ground motion is needed. With respect to the modeling of the soil-foundation-substructure system, focused research is needed on the (i) rotational stiffness of shallow foundations with non-rigid foundation elements, (ii) stiffness, damping, and ultimate capacity of nonlinear piles in nonlinear soil, particularly soil undergoing lateral spreading, and (iii) quantification of kinematic effects for different types of foundations and embedment.		

GEOTECHNICAL AND GROUND MOTION CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category**	**Priority**
3	**GGM9**	**Liquefaction effects on buildings**	**Ph1: 100B** **Ph2: 750C**	**Ph1: 1** **Ph2: 2**
		A subcommittee of PUC IT 8 is investigating how to best specify performance criteria for building foundations in liquefiable soil. The goal is to generate a proposal for PUC consideration this cycle. Depending on the outcome, more research may need to be conducted on this topic. One topic for consideration is the approach for computing the seismic response of pile-supported buildings, where the piles penetrate through liquefiable soil. Is the present two-step approach adequate? In the first step, the surface ground motion is specified and input to the above-ground above-pile building model, which in turn generates the base shear and overturning moment. Step two consists of applying these forces to the pile foundation and computing the pile response by with programs such as LPILE and APILE, which use nonlinear *p-y* and *t-z* curves to model the soil-pile interaction in the soils' liquefied and non-liquefied states. Research is needed to determine whether this procedure, as opposed to a more direct procedure that models the soil-pile-foundation-structure interaction together in one step, is sufficient for design. Broaden this topic to include shallow foundations (mats and spread footings). Split the topic into two phases. Phase 1 would consist of gathering relevant information on the liquefaction issue from the various ports (e.g., Ports of Los Angeles, Long Beach, and Oakland) and state bridge departments (e.g., Caltrans and WSDOT) and use it to prepare a roadmap for future research in Phase 2.		
3	**GGM10**	**Topographic and other regional geologic effects on ground motion**	**N/A**	**N/A**
		The effect of topography on earthquake ground motion has been observed at some sites and simple theoretical models have demonstrated its effect. However, no terms have been introduced in GMPEs to model it. Research is needed to determine whether topographic effects can be modeled within GMPEs and provide reliable predictions of ground motion. The geology beneath the surface (not just the topography) also needs to be considered. Improved methods to account for basin effects in the ground-motion maps also need to be investigated. This topic is not in NIST's purview.		
3	**GGM11**	**Revisions to ground-motion hazard maps following great earthquake**	**100B**	**3**
		Investigate the change in the regional ground-motion hazard following a great earthquake (e.g., M~9 on Cascadia subduction zone; M~8 on San Andreas fault) and revise regional ground-motion maps, as appropriate.		

348 [1]PEN is the abbreviation for Program Element Number

PERFORMANCE-BASED SEISMIC DESIGN				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
2	**PBSD1**	**Obtain historical testing data (much may be proprietary) from testing labs for development of nonstructural fragilities.**	**500B**	**2**
		It is known that many components have been tested for seismic performance over the years. It is unclear what data exist and to what extent it may be applied to current systems and components and whether the data are available for PBSD use. However, given the lack of hard fragility data, a concerted and organized effort should be made to collect all information that might be available. Collect for nonstructural systems/components Perform analytical simulations to better extrapolate data Use to understand how code systems perform (FEMA P-795)		
2	**PBSD2**	**Study structural fragilities that have been developed and make recommendations for developing improvements, including when new testing may be required.**	**500B**	
		The following are the structural systems that have the highest need for reliable fragilities: Could be huge validation effort of FEMA P-58 or Could be small individual PI checking results Lateral-Force-Resisting Systems: • Steel braced frames • Steel or concrete frames with masonry infill • Concrete shear walls • Reinforced masonry • Light steel stick framing systems • Light wood stick framing systems • Limited ductility steel moment frames Other lateral force components that need study: • Diaphragm chords and collectors • Wood diaphragms • Precast concrete with and without concrete topping • Steel deck with concrete topping • Steel ribbed deck roof Gravity systems that need study: • Precast concrete • Concrete gravity frames		

PERFORMANCE-BASED SEISMIC DESIGN				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
2	**PBSD3**	**Develop protocol for testing and documentation of results to enable development of consequence functions for both structural and nonstructural systems and components.**	**100B**	**1**
		Currently some testing that may be adequate for development of fragilities is not sufficiently robust or documented to enable development of consequence functions. Guidance (in the form of a Technical Brief) is needed for future testing.		
2	**PBSD4**	**Develop consequence functions for structural and nonstructural systems where they are not available.**	**750C**	**1**
		Although future testing for development of fragilities may include the necessary data for consequence functions, it is unclear if the cost estimating and other considerations needed for consequence functions will be completed by the same researchers. Review currently available research results, identify those that might be useful for PBSD, and develop consequence functions consistent with those already available. This data is essential to PBSD. Envisions development of consequence functions in accordance with protocol from PBSD 3.		
2	**PBSD5**	**Improve ability to predict damage to structures and contents from soil movements including liquefaction, lateral spread, landslide, and soil failure at foundations.**	**500C**	**2**
		Soil movements can contribute to building damage and these effects should be included in comprehensive performance assessments.		
3	**PBSD6**	**Develop representative losses for primary categories of code-designed buildings to improve consistency of performance among systems.**		
		Ongoing studies related to P695 are, for the first time, developing data enabling comparison of probable performance of various buildings types, at least related to collapse. Other losses implied by code design are unknown and only tangentially mentioned in published code "intents." An important use of PBSD will be to make code performance more consistent and better targeted at desirable goals. In addition, such studies will enable owners to make better decisions about requesting designs to provide better than "code performance."	Not considered for this Roadmap. This project has been started as part of follow-up to ATC 58 (ATC 63 2-3)	
3	**PBSD7**	**Engage the public and policy makers in setting performance goals for the building code by appropriately presenting representative loss data for primary categories of code-designed buildings**	**250B**	**1**
		A wider based consensus is needed concerning the current life-safety goal (e.g., CP @ MCE), and additional data is needed for policy makers to consider appropriate loss goals for damage, reparability, and downtime. Consideration of optimum goals for individual owners (e.g., individual cost-benefit) and communities (e.g., resilience) may be different. Need to engage insurance industry in addition to policy makers. Also, policy makers may not know what they need		

PERFORMANCE-BASED SEISMIC DESIGN				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
2	**PBSD8**	**Identify new ground motion characteristics or parameters that will improve correlation between analysis predictions and observed damage.**		**X**
		Currently, the performance of structural systems is typically correlated with simple ground motion characteristics or parameters such as peak ground acceleration or spectral acceleration at the fundamental elastic structural period. Other ground motion characteristics or parameters need to be identified that correlate better with performance, particularly when the structural system becomes nonlinear and its dynamic characteristics are changing with ground motion intensity, when its response is driven by multiple modes of vibration, or when duration effects may be prevalent. Couple with GM group activities		
2	**PBSD9**	**Develop capability to consider post-earthquake fire damage from sources internal to the building.**	**n/a (as is) 100B (as a tech-brief)**	**X (as is) 1 (as a tech-brief)**
		In any one building, losses from earthquake-caused fire may be more significant than shaking damage. In addition, if recognized, the risks from within the building can probably be mitigated. This risk may only be applicable in certain regions, neighborhoods, or for certain building types or occupancies, but a complete performance-based assessment methodology should include this capability. Technology exists in fire industry Low probability of occurrence Change to: What can be done to reduce risk/loss? A Technical Brief on this topic would be of great help.		
2	**PBSD10**	**Improve capability to consider losses from water damage from broken pipes or tanks.**	**250B**	**2**
		The vulnerability of buildings to losses from water damage, particularly downtime, is well known. However, little data are available from which loss functions can be developed. However, such a capability will be important to improve restraint requirements and to encourage restraint of piping systems. Real world major problem Study to develop an improved loss model Suggest a Technical Brief about this in addition to improved loss models.		

PERFORMANCE-BASED SEISMIC DESIGN				
PEN[1]	No.	Task	Cost Category/ Project Type	Priority
2	PBSD11	**Develop capability to consider losses from internal releases of hazardous materials**		X
		This risk may only apply to a small number of buildings, but for those buildings, the losses may be more significant than shaking losses. The importance of containment systems can only be demonstrated by estimating potential effects on the building and its occupants. This issue affects a small population of buildings but would require significant resources to be studied at this time. Change to: what can be done to reduce risk/loss (Technical Brief?)		
4	PBSD12	**Develop a Technical Brief on "Use of Probability Theory in Structural Engineering"**	100B	1
		This information is available in various places (certainly in standard probability text books) and has been approached in ATC-58, but a more complete concentration of this information will be useful to engineers in the next decade.		
2	PBSD13	**Improve the characterization of uncertainties in the PBSD process**	500C	
		Better understanding of the source of uncertainties will guide improvements in the process and give engineers a better perspective for communicating results. Systematically study uncertainties in all aspects of loss estimation, and see where they can be tightened. Could result in improved ways of characterizing selected uncertainties (e.g., modeling uncertainty: does it affect median or beta?)		
2	PBSD14	**Develop a plan to establish a permanent home for a database of building component fragilities.**	100B	
		Procedures to store, improve, and expand the current database of fragilities used in ATC-58 have not been established. Such a plan is needed to encourage continuous improvement and expansion. Question about implementation: How do you maintain? How to vet before uploading? Possibly create a Fragility "wiki" A workshop is suggested to investigate potential direction		

PERFORMANCE-BASED SEISMIC DESIGN

PEN[1]	No.	Task	Cost Category/ Project Type	Priority
2	**PBSD15**	**Improve analytical models and simulation capabilities for buildings in near-collapse seismic loading.**	**>750C**	
		In current performance-based assessment approaches, a prevalent performance objective is the avoidance of collapse for some maximum considered seismic loading. In the performance assessment methodology developed in the ATC-58 project, the results of collapse prediction are dominant in assessing casualty rates. Typically, collapse assessment analysis does not directly simulate collapse, but monitors other demands (e.g., drift) that can be associated with collapse. These methods are necessarily approximate and usually conservative. Collapse simulation capabilities should be developed to directly simulate the initiation and progression of collapse. Projects for older concrete buildings are ongoing in this regard but little has been done for other buildings materials and types, particularly walled buildings. Incorporate analytical technologies from other industries, such as automotive crash simulations.		
3	**PBSD16**	**Develop a systematic comparison of the reparability of various structural materials and systems under various loading intensities.**	**500C**	
		Although collapse prevention will probably be the primary code goal for quite some time, owners may be encouraged to use better systems if this knowledge were available. Much data could be pulled from ATC-58 fragility database to form the basis of such a document. Design guidance on what systems are repairable or not. Study available fragility data and report results (Technical Brief?) Run PACT and study results and report.		
4	**PBSD17**	**Develop a Technical Brief on "Loss Estimation based on ATC-58"**	**100B**	**1**
		The information in ATC-58 is likely overwhelming for the average engineer to digest at first reading, and it may be some time before implementation products are developed within the project. An interim Technical Brief on the ATC-58 methodology and the capabilities of the existing PACT software would be useful and may encourage early adopters. Important to promote use of newly completed ATC-58		
2	**PBSD18**	**Catalog information from past earthquakes to attempt to find correlations between localized ground motion intensity or damage levels and total downtime.**	**500C**	
		ATC-58 methodology includes a computation of repair time, but what is more important for building owners is the time from the moment of the earthquake until they can reoccupy their building. Data is needed to enable development of a method to estimate total downtime with a better understood uncertainty. Such information is also important for communities improving resilience. Need to involve insurance industry? Collect, study, and analyze past earthquake data to extrapolate for future loss estimation		

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STRUCTURAL MATERIAL AND SYSTEMS 1: CONCRETE, MASONRY, AND NEW SYSTEMS				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
1	**C1**	**Flexural detailing requirements for concrete shear walls**	**750C/D**	**1**
		The current design code for concrete buildings provides detailed provisions for the seismic design of shear walls. Earthquakes in Chile (2010) and New Zealand (2011) showed many examples of inadequate building performance. Lessons from these events and additional research should form the basis for updated detailing provisions.		
1	**C2**	**Shear detailing requirements for slender concrete shear walls**	**500D**	**1**
		The current design code for concrete buildings provides detailed provisions for the seismic design of slender shear walls based primarily on flexural performance considerations, with less attention paid to details for shear reinforcement. Some details for shear reinforcement have been questioned, especially including lap splices of horizontal reinforcement in the web and lap splicing of horizontal reinforcement with boundary element transverse reinforcement. Consideration also should be given to whether details should be a function of anticipated ductility level or behavior mode (shear versus flexure-controlled). There also may be opportunities to remove some restrictions on shear wall design, such as the current limit of 60 ksi for shear reinforcement.		
1	**C3**	**Shear detailing requirements for squat concrete shear walls**	**250B**	**2**
		The current design code for concrete buildings provides detailed provisions for the seismic design of shear walls based primarily on flexural performance considerations. In practice, however, many squat shear walls have proportions and loading that result in their performance being governed by shear, rather than flexural, considerations. Requirements for the detailing of “shear-controlled” squat shear walls need to be developed.		
1	**C4**	**Design shear in concrete shear walls and similar structures**	**250C**	**1**
		Numerous analytical studies have suggested that design shear forces for shear walls (and similar structures) designed by U.S. codes are well below forces that may actually develop. Other codes (e.g., Eurocode 8) have adopted much higher design shears. Studies considering demands, capacities, and acceptable risk are needed to determine whether the U.S. design approach should be updated. Studies should determine whether similar provisions are required for other systems such as steel braced frames, steel shear walls, etc.		
1	**C5**	**Design requirements for anchoring to concrete**	**750D**	**1**
		The current seismic design requirements for anchoring to concrete are not well validated. The provisions of ACI 318 Appendix D and ASCE 7-05 need to be unified so that lower strength-reduction factors in the ACI standard are not combined with the increased load factors in ASCE 7 unless justified by test data and reliability analyses. Research is needed to improve requirements for cast-in-place anchors typical of those used in foundations of building and non-building structures, including use of large diameter anchor bolts (greater than 2 inches in diameter). The goals of this study include simplified design procedures and more constructible details.		

