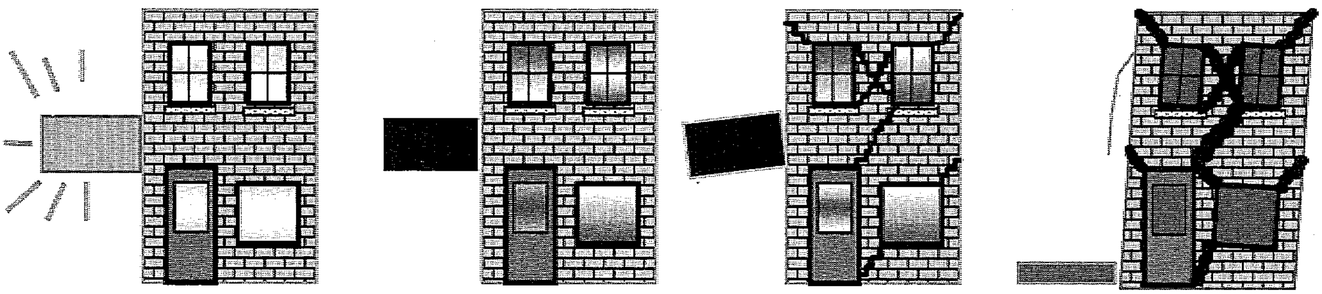
FEDERAL EMERGENCY MANAGEMENT AGENCY FEMA-349/April 2000

ACTION PLAN

FOR

PERFORMANCE BASED SEISMIC DESIGN



Prepared for the
Federal Emergency Management Agency
By the
Earthquake Engineering Research Institute

FORWARD

One of the primary goals of the Federal Emergency Management Agency (FEMA) is the prevention, or mitigation, of this country's losses from natural hazards. To achieve this goal, we as a nation need to ask what level of performance do we expect from our buildings during an event such as an earthquake. In order to answer this question, FEMA is exploring the possible development of "performance-based seismic design" criteria. Such criteria could be voluntarily used by this nation's engineers and designers to improve the performance of critical classes of buildings that are currently only designed to a "lifesafety" level to avoid collapse, but would in fact probably still suffer significant damage in a design event.

FEMA contracted with the Earthquake Engineering Research Institute (EERI) (contract number EMW-92-K-3955, Task 13) to solicit the input of the nation's leading seismic professionals in developing an action plan that could be used to develop performance-based seismic design criteria. This project and the resulting action plan have gone a long way in identifying key issues that will need to be addressed in this process.

This action plan builds upon a similar effort that FEMA funded in 1993 with the Earthquake Engineering Research Center, now the Pacific Earthquake Engineering Research Center (PEER). The end product of that study was a similar plan, "Performance Based Seismic Design of Buildings" (FEMA-283), published by FEMA in September 1996. The material in that plan had an emphasis on the research that would be required, and has in fact been used by PEER in the last several years as the basis for their research work in this arena.

While this action plan does an excellent job of describing the requirements that would be needed to successfully develop performance based seismic design criteria, FEMA does has some concerns, such as the proposed budget, which exceeds what FEMA is capable of devoting within the recommended time frame. FEMA is planning to identify some of the key elements of the plan and to begin to address them through a series of projects under its Problem Focused Studies program. However, without additional specific funding for this plan, it will be very difficult to accomplish the entire plan. To avoid further delay, FEMA has decided to publish this document as a "final draft" for informational purposes only. Publication of this document in no way obligates this or any other Federal agency to any portion of plan contained herein. The information and opinions contained in this document are solely those of EERI and the project participants and do not necessarily represent the views of FEMA.

In closing, FEMA sincerely wishes to express its gratitude to all who were involved in this project. The results of their hard work will play an important role as this country moves forward towards performance-based seismic design and reducing the losses suffered by this nation's citizens after the next earthquake.

Cover Art: Part of a presentation developed by Ronald O. Hamburger, EQE International

ACTION PLAN

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Executive Summary

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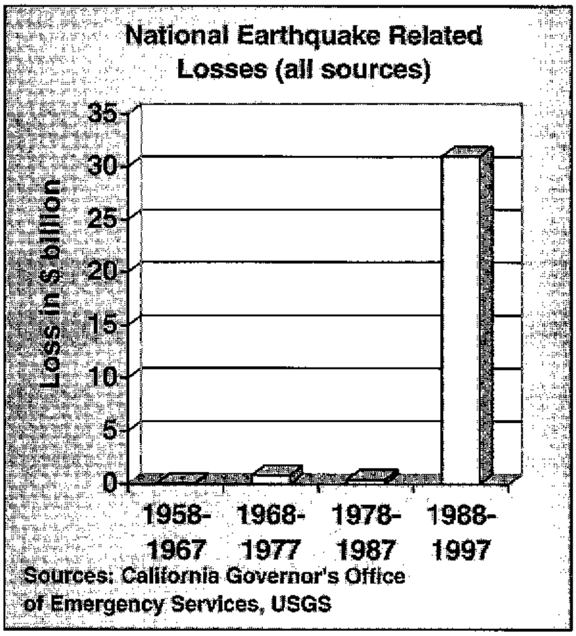
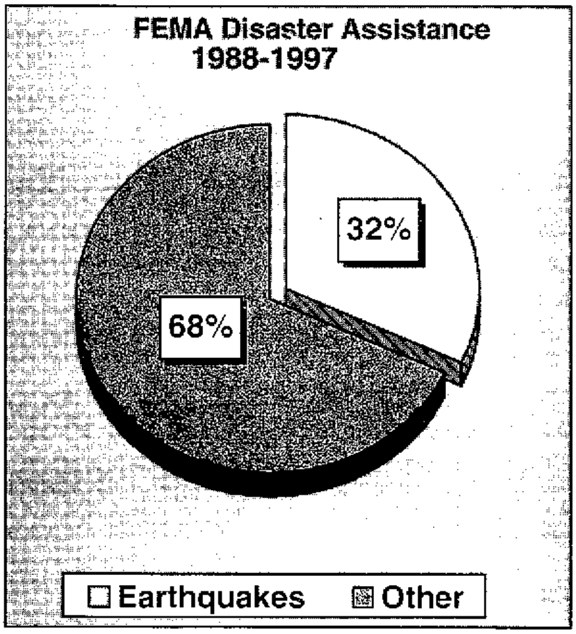
The Need for Changes in Current Seismic Design Practice



Recent decades have seen a dramatic rise in insured and uninsured earthquake related losses. In the past ten years estimated losses were twenty times larger than in the previous 30 years combined. FEMA's expenditures related to earthquake losses have become an increasing percentage of its disaster assistance budget.[1] Predictions are that future single earthquakes, which will inevitably occur, may result in losses of $50-100 billion each.[2]

Losses are rising due to several factors. These include: a denser population of buildings being located in seismically active regions, an aging building stock and the increasing cost of business interruption. Nonstructural and contents damage are also large contributors to loss, especially in regions with high-technology manufacturing and health-care industries.