STRUCTURAL MATERIAL AND SYSTEMS 1: CONCRETE, MASONRY, AND NEW SYSTEMS				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
1	**C6**	**Requirements for tilt-up wall systems**	**500D**	**2**
		Design requirements for tilt-up wall systems are based primarily on data for box-like systems with plywood and timber roofs. Many modern tilt-up systems use other roofing systems, and many tilt-ups now are more similar to multi-story frames than the single-story, solid walls of past years. Seismic design requirements for the walls of such structures and for wall-to-wall and wall-to-diaphragm connections are needed.		
1	**C7**	**Lightweight concrete strength limits**		**X**
		Studies are needed of the seismic performance of lightweight concrete structures with specified concrete strengths greater than the 5 ksi limit currently imposed by ACI 318.		
1	**CMN7**	**Required column-to-beam flexural strength ratios**		
		FEMA P-695 and other studies have rediscovered that current design procedures do not guarantee beam-yielding mechanisms in special moment frames (SMFs). Studies are needed to evaluate whether current design procedures for concrete and steel SMFs result in acceptable risk levels. Study how this requirement affects design and economy and its relationship to the minimum base shear requirement.	**Not considered for this Roadmap. Covered in DMA11.**	
3	**M1**	**Masonry shear wall technology transfer**	**100B**	**1**
		Recent laboratory and analytical studies have expanded knowledge regarding performance and analytical modeling of reinforced masonry shear walls with various aspect ratios, axial loads, and reinforcement configurations. The proposed technology transfer effort will consolidate this information and present it in a form readily usable by engineering practitioners.		
3	**M2**	**Masonry shear walls with irregular openings**	**500C/D**	**2**
		Although some research studies on masonry walls with irregular openings has been conducted or is under way, additional laboratory study is required to leverage ongoing work and more fully advance our understanding of the key behavior and design issues. The study would include a technology transfer activity to bring the information together in a form readily usable by engineering practitioners.		
3	**M3**	**Masonry walls with boundary members**	**100B**	**3**
		Research is needed to provide for experimental and analytical verification of the hysteretic behavior of masonry shear walls with confined boundary elements.		
1	**M4**	**Partially grouted masonry walls**	**250B**	**1**
		Some research has indicated that the actual shear strength of partially grouted hollow unit masonry is lower than the design shear strength calculated by current standards. A panel should be convened to evaluate available test data and develop a consensus on improved procedures that can be incorporated in U.S. standards.		
3	**NS1**	**Design of structural systems with replaceable fuses**	**250B**	**3**
		Basic concepts on the use of energy-dissipating systems including replaceable fuses have been advanced and demonstrated through laboratory testing. Efforts now are needed to move these concepts into building codes where they will gain more widespread acceptance and use.		

STRUCTURAL MATERIAL AND SYSTEMS 1: CONCRETE, MASONRY, AND NEW SYSTEMS				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
3	**NS2**	**Rocking systems**	**250B**	**2**
		Basic concepts on the behavior of rocking systems have been developed and demonstrated through laboratory testing. Efforts now are needed to move these concepts into building codes where they will gain more widespread acceptance and use. The concepts should apply, as appropriate, to a range of systems, from low-rise walls rocking on spread footings to unbonded, post-tensioned systems.		
3	**NS3 & NS4**	**High-performance buildings**	**NS3: 100B NS4: >750C**	**NS3: 1 NS4: 1**
		Conventional design of buildings relies on inelastic response of the structural components to control earthquake design forces. Buildings so designed can be expected to be damaged following design-level earthquakes. Resilient communities require buildings of reduced damage. This task is to explore structural materials and systems that deliver higher performance with reduced repair requirements; conduct component and structural system tests to demonstrate performance; and develop design guidelines, building code provisions, and technology transfer to facilitate their use. This project may require multiple phases, with an initial phase to identify the most promising systems. Studied systems should include conventional systems with minor modifications to achieve higher performance as well as new systems. NS3: Workshop NS4: Follow-on research		
3	**NS5**	**High-performance, high-rise buildings**	**500C**	**2**
		Design guidance for high-rise buildings in the U.S. is limited to conventional construction forms involving structural steel, structural concrete, or combinations of these. Greater economy of construction and enhanced performance sometimes can be achieved by using seismic isolation, energy-dissipation devices, or combinations. Of particular importance, given their size and the challenges of repair or deconstruction, is achieving low-repair performance states. This project could be considered as a follow-on project to similar projects recently completed for conventional high-rise buildings.		
3	**NS6**	**Development of smart, innovative, adaptive, and sustainable materials and framing systems**	**>750 A/B/C/D**	**3**
		Construction materials and framing systems are by-and-large unchanged from those used 50 years ago. Smart/innovative/adaptive/sustainable structural materials and framing systems provide new opportunities for construction and warrant speedy development. Include complete structural system detailing and specification; verification tests on components and structural systems; design tools, standards, and technology transfer materials; consequence functions; and measurement systems to gauge the performance of new materials and systems.		

STRUCTURAL MATERIAL AND SYSTEMS 1: CONCRETE, MASONRY, AND NEW SYSTEMS				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
	C8	**Performance of shotcrete walls**	**500D**	**3**
		Shotcrete walls are sometimes used to place concrete in shear walls, yet few, if any, studies have been reported on performance of such walls, including response in flexure, shear, and bond/splicing. Laboratory research is required to explore performance requirements for shotcrete walls.		
	C9	**Seismic Response of intermediate and ordinary Systems**	**750C/D**	**1**
		In Christchurch, several buildings were designed using intermediate or ordinary seismic-force-resisting systems, sometimes with unsatisfactory results in the Christchurch earthquake. U.S. design practice distinguishes between ordinary, intermediate, and special systems, yet the actual performance of different structural elements falling in the different categories is thought to vary widely. This study would explore performance expectations for different elements in the different categories and suggest modifications to details or reclassification of the elements.		
	C10	**Design shear in columns in special moment frames**	**250C**	**2**
		Columns typically are not designed to resist the shear corresponding to the development of plastic hinges at the top and bottom of the column. ACI 318 provides two alternative methods for shear calculation, but neither one has been calibrated, and the degree of safety provided by these methods is unknown. This study would examine these methods and suggest modifications if appropriate.		
	C11	**Shear in deep mat foundations**	**> 750C/D**	**1**
		Shear design of deep mat foundations generally follows the long-accepted methods for shear design of shallow footings, including (a) use the full width as an effective width for one-way shear, and (b) select a depth so that shear reinforcement is not required. The validity/safety of this approach for deep mat foundations is unclear. In addition to exploring (a) and (b), this study also should consider (c), determination of a safe design strength level considering size effect. Some field testing likely is required, in addition to a panel that formulates an approach that likely can gain consensus in the code-writing committees.		

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STRUCTURAL MATERIAL AND SYSTEMS 2: STEEL AND WOOD				
PEN[1]	No.	Task	Cost Category/ Project Type	Priority
3	**S1**	**Braced frames without out-of-plane lateral bracing**	**500D**	**1**
		Current design standards do not include procedures to cover out-of-plane bracing for braced frames with any of the following features: 1) columns that extend over several beam and brace intersections without out-of-plane braces because there are not intermediate floors, 2) beams without out-of-plane bracing between columns, and 3) braces that extend across multiple levels of beams. Common examples include multi-panel braced frames in tall public spaces like theaters and arenas, industrial structures with open framing, and architecturally exposed bracing, such as the John Hancock Building in Chicago or the Bank of China. Research is needed to develop and validate the necessary design provisions. The scope should include concentrically and eccentrically braced frames. Limited component testing combined with analysis is envisioned.		
3	**S2**	**Steel ordinary braced frames**	**250C**	**2**
		Current design standards severely limit the application of steel ordinary concentrically braced frames (OCBF) in higher seismic design categories, although there are significant differences in detailing between the OCBF and those braced frames designed with no seismic detailing (the R=3 option). Research is needed on the seismic capacity of steel OCBFs for a variety of configurations commonly used in buildings and industrial (non-building) structures designed to reflect the current standards, including ASCE 7-10 and AISC 341-10. Relaxation of the height and other limitations of lower ductility systems should be considered. Opportunities for such limit relaxations on non-building structures similar to buildings should be studied, perhaps including a FEMA P-695 analysis. This project should follow and extend the recently awarded NEES project on braced frame detailing for use in regions of low seismic hazard, which also will study the R=3 type of frame.		
3	**S3**	**Steel ordinary moment frames**	**250C**	**2**
		Current design standards severely limit the application of steel ordinary moment frames (OMF) in higher seismic design categories, although there are significant differences in detailing between the OMF and those moment frames designed with no seismic detailing (the R=3 option). Research is needed on the seismic capacity of steel OMFs for a variety of configurations commonly used in buildings and industrial (non-building) structures designed to reflect the current standards, including ASCE 7-10 and AISC 341-10. Relaxation of the height and other limitations for lower ductility systems should be considered. Opportunities for such limit relaxations on non-building structures similar to buildings should be studied, perhaps including a FEMA P-695 analysis. NIST might be able to assist with physical testing.		

STRUCTURAL MATERIAL AND SYSTEMS 2: STEEL AND WOOD				
PEN[1]	No.	Task	Cost Category/ Project Type	Priority
1	S4	**Design forces for columns in steel braced frames and steel plate shear walls**	250C	3
		Research is needed to establish a method for determining appropriate design forces for columns of multistory steel braced frames and steel plate shear walls. Design based on linear analysis with response modification parameters, such as the R factor, have recently been using a system over-strength factor to arrive at design requirements for such columns. The method is relatively crude and is due for a critical review and potential improvement. This project is essentially an analytical effort and should take advantage of a similar project to study the flexural demands on reinforced concrete shear walls. All types of braced frames, special and ordinary concentric, eccentric, buckling restrained bracing, should be studied, as well as steel plate shear wall systems.		
3	S5	**Braced frame (BRBF and EBF) connection ductility demands**	250C	2
		Research is needed to establish a method for estimating ductility demands at connections of relatively flexible braced frames. The focus is on gusset plates and link beams in buckling restrained braced frames and eccentrically braced frames. Design is generally based upon linear analysis with response modification factors, which are not necessarily well calibrated for connection demands in these types of systems. The research should study realistically proportioned connections, specifically including gusset plates, to assess the demands at MCE-level ground motions. The research should build upon prior research on gusset plate connections in special concentrically braced frames. Braces that carry significant gravity load need to be included in the study.		
3	S6	**Development of design recommendations for SCBF and BRBF gusset plates, EBF link beams, and connections**	150B	2
		Research synthesis and development is needed to develop recommendations for design of connections, including gusset plates for special concentrically braced frames and buckling restrained braced frames (BRBFs) and link beams in eccentrically braced frames (EBFs). This work should take advantage of existing test and analytical results, including that developed in the related project to study ductility demands on connections within BRBFs and EBFs. The goal is to develop methods that provide reliable results when applied to structures designed by linear analysis methods that make use of seismic response modifications factors.		
1	S7	**Attachments to protected zones in steel framing**	250B	1
		Research is needed to study the effect, if any, of attachments to protected zones such as flanges of shear-governed EBF links, SCBF braces, SPSW web plates and SMF/IMF webs. The current prohibitions are based upon fairly limited study. The project should include component testing of realistic braces, moment frame and link beam webs, and wall plates with various types of fasteners. The result may be different recommendations for different anchors and connections within different types of yielding zones.		

STRUCTURAL MATERIAL AND SYSTEMS 2: STEEL AND WOOD				
PEN[1]	No.	Task	Cost Category/ Project Type	Priority
3	**S8**	**Steel and concrete composite systems**	**2000D**	**3**
		A more robust basis for system design and detailing procedures is needed for composite steel and structures. Early focus should be on: • More detailed design provisions are needed for both braced and unbraced frames to facilitate the design of such systems. • Column splice requirements in all types of systems. • Concrete-filled steel tube beam-columns need more accurate axial, flexural, and interaction formulas, particularly with respect to the use of high-strength concrete and high-performance steel materials. • Data are needed on the behavior of long encased composite columns under cyclic loads, particularly when high-strength steel or concrete is used. Moreover, data on the importance of the detailing of the transverse reinforcement on the performance of these columns are lacking. • Should the R = 3 option exist for composite systems? Composite systems offer potential economies for many types of construction, such as partially restrained moment frames in low-rise buildings and improved stiffness in drift sensitive tall buildings. Lack of interest on the part of individual industries and the small stock of engineers and builders with experience has hampered rapid progress in the development of reliable design provisions. BSSC introduced the concepts and AISC has carried forward, both borrowing from various sources in the development of the current provisions.		
1	**S9**	**Steel base plates**	**500D**	**2**
		The methodology for design of base plates and their anchorage for moment frames and braced frames is not robust, and the development of assumed yield mechanisms in these structures may be compromised. A project is needed to consolidate existing research, test viable concepts, and synthesize design provisions is needed. Current research at NIST on deep section columns, as well as current research being funded by the Pankow Foundation should be reviewed as this project is developed.		

STRUCTURAL MATERIAL AND SYSTEMS 2: STEEL AND WOOD				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
3	**W1**	**Requirements for light-frame shear walls**	**900C**	**1**
		By a wide margin, light-frame construction constitutes more building construction than any other structural system. The life safety experience in earthquake ground shaking has been relatively good, but there have been problems in terms of economic loss and disruption from loss of shelter. Innovations in framing materials and methods constantly introduce new aspects for which the seismic performance is not well understood. Design methods grossly simply the actual performance of such structures. Much of our design methodology is rooted in past performance of systems that are not quite the same as currently constructed and in testing that was essentially static. Detailing rules in building codes have grown by accretion from damage observations following earthquakes, and they do not seem to form a well-integrated and robust design procedure. Issue focused research is needed to determine analysis, design, and detailing requirements to achieve intended seismic performance of engineered light-frame shear walls. This work needs to include both wood and cold-formed steel framing, single and multi-story, and the configurations currently permitted. Among the conflicts to be resolved: 1) Is detailing for over-strength necessary given the practical observation that much of the testing conducted to date has shown detailing without over-strength provisions to be adequate? 2) The CUREE and NEES wood frame projects showed needs for detailing provisions that are not yet implemented in current standards. 3) The FEMA P695 project found that nonstructural finishes must be present to justify the current seismic design parameters, yet system detailing rules do not include any such requirements 4) Current design methods encourage walls with high unit shear capacities and hold-downs to prevent uplift (overturning or rocking), yet the vast majority of structures upon which judgments of past performance have are based did not have such hold-downs devices and thus developed much lower unit shear resistance. New testing is not envisioned, but a very substantial analytical effort is envisioned. The outcome should clarify the currently murky boundaries between design adapted from empirical observations of performance and laboratory tested solutions, between bare structural systems and the integrated system with specific finishes, and between collapse prevention and damage control.		
1	**W2**	**Conventional construction**	**150B**	**3**
		The attention given in building codes to non-engineered lateral force systems in light-frame construction has consistently increased over the past few decades, and the use of these provisions is widespread. To some the provisions are controversial and not well justified. Project W1 will provide tools for a systematic examination of the limits on applicability of prescriptive rules for non-engineered lateral force systems of light-frame construction.		

STRUCTURAL MATERIAL AND SYSTEMS 2: STEEL AND WOOD				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
1	**W3**	**Effects of uplift on light-frame shear walls**	**150B**	
		Evaluate performance of light-frame shear walls as a function of the uplift deflection permitted at tie-down devices and reconsider the current detailing requirements for steel plate washers. Develop criteria for uplift limitations and sill plate connections as required to ensure shear wall performance. This project has been folded into W1, where it will be one of many topics studied in a coordinated fashion.		
3	**SW10**	**Seismic design of structural glued laminated timber arches and their connections**	**X**	**X**
		Critical review is needed of the seismic design coefficients recommended in Resource Paper 7, "Special Requirements for Seismic Design of Structural Glued Laminated Timber (Glulam) Arch Members and Their Connections in Three-Hinge Arch Systems," in Part 3 of the 2009 *NEHRP Recommended Provisions*. Currently recommended seismic design coefficients are based on calibration with past seismic base shear determined using the 1997 Uniform Building Code; however, it is preferred that such coefficients be based on methods defined in FEMA P-695. Full-scale testing of frames and connections is needed as is development of structural models to permit full analysis in accordance with FEMA P-695. Testing of critical frame connections in a manner commensurate with those associated with Cold Formed Steel special bolted moment frames also should be conducted to enable extension of tested and modeled connection behavior to overall frame behavior. Capacity-based design is used in the Resource Paper 7 detailing recommendations. If such a study were pursued, evaluation of the detailing recommendations would occur and could enable extension of the capacity-based design concept to other wood frames. In addition, conducting an analysis in accordance with FEMA P-695 would provide a sound basis for substantiating seismic design coefficients for this familiar structure type. While this project is well defined and would advance the state of practice, it does not make the list of projects highly recommended for funding by NIST because a relatively small number of buildings utilize this system, and at least the initial research on the topic should be funded by industry.		

351 [1]PEN is the abbreviation for Program Element Number

NONSTRUCTURAL CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
3	**N1**	**Develop performance criteria for nonstructural components and metrics to assess the reliability of such criteria**	**500C**	**1**
		There has been a major shift toward performance-based design of structures with the move toward classifying performance in terms of conditional and absolute risk of collapse. Reliability-based metrics have been established for structural collapse, and an effort is underway to do so for structural function loss. However, very little has been done to classify the performance of nonstructural components. Significant research, both numerically and physically, is needed to create performance criteria for nonstructural elements. This would include leveraging and expanding on the fragilities that have been developed in ATC-58. This study would first ascertain what we are getting from our current code provisions. ATC-58 fragilities would be used, and the results from the ATC 63-2 also studied. From that information, the study could then propose recommendations to either ATC-84 or the NEHRP provisions.		
1	**N2**	**Develop improved equations for approximating nonstructural design using code-based design procedures, i.e., a new F_p equation**	**500C for N2, N3, N4**	**1**
		Consider Tasks N2, N3, and N4 together. Recent studies have shown that the current equations in ASCE 7 and ASCE 41 for determining design forces for the anchorage of nonstructural components can be overly conservative. This conservatism is very apparent at the higher stories of mid-rise and high-rise buildings. Work is needed to review the work that has already been done and possibly do more analytical work to determine better equations to represent accurate nonstructural design forces. This one component is part of a greater overarching issue related to the design forces for nonstructural components and their anchorage. The force equation needs to be reviewed in conjunction with the R_p factor and any over-strength requirements.		
3	**N3**	**Review and potentially revise the Rp factors**	**See N2**	**See N2**
		Consider Tasks N2, N3, and N4 together. The majority of the R_p factors used in nonstructural component and anchorage design were developed using engineering judgment and have not been validated with testing. If nonstructural design is to become more performance-based, then the R_p factors need to be calibrated to reliability and risk metrics as is currently being done for structural R factors. The R_p factor should be reviewed based on all the component testing that has been performed in recent years. Additionally, a FEMA P695 methodology may also need to be used to come up with a method for determining R_p factors. In some cases there may be systems for which R_p is not appropriate.		

NONSTRUCTURAL CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
3	**N4**	**Evaluate the need for a nonstructural "over-strength" factor**	**See N2**	**See N2**
		Consider Tasks N2, N3, and N4 together. Due to issues arising from ACI 318 Appendix D and the desire to prevent brittle failure, there was a proposal to include an over-strength factor, akin to the omega-zero factor in structural design, for nonstructural anchorage design in ASCE 7-10 Supplement 1. This factor was estimated without much basis, and it was acknowledged that studies were needed to assign different over-strength factors to different nonstructural components. The component testing that has been done in the past years, plus all the nonstructural research, could lead to some recommendations for more appropriate over-strength factors both for the component design and the anchorage design.		
3	**N5**	**Create a database of recent earthquake performance of nonstructural components**	**250B**	**2**
		This task is related to PBSD1 and may be combined into it. There have been a significant number of major earthquakes in populated areas of developed countries in the past two years. Therefore a number of buildings with modern architectural, mechanical, and electrical systems underwent design-level or larger shaking. It is desirable to create a database to collect and compile all this information. This information can then be correlated with some of the analytical and laboratory performance data. This database would then become a living entity that contains nonstructural data from tests and building response data from earthquakes as they occur. In addition to the study of past earthquakes, this task should create a framework for a systematic collection of nonstructural damage to be included in the disaster and failure events database.		

NONSTRUCTURAL CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
4	**N6**	**Technical Brief on nonstructural protection in new buildings**	**N6A: 100B** **N6-B: 100B** **N6-C: 100B**	**2** **1** **3**
		Nonstructural design and detailing has been shown over and over to contribute to more earthquake-related financial loss than building structure damage. Yet a great number of engineers are unfamiliar with assessing and addressing nonstructural performance. Three Technical Briefs are proposed. N6A: The first Technical Brief could summarize basic non-structural, performance, FEMA E74 material, and design examples for both life safety and operational nonstructural performance. The intended audience of this tech-brief would be practicing structural engineers. N6B: The second Technical Brief would discuss nonstructural performance, consequences of nonstructural earthquake damage, and the different levels of performance from life safety to operational. The intended audience for this Technical Brief would be building owners, architects, mechanical/electrical engineers, and contractors. N6C: The third Technical Brief would discuss more detailed modeling and analysis of nonstructural components. The level of detail would be beyond what the typical engineer would commonly perform per Chapter 13 of ASCE 7. Examples would be modeling the entire piping system in a model of the structure.		
3	**N7**	**Loss studies using ATC 58 methodology and experience from past earthquakes to determine appropriate boundaries (S_a) for various code requirements**	**250C**	**1**
		There is a lot of debate as to when engineers should actually consider nonstructural performance in their design. Past earthquakes have shown that various nonstructural elements and systems experience damage at different earthquake intensities. Therefore there should be a parameter, either the S_DS value or possibly a floor acceleration that triggers consideration of seismic effects on specific or specific groups of nonstructural elements. A focused study using ATC-58 methods, backed up by past earthquake data when available, could be useful. This task should draw upon task N1 and the database developed in N5. While this is a high priority, it should be completed after tasks N1 – N5.		
	N8	**Workshop on integration of BIM modeling with nonstructural component analysis and design**	**100B**	**3**
		Eventually every system in the building will be part of the BIM model. How can we take advantage of this for nonstructural analyses? One idea would be to coordinate the BIM model into PACT. Another idea would be to link the BIM model of nonstructural components to structural analysis models. A workshop involving software representatives, engineers, and architects to discuss these ideas would be convened by NIST.		

[1]PEN is the abbreviation for Program Element Number

PERFORMANCE-BASED SEISMIC DESIGN				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
3	**EB1**	**Calibration of Deficiency-Based Procedures of ASCE 31 and 41 (Tier 1, Tier 2, and simplified rehabilitation) with recent earthquake building performance.**	**500C**	**3A**
		The Tier 1 Checklist and Tier 2 Deficiency-only evaluation procedures are rooted in experiences and observations from past earthquakes. The 2010 Chile and the 2010 and 2011 Christchurch earthquakes could provide a substantial number of case studies to assess the accuracy of these methods. Many modern buildings that experienced strong ground shaking were located near recorders and have drawings available. This study would take a subset of buildings from each of the three earthquakes and carry out ASCE 41-13 (since it will be the standard when these studies occur) Tier 1 and Tier 2 evaluations (and possibly Tier 3) of each building. Then the results of the ASCE 41 evaluation would be correlated with what actually occurred, providing real-world examples to assess the accuracy of the provisions.		
1	**EB2**	**Study the variability of existing material properties and their impact on whole building performance to determine what matters and what does not matter. This study could lead to a refinement of the knowledge-factor provisions in ASCE 41 based on the specific action instead of one blanket factor or require a completely new approach to dealing with the variability and uncertainties of material properties in existing buildings.**	**500C**	**3A**
		ASCE 41 currently requires a substantial amount of material testing. Many engineers have remarked that the amount of testing required is excessive, particularly on materials that do not have much variability like structural steel. When material variability has a great effect on the structural action, there should be enough testing to provide confidence in the material or a significant penalty for no testing. On the other hand, some actions are not affected as much by variations in the material strength, and therefore do not require as much testing or subject to as large a penalty when there is no testing. This study would provide guidance to revise the testing requirements and knowledge-factor penalty for no testing. This study may also find that there are better ways than the current knowledge factor in ASCE 41 to address material uncertainty and variability for existing buildings then using a penalty factor.		

PERFORMANCE-BASED SEISMIC DESIGN				
PEN[1]	No.	Task	Cost Category/ Project Type	Priority
1	**EB3**	**Develop tools to identify and inventory existing buildings that are a collapse risk – the "killer buildings."**	**1000C**	**3A**
		Engineers have a general sense of which types of buildings are the worst of the worst, e.g., non-ductile concrete, tilt-up, unreinforced masonry, and wood soft-story multi-family or commercial buildings. However there are not sufficient procedures to classify which buildings within those overarching types are the true "killer buildings" or what other buildings could be "killer buildings." There are currently on-going research efforts on non-ductile concrete buildings and wood soft-story multi-familiar buildings, with a considerable body of research in the past on unreinforced masonry. The issues with concrete tilt-up are somewhat known. The focus of this study would be to current knowledge base and develop an overarching method to screen a building and determine if it is a substantial collapse risk. Such a method could focus on high-risk seismic regions, but also be adaptable to moderate seismic regions as well.		
1	**EB4**	**Research program to provide better modeling and acceptance criteria for concrete elements – beams, columns, walls, and slabs – that do not conform to current special detailing provisions and those that do not even conform to current ACI 318 non-seismic provisions.**	**5000D**	**3A**
		Non-ductile concrete buildings are known to pose some of the greatest risks to the public in major earthquakes. However, current provisions within ASCE 41-06 are not sufficiently accurate to model these buildings. As nonlinear modeling is used more and more for assessing existing buildings, the need for better modeling criteria becomes more critical. Additionally, there is considerable disagreement among practitioners who deal with existing concrete buildings as to whether the linear acceptance criteria of ASCE 41-06 are too conservative or not sufficiently conservative. The program would be based on NIST GCR 10-917-7 and take the recommendations from ATC-95 to create a multi-year research project that includes physical testing of elements and subassemblies of concrete elements commonly encountered in existing concrete buildings designed before modern special detailing was implemented. The goal of this project would be to provide guidance to engineers on what are the collapse indicators, the proper modeling parameters, and different acceptance criteria so that they may more accurately classify the behavior of non-ductile concrete buildings.		
3	**EB5**	**Calibration of ASCE 41 "Collapse Prevention" with ASCE 7 10% conditional probability of collapse in the MCE_R**	**3000C**	**3A**
		ASCE 7 states that buildings designed in accordance with these procedures will have a 10% probability of collapse in the risk adjusted MCE. ASCE 41's collapse prevention performance level is intended to have a similar reliability, but that has never been verified. This study of the ASCE 41 Collapse Prevention acceptance criteria in a FEMA P695 approach to determine if the criteria are providing similar conditional probability of collapse. If not, then recommendations to the criteria would be proposed.		