It is this increase in losses from all hazards that has led FEMA to support actions to reduce future losses. One of these is Project Impact, an initiative to encourage loss reduction activities through partnerships at the local community level. One of the key components of Project Impact is the community's adoption and enforcement of an adequate building code

Historically, building codes have required that buildings be built to a minimum level of safety. Specifically, structures designed to the Uniform Building Code are expected to "resist a minor level of earthquake... without damage,...a moderate level.. with some nonstructural damage, [and] a major level of earthquake...without collapse."[3]

Deaths in recent California earthquakes have been few, showing that the intent of the code has been met. However, there is a major misperception on the part of many owners, insurers, lending institutions and government agencies about the expected performance of a code conforming building. This has led to losses that were unexpected and in many cases financially ruinous. Building stakeholders--those with a financial or social interest in the built environment--who expect that their buildings are "earthquake proof" because they meet the code, have often been very disappointed. It must be said, too, that none of these recent events has been of an intensity that would typically be considered catastrophic. Catastrophic temblors with a magnitude similar to the 1812 New Madrid or 1906 San Francisco earthquakes will now likely result in losses several times larger than anything previously experienced if they occur in a densely populated area.

Many building owners are unaware of the tradeoffs they face when using the current state of design practice. Interestingly, people make similar tradeoffs with more everyday choices. For example, the number of highway fatalities could be dramatically reduced if everyone drove tanks. Yet most people are unwilling or cannot afford to do so, and instead accept the increased risk of driving a car. Consciously or not, car buyers perform cost-benefit analyses when weighing the risk of an accident against a car's cost. A careful consumer may decide to spend more to buy a safer car or he may opt to spend the same amount of money, but research much more closely the safety records of similarly priced cars. This consumer is reducing risk either by increasing his investment or by reducing his uncertainty.

Current codes clearly serve an essential and effective role in protecting building occupants. The design basis of the code is intended to provide a basic level of safety and a relatively economical means by which to construct buildings. However, using current code methods to design and build to a higher level of performance may add significantly to a project's cost.

Stakeholders, however, have become painfully aware of the financial and social consequences of earthquakes and are demanding that practical and cost-effective means be developed to address the issues of damage control and loss reduction.

The community of design professionals needs to be able to respond to this demand with the development of design and evaluation methodologies that look at a broad range of building performance and construction techniques.

Current codes represent an evolution of prescriptive rules that have changed every three years as more is learned about building behavior. The expected performance of new code designed buildings is poorly understood, and probably inconsistent among building types. It is currently difficult for rational advanced design techniques and innovative systems to be fit into the code framework. It is also difficult to apply building codes for new buildings to evaluation and retrofit of existing buildings. Special guidelines have been developed for these purposes, potentially creating a double standard.

Performance Based Seismic Design (PBSD) is a methodology that provides a means to more reliably predict seismic risk in all buildings in terms more useful to building users. It permits owners to:

- Make an efficient use of their design and construction budgets, resulting in more reliable performance for the money spent.

- Consider spending more money to achieve quantifiably higher performance than provided for in the code, thereby reducing risk and potential losses.

PBSD will benefit nearly all building users. The PBSD methodology will be used by code writers to develop building codes that more accurately and consistently reflect the minimum standards desired by the community. A performance based design option in the code will facilitate design of buildings to higher standards and will allow rapid implementation of innovative technology. When performance levels are tied to probable losses in a reliability framework, the building design process can be tied into owner's long-term capital planning strategies, as well as numerical life cycle cost models.

PBSD is not limited to the design of new buildings. With it, existing facilities can be evaluated and/or retrofitted to reliable performance objectives. Sharing the common framework of PBSD, existing buildings and new buildings can be compared equitably. It is expected that a rating system will develop to replace the currently used *Probable Maximum Loss* (PML) system. Such a system is highly desirable to owners, tenants, insurers, lenders, and others involved with building financial transactions. Despite its inconsistency and lack of transparency, the PML system is widely used and a poor rating often creates the financial incentive needed for retrofit decisions.

PBSD will provide a common base for design of new buildings, evaluation of existing buildings, and prediction of future damages. This will enable the results of regional loss estimates to be directly interpreted in terms of building code and retrofit strategies. PBSD will thus support and encourage efficient mitigation on both an individual and a regional scale, resulting in safer and economically stronger communities.

The availability and use of PBSD will also allow building owners and a local community to determine the performance level of buildings within their jurisdiction. This is especially true for structures that are critical to the continued function and livability of a community. For this reason, PBSD can play a significant role in meeting the intent and goals of FEMA's Project Impact initiative to reduce future losses.

This *Action Plan* presents a rational and cost effective approach by which building stakeholders: owners, financial institutions, engineers, architects, contractors, researchers, the public and governing agencies, will be able to move to a performance based design and evaluation system.

The Plan recognizes that there is a strong demand from stakeholder groups for more reliable, quantifiable and practical means to control building damage. It also recognizes that there is not a focused understanding among these groups as to how these goals can be obtained. This Plan describes how performance based seismic design guidelines can be developed and used to achieve these goals. It will be a vehicle to bring together the diverse sets of demands from within the stakeholder groups and distill them into cohesive and practical guidelines. It engages each of the groups in the development these guidelines, by which future building design will become more efficient and reliable.

What is Performance Based Seismic Design (PBSD)?

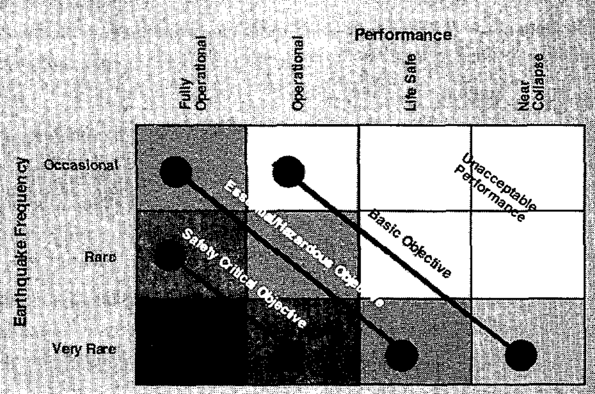
The basic concept of performance based seismic design is to provide engineers with the capability to design buildings that have a predictable and reliable performance in earthquakes.[4] Further, it permits owners and other stakeholders to quantify financially or otherwise the expected risks to their buildings and to select a level of performance that meets their needs while maintaining a basic level of safety.

PBSD employs the concept *of performance objectives*. A performance objective is the specification of an acceptable level of damage to a building if it experiences an earthquake of a given severity.[5] This creates a "sliding scale" whereby a building can be designed to perform in a manner that meets the owner's economic and safety goals. A single performance objective that requires buildings remain operational even in the largest events, will result in extraordinarily high costs. Conversely, a design where life safety is the only consideration may not adequately protect the economic interests of building stakeholders.

A key to knowing how a building will perform in a given earthquake is having the ability to estimate the damage it will sustain and the consequences of that damage. Current codes do not evaluate a building's performance after the onset of damage. Instead, they obtain compliance with a minimum safety standard by specifying a design which historically has protected life safety in earthquakes. In some cases, the code may actually be unconservative, if a building's irregularities are very substantial, or if a higher performance level such as damage control is the desired.

The Concept of Performance Objectives

Recently, the SEAOC Vision 2000 and FEMA 273 projects have described one concept of performance based seismic design. In the chart below, performance is shown on the horizontal axis (with increasing damage to the right) and the severity of earthquake (in terms of frequency) is shown on the vertical axis. Each square represents a *performance objective*: a performance state at a given earthquake intensity. The diagonal lines represent design criteria that an owner might impose on the building. For example, the most cost-effective design for a retail store might be to the "basic" criteria, whereas a high-tech manufacturer may want the reduced risk obtained with the "essential/hazardous" criteria. A local jurisdiction, on the other hand, may require that a hospital meet the "safety critical" criteria.



Source, Vision 2000

PBSD differs from current codes in that it focuses on a building's individual performance. It provides a road map that permits design professionals, owners and other stakeholders to learn more about a building's performance in different earthquakes, and implement a design that optimizes design and construction costs with respect to life-cycle performance. In its broadest sense, PBSD creates global planning opportunities for reducing economic and social losses to whole communities, regions and states.

To implement PBSD several issues must be resolved. PBSD will change the way stakeholders look at the built environment. It will require a comprehensive effort to bring the various interested parties to a consensus. Six challenges to adoption exist. They are:

- Increasing the current knowledge base of building behavior. This fundamental issue will require that broader and more accurate information be developed and collected on structural and nonstructural performance.
- Raising awareness among stakeholders about how PBSD can address many of the problems they already perceive with current design practice.
- Developing PBSD to be compatible the stakeholders' economic interests.
- Communicating the complex concepts and information in a way that is understandable to all stakeholders.
- Reducing uncertainty about how PBSD will effect stakeholders, in terms of cost and possible changes in liability exposures.
- Implementing incremental changes in the current standards, to create a continuum of design improvement rather than a perceived radical change.

This *Action Plan* identifies the specific tasks required to develop a cohesive set of products and guidelines that will meet these challenges. These products will be more than just technical documents. The Plan calls for going beyond earlier and more purely analytical performance based efforts by creating education and implementation programs to bring all stakeholders on board.

This Plan is to be used by the teams developing the guidelines. It will provide a mechanism to ensure that the goals of PBSD are being tracked. It encourages creativity while capturing the required elements of a successful program. For each of the products, a proposed budget and schedule are presented. A priority is assigned to individual tasks so that the program can be tailored to an overall funding level.

A Successful Use of PBSD

A major institution recently completed the seismic retrofit of a four-story concrete frame building using PBSD. The building was considered to represent a life safety hazard in the event of a large, nearby earthquake. The expected loss of lives and capital was unacceptable. A conventional, code based strengthening scheme would have resulted in such a high retrofit cost that replacing the entire facility might have been more practical. The cost and temporary loss of operations during replacement, however, were unacceptably high.

Using PBSD, engineers evaluated the building's performance, identifying the specific elements that contributed most to expected loss. A strengthening methodology was devised which focused on protecting these elements. To educate local building officials and the building users, the engineers made several presentations describing the methodology. The resulting design cost was less than one-third of the conventional scheme and required no disruption to the occupants. In fact, the strengthening is expected to produce a performance that exceeded the owner's minimum requirements. Formerly, this building represented a significant fraction of the institution's total expected earthquake losses. Now, the owner will be able to reallocate its limited emergency disaster funds to the next most needy facilities.

Products Necessary to Implement Performance Based Seismic Design

Six "products" are needed to create a PBSD standard that is comprehensive and acceptable to stakeholders. They are:

1. A **Planning and Management Program.** Currently there is a demand within the stakeholder community for more reliable ways to predict and control building performance. These demands, however, are not clearly articulated and are often conflicting. Clearly, though, there is increasing recognition that problems exist with current design practice. The greatest challenge to creating a successful PBSD program is distilling the most important needs within these demands and synthesizing from them a cohesive guideline for performance based design. A significant effort will be required to ensure that the PBSD guidelines respond to these needs fairly, are accepted by stakeholders and are implemented effectively. The *Action Plan* must be a vehicle to communicate these needs to the entire community, so that the solutions are appropriate and widely acceptable. A formal program will be necessary to educate people about how PBSD can respond to many of their current demands for more reliable and cost effective performance. The Planning and Management Program will consist of the following components:

- A **steering committee** to shepherd and promote the development of the Guidelines. This group will be responsible for insuring that the efforts by the various working groups are tracking towards the goals laid down in this *Action Plan.* It will work collaboratively with the stakeholders to create an effective coalition of interests. It will question stakeholders directly in a series of forums about what they see as concerns and benefits. This group needs to function as facilitators and encouragers to promote adoption.
- An **education strategy** to facilitate the use of the Guidelines. This will require a concentrated effort including conferences, workshops and publications to raise awareness and assist stakeholders in using the guidelines. Integration of the guidelines into codes and practice, and adoption by local and state jurisdictions needs to be accomplished in an incremental way yet with a defined timetable and strategy.

2. **Structural Performance Products (SPP)** The **SPP** will form the core reference material for the guidelines. They will consist of technical documents that quantify performance levels, define how to evaluate a building's performance, and develop methods for designing a structure to meet a performance level with defined reliability. They will present the necessary analytical information needed by engineers. A goal is to address new and existing buildings so that the guidelines will be appropriate for new design as well as retrofit. The creation of these products will require major technical research in order to

produce a comprehensive framework for structural design.

3. **Nonstructural Performance Products (NPP)**The **NPP** function similarly to the **SPP** but focus on the nonstructural components of a building: partitions, piping, equipment, contents, etc... In the 1994 Northridge Earthquake, several prominent buildings had significant losses not because of structural damage, but because of nonstructural damage such as broken sprinkler pipes. To truly achieve a desired performance, design of nonstructural components is as critical as the design of the structure itself. Engineers from many disciplines, architects and manufacturers who design and supply a building's nonstructural components will develop these products. Like the **SPP**, the **NPP** will require significant research, especially in the areas of equipment testing and certification. Also like the **SPP**, the **NPP** must include research focused on existing building stock.

4. **Risk Management Products (RMP)** The **RMP** are the key to bringing owners, financial institutions and governing agencies into the PBSD process. These documents will be financially oriented and will develop methodologies for calculating the benefits of designing to various performance objectives and for selecting appropriate design bases for individual and classes of buildings. The goal will be to provide a basis for stakeholders to make rational economic choices about the level of performance and the comparative costs to reach those levels.

5. The **PBSD Guidelines.** The PBSD Guidelines will be the actual document used by design professionals, building officials, material suppliers and equipment manufacturers to implement performance based design. It will distill and synthesize information from the **SPP, NPP** and **RMP** into one document that is usable by each of the groups. It is intended that this document will be published as a FEMA guideline and will serve as a basis for codes and practice thereafter. The guidelines will contain a technical commentary for reference. It will address new design as well as retrofit and it will serve as a basis for development of building "rating" systems, to provide financial guidance to stakeholders.

6. **A Stakeholders' Guide.** This document will function as a non-technical commentary to the Guidelines, explaining PBSD and providing instruction to the non-technical audience. PBSD will require a shift in the role owners, lending institutions and others play within the design process. These stakeholders will now be a fundamental part of developing the design strategy. The Stakeholders' Guide will help these groups choose objectives that best meet their cost and performance goals.