PERFORMANCE-BASED SEISMIC DESIGN				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
4	**EB6**	**Technical Briefs on seismic evaluation and retrofit of existing buildings**	**1000B**	**3A**
		One of the most frequent comments about ASCE 41 is that it is too complicated. Between the SEAOC Design Manuals and the Technical Briefs that have been published, there is a significant amount of material to assist an engineer in the use of ASCE 7 and the material design standards for new construction. The following Technical Briefs are proposed: Seismic Evaluation and Retrofit of: • Reinforced Concrete Moment Frames • Reinforce Concrete Shear Walls • Concrete Tilt-ups • Wood soft-stories • Wood industrial buildings • Unreinforced masonry buildings • Steel moment frames • Steel braced frames The Technical Briefs would need to use real buildings, similar to the case studies done as part of the ATC-33 project.		
4	**EB7**	**Design examples on seismic evaluation and retrofit of existing buildings**	**1000B**	**3A**
		One of the most frequent comments about ASCE 41 is that it is too complicated, and there are no example problems to reference. Between the SEAOC Design Manuals and the Technical Briefs that have been published, there is a significant amount of material to assist an engineer in the use of ASCE 7 and the material design standards for new construction. The following design examples are proposed: Seismic Evaluation and Retrofit of: • Reinforced Concrete Moment Frames • Reinforce Concrete Shear Walls • Concrete Tilt-ups • Wood soft-stories • Wood industrial buildings • Unreinforced masonry buildings • Steel moment frames • Steel braced frames The design examples would need to use real buildings, similar to the case studies done with the FEMA 4517/751 publications that FEMA publishes for the NEHRP Provisions.		

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PERFORMANCE-BASED SEISMIC DESIGN				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
1	**EB8**	**Study on concrete encased steel framing with and without masonry infill.**	**2000D**	**3A**
		Most steel buildings built before the 1970s contained steel frames encased in concrete. Those before the 1940s also commonly had masonry infill. These buildings have traditionally performed much better in earthquakes than analysis of them would predict. Therefore, the analysis provisions, modeling, and acceptance criteria need to be revised. This will require a study with physical testing.		
1	**EB9**	**Study on reinforced concrete frames with masonry infill**	**250B**	**3B**
		Many non-ductile reinforced concrete frames with masonry infill were constructed before 1950. The benefits or performance degradation that may come from the masonry infill is not widely understood. Modeling methods are somewhat crude, and some engineers have indicated these models do not correlate well with testing. There has been some work, through the NEES Network, on this already. This study would be to compile what has been done, assess the current research, and determine where the gaps are or what else is needed. The product would be updated evaluation and modeling recommendations and a plan for additional research.		
1	**EB10**	**New tools for non-destructive investigation of buildings components.**	**1000D**	**3B**
		It is not uncommon to encounter existing buildings that do not have construction documents. Additionally, construction quality control was not as stringent as it is today, leaving questions as to whether the material in the existing building is what was specified on the drawings. Currently the most common way to ascertain this, and the way dictated in ASCE 41, is to perform destructive testing. However, there is significant cost and disruption associate with destructive testing. Better nondestructive testing methods that could be shown to reliably ascertain existing material mechanical properties would be of great help.		

354 [1]PEN is the abbreviation for Program Element Number

In order to provide more meaningful abbreviations for the research topics, the following changes were made to translate the research topic identifiers from the workshop list to the final list.

Re-assigned Research Topic Abbreviations: CMN

No.	Task
CMN1:C1	Flexural detailing requirements for concrete shear walls
CMN2A:C2	Shear detailing requirements for slender concrete shear walls
CMN2B:C3	Shear detailing requirements for squat concrete shear walls
CMN3:C4	Design shear in concrete shear walls and similar structures
CMN4:C5	Design requirements for anchoring to concrete
CMN5:C6	Requirements for tilt-up wall systems
CMN6:C7	Lightweight concrete strength limits
CMN7:None	Required column-to-beam flexural strength ratios
CMN8A:M1	Masonry shear wall technology transfer
CMN8B:M2	Masonry shear walls with irregular openings
CMN9:M3	Masonry walls with boundary members
CMN10:M4	Partially grouted masonry walls
CMN11:NS1	Design of structural systems with replaceable fuses
CMN12:NS2	Rocking systems
CMN13:None	High-performance buildings
CMN13A:NS3 CMN13B:NS4	CMN13A: Workshop CMN13B: Follow-on research
CMN14:NS5	High-performance, high-rise buildings
CMN15:NS6	Development of smart, innovative, adaptive, and sustainable materials and framing systems
CMN16:C8	Performance of shotcrete walls
CMN17:C9	Seismic Response of intermediate and ordinary systems
CMN18:C10	Design shear in columns in special moment Frames
CMN19:C11	Shear in deep mat foundations

Re-assigned Research Topic Abbreviations: SW

No.	Task
SW1:S1	Braced frames without out-of-plane lateral bracing
SW2a:S2	Steel ordinary braced frames
SW2b:S3	Steel ordinary moment frames
SW3:S4	Design forces for columns in steel braced frames and steel plate shear walls
SW4a:S5	Braced frame (BRBF and EBF) connection ductility demands
SW4b:S6	Development of design recommendations for SCBF and BRBF gusset plates, EBF link beams, and connections
SW5:S7	Attachments to protected zones in steel framing
SW6:S8	Steel and concrete composite systems
SW11:S9	Steel base plates
SW7:W1	Requirements for light-frame shear walls
SW8:W2	Conventional construction
SW9:W3	Effects of uplift on light-frame shear walls
SW10:None	Seismic design of structural glued laminated timber arches and their connections

Appendix B—Workshop Materials

Final Workshop Agenda

Development of NIST Measurement Science R&D Roadmap:
Earthquake Risk Reduction in Buildings
Workshop Agenda

Day 1 May 15th, 2012

9:00 Welcome/Self Introductions

9:10 NIST Program and Objectives

9:30 Purpose and organization of the Workshop

9:45 Overview of Research Categories

1. Design Methodologies and Analysis
2. Geotechnical and Ground Motion
3. Performance-Based Seismic Design

10:45 Break

10:55 Overview of Research Categories, continued

4. Structural Material and Systems 1: Concrete, Masonry and New Systems
5. Structural Material and Systems 2: Steel and Wood
6. Nonstructural Systems

11:45 Comments/questions from attendees

12:00 Lunch (training discussion for breakout leaders and recorders)

1:00 Breakout Session 1: Research Categories 2, 3, 5

3:00 Break

3:15 Breakout Session 2: Research Categories 1, 4, 6

5:15 Adjourn

Day 2 May 16th, 2012

8:30 Breakout Reports—Session 1: Research Categories 1, 2, 3

10:00 Break

10:15 Breakout Reports—Session 2: Research Categories 4, 5, 6

11:30 Ballot Instructions/Balloting for Priorities

12:00 Adjourn

Workshop Invitees

Name	Company/University	Academic/Practitioner
Hooper, John	MKA	
Crouse, C.B.	URS Corporation	
Harris, James	J. R. Harris and Company	
Holmes, William T.	Rutherford & Chekene	
Moehle, Jack	UC Berkeley	
Pekelnicky, Robert	Degenkolb Engineers	
Hayes, John (Jack)	NIST	
McCabe, Steven	NIST	
Rouland, Drew	NIBS	
Smith, Deke	NIBS	
Andre Filiatrault	SUNY – Buffalo	Academic
Andy Taylor	KPFF	Practitioner
Benson Shing	UCSD	Academic
Bret Lizunda	Rutherford & Chekene	Practitioner
Charlie Kircher	C.A. Kircher & Associates	Practitioner
Curt Haselton	California State University, Chico	Academic
Dan Dolan	Washington State University	Academic
David Bonneville	Degenkolb Engineers	Practitioner
Greg Deierlein	Stanford University	Academic
Gyimah Kasali	Rutherford & Chekene	Practitioner
Jim Jirsa	UT Austn	Academic
John Rolfes	Computerized Structural Design	Practitioner
Jon Heintz	Applied Technology Council	Practitioner
Kelly Cobeen	Wiss Janney Elstner	Practitioner
Ken Elwood	University of British Columbia	Academic
Larry Fahenestock	University of Illinois	Academic
Laura Lowes	University of Washington	Academic
Marshall Lew	Amec	Practitioner
Mason Walters	Forell Elsesser	Practitioner
Michael Willford	Arup	Practitioner
Mike Schuller	Atkinson Noland	Practitioner
Nathan Gould	ABS	Practitioner
Nicolas 'Nico' Luco	USGS	Academic
Peter Somers	MKA	Practitioner
Ramon Gilsanz	GMSLLP	Practitioner
Robert Bachman	R.E. Bachman Consulting	Practitioner

	Engineer	
Robert Hanson	FEMA	Academic
Scott Olson	University of Illinois	Academic
Shahriar Vahdani	Fugro West, Inc.	Practitioner
Sharon Wood	UT Austn	Academic
Steve Mahin	UC Berkeley	Academic
Tom Sabol	Englekirk Institutional	Practitioner
Youssef Hashash	University of Illinois	Academic

Number of Practioners:	18
Number of Academics:	15
Total Attendees:	**33**

Workshop Assignments and Instructions

Breakout Session 1—1:00-3:00 PM

Research Topic 2	Research Topic 3	Research Topic 5
Geotechnical and Ground Motion	**PBSD**	**SM&S2: Steel and Wood**
Crouse, C.B.	Holmes, William	Harris, James
Hooper, John	Pekelnicky, Robert	Moehle, Jack
Haselton, Curt	Bonneville, David	Bachman, Bob
Kasali, Gyimah	Deierlein, Greg	Cobeen, Kelly*
Lew, Marshall	Elwood, Ken	Dolan, Dan
Luco, Nico*	Gould, Nathan	Fahenestock, Larry
Olson, Scott*	Heintz, Jon*	Filiatrault, Andre
Shing, Benson	Jirsa, Jim	Gilsanz, Ramon
Somers, Peter	Kircher, Charlie	Hanson, Bob
Vahdani, Shahriar	Lowes, Laura	Lizunda, Bret
Walters, Mason	Mahin, Steve*	Rolfes, John
Wood, Sharon	Taylor, Andy	Sabol, Tom*
	Willford, Michael	Schuller, Mike

*Session Leader/Recorder

Instructions for Breakout Sessions

1. **Cost Category/Project Type** column on the Research Topics Lists needs to be filled in.
   Cost Category[1]:
   - **100**—Projects expected to cost about $100k
   - **250**—Projects expected to cost about $250k
   - **500**—Projects expected to cost about $500k
   - **750**—Projects expected to cost about $750k
   - **>750**—Projects expected to cost substantially more than $750 (like $1M or more)

   Project Type:
   - **A**—Individual investigator
   - **B**—Small technical group
   - **C**—Technical committee including specialized analysis expertise
   - **D**—Technical committee including laboratory testing

2. **Priority** boxes can be completely filled out, but that is not necessarily expected. Overall priorities recommended by the workshop will be determined by ballot at the end of the workshop. The following priorities will be used:
   - **1**—Highest
   - **2**—Higher
   - **3**—High
   - **X**—Need not consider at this time

3. Identification of top priority items. Your breakout group will have the opportunity to influence the other workshop participants by identifying extremely important topics in your area and "lobbying" for them in your breakout report.

Breakout Session 2—3:15-5:15 PM

Research Topic 1	Research Topic 4	Research Topic 6
Design Methods and Analysis	**SM&S1: Concrete, Masonry, and New Systems**	**Nonstructural**
Hooper, John	Moehle, Jack	Pekelnicky, Robert
Crouse, C.B.	Harris, James	Holmes, William
Cobeen, Kelly	Dolan, Dan	Bachman, Bob
Deierlein, Greg	Elwood, Ken	Bonneville, David*
Fahenestock, Larry	Jirsa, Jim	Filiatrault, Andre*
Haselton, Curt*	Lew, Marshall	Gilsanz, Ramon
Kasali, Gyimah	Lowes, Laura	Gould, Nathan
Kircher, Charlie	Luco, Nico	Hanson, Bob
Mahin, Steve	Schuller, Mike	Heintz, Jon
Olson, Scott	Shing, Benson	Lizunda, Bret
Somers, Peter*	Taylor, Andy	Rolfes, John
Vahdani, Shahriar	Walters, Mason*	Sabol, Tom
Willford, Michael	Wood, Sharon*	

*Session Leader/Recorder

Instructions for Breakout Sessions

1. **Cost Category/Project Type** column on the Research Topics Lists needs to be filled in:
   Cost Category[1]:
   - **100**—Projects expected to cost about $100k
   - **250**—Projects expected to cost about $250k
   - **500**—Projects expected to cost about $500k
   - **750**—Projects expected to cost about $750k
   - **>750**—Projects expected to cost substantially more than $750 (like $1M or more)

   Project Type:
   - **A**—Individual investigator
   - **B**—Small technical group
   - **C**—Technical committee including specialized analysis expertise
   - **D**—Technical committee including laboratory testing

2. **Priority** boxes can be completely filled out, but that is not necessarily expected. Overall priorities recommended by the workshop will be determined by ballot at the end of the workshop. The following priorities will be used:
   - **1**—Highest
   - **2**—Higher
   - **3**—High
   - **X**—Need not consider at this time

3. Identification of top priority items. Your breakout group will have the opportunity to influence the other workshop participants by identifying extremely important topics in your area and "lobbying" for them in your breakout report.