Schedule and Budget

Given adequate funding, implementation of the *Action Plan* can occur over a ten-year period. This is an ambitious schedule, as the products require major research and consensus building efforts. The steering committee will be a constant throughout the process, to facilitate and coordinate the various products. The products will be developed somewhat concurrently, with the Structural and Nonstructural Performance Products and the Risk Management Product leading the Guidelines and the Stakeholders' Guide. At milestones throughout the project, drafts of the Guidelines and Stakeholders' Guide will be prepared using information from the technical products. The provisions will be verified through example applications and stakeholder review, resulting in refinement or modification of the research efforts. In this way, the project will remain on track and under the scrutiny of the involved stakeholders. Throughout the project, the Planning and Management Program must be developed and employed, in order to gain acceptance from the stakeholders. In order to achieve wide acceptance of PBSD, it is imperative that participation be sought from a diverse group of stakeholders in broad geographical regions, and from both small and large businesses and municipalities. The participants must have the skills needed to develop each product, and represent as many points of view as possible.

The costs shown below are given as a range, the lower number representing the minimum essential funding level required to obtain a basic framework for PBSD, and the higher number representing the optimal level needed for full and effective implementation. Within the *Action Plan* a more detailed breakdown of the costs is presented, describing the specific tasks associated with each product, along with a flowchart describing the relationships between the six products. Priorities are attached to each task so that funding decisions can be made more easily.

Cost	Product	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
$3.8-4.3	Planning and Management Program										
$6.0-7.5	Structural Performance Products										
$3.0-4.6	Nonstructural Performance Products										
$2.8-4.6	Risk Management Products										
$3.5-4.4	PBSD Guidelines										
$1.2-1.9	Stakeholders' Guide										
$20.4-27.3		1.1	2.1-2.4	2.0	2.4-2.9	2.0-2.8	2.6-3.9	2.1-3.0	2.5-3.6	2.1-2.8	1.5-2.7

Range represents essential and essential + optimal tasks
Amounts shown are in 1998 dollars

Conclusion

Few lives have been lost in major seismic events, in buildings designed under modern codes. The economic losses in recent earthquakes, however, have put a strain on communities, owners, lenders, insurers, governments and building users. The process of building design and construction must undergo a significant change in order to reduce future losses to these stakeholders. Current codes simply are not sophisticated or robust enough to allow designs to be refined to the extent that loss prediction and reduction are reliable.

Performance based seismic design has been in development for several years and represents a necessary strategy for reducing earthquake losses. It focuses on the economic and social goals of building stakeholders and integrates financial modeling with the latest engineering research. The various efforts within PBSD, however, have yet to be fully developed and synthesized into a comprehensive workable guideline. This major step is key to fulfilling the promise of PBSD and reaping its benefits.

This *Action Plan* lays out a rational, cost-effective and achievable program for establishing and implementing PBSD in a manner that will benefit each of the groups with a stake in the built environment. On an individual building basis and on community, county and statewide levels, PBSD offers opportunities to more reliably predict building performance and to reduce the social and economic impacts of earthquakes.

PBSD – A Regional Perspective

Stanford University is a microcosm of many large, highly developed, communities. It comprises nearly 900 buildings and over 12 million square feet of residences, classrooms, auditoriums, laboratories, and administrative buildings. The total population, including students, faculty and staff exceeds 20,000. The building inventory is diverse, ranging in age from over 100 years old to brand new and including masonry, concrete, steel, and wood frame construction.

Stanford, located less than five miles from the San Andreas Fault, faces a considerable seismic hazard. In a large nearby earthquake, the exposure--human lives, capital investment, and business income--is sizable. To reduce potential losses, the University has been using some of the fundamental concepts of PBSD on a campus-wide level to rehabilitate existing and build new facilities for nearly ten years. The total investment amounts to hundreds of millions of dollars.

Over time, PBSD at Stanford has evolved from an innovative standard for retrofit of hazardous existing buildings into a regional planning tool. Engineers identify specific risks associated with individual buildings using performance based evaluation techniques. Concurrently, university planners and managers establish the relative importance of their facilities in terms of occupancy load, replacement value, and impact on the academic mission. There are two important results of this process. First, Stanford optimizes mitigation funding by investing where the reduction in potential losses is most productive. Second, Stanford knows what to expect when it comes to response and recovery planning for earthquakes.

The experience at Stanford illustrates both the usefulness of PBSD and its long-range possibilities - safer and economically stronger communities.

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[3] SEAOC 1996, *Recommended Lateral Force Requirements and Commentary,* Structural Engineers Association of California, 1996.

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See *Action Plan* for additional references

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I Introduction

This *Action Plan* provides as its primary goal:

A strategy, definable tasks, a budget and a schedule for the development and implementation of usable and widely-acceptable performance based seismic design (PBSD) guidelines.

The Plan can function as a road map for the teams of people who will eventually create and implement these guidelines. The guidelines will provide a means for moving from the current practice of building design and construction intended primarily to protect life safety, to a system that also addresses the protection of the economic welfare of the public. It is not intended that this Plan limit the creativity of the development teams. Rather, it should serve as a means to track progress toward the project's goals, and offer guidance about the major challenges along the way. In fact, the Plan encourages innovation in the design and analysis of building systems, and in the way we view the relationships between members of the building development community.

The current state of the art contains valuable and practical information that has been implemented on some individual projects. A goal is to use this information where possible, filling in the gaps with new research and evaluation methods. References are included at the end of the document which describe the historical issues surrounding PBSD.

This document is, as its name implies, an *action plan*, focusing on the specific tasks that must be accomplished to implement PBSD broadly. The Plan centers about development of six "products," which are considered necessary for the full, effective adoption and implementation of PBSD. Each contributes to meeting a specific portion of the primary goal. The term "product" does not refer exclusively to written documents, but implies any means by which information is delivered to the intended audience. The products may also include presentations, workshops, audio/visual material, ad-hoc committees, teaching materials, etc.

An important challenge to implementing PBSD is overcoming the perception that it is only of benefit and interest to structural engineers and always adds cost to a project. To be successful, PBSD must come from and be embraced by the full spectrum of "stakeholders" within the building development community. The term "stakeholder" refers to owners, engineers, architects, researchers, financial institutions, materials suppliers, contractors, building officials, government agencies, and the building occupants: in essence, society at large. This obviously is a large group, but buy in from each is vital if PBSD is to work.

In fact, many of these groups are already calling for changes to the current state of design practice, and asking for more reliable ways to predict and control building performance. The *Action Plan,* therefore, solicits the involvement of each group. The Plan holds as a basic philosophy that the development of the products should not be dominated by one group. Clearly, each will have areas of expertise, but at all levels, an equal measure of respect is important in obtaining broad acceptance. PBSD, in its broadest sense, should be used as a global planning tool for large businesses, cities, counties and states.

At its heart, PBSD requires stakeholders to look differently at the built environment. By definition, it implies multidisciplinary collaboration to insure that buildings are built more efficiently, reliably and with predictable performance.

Product Summary

Each of the six products and the tasks and budget associated with its development is presented in a separate section. It is important to understand how each will come together to build a working framework for PBSD.

The six products are described below. The first product tracks through the entire project, shepherding the development of the other products and obtaining stakeholder support.

- **Planning and Management Program.** A formal program will be developed to educate stakeholders about PBSD. The Planning and Management Program will be implemented by a **steering committee** to shepherd and promote the development of the Guidelines and an **education strategy** to facilitate their use and adoption. The goal will be to ensure that the project accomplishes its purpose and that it is accessible and relevant to the stakeholders.

The next three products form the core technical basis for the guidelines. They will require substantial research, analysis, verification and possibly testing.

- **Structural Performance Products (SPP).** The **SPP** will quantify methods for predicting structural performance for various levels of seismic hazard. They will contain design and evaluation methodologies for both new and existing buildings. A focus of the research will be to increase reliability in the design and analysis process, thereby reducing uncertainties. Effort will be made to address existing as well as new construction. Early in the development of this product, an effort will be made to address the current state of the art and inherent uncertainties and gaps therein, and from that identify research needs and goals appropriate to reducing these uncertainties and gaps.

- **Nonstructural Performance Products (NPP).** The **NPP** function similar to the **SPP** but focus on the nonstructural components of a building: partitions, piping, equipment, contents, etc. The **NPP** should address new components and components already in place within existing buildings. Development of guidelines for component testing and certification will be part of these products. The goals and scope of separately funded programs to collect information on performance in past and future earthquakes and to test equipment will also be developed. Similar to the SPP, an initial effort will be made to assess the state of the art and develop a research plan.

- **Risk Management Products (RMP).** The **RMP** will be financially oriented and will develop methodologies for calculating the costs and benefits of implementing PBSD. A major effort will be to combine various levels of risk, performance and hazard to allow a wide range of design objectives to be evaluated as potential bases for new procedures. Research will include studies on reliability, cost-benefit modeling, loss reduction, capital planning, etc. A focus will be to provide owners with tools that can reliably be used to select appropriate performance objectives for projects. The information produced in the RMP should also serve as the basis for the development of a building rating system.

The last two products comprise the end use documents, which are distilled and synthesized from the technical reference products.

- The **PBSD Guidelines.** The Guidelines will be the actual document containing the performance based design procedures. It is intended that this document will be published as a FEMA guideline and can be incorporated into future codes and practice. It will form the technical basis for design and analysis and be written to bring consistency throughout the industry. It will be usable for both new design and existing building retrofit. It will also contain a technical commentary to the Guidelines.

- A **Stakeholders' Guide.** This document will function as a reference and planning guide for owners, financial interests and other non-technical stakeholders. It will include financial tools that permit owners to make funding decisions about buildings using performance based design concepts. The guide will be written for a non-technical audience and contain graphic aids and example applications.

Summary Budget and Schedule

This section summarizes the overall funding request for the development of the PBSD products, and a schedule for completion within ten years. Detailed breakdowns of the cost and duration of each product are contained in the following sections.

The ten-year timeframe for completing the six products is ambitious. It will require that teams work concurrently where possible to reduce the overall schedule. This will mean that the number of people involved with the project will be large. While this creates an administrative challenge, it is consistent with the desire to obtain broad ownership of the resulting guidelines.

Each product contains "essential" and "optimal" funding levels. Material that is essential is required to create a basic framework for PBSD. Without this material, fundamental gaps will be left. These gaps may significantly reduce the likelihood that PBSD will be widely adopted. **The optimal material is very important if PBSD is to be truly effective.** The momentum established with the framework development should be continued, by implementing the optimal tasks. This lesson has been learned through previous efforts at developing guidelines. In each product section, tasks are identified as either essential or optimal, and from these the summary numbers are drawn.

Several tasks consist of supporting programs of research, testing or information gathering.

The funding requests for these tasks represent the costs to set up the programs and to identify an ongoing source of funding for their implementation.

Several outside sources will be tapped for these efforts, including owners' groups, materials and equipment manufacturers, and government agencies.

The budget also provides a general funding breakdown by year. As one of its first tasks, the project steering committee will refine these allocations based on the establishment of the working teams. Because work on all six products is done somewhat in parallel, the steering committee may reschedule tasks and funding as the project progresses.

The funding request is shown in 1998 dollars and will need to be escalated over the duration of the project.

Following the budget is a flowchart showing the relationships between the products. This is a very important part of PBSD development. Rather than a linear process, where the technical documents are developed and the end use documents are prepared following, the flowchart describes a more parallel process. At milestones during the technical research, information is gathered and fed into a framework for the Guidelines and Stakeholders' Guide. The Guidelines are then reviewed and verified, and as necessary the direction of the technical work is refined or changed. In similar past projects of this scale, this has allowed a regular review of the material being developed by the stakeholders. The steering committee will have an important responsibility in managing this process. The Planning and Management Program continues throughout the project to ensure proper coordination. The schedule of tasks and subtasks within each product should generally follow the descriptions within the flowchart, but may be revised by the steering committee based on stakeholder review.

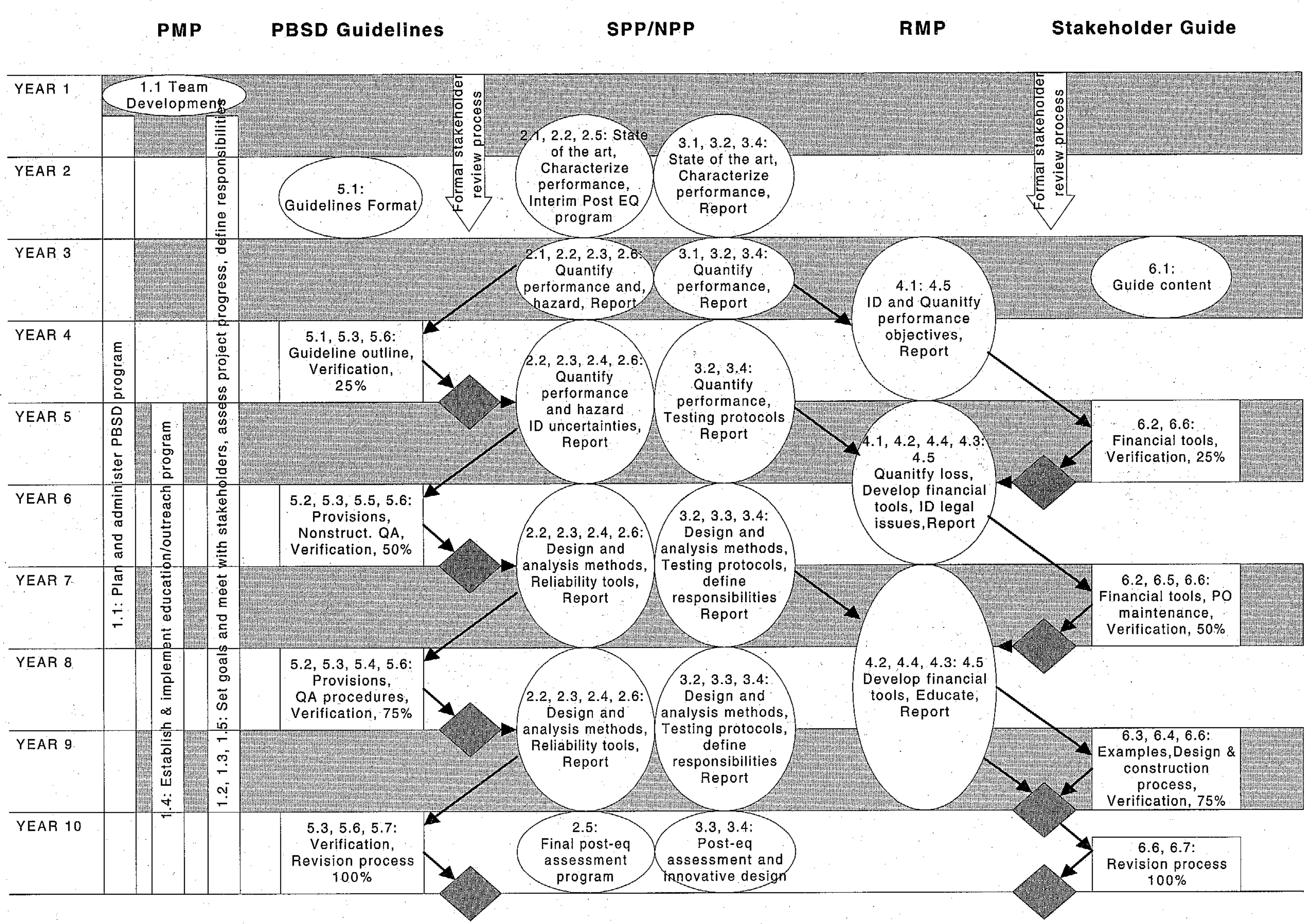
The goal of this schedule is not to rigidly define the process, but to identify the relationships between the products and their tasks.