[1]The Project Technical Committee found that the Cost Category was strongly correlated with the Project Type list, and simply preserved the Project Type until refining the costs for each project in preparing the final recommendation.

Pre-Workshop Memorandum and Associated Package and Instructions

MEMORANDUM

To: Participants in the May 15-16, 2012 National Institute of Standards and Technology (NIST) Workshop for the *Development of NIST Measurement Science R&D Roadmap: Earthquake Risk Reduction in Buildings*

From: John Hooper, PTC Chair, on behalf of the PTC—C.B. Crouse, Jim Harris, Bill Holmes, Jack Moehle, Bob Pekelnicky

Date: May 3, 2012

Subject: Pre-Workshop Information Package and Instructions

Thanks again for participating in this important workshop. The purpose is to develop priorities for future NEHRP-related activities of NIST. Subject to available funding, NIST intends to pursue these activities over the next 8 years both through an externally funded program and through its internal research activities. Based on the results of the workshop, the Project Technical Committee (PTC) will develop a report documenting the priorities for use by NIST. Your experience, wisdom, and active participation in the workshop are key to the success of this effort.

Enclosed are the following:

- *Pre-workshop Preparation Agenda*

    - Please glance at the right-hand column of the agenda to get a brief overview of how the workshop will be conducted.

- *Pre-workshop Research Topics List*

    - The list consists of the following six research categories which have been mined by the PTC from several recent reports on research needs. Please note that research topics regarding existing buildings are not included in the list below. Research topics regarding existing buildings will be dealt with separately by the PTC since they have already been identified as being in the long-term (5-8 year) time frame.

        1. Design Methodologies and Analysis
        2. Geotechnical and Ground Motion
        3. Performance-Based Seismic Design

4. Structural Material and Systems 1: Concrete, Masonry and New Systems
5. Structural Material and Systems 2: Steel and Wood
6. Nonstructural Systems

- As noted in the Pre-workshop Preparation Agenda, if you feel that a crucial research need is missing from the Pre-workshop Research Topics List, YOU MUST SUBMIT A REQUEST TO BSSC TO PRESENT A PROPOSAL BY MAY 9, 2012 (please send the request by email to Drew Rouland at drouland@nibs.org and John Hooper at jdh@mka.com). If approved, you will have approximately 5 minutes to present the proposed topic at the workshop, and then the workshop participants will decide if the topic will be added to the Research Topics List.

Each of the above six research categories will be presented by a member of the PTC, and then workshop participants will have the opportunity to discuss and prioritize the research needs into three timeframes, specifically: short-term (1-3 years), mid-term (3-5 years), and long-term (5-8 years) needs. The workshop will have breakout sessions focused on the six research categories outlined above, where you will be asked to assist in their prioritization and estimated cost. You will be pre-assigned to a breakout session in accordance with your experience and expertise as well as a need for balanced representation in each session. Familiarity with ATC-57 is important for meaningful participation in the workshop, so if you do not have access to it, here is a link to the document: http://www.atcouncil.org/pdfs/atc57toc.pdf

If you have pre-workshop questions, feel free to discuss them with any of the members of the PTC noted below. Also, you may reserve a room at a discounted rate at the Embassy Suites, using code "SFY" or by calling 650-342-4600. If you have any problems with your reservations, please contact Drew Rouland at 202-289-7800x121.

Again, thanks for participating,

John Hooper, Program Director of the Project Technical Committee (PTC) (jdh@mka.com)
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Draft Workshop Agenda Sent to Invitees

Development of NIST Measurement Science R&D Roadmap: Earthquake Risk Reduction in Buildings Workshop Agenda

Day 1 May 15th, 2012

9:00 Welcome/Self Introductions

9:10 NIST Program and Objectives

9:30 Purpose and organization of the Workshop

9:45 Overview of Research Categories

7. Design Methodologies and Analysis
8. Geotechnical and Ground Motion
9. Performance-Based Seismic Design

10:45 Break

10:55 Overview of Research Categories, continued

10. Structural Material and Systems 1: Concrete, Masonry and New Systems
11. Structural Material and Systems 2: Steel and Wood
12. Nonstructural Systems

11:45 Comments/questions from attendees

12:00 Lunch (training discussion for breakout leaders and recorders)

1:00 Breakout Session 1: Research Categories 2, 3, 5

3:00 Break

3:15 Breakout Session 2: Research Categories 1, 4, 6

5:15 Adjourn

Day 2 May 16th, 2012

8:30 Breakout Reports—Session 1: Research Categories 1, 2, 3

10:00 Break

10:15 Breakout Reports—Session 2: Research Categories 4, 5, 6

11:30 Ballot Instructions/Balloting for Priorities

12:00 Adjourn

Research Topics Tables sent to Workshop Invitees

DESIGN METHODOLOGY AND ANALYSIS CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
1	**DMA1**	**Evaluate Linear Analysis Procedures, especially for structures with significant higher mode effects**		
		Recent ATC studies (ATC-63, -76 and -84) have identified that the use of Modal Response Spectrum Analysis (MRSA) results in a rate of collapse that exceeds the target value (10% given MCE_R ground shaking) as compared to Equivalent Lateral Force (ELF) procedures, especially for buildings with significant higher mode effects.		
1	**DMA2**	**Evaluate irregularity (vertical and horizontal) triggers and the associated requirements**		
		The torsional irregularity triggers, through a BSSC Simplified Design Project, have been found to be not important to the collapse risk for SDC B buildings. Similar studies of the other irregularity triggers and requirements in all SDCs should be evaluated and determine the extent that they are needed.		
3	**DMA3**	**Evaluate P-delta requirements**		
		P-delta checks are evaluated using an elastic analysis, but at amplified drifts. Since it is more important to evaluate P-delta during nonlinear response, the current requirements should be evaluated in order to determine their influence on collapse capacity.		
3	**DMA4**	**Further evaluate seismic performance factors (R, Cd and Ω) for all range of building periods**		
		ATC-63 evaluated the current seismic performance factors to determine whether the resulting values produced acceptable collapse capacities. ATC-84 further evaluated seismic performance factors, focusing on short- and long-period building behavior. The results of these studies indicated additional investigation is needed to determine whether the current seismic performance factors and associated earthquake demands result in acceptable collapse capacities.		
3	**DMA5**	**Evaluate system limitations requirements**		
		As part of the current BSSC PUC effort developing the 2014 NEHRP Provisions, an issue team (IT-7) was assigned the task of evaluating the systems limitation requirements (height limits and system exclusions shown on ASCE 7-10 Table 12.2-1) and suggesting changes to the current list. Additional technical studies are likely needed to support suggested changes to the current requirements.		
3	**DMA6**	**Evaluate the redundancy factor provisions**		
		The redundancy factor has been in the building code since 1997, although the form of the requirement has changed. A detailed study is needed to determine whether the current requirements affect the collapse capacity or whether such an evaluation is needed.		

DESIGN METHODOLOGY AND ANALYSIS CATEGORY				
PEN[1]	No.	Task	Cost Category/ Project Type	Priority
1	DMA7	**Evaluate the Seismic Design Categories (SDC)**		
		As part of the current BSSC PUC effort developing the 2014 NEHRP Provisions, an issue team (IT-2 and IT-7) was assigned the task of evaluating the SDC and whether the current number of categories are needed and whether the current spectral acceleration cut-offs are appropriate. Additional technical studies may be needed to support suggested changes to the current requirements.		
3	DMA8	**Investigate vertical ground motions and their effect on building performance**		
		Vertical acceleration spectra were developed during the 2009 Provisions update, but an in-depth assessment of these spectra should be conducted. Results from this study could be used to determine both vertical acceleration requirements for the ASCE 7 load combinations (e.g., a critical review of the term 0.2SDS) and the vertical period appropriate for analysis and design.		
3	DMA9	**Provide additional guidance for nonlinear response history analysis and modeling requirements**		
		Chapter 16 of ASCE 7-10 is being studied/modified as part of the current BSSC PUC effort (IT-4) in support of the 2014 NEHRP Provisions. Additional research is likely needed to verify the recommended changes achieve the intended collapse capacity.		
1	DMA10	**Evaluate the dual frame requirements and assess their appropriateness**		
		Needed is a review and potential modification to the dual frame system requirements and associated design coefficients. This is notably relevant to dual systems with both special and intermediate moment frame back-up systems. It is not clear whether the design requirements currently prescribed will provide the desired low probability of collapse given MCER ground shaking at the site. The methodology outlined in FEMA P-695 could be used to assess these requirements.		
1	DMA11	**Evaluate strong column-weak beam requirements**		
		Research and testing is needed to evaluate a proposed change (Proposal 2-1) not adopted for the 2009 Provisions. This proposal focused on the minimum flexural strength of columns in special and intermediate steel and concrete moment frames (strong-column/weak-beam). The intent of the proposal was to encourage researchers to test the nonlinear response and seismic performance associated with the proposed requirements as well as their effects on the economy of the resulting design.		
1	DMA12	**Evaluate the drift requirements and their effect on building performance**		
		Research is needed to determine whether any changes to the drift analysis requirements are warranted given the adoption of the MCER ground motions associated with a 10% probability of collapse given their occurrence. Additionally, the drift requirements are thought to ensure appropriate response of non-structure components at the Design Earthquake Level, which also needs to be evaluated. A critical evaluation of the Cd value, and whether it should be set equal to R, is also needed.		

DESIGN METHODOLOGY AND ANALYSIS CATEGORY				
PEN[1]	No.	Task	Cost Category/ Project Type	Priority
3	DMA13	**Evaluate the effectiveness of the earthquake importance factors (I_E) on the performance of Risk Category III and IV buildings**		
		Risk Category III and IV Buildings require the use of importance factors of 1.25 and 1.5, respectively. It's not clear to what extent the performance for these buildings is enhanced over ordinary buildings when using these factors. Research is needed to assess building performance using I_E and to make recommendations, if necessary, to adjust the values.		
3	DMA14	**Evaluate the minimum base shear equations for long-period structures and their effect on collapse risk**		
		As part of the ATC-63, ATC-76 and ATC-84 projects, a minimum base shear was found necessary to achieve the intended collapse risk. Additional investigations are needed to fully develop an acceptable approach.		
3	DMA15	**Investigate the use of multi-point spectra for use in design**		
		USGS is capable of providing multi-point spectra for use in design. A study is needed to determine whether additional spectral accelerations would support the design process and further provide for more consistent collapse capacities. Coordinate this effort with GGM1.		
3	DMA16	**Evaluate the over strength requirements**		
		ATC-63 indicated that the system-based over strength factors can vary widely. This was further studied as part of ATC-84, and it was concluded that additional analysis is needed to develop a consistent set of requirements that will result in acceptable and consistent collapse performance.		
3	DMA17	**Evaluate diaphragm design equations and methodology**		
		As part of the current BSSC PUC effort developing the 2014 NEHRP Provisions, an issue team (IT-6) was assigned the task of evaluating diaphragm design. Additional research is needed to fully develop any necessary changes to diaphragm design as it relates to acceptable collapse performance.		
3	DMA18	**Further evaluate risk-targeted approach to defining performance**		
		As part of the 2009 NEHRP Provisions Update, a risk-targeted methodology was adopted to determine the spectral accelerations that are needed to achieve acceptable collapse performance. As part of ATC-84 and BSSC IT-2/-7, this risk-targeted methodology is being developed for other performance levels (serviceability and functionality). Additional research will be needed to fully develop the approach.		
3	DMA19	**Benchmark currently available 3-D nonlinear analysis software**		
		There is a need to benchmark the available 3-D nonlinear dynamic analysis software currently being used by practicing engineers to compute gravity and seismic response simultaneously. Not only is there potential issues regarding the detailed component modeling, but also the modeling of: (1) nonlinear soil-structural interaction, and (2) vertical input motions. Benchmarking of currently available commercial software is needed to assess their capabilities.		

DESIGN METHODOLOGY AND ANALYSIS CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
4	**DMA20**	**Continue the development of Technical Briefs for use by practicing engineers and academicians**		
		Over the past several years, numerous Technical Briefs have been developed that provide guidance for engineers in the design of specific seismic systems. The following issues, among others, should be considered for future Technical Briefs: • Gravity-only Framing • Tilt-up Wall Buildings • Precast Concrete Diaphragms • Seismically Isolated Buildings • Untopped Steel Deck Diaphragms • Plywood Diaphragms		
3	**DMA21**	**Suitability of maximum direction ground motions for use in seismic design codes**		
		There may be a significant degree of over-conservatism associated with the switch from the geometric mean horizontal component to the maximum direction component, a change made in the 2009 NEHRP provisions and subsequently adopted into ASCE 7-10 and IBC. A study should be undertaken to examine collapsed buildings with nearby ground motion records and evaluate whether there is any relationship between the maximum direction of ground motion and the collapse direction (if known). Also, nonlinear response history analyses should be carried out for typical building geometries to see if the results of such analysis support the use of this ground motion definition, or an alternative definition of ground motion, for building code applications.		
3	**DMA22**	**Effect of aftershocks on the design and evaluation of buildings**		
		Recent earthquakes (e.g., Chile, Christchurch and Japan) re-emphasized the occurrence of large and numerous aftershocks and the associated demands on buildings. The design seismic hazard for new buildings should be evaluated considering the potential of these aftershocks to assess if changes are warranted, and the post-earthquake evaluation of buildings should be critically reviewed to determine if changes are needed.		

[1]PEN is the abbreviation for Program Element Number

GEOTECHNICAL AND GROUND MOTION CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
3	**GGM1**	**Design response spectrum construction and update seismic hazard maps with NGA-east and NGA subduction equations**		
		ASCE 7-05 and 7-10 still employ the TL parameter to obtain the long-period constant-spectral displacement segment of the design spectrum. This approach is inconsistent with the approach to construct the constant acceleration and constant velocity segments, which are derived using PSHA and DSHA procedures. The long period portion can be derived using the same PSHA and DSHA approach, but presently, it can only be done for the WUS region outside the PNW. The NGA-east and NGA-subduction equations must be developed to 10-second period in order to develop long period ground-motion maps for the rest of the U.S. The NGA-east effort has been progressing over the last 2 years while the NGA-subduction effort has just started. Equations from these two research programs will hopefully be available in the next code cycle. However, one or both may need extra funding (from NIST?) to finish. With all three equations (NGA-east, NGA-west, and NGA-subduction) a smooth continuous design response spectrum can be constructed from 0 to 10-second period for any region in the U.S. This spectrum could replace the standard Design Response spectrum in Ch. 11.4 of ASCE 7-10. Investigations on the feasibility of a smooth spectrum, versus the standard spectrum from the general procedure, are suggested by comparing both spectra at a number of U.S. locations.	Not considered for this Roadmap. This research is mainly in the purview of USGS.	

GEOTECHNICAL AND GROUND MOTION CATEGORY				
PEN[1]	No.	Task	Cost Category/ Project Type	Priority
3	GGM2	**Develop site amplification factors and/or ground-motion maps that specifically account for local/regional geology**		
		Update F_a & F_v Site Coefficient Tables in ASCE 7-10 and develop an F_d Site Coefficient Table, for the constant displacement portion of spectrum extended to 10-second period. The research for the F_a & F_v update is sponsored by PEER and is nearing completion. The F_a & F_v update will be based on the NGA-west equations, and a proposal to the PUC this cycle is anticipated. Another option is to develop equations for F_a and F_v that are continuous functions of the Vs30 parameter, which is the primary basis for classifying a site into one of the site categories, A, B, C, D, and E. A proposal for this alternative may also be prepared and submitted to the PUC this cycle. However, research needs to be conducted to determine the feasibility of bypassing the present approach to determine the design response spectrum, which is to first obtain the bedrock spectrum and then amplify it with F_a and Fv factors. The alternative is instead to develop ground-motion maps directly from the NGA-equations by substituting the Vs30 into the equations and conducting the PSHA & DSHA. Thus, maps would be prepared for discrete values of Vs30 between 500 and 5,000 fps, and along with an interpolation algorithm, the map values would be programmed into the USGS calculator tool software. The feasibility of this approach needs to be investigated. The approach to determine the Fd site coefficients also needs investigation because the term "site", as it is normally understood (i.e., as the geology under the building footprint), is generally not relevant for the determination of long period motions, which are governed more by the regional, rather than local geology. Basin effects become increasingly important for these long periods, and the question is whether the NGA-west equations will produce F_d values that adequately account for basin effects, regardless of location within the US. Thus, the feasibility of region-specific maps should be investigated, and the possibility of using 3-D seismological simulations to develop these maps should be considered. Some 3-D numerical simulations have already been done and 2,475-yr maps for 3-second period spectral accelerations have been prepared for the Los Angeles and Seattle regions.		
3	GGM3	**Region-specific site factors**		
		Recent work in the NGA projects has shown that site response within NEHRP site categories is regionally variable; hence the same site factors used for shallow crustal earthquakes in California may not applicable in the Pacific NW, and are probably not applicable in the central and eastern US. Additional funds could be used to enhance existing work in this area being undertaken at PEER. In particular, most of the site effects work for the east is not currently funded and is in need of support.		

GEOTECHNICAL AND GROUND MOTION CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
3	**GGM4**	**Vertical ground-motion maps**		
		As part of its NGA-West2 project, PEER is currently developing ground-motion prediction equations (GMPEs) for the vertical component. Similar efforts should be undertaken for NGA-east and NGA-subduction GMPEs. Once these equations are developed, then research will be required to determine the best way to generate the vertical ground-motion maps, either with vertical GMPEs in separate PSHA & DSHA for this component, or though V/H ratios applied to horizontal-component maps. Tables of F_a and F_v (and F_d) values, and equations for F_a & F_v in terms of Vs30, would also need to be developed for the vertical component.		
3	**GGM5**	**Maximum direction ground motions**		
		As part of the NGA-West2 project, PEER is examining the sensitivity of the maximum direction component with respect to independent variables such as magnitude and distance. GMPEs should be developed for the maximum direction component, and a study should be done to determine whether these equations will lead to significantly different design response spectra than the current approach of applying period-dependent scale factors to the ground-motion maps derived from NGA equations based on geometric mean values.		
3	**GGM6**	**Continue to augment inventory of ground-motion time histories for use in response history analyses**		
		While catalogs, such as the COSMOS VDC, PEER, and CESMD, are available to select ground-motion time histories for use in analysis, recent events (Chile, Christchurch, Tohoku) provide a unique opportunity to augment these databases. An effort needs to be made to document these records, and their site characteristics, so they can be readily used by the design and research community.		
3	**GGM7**	**Include accelerograms from subduction zones & stable continental regions in database software used to select time histories for response history analysis**		
		Within the current framework for selecting time histories, many practitioners use the PEER DGML software for selecting accelerograms from shallow crustal earthquakes. However, this software needs to be enhanced to include subduction-zone accelerograms and the relatively small number of accelerograms from stable continental regions.		
	GGM8	**Benchmark currently available structural dynamic response software**		
		There is a need to benchmark the available structural dynamic response software currently being used by practicing engineers focusing on the following modeling issues: (i) the input motion to the substructure, (ii) the interaction of the substructure with the surrounding soil, and (iii) the nonlinear response of the soil and substructure. Also, evaluate the capability to model vertical response due to vertical ground motion. With respect to the modeling of the soil-foundation-substructure system, focused research is needed on the (i) rotational stiffness of shallow foundations with non-rigid foundation elements, (ii) stiffness, damping, and ultimate capacity of nonlinear piles in nonlinear soil, particularly soil undergoing lateral spreading, and (iii) quantification of kinematic effects for different types of foundations and embedment.		

GEOTECHNICAL AND GROUND MOTION CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
3	**GGM9**	**Liquefaction effects on buildings**		
		A subcommittee of PUC IT 8 is investigating how to best specify performance criteria for building foundations in liquefiable soil. The goal is to generate a proposal for PUC consideration this cycle. Depending on the outcome, more research may need to be conducted on this topic. One topic for consideration is the approach for computing the seismic response of pile-supported buildings, where the piles penetrate through liquefiable soil. Is the present two-step approach adequate? In the first step, the surface ground motion is specified and input to the above-ground above-pile building model, which in turn generates the base shear and overturning moment. Step two consists of applying these forces to the pile foundation and computing the pile response by with programs such as LPILE & APILE, which use nonlinear p-y and t-z curves to model the soil-pile interaction in the soils' liquefied and non-liquefied states. Research is needed to determine whether this procedure, as opposed to a more direct procedure that models the soil-pile-foundation-structure interaction together in one step, is sufficient for design.		
3	**GGM10**	**Topographic & other regional geologic effects on ground motion**		
		The effect of topography on earthquake ground motion has been observed at some sites and simple theoretical models have demonstrated its effect. However, no terms have been introduced in GMPEs to model it. Research is needed to determine whether topographic effects can be modeled within GMPEs and provide reliable predictions of ground motion. The geology beneath the surface (not just the topography) also needs to be considered. Improved methods to account for basin effects in the ground-motion maps also need to be investigated.		
3	**GGM11**	**Revisions to ground-motion hazard maps following great earthquake**		
		Investigate the change in the regional ground-motion hazard following a great earthquake (e.g., M~9 on Cascadia subduction zone; M~8 on San Andreas fault) and revise regional ground-motion maps, as appropriate.		

[1]PEN is the abbreviation for Program Element Number

PERFORMANCE-BASED SEISMIC DESIGN				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
2	**PBSD1**	**Obtain historical testing data (much may be proprietary) from testing labs for development of fragilities.6**		
		It is known that many components have been tested for seismic performance over the years. It is unclear what data exist and to what extent it may be applied to current systems and components and whether the data are available for PBSD use. However, given the lack of hard fragility data, a concerted and organized effort should be made to collect all information that might be available.		
2	**PBSD2**	**Study structural fragilities that have been developed and make recommendations for developing improvements, including when new testing may be required.**		
		The following are the structural systems that have the highest need for reliable fragilities: Lateral-Force-Resisting Systems: • Steel braced frames • Steel or concrete frames with masonry infill • Concrete shear walls • Reinforced masonry • Light steel stick framing systems • Light wood stick framing systems • Limited ductility steel moment frames Other lateral force components that need study: • Diaphragm chords and collectors • Wood diaphragms • Precast concrete with and without concrete topping • Steel deck with concrete topping • Steel ribbed deck roof Gravity systems that need study: • Precast concrete • Concrete gravity frames		
2	**PBSD3**	**Develop protocol for testing and documentation of results to enable development of consequence functions for both structural and nonstructural systems and components.**		
		Currently some testing that may be adequate for development of fragilities is not sufficiently robust or documented to enable development of consequence functions. Guidance is needed for future testing.		

PERFORMANCE-BASED SEISMIC DESIGN				
PEN[1]	No.	Task	Cost Category/ Project Type	Priority
2	PBSD4	**Develop consequence functions for structural and nonstructural systems where not available.**		
		Although future testing for development of fragilities may include the necessary data for consequence functions, it is unclear if the cost estimating and other considerations needed for consequence functions will be completed by the same researchers. Review currently available research results, identify those that might be useful for PBSD, and develop consequence functions consistent with those already available. This data is essential to PBSD.		
2	PBSD5	**Improve ability to predict damage to structures and contents from soil movements including liquefaction, lateral spread, landslide, and soil failure at foundations.**		
		Soil movements can contribute to building damage and these effects should be included in comprehensive performance assessments.		
3	PBSD6	**Develop representative losses for primary categories of code-designed buildings to improve consistency of performance among systems.**		
		Ongoing studies related to P695 are, for the first time, developing data enabling comparison of probable performance of various buildings types, at least related to collapse. Other losses implied by code design are unknown and only tangentially mentioned in published code "intents." An important use of PBSD will be to make code performance more consistent and better targeted at desirable goals. In addition, such studies will enable owners to make better decisions about requesting designs to provide better than "code performance."	Not considered for this Roadmap. This project has been started as part of follow-up to ATC 58 (ATC 63 2-3)	
3	PBSD7	**Engage the public and policy makers in setting performance goals for the building code by appropriately presenting representative loss data for primary categories of code-designed buildings**		
		A wider based consensus is needed concerning the current life safety goal (e.g., CP @ MCE) and additional data is needed for policy makers to consider appropriate loss goals for damage, reparability, and downtime. Consideration of optimum goals for individual owners (e.g., individual cost-benefit) and communities (e.g., resilience) may be different.		
2	PBSD8	**Identify new ground motion characteristics or parameters that will improve correlation between analysis predictions and observed damage.**		
		Currently, the performance of structural systems is typically correlated with simple ground motion characteristics or parameters such as peak ground acceleration or spectral acceleration at the fundamental elastic structural period. Other ground motion characteristics or parameters need to be identified that correlate better with performance, particularly when the structural system becomes nonlinear and its dynamic characteristics are changing with ground motion intensity, when its response is driven by multiple modes of vibration, or when duration effects may be prevalent.		

PERFORMANCE-BASED SEISMIC DESIGN				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
2	**PBSD9**	**Develop capability to consider post-earthquake fire damage from sources internal to the building.**		
		In any one building, losses from earthquake-caused fire may be more significant than shaking damage. In addition, if recognized, the risks from within the building can probably be mitigated. This risk may only be applicable in certain regions, neighborhoods, or for certain building types or occupancies, but a complete performance-based assessment methodology should include this capability.		
2	**PBSD10**	**Improve capability to consider losses from water damage from broken pipes or tanks.**		
		The vulnerability of buildings to losses from water damage, particularly downtime, is well known. However, little data are available from which loss functions can be developed. However, such a capability will be important to improve restraint requirements and to encourage restraint of piping systems.		
2	**PBSD11**	**Develop capability to consider losses from internal releases of hazardous materials**		
		This risk may only apply to a small number of buildings, but for those buildings, the losses may be more significant than shaking losses. The importance of containment systems can only be demonstrated by estimating potential effects on the building and its occupants.		
4	**PBSD12**	**Develop a Tech-brief on "Use of Probability Theory in Structural Engineering"**		
		This information is available in various places (certainly in standard probability text books), and has been approached in ATC-58, but a more complete concentration of this information will be useful to engineers in the next decade.		
2	**PBSD13**	**Improve the characterization of uncertainties in the PBSD process**		
		Better understanding of the source of uncertainties will guide improvements in the process and give engineers a better perspective for communicating results.		
2	**PBSD14**	**Develop a plan to establish a permanent home for a database of building component fragilities.**		
		Procedures to store, improve, and expand the current database of fragilities used in ATC-58 have not been established. Such a plan is needed to encourage continuous improvement and expansion.		