FUNDING REQUEST: SUMMARY TABLE (DOLLARS IN MILLIONS)

Cost	Product	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
$3.8-4.3	Planning and Management Program	$0.31	$0.36	$0.21	$0.21	$0.45	$0.45-0.61	$0.45-0.61	$0.45-0.51	$0.45-0.51	$0.45-0.51
$6.0-7.5	Structural Performance Products	$0.35	$0.93-1.3	$0.54	$0.70-0.93	$0.70-0.93	$0.70-0.93	$0.70-0.79	$0.70-0.79	$0.70-0.79	$0-0.16
$3.0-4.6	Nonstructural Performance Products	$0.45	$0.7	$0.27	$0.27	$0.27-0.47	$0.27-0.47	$0.27-0.47	$0.27-0.47	$0.27-0.47	$0-0.6
$2.8-4.6	Risk Management Products			$0.85	$0.34-0.60	$0.39-0.76	$0.39-0.76	$0.29-0.53	$0.29-0.53	$0.28-0.52	
$3.5-4.4	PBSD Guidelines		$0.08		$0.91		$0.83-1.13		$0.83-1.28		$0.83-0.98
$1.2-1.9	Stakeholders' Guide			$0.15		$0.17		$0.37-0.62		$0.37-0.52	$0.17-0.42
$20.4-27.3		$1.1	$2.1-2.4	$2.0	$2.4-2.9	$2.0-2.8	$2.6-3.9	$2.1-3.0	$2.5-3.6	$2.1-2.8	$1.5-2.7

Range represents essential and essential + optimal tasks
Values are rounded
Amounts shown are in 1998 dollars

Action Plan for Performance Based Seismic Design



FLOWCHART SHOWING RELATIONSHIPS BETWEEN PRODUCTS AND TASKS

Layout of Product Sections

The following sections are devoted to the six products described above. Each begins with a general description of the product. The description mentions the core material that will be included; however, as development occurs additional or alternative approaches may be desirable. In order to provide some flexibility in project funding, the Plan describes the material as either essential or optimal, as described in the previous section.

A list of tasks follows the product description. A list of primary team members involved with the task and a preliminary budget is shown. Other stakeholders with a more indirect interest are shown in parenthesis. The budget assumes a rate of $130 per person-hour (this includes a markup for support staff, expenses and funding for workshops, travel, etc. as required). Task duration is listed as well. Most of the tasks continue over several years, so that the duration is better considered using the flowchart in the previous section. It is not expected that effort will be continuous over the entire duration of a task. The task budgets are based on teams working at about one-quarter time. Some tasks will require that the teams be larger or smaller or that the effort steps up at some period then relaxes during review cycles. Where this is the case, the budget has been modified accordingly. It will be up to the steering committee to monitor this carefully.

Several tasks include the identification of additional funding sources for the full implementation of post earthquake data collection, instrumentation, component testing, future revisions to the Guidelines, ongoing education efforts, etc. The budget figure shown for each of these tasks includes the team's effort to identify these funding sources and to set up the protocols and goals for these programs. The funds necessary to actually implement the programs may be high (more than $1 million each) and are not part of this *Action Plan*. Sources of funding may include government agencies, research consortia, equipment manufacturers, material suppliers, professional societies, building owner groups, etc.

Many complex issues must be researched and resolved when developing each of the products. Several authors have written issue papers in preparation for the development of this *Action Plan*. The papers describe some of these issues as well as potential paths of resolution. As a reference, they are included in an appendix to the Plan. Following the description of each of the products, a brief discussion of the main challenges is presented. The product teams will need to devote a special effort to meeting them. The challenges can be grouped topically as follows:

- Analysis and modeling approaches
- Ground motion characterization
- Performance levels and damage state definition and quantification
- Acceptability evaluation procedures and criteria
- Reliability quantification and assessment
- Funding
- Administration
- Education and Incentives
- Data Acquisition

PRODUCT 1 - Planning and Management Program

Currently there is a demand within the stakeholder community for more reliable ways to predict and control building performance. These demands, however, are not clearly articulated and are often conflicting. Clearly, though, there is increasing recognition that problems exist with current design practice. The greatest challenge to creating a successful PBSD program is distilling the most important needs within these demands and synthesizing from them a cohesive guideline for performance based design. A significant effort will be required to ensure that the PBSD guidelines respond to these needs fairly, are accepted by stakeholders and are implemented effectively. The *Action Plan* must be a vehicle to communicate these needs to the entire community, so that the solutions are appropriate and widely acceptable. A formal program will be necessary to educate people about how PBSD can respond to many of their current demands for more reliable and cost effective performance. The Planning and Management Program will consist of the following components:

➢ *An administrative steering committee to shepherd and promote the development of the Guidelines.*

The steering committee will create the teams that are responsible for developing the various products described in the preceding sections. It will establish the overall schedule for the project and insure that the efforts by the various working groups are tracking towards the goals laid down in this *Action Plan.*

The committee will work collaboratively with the stakeholders to create an effective coalition of interests. It will question stakeholders directly in a series of forums about what they see as concerns and benefits. The committee needs to function as facilitator, encourager and promoter to insure adoption.

The steering committee will not serve as the program manager. It is intended that the funding agency will either directly assume this effort or will assign it to a third party. The committee will work closely with the program manager to ensure good coordination of the project.

➢ *Stakeholder meetings to gain support from the broad range of participants within the built environment.*

PBSD will have a much greater chance of success if, rather than being "sold" to an unreceptive audience, it is developed from within the audience itself. A major goal of this project is to create an end product in which all stakeholders take ownership. To this end, the Planning and Management Program will establish and facilitate forums where stakeholders are queried about their specific needs and asked to participate in the development of each of the products.

- *An education strategy to facilitate the use of the Guidelines.*

  The education strategy will require a concentrated effort of conferences, workshops and publications to raise awareness and gain acceptance of the guidelines. Integration of the guidelines into codes and adoption by local jurisdictions needs to be accomplished in an incremental way yet with a defined timetable and strategy. The steering committee, stakeholders involved with the development of the guidelines and professional educators will lead seminars, write articles and assist with the implementation of the guidelines nationwide.