PERFORMANCE-BASED SEISMIC DESIGN

PEN[1]	No.	Task	Cost Category/ Project Type	Priority
2	PBSD15	**Improve analytical models and simulation capabilities for buildings in near-collapse seismic loading.**		
		In current performance-based assessment approaches, a prevalent performance objective is the avoidance of collapse for some maximum considered seismic loading. In the performance assessment methodology developed in the ATC-58 project, the results of collapse prediction is dominant in assessing casualty rates. Collapse assessment today is usually done with analysis that does not directly simulate collapse, but that monitors other demands (e.g. drift) that can be associated with collapse. These methods are necessarily approximate and usually conservative. Collapse simulation capabilities should be developed to directly simulate the initiation and progression of collapse. Projects are ongoing in this regard for older concrete buildings but little has been done for other buildings materials and types, particularly walled buildings.		
3	PBSD16	**Develop a systematic comparison of the reparability of various structural materials and systems under various loading intensities.**		
		Although collapse prevention will probably be the primary code goal for quite some time, owners may be encouraged to use better systems if this knowledge was available. Much data could be pulled from ATC-58 fragility database to form the basis of such a document.		
4	PBSD17	**Develop a Tech-brief on "Loss Estimation based on ATC-58"**		
		The information in ATC-58 is likely overwhelming for the average engineer to digest at first reading and it may be some time before implementation products are developed within the project. An interim Tech-brief on the ATC-58 methodology and the capabilities of the existing PACT software would be useful and may encourage early adopters.		
2	PBSD18	**Catalog information from past earthquakes to attempt to find correlations between localized ground motion intensity or damage levels and total downtime.**		
		ATC-58 methodology includes a computation of repair time, but what is more important for building owners is the time from the moment of the earthquake until they can reoccupy their building. Data is needed to enable development of a method to estimate total downtime with a better understood uncertainty. Such information is also key for communities improving resilience.		

612 [1]PEN is the abbreviation for Program Element Number

STRUCTURAL MATERIAL AND SYSTEMS 1: CONCRETE, MASONRY AND NEW SYSTEMS				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
1	**CMN1**	**Flexural detailing requirements for concrete shear walls**		
		The current design code for concrete buildings provides detailed provisions for the seismic design of shear walls. Earthquakes in Chile (2010) and New Zealand (2011) showed many examples of inadequate building performance. Lessons from these events and additional research should form the basis for updated detailing provisions.		
1	**CMN2**	**Shear detailing requirements for concrete shear walls**		
		The current design code for concrete buildings provides detailed provisions for the seismic design of shear walls based primarily on flexural performance considerations. In practice, however, many concrete shear walls have proportions and loading that result in their performance being governed by shear, rather than flexural, considerations. Requirements for the detailing of shear walls whose behavior is shear controlled need to be developed.		
1	**CMN3**	**Design shear in concrete shear walls and similar structures**		
		Numerous analytical studies have suggested that design shear forces for shear walls (and similar structures) in US practice are well below forces that may actually develop. Other codes (e.g., Eurocode 8) have adopted much higher design shears. Studies considering demands, capacities, and acceptable risk are needed to determine whether US design approach should be updated. Studies should determine whether similar provisions are required for other systems such as steel braced frames, steel shear walls, etc.		
1	**CMN4**	**Design requirements for anchoring to concrete**		
		The current seismic design requirements for anchoring to concrete are not well validated. The provisions of ACI 318 Appendix D and ASCE 7-05 need to be unified so that lower strength-reduction factors in the ACI standard are not combined with the increased load factors in ASCE 7 unless justified by test data and reliability analyses. Research is needed to improve requirements for cast-in-place anchors typical of those used in foundations of building and non-building structures, and for large diameter anchor bolts (greater than 2 inches in diameter). One goal would be to justify the elimination of anchor reinforcement. Another would be to achieve code simplification.		
1	**CMN5**	**Requirements for tilt-up wall systems**		
		Design requirements for tilt-up wall systems are based primarily on data for systems with plywood and timber roofs. Many modern tilt-up systems use other roofing systems. Seismic design requirements for the walls of such structures and the anchorage of the walls of such structures to the diaphragms need correlation with the performance of such structures as measured in recent earthquakes.		
1	**CMN6**	**Lightweight concrete strength limits**		
		Studies are needed of the seismic performance of lightweight concrete structures with specified concrete strengths greater than the 5 ksi limit currently imposed by ACI 318.		

STRUCTURAL MATERIAL AND SYSTEMS 1: CONCRETE, MASONRY AND NEW SYSTEMS				
PEN[1]	No.	Task	Cost Category/ Project Type	Priority
1	CMN7	**Required column-to-beam flexural strength ratios**		
		FEMA P-695 and other studies have rediscovered that current design procedures do not guarantee beam-yielding mechanisms in special moment frames. Studies are needed to evaluate whether current design procedures for concrete SMFs result in acceptable risk levels. Study how this requirement affects design and economy and its relationship to the minimum base shear requirement.	Not considered for this Roadmap. Covered in DMA11	
3	CMN8	**Masonry shear wall variations**		
		Research is needed to provide experimental and analytical verification of the hysteretic behavior and failure modes of masonry shear walls with different aspect ratios, axial loads, configurations of prescriptive reinforcement, and irregular configurations of openings.		
3	CMN9	**Masonry walls with boundary members**		
		Research is needed to provide for experimental and analytical verification of the hysteretic behavior of masonry shear walls with confined boundary elements.		
1	CMN10	**Partially grouted masonry walls**		
		Some research has indicated that the equations for predicting nominal shear strength used in current standards is unsafe for partially grouted hollow unit masonry. Further research is needed to define the issue and provide more appropriate predictive equations for design.		
3	CMN11	**Design of structural systems with replaceable fuses**		
		The design of systems in which energy dissipation is focused in optimized replaceable energy-dissipating fuses should be examined. Ideally, such research will include self-centering capabilities to maximize the value of fuse replacement.		
3	CMN12	**Rocking systems**		
		Study performance of rocking systems to better understand behavior and design requirements. Include a range of systems, from low-rise walls rocking on spread footings to unbonded, post-tensioned systems. Conduct laboratory experiments on components and structural systems to demonstrate performance. Develop design guidelines and building code provisions.		
3	CMN13	**High-performance buildings**		
		Conventional design of buildings relies on inelastic response of the structural components to control earthquake design forces. Buildings so designed can be expected to be damaged following design-level earthquakes. Resilient communities require buildings of reduced damage. This task is to explore structural materials and systems that deliver higher performance with reduced repair requirements; conduct component and structural system tests to demonstrate performance; and develop design guidelines, building code provisions, and technology transfer to facilitate their use.		

**STRUCTURAL MATERIAL AND SYSTEMS 1:
CONCRETE, MASONRY AND NEW SYSTEMS**

PEN[1]	No.	Task	Cost Category/ Project Type	Priority
3	**CMN14**	**High-performance, high-rise buildings**		
		Design guidance for high-rise buildings in the US is limited to conventional construction forms involving structural steel, structural concrete, or combinations of these. Greater economy of construction and enhanced performance sometimes can be achieved by using seismic isolation, energy dissipation devices, or combinations. Of particular importance, given their size and the challenges of repair or deconstruction, is achieving low-repair performance states.		
3	**CMN15**	**Development of smart, innovative, adaptive, sustainable materials and framing systems**		
		Construction materials and framing systems are by-and-large unchanged from those used 50 years ago. Smart/innovative/adaptive/sustainable structural materials and framing systems provide new opportunities for construction and warrant speedy development. Include complete structural system detailing and specification; verification tests on components and structural systems; design tools, standards, and technology transfer materials; consequence functions; and measurement systems to gauge the performance of new materials and systems.		

[1]PEN is the abbreviation for Program Element Number

STRUCTURAL MATERIAL AND SYSTEMS 2: STEEL AND WOOD				
PEN[1]	No.	Task	Cost Category/ Project Type	Priority
3	SW1	**Braced frames without out-of-plane lateral bracing**		
		Research is needed to develop and validate a design method for special concentrically braced frame (SCBF) columns without lateral bracing at beam levels (e.g., a three-level frame with out-of-plane bracing only at top and bottom). Research also is needed to develop and validate a design method for concentrically braced frame (CBF) and eccentrically braced frame (EBF) beams without lateral bracing between columns.		
3	SW2	**Steel ordinary braced frames and ordinary moment frames**		
		Research is needed on the seismic capacity of steel ordinary concentrically braced frames and steel ordinary moment frames for a variety of configurations commonly used in buildings and non-building structures designed to reflect the *Provisions*, including ASCE 7-10 and AISC 341-10. Relaxation of the height and other limitations of lower ductility systems (e.g., ordinary concentrically braced frames) should be considered. Opportunities for such limit relaxations on non-building structures similar to buildings should be studied, perhaps including a FEMA P-695 analysis.		
1	SW3	**Design forces for columns in steel braced frames and steel plate shear walls**		
		Research is needed to establish a method for determining appropriate design forces for columns of multistory steel braced frames and steel plate shear walls, based on linear analysis. Note: This is similar to the item for flexural demands in concrete shear walls.		
3	SW4	**Braced frame seismic design demands**		
		Research is needed to establish a method for estimating ductility demands at buckling restrained braced frame connections and link in EBFs based on the type of linear analyses used for design.		
1	SW5	**Attachments to protected zones in steel framing**		
		An investigation is needed to study the effect, if any, of attachments to protected zones such as flanges of shear-governed EBF links, SCBF braces, and SPSW web plates.		
3	SW6	**Steel and concrete composite systems**		
		System design and detailing procedures are needed for steel and composite structures. Early focus should be on: • More detailed design provisions are needed for both braced and unbraced frames to facilitate the design of such systems. • Column splice requirements in all types of systems. • Concrete-filled steel tube beam-columns need more accurate axial, flexural, and interaction formulas, particularly with respect to the use of high strength concrete and high performance steel materials. • Data are needed on the behavior of long encased composite columns under cyclic loads, particularly when high-strength steel or concrete is used. Moreover, data on the importance of the detailing of the transverse reinforcement on the performance of these columns are lacking. • Should the R = 3 option exist for composite systems?		

STRUCTURAL MATERIAL AND SYSTEMS 2: STEEL AND WOOD				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
3	**SW7**	**Requirements for light-frame shear walls**		
		Research is needed to determine detailing requirements to achieve intended seismic performance of engineered light-frame shear walls. A conflict currently exists between the philosophical concepts that detailing for over-strength should be provided and the practical observation that much of the testing conducted to date has shown detailing without over-strength provisions to be adequate. Issue-focused research is needed to determine whether current detailing practice can consistently provide adequate performance. There are also conflicts between current design/detailing provisions and the results of the CUREE and NEES wood frame projects. The research should consider both wood and CFS framing, the range of wall configurations and sheathing materials permitted under current design standards, and implications for both single-story and multistory walls. Detailing considerations should include both force and deformation. The work should be combined with FEMA P-695 studies for design factors, and should consider effects of nonstructural and exterior wall finishes.		
1	**SW8**	**Conventional Construction**		
		Re-examine the limits on applicability of prescriptive rules for non-engineered lateral force systems in light of the results of project SW7.		
1	**SW9**	**Effects of uplift on light-frame shear walls**		
		Evaluate performance of light-frame shear walls as a function of the uplift deflection permitted at tie-down devices and reconsider the current detailing requirements for steel plate washers. Develop criteria for uplift limitations and sill plate connections as required to ensure shear wall performance.		
3	**SW10**	**Seismic design of structural glued laminated timber arches and their connections**		
		Critical review is needed of the seismic design coefficients recommended in Resource Paper 7, "Special Requirements for Seismic Design of Structural Glued Laminated Timber (Glulam) Arch Members and Their Connections in Three-Hinge Arch Systems," in Part 3 of the 2009 *Provisions*. Currently recommended seismic design coefficients are based on calibration with past seismic base shear determined using the 1997 Uniform Building Code; however, it is preferred that such coefficients be based on methods defined in FEMA P-695. Full-scale testing of frames and connections is needed as is development of structural models to permit full analysis in accordance with FEMA P-695. Testing of critical frame connections in a manner commensurate with those associated with Cold Formed Steel special bolted moment frames also should be conducted to enable extension of tested and modeled connection behavior to overall frame behavior. Capacity-based design is used in the Resource Paper 7 detailing recommendations. If such a study were pursued, evaluation of the detailing recommendations would occur and could enable extension of the capacity-based design concept to other wood frames. In addition, conducting an analysis in accordance with FEMA P-695 would provide a sound basis for substantiating seismic design coefficients for this familiar structure type.		

614 [1]PEN is the abbreviation for Program Element Number

NONSTRUCTURAL CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
3	**N1**	**Develop performance criteria for nonstructural components and metrics to assess the reliability of such criteria**		
		There has been a major shift toward performance-based design of structures with the move toward classify performance in terms of conditional and absolute risk of collapse. Reliability-based metrics have been established for structural collapse and an effort is underway to do so for structural function loss. However, very little has been done to classify the performance of nonstructural components. Significant research, both numerically and physically, is needed to create performance criteria for nonstructural elements. This would include leveraging and expanding on the fragilities that have been developed in ATC-58.		
1	**N2**	**Develop improved equations for approximating nonstructural design using code-based design procedures, i.e., a new F_p equation**		
		Recent studies have shown that the current equations in ASCE 7 and ASCE 41 for determining design forces for the anchorage of nonstructural components can be overly conservative. This conservatism is very apparent at the higher stories of mid-rise and high-rise buildings. Work is needed to review the work that has already been done and possibly do more analytical work to determine better equations to represent accurate nonstructural design forces.		
3	**N3**	**Review and potentially revise the R_p factors**		
		The majority of the R_p factors used in nonstructural component and anchorage design were developed using judgment and have not been validated with testing. If nonstructural design is to become more performance-based, then the R_p factors need to be calibrated to reliability and risk metrics as is currently being done for structural R factors.		
3	**N4**	**Evaluate the need for a nonstructural "over-strength" factor**		
		Due to issues arising from ACI 318 Appendix D and the desire to prevent brittle failure, there was a proposal to include an over-strength factor, akin to the omega-zero factor in structural design, for nonstructural anchorage design in ASCE 7-10 Supplement 1. This factor was estimated without much basis and it was acknowledged that studies were needed to assign different over-strength factors to different nonstructural components.		
3	**N5**	**Create a database of recent earthquake performance of nonstructural components**		
		There have been a significant number of major earthquakes in populated areas of developed countries in the past two years. Therefor a number of buildings with modern architectural, mechanical, and electrical systems underwent design-level or larger shaking. It is desirable to create a database to collect and compile all this information. This information can then be correlated with some of the analytical and laboratory performance data. This database would then become a living entity which contains nonstructural data from tests and other earthquakes added to it.		