Task 1.1 – Team development

Task 1.1.1 – Create a steering committee

Description:

The first major task is for a steering committee to be created. This group will remain together for the duration of the project. The goal of the group will be to shepherd the development of the PBSD Guidelines. The committee will include a broad spectrum of people from all stakeholder groups. It is important that the group not be seen as too heavily weighted with any one group. Key to successful implementation of PBSD is input from all users. The group will layout the basic outline for each of the product development teams, and will select the team members and reviewers. These teams will consist of experts on the product material, although diversity will still be important to include different points of view. The steering committee will be responsible for overall project coordination, ensuring that work by each team is produced in a timely manner and has been reviewed for both technical accuracy and for usefulness. The group will develop status report formats for each team to use on a regular basis. It will act as a liaison with other concurrent research projects, to facilitate the free exchange of ideas. It will hold regular meetings to discuss progress of the project and resolve any conflicts. It will serve as a means to transfer information between teams, ensuring that the efforts are complimentary and supplementary.

The committee will coordinate their efforts with the program management structure established by the funding agency.

The committee will review management models for other development projects (SAC, NEHRP Guidelines, FEMA 273, HAZUS, etc.) and assist FEMA in developing the most appropriate model for this effort.

Personnel: Design professionals, Researchers, Contractors, Material suppliers, Financial interests, Owners, Building officials, Government agencies

Priority: Essential
Budget: $1,500,000
Duration: Throughout the project

Task 1.1.2 – Establish product development teams

Description:

The steering committee will provide oversight for the selection of teams to develop each of the products and perform each of the tasks described in this *Action Plan*. The group will establish a means to fill the teams with a wide range of talented individuals expert in their fields. The group will establish terms of compensation and job responsibilities. The group will review the status and progress of the teams on a regular basis. It will make changes to their composition as necessary to maintain effective progress that meets budget and scheduling constraints.

Personnel: Design professionals, Researchers, Contractors, Material suppliers, Financial interests, Owners, Building officials, Government agencies

Priority: Essential
Budget: $100,000 (budget for the product development teams themselves are included within associated tasks)
Duration: Throughout the project

Task 1.2 – Set goals with stakeholders

Description:

The steering committee will convene a series of workshops with stakeholder representatives through which several issues will be resolved. These include identifying the most important concerns owners and other financial stakeholders have when managing risk, and the benefits that these stakeholders expect from PBSD (reducing construction costs, optimizing overall life-cycle costs, developing a building rating system, minimizing down-time, etc.). The team will also identify the positive and negative aspects of current codes and design standards from design, cost and usability points of view. The workshops will also focus on establishing levels of analysis and design complexity. This will require that a broad section of the stakeholder communities be involved. A goal is to be able to quantify the level of effort that will be required of the designers in terms of cost, time and sophistication, so as to be as flexible as possible. The team will reach a consensus about the style of presentation.

Personnel: Design professionals, Researchers, Material suppliers, Architects, Contractors, Financial and insurance interests, Owners, Building officials, Government agencies

Priority: Essential
Budget: $200,000
Duration: 2 years

Task 1.3 –Assess project progress with stakeholders' groups

Description:

The steering committee will identify interested parties from all the stakeholder communities and bring them into the PBSD development process. The team will establish regular lines of communication and dissemination of information. It may tap from these parties, people to serve on other task teams.

The steering committee will hold a series of meetings with the stakeholders' groups throughout the project to gauge and review the progress of the project. The goals will be to present the status of the project to the stakeholders, to insure that the project continues to address their needs and to give them a voice in refining the project's direction. To achieve the most efficiency, the meetings should be conducted by professional facilitators. The team will establish recording procedures and formats for agendas, presentations, minutes, etc. The team will collect and disseminate the information developed in the meetings.

The steering committee will make a special effort to remain in contact with the stakeholders' groups throughout the project with correspondence, ad hoc meetings, etc. so that at no point does the project disconnect itself from their input. Gaining broad acceptance of PBSD will only be possible through continual interaction with the people who will be using it.

Personnel: Design professionals, Researchers, Financial interests, Owners, Contractors, Material suppliers, Building officials, Government agencies

Priority: Essential
Budget: $600,000
Duration: On a regular basis throughout the project.

Task 1.4 – Develop education and incentive programs

Task 1.4.1 – Develop an education program

Description:

The steering committee will disseminate information about PBSD to users. This will be accomplished with a variety of teaching tools including, publications, tutorials, seminars, workshops, continuing education classes, multimedia tools, etc. The team will make a concerted effort to reach those outside the engineering community, including architects, contractors, owners, financial interests and material suppliers. It also must reach users in all regions of the country.

The steering committee will develop core teaching materials and identify funding sources to provide ongoing educational efforts. Training materials should be professionally developed and be of the highest quality. The team will identify and train teachers from a broad range of backgrounds to present the material. The team will be composed of experts with specialization in outreach, dissemination, and education. It will receive input from the design professionals, researchers and others who have developed the technical and end-use products.

The steering committee must also reach indirect stakeholders such as building occupants, regulatory agencies and the public at large. Material should utilize various media to clearly explain PBSD. The team will identify funding sources to permit an ongoing outreach effort beyond the ten-year duration set forth in this *Action Plan.*

Personnel: Outside experts with specialization in outreach, dissemination, and education. (Design professionals, Researchers, Contractors, Material suppliers, Financial interests, Owners, Building officials, Government agencies)

Priority: Essential
Budget: $1,300,000
Duration: 6 years

Task 1.4.2 – Develop an incentive program for using PBSD

Description:

The steering committee will establish a collaborative program by which the benefits of using PBSD will be spread among all the stakeholders involved. It will identify funding sources, both private and public, which will offer incentives for using PBSD, especially in the short term when it is still seen as an emerging technology.

The steering committee will establish cooperative relationships between buyers, sellers and installers, to develop better performing nonstructural components. Among these three groups sources will be identified to create a fund for developing innovative designs.

Personnel: Outside experts, Design professionals, Researchers, Contractors, Material suppliers, Financial interests, Owners, Building officials, Government agencies

Priority: Optimal
Budget: $300,000
Duration: 3 years

Task 1.5 – Clarify responsibilities between stakeholders

Description:

The steering committee will write a plan for the division of responsibility between designers, contractors, manufacturers, installers and owners so that at all stages of a building's life, responsibility for the seismic performance of the structural and nonstructural components is maintained. It will identify the effects that this division will have on these groups, practically, financially and with respect to liability. The team will develop a "hand-off" program so that information is smoothly passed between groups. A goal of this task will be to find ways for each of these groups to work collaboratively toward the same ends.

Personnel: Design professionals, Contractors, Material suppliers, Owners, Building officials, Government agencies

Priority: Optimal
Budget: $200,000
Duration: 2 years

Challenges

➢ *Funding*

The government cannot and should not fund all of the research and support all of the incentive programs that will be necessary to implement PBSD. Many stakeholders will benefit from PBSD and should share in these costs. It will be a challenge to identify sources of funding for these projects from within the other stakeholder communities. Stakeholders will need to be convinced that spending money on research will be in their long-term financial interests.