NONSTRUCTURAL CATEGORY				
PEN[1]	**No.**	**Task**	**Cost Category/ Project Type**	**Priority**
4	**N6**	**Tech-brief on nonstructural protection in new buildings**		
		Non-structural design and detailing has been shown over and over to contribute to more earthquake-related financial loss than building structure damage. Yet a great number of engineers are unfamiliar with assessing and addressing nonstructural performance. The tech-brief could summarize basic nonstructural performance, FEMA E74 material, and design examples for both life safe and operational nonstructural performance.		
3	**N7**	**Loss studies using ATC 58 methodology and experience from past earthquakes to determine appropriate cut-off (Sa) for various code requirements**		
		There is a lot of debate as to when engineers should actually consider nonstructural performance in their design. Past earthquakes have shown that various nonstructural elements and systems are experience damage at different earthquake intensities. Therefore there should be a parameter, either the S_DS value or possibly a floor acceleration that triggers consideration of seismic effects on specific or specific groups of nonstructural elements. A focused study using ATC-58 methods, backed up by past earthquake data when available, could provide useful to this.		

615 [1]PEN is the abbreviation for Program Element Number

Initial Workshop Invitation

National Institute of Standards and Technology Presents, Workshop for the *Development of NIST Measurement Science R&D Roadmap: Earthquake Risk Reduction in Buildings*

Workshop Invitation
Date and Location: May 15th & 16th 2012, Burlingame, CA (Embassy Suites)

Dear Invited Guest:

On behalf of National Institute of Standards and Technology (NIST) and Building Safety Seismic Council (a NIBS council), we would like to extend an invitation to participate in an upcoming workshop involving the development of future research needs for the earthquake risk reduction in buildings. This workshop is designed to review and prioritize a list of research needs following slightly revised ATC-57 Program Elements. As a participant, we would like your valuable input on the following research categories:

1. Design Methodologies and Analysis
2. Geotechnical and Ground Motion
3. Performance-Based Seismic Design (PBSD)
4. Structural Material and Systems (e.g., Concrete Structures, Steel Structures, Masonry Structures, Light-framed Structures)
5. Nonstructural Systems
6. New Systems (e.g., rocking systems, self-centering, damping systems, new materials, system reparability, better performing, more cost-effective systems, etc.)

Each of the above six research categories will be presented by a member of the project technical committee and the objective is to prioritize the research needs into three categories for future exploration. NIST would like to align their research objectives and plans in short term (1-3years), mid-term (3-8 years), and long term (8+ years) needs. The workshop will have breakout sessions focused on the six (6) research categories outlined above and you will be asked to assist in their prioritization. You will be pre-assigned to a breakout session in accordance with your experience and expertise as well as a need for balanced representation in each session.

Enclosed with this invitation to the workshop is the tentative agenda. Prior to the workshop, you will be provided a draft research needs list for each of the above categories. As part of the workshop, you'll be asked to provide research needs that are missing from this initial list. Familiarity with

ATC-57 is important for meaningful participation in the workshop so if you do not have access to it here is a link to the document: http://www.atcouncil.org/pdfs/atc57toc.pdf.

Please respond by March 26, 2012 to Drew Rouland at drouland@nibs.org of your plans to attend the workshop. Please note that travel expenses to the workshop will be provided.

If you have any questions, feel free to discuss them with any members of the PTC listed below.

Thank you,

John Hooper, Program Director of the Project Technical Committee (PTC) (jdh@mka.com)
PTC members:
C.B. Crouse (cb.crouse@urscorp.com)
Jim Harris (jim.harris@jrharrisandco.com)
Bill Holmes (wholmes@ruthchek.com)
Jack Moehle (moehle@berkeley.edu)
Bob Pekelnicky (rpekelnicky@degenkolb.com)

Proposed Workshop Tentative Agenda

Day 1 May 15th, 2012

9:00 Welcome/Self Introductions

9:10 NIST Program and Objectives

9:30 Purpose and organization of the Workshop

9:45 Overview of Research Categories (6 presentations in all)

10:30 Break

10:45 Overview of Research Categories (6 presentations in all), continued

11:45 Input of research ideas from attendees

12:00 Lunch (training discussion for breakout leaders and recorders)

1:00 Breakout Sessions 1-3 (validate and prioritize research and estimate costs

3:00 Break

3:15 Breakout Sessions 4-6 (validate and prioritize research and estimate costs

5:15 Adjourn

Day 2 May 16th, 2012

8:30 Breakout Session Reports (1-6), including feedback from attendees

10:00 Break

10:15 Breakout Session Reports (1-6), cont.

11:30 Ballot Instructions/Balloting

12:00 Adjourn

Appendix C – List of Recently Completed NIST Projects

Overall there were 30 Task Orders for external projects that have been issued. Listed are a few select projects that provided information for the Roadmap report.

Since 2013

- ATC-82/TO9 – Improved Procedures for Selecting and Scaling Earthquake Ground Motions for Performing Time-History Analyses
- ATC-83/TO 10: Improved Procedures for Characterizing and Modeling Soil-Structure Interaction for Performance-Based Seismic Engineering
- ATC-76-1/TO 11: Quantification of Building System Performance and Response Parameters
- ATC-90/TO 17: Seismic Behavior and Design of Deep, Slender Wide-Flanged Structural Steel Beam-Column Members
- ATC-89/TO 16: Cost-Benefit Analysis of Codes and Standards for Earthquake-Resistant Construction in Selected US Regions
  Phase 1 Moderate Seismicity Cost Study for Memphis
- ATC-92/TO 19: Comparison of Chilean and U.S. Model Building Code Seismic Provisions and Seismic Design Practices
- ATC-93/T0 20: Ground Motion and Building Performance Data from the 2010 Chile Earthquake – completed
- ATC-94/TO 21: Performance of Chilean Buildings and Walls

FY 2012 Projects

- NEHRP Workshop on Post-Earthquake Investigation Issues
- Workshop on Lifeline Research/Implementation Needs
- TechBrief on Special Concentrically Braced Steel Frames
- TechBrief on Structural Wood Diaphragms
- Experimental Testing of Steel Beam -Columns

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Appendix D—Project Management Plan for NIST

Project Management Plan for NIST

Development of NIST Measurement Science R&D Roadmap: Earthquake Risk Reduction in Buildings

Program Goals:

There are three task order goals of the Contractor are:

1. Analyze ATC-57 and formulate a broad strategic approach for NIST earthquake risk reduction research for new and existing buildings.
2. Examine the research recommendations provided by references 2 through 7 and supplement that examination by conducting a focused Earthquake Risk Reduction in Buildings workshop of leading earthquake engineering researchers and practitioners. Review the resulting recommendations then identify gaps or additional areas of needed research to fulfill the broad objectives of ATC-57. Next develop a prioritized listing of applied (problem-focused) research needs. This listing of research needs shall also consider the conclusions drawn by a NIST Disaster Resilience Workshop (Sept. 2011).
3. Develop a Measurement Science R&D Roadmap for the NIST EL Earthquake Risk Reduction in Buildings and Infrastructure program.

Technical Requirements

Task 1: The BSSC will appoint a Project Director (PD) who will have overall responsibility for project management. The BSSC will ensure that the PD is a practicing structural engineer who has strong ties to the research and codes and standards communities.

The BSSC also will appoint a Project Technical Committee (PTC) composed of the PD as chair and from three to five other eminently qualified academic and practicing experts who have worked in the field of earthquake engineering. The BSSC will ensure that the PTC includes both structural engineering and geotechnical engineering expertise. BSSC will consider experience; expertise; and geographic, gender, and ethnic diversity in selecting the PD and PTC members. All PTC selections will be made in consultation with the NIST COTR. Representatives from FEMA, NIST, NSF, and USGS will be included as *ex-officio* members of the PTC.

The PTC will be responsible for the technical quality and practical direction of the project, under the direction of the PD. PTC members will not be associated with any specific materials industries or be in the employment of any industry associations or interests. This will not be interpreted to mean that researchers who have been occasionally funded by such interests would be exempt from participation. The PTC will review project activities on a regular basis and be available for immediate consultation with the PD and/or NIST COTR as required. All project documents shall be developed and approved by the PTC prior to distribution. The PTC also will be responsible for reviewing project deliverables, providing advice and consultation throughout the project, and serving as a liaison to the materials industries and model building code and standards organizations.

Task 2: The National Institute of Building Sciences will develop, in consultation with the NIST COTR, an outline for accomplishing all project tasks. Based on this outline and contractual requirements, the BSSC will develop a Project Work Plan (PWP) that outlines the overall project performance strategy and estimates NIBS resource requirements for roadmap completion. NIBS will submit a draft PWP to the NIST COTR for review and comments and resubmit a final version to the NIST COTR.

Task 3: The PTC will analyze ATC-57 to formulate a broad strategic approach for NIST earthquake risk reduction research for both new and existing buildings. This approach will consider the activity areas outlined in the above Background statement and defined broadly as Program Elements 1 through 4 in ATC-57. The PTC will not include ATC-57 Program Element 5 in the strategic approach.

Task 4: The PTC will review the recommendations advanced by the various documents related to ATC-57 and will identify gaps or additional areas of needed research to fulfill the broad objectives of ATC-57. The PTC also will review the conclusions drawn by the NIST Disaster Resilience[3] Workshop scheduled for September 2011. In addition, consideration will be given to the interaction of any proposed research with ongoing or proposed studies that are supported by FEMA to ensure appropriate project coordination. Based on this review, the PTC will develop a draft prioritized listing of applied (problem-focused) research needs for improved resilience of both new and existing buildings (this efforts will not include lifelines research). It is anticipated that the proposed research will be full spectrum, including general studies, analytical efforts, and experimental activities.

Task 5: The PD and PTC will organize an invitation-only workshop of leading earthquake engineering researchers and practitioners.

The workshop will be structured to review the draft listing of prioritized applied (problem focused) research needs from Task 4, validate it, and identify any omissions or inconsistencies. Workshop participants will be asked to consider basic research results, new practitioner needs, and other work that has been done since publication of documents cited in the Background statement above. The PD and PTC will format the workshop to accomplish this overall goal and coordinate the format with the COTR.

Workshop participation will be by invitation only. The workshop will include a maximum of 25 invited participants in addition to the members of the PTC (including the ex-officio NEHRP agency representatives). Participants will include structural and geotechnical engineering researchers and practitioners. Further, the practitioners group will include representatives of primary codes and standards development organizations. The BSSC and PTC will consider experience and expertise as well as geographic, gender, and ethnic diversity in selecting workshop participants. All invited participant selections shall be made in consultation with the NIST

COTR. The PD and PTC will submit the proposed workshop location and participants' names to the COTR for approval prior to issuing invitations. It is anticipated that the workshop will be 1-1/2 to 2 days in length.

Task 6: Following the conduct of the workshop outlined in Task 5, the PTC will develop a draft technical report that presents a prioritized listing (roadmap) of applied (problem-focused) earthquake engineering research activities that NIST should undertake over the upcoming five to eight years. At a minimum, the roadmap will:

- Categorize research activities consistently with the ATC-57 Program Elements 1-4;
- Support the NEHRP *Strategic Plan for the National Earthquake Hazards Reduction Program, Fiscal Years 2009-2013*;
- Address the relevant recommendations of the 2011 National Research Council (NRC) report *National Earthquake Resilience: Research, Implementation, and Outreach*; and
- Reflect the broad context of improving building performance to achieve greater national resilience.

To facilitate cost-effective use of the roadmap, proposed research initiatives will be prioritized to reflect their relative importance and practitioner-specified sequence of investigation. The roadmap will include the needed analytical and experimental research as well as more general studies needed to provide improved building performance in earthquakes. Impacts on community, regional, and national resilience will be addressed. The roadmap will briefly describe each proposed research project, including estimated levels of effort and associated costs, but will not necessarily detail the "how-to" of needed research steps. In describing research projects, consideration will be given to use of the research facilities and information technology (IT) infrastructure of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES).

Research projects for new and existing buildings will be listed separately except for any items that specifically address both new and existing buildings. The recommended activities will be prioritized as near-term needs (less than three years); mid-term needs (3-5 years), and longer-term needs (5-8 years). The PD, PTC and BSSC will assume, for general planning, that the proposed roadmap budget does not exceed $10 million per year.

The PTC will submit a draft of the roadmap to the COTR for review.

Task 7: Following NIST COTR review of the draft roadmap, the PTC will incorporate any COTR recommendations and produce a final written roadmap technical report that is suitable for release as a NIST Government Contractor Report (GCR). The PTC will obtain the GCR number from the NIST COTR prior to submitting the final report.

Acknowledgements

The National Institute of Building Sciences, Building Seismic Safety Council (BSSC) would like to acknowledge project guidance provided by Jack Hayes NEHRP Director and Steve McCabe, NERHRP Deputy Director at NIST. The Roadmap Report project was led by the efforts of the following Project Technical Committee members:

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The materials and recommendations contained in this report were also produced from the expertise of the workshop attendees listed in Appendix B. Together with the assistance of the National Institute of Building Science's, BSSC the NIST Roadmap Report was formed.