➢ *Administration*

The aggressive schedule and need for consensus building require that many people be involved with the project. Management of these teams and their interests will perhaps be the most difficult challenge. The steering committee will need to be diverse and must be able to reach consensus on major issues. Substantial energy should be devoted to building strong teams and developing relationships within them. These groups will be together for many years, so they need to work well together. A strong management structure and project manager will be essential to insure that this Plan is implemented properly and remains on schedule and on budget.

Issues of equity and responsibility will be important challenges. Each of the stakeholders needs to see PBSD as a "win" for them. Compromise will be an inevitable part of the process. The steering committee must insure that each group is heard and its needs accounted for.

Understanding changes in liability will be a major challenge, as groups become responsible for different things during the entire life of a building. The legal ramifications of these changes may affect how widely PBSD is used. The steering committee must address these concerns early on and with compromises that satisfy each group but do not reduce PBSD to an ineffective tool. The group will need to bring in legal expertise to help resolve this issue.

➢ *Education and Incentives*

Overcoming long held beliefs about the nature and importance of design and about its relation to other aspects of financing, construction and maintaining a building will be difficult. The steering committee and education groups must be supporters of the process and its expected benefits.

Many potential PBSD users will be overwhelmed by the changes required of them. It will be important to allow for an incremental infusion of the guidelines into general use and into building codes. The steering committee will face the challenge of bringing PBSD online quickly yet in ways which are not threatening to users.

PRODUCT 2 - Structural Performance Products

These products will form the core reference material of the PBSD Guidelines. They will include three main areas of focus:

- *Methodologies for quantifiably and reliably defining structural performance and acceptability criteria on a building and component basis.*

  This effort will define performance levels in terms of drift, damage, ductility or other parameters for each building type. The work will synthesize the results of analytical and experimental data. It will consider the variability and uncertainties involved, with the goal of obtaining reliable estimates of material, component and system performance.

- *Analytical and design procedures by which engineers can predict a building's expected performance with well defined reliability.*

  Performance engines will need to be developed to permit structural evaluation by the entire engineering community. It is important that they be sophisticated, but broadly usable. Methodologies need to be developed for design of new and retrofit of existing buildings. Techniques need to account for current computer technology that is widely available and that which can be expected in the future.

- *Tools that can more reliably predict and appropriately quantify expected ground motions.*

  These tools will characterize the seismic demand requirements for linear and nonlinear analyses, using response spectra and time-histories. Ground motion parameters that correlate to performance will be identified and quantified. Simplified representations of these parameters into static base shear and lateral force distribution formulas will also need to be developed. Issues of reliability, uncertainty and confidence levels need to be incorporated into the determination and effects of ground motion. The information will have to be flexible enough to be used by a wide audience. A procedure for data collection through instrumentation will be developed.

It will be highly desirable to identify other sources of funding to promote basic research in the areas defined by the tasks. These sources may include government agencies, the materials industry, and others. The budget amounts shown for each will likely be sufficient to achieve a working framework for PBSD, but expanded research will broaden its scope and usefulness.

Task 2.1 – Identify current PBSD information and additional research needs

Task 2.1.1 – Assess the state of the art in structural performance and analysis

Description:

The team will gather existing information on structural analysis and design methods and identify gaps in current knowledge. A strong effort will be made to use available information so that research funding can be most efficiently spent. The current state of the art should not define the scope of this project or limit the direction research might take, but rather allow researchers to avoid unnecessary duplication of effort. The team will also assess the usefulness of available information on material performance, component acceptability, geotechnical parameters and hazard quantification. An effort will be made to characterize the reliability of existing procedures and information.

Personnel: Design professionals, Researchers

Priority: Essential
Budget: $150,000
Duration: 1 year

Task 2.1.2 – Develop a research plan to advance the state of the art

Description:

Once gaps in existing knowledge have been identified, the group will develop a research plan to fill them. The goal will be to develop a road map of research by which the tasks within this *Action Plan* can be accomplished. The plan will be detailed enough to be used by stakeholders, laying out tasks and schedules. An effort will be made to identify outside sources of funding to augment the budgets assigned to each task within the Plan, considering public and private resources.

Personnel: Design professionals, Researchers,

Priority: Essential
Budget: $150,000
Duration: 1 year

Task 2.2 – Develop means by which to characterize, quantify and predict performance

Task 2.2.1 – Develop performance characterization

Description:

The team will reach consensus on the definitions of performance to be used as the basis for PBSD. These characterizations will be quantified in a later task. The goal in this task is to agree on concepts such as life safety, immediate occupancy, etc. The team will decide what these terms mean in relation to casualties, capital loss, down time, and other important parameters. Reaching a firm decision on performance definitions is critical to the rest of the project. It therefore must incorporate the opinions of all stakeholders. Meetings among stakeholder groups will be held to determine which measures of performance are considered the most important and how they relate to analytically predictable behavior. These performance measures will later be coupled with hazard information from Task 2.3, to obtain performance and overall design criteria.

Personnel:	Design professionals, Researchers, Owners, Building officials, Government agencies, Financial interests
Priority:	Essential
Budget:	$250,000
Duration:	2 years

Task 2.2.2 – Develop building and component acceptance criteria

Description:

The team will gather and review existing information on acceptance criteria, and identify gaps in current knowledge. Research will be targeted to fill in these gaps and will include both analytical and empirical processes. Collaboration with testing programs will be important to obtain useful information on component behavior.

Results of this task should be verified with current knowledge about material behavior.

A strong effort will be dedicated to extrapolating component behavior, which is more clearly known, to building behavior, which currently contains more uncertainty. A goal will be to identify and quantify in practical terms criteria for overall building performance.

Personnel:	Engineers, Researchers, Material suppliers
Priority:	Essential
Budget:	$1,000,000
Duration:	Throughout the project

Task 2.2.3 – Develop geotechnical predictors of building performance.

Description:

The team will gather and review existing information on the effects on building performance of subsurface conditions. These will include the effects of soils, soil-structure interaction, and foundations. The team will identify gaps in current knowledge. Research will be targeted to fill in these gaps and will include both analytical and empirical processes. A strong effort will be dedicated to identifying ways to reduce uncertainties related to geotechnical and substructure analysis and design.

Personnel:	Engineers, Researchers, Material suppliers
Priority:	Essential
Budget:	$650,000
Duration:	Throughout the project

Task 2.2.4 – Quantify performance levels.

Description:

Using the definitions developed in Tasks 2.2.1 and 2.2.2, the team will quantify performance levels using appropriate parameters (drift, damage, loss, business interruption, casualties, etc.). The goal in this task is to set the performance parameters so that the evaluation and design methodologies developed in the PBSD Guidelines product can be targeted to definitive numerical quantities.

Personnel: Engineers, Researchers, Government agencies, Building officials,

Priority: Essential
Budget: $450,000
Duration: Throughout the project

Task 2.2.5 – Develop analytic methodologies for achieving performance levels

Description:

The team will fill in the gaps in existing knowledge identified in Task 2.1.1. Research will consist primarily of analytical efforts and development of practical tools. The team will identify promising new techniques and devote research to making them usable within the PBSD framework. A forum will be held, bringing together engineers and building officials to discuss design and analysis methodologies. The purpose of this activity is to understand the broad range of engineering styles used throughout the country.

Following this, the team will develop design and analysis methodologies, which will be usable by the entire design community. A focus will be on developing comprehensive and accurate methods that can be refined and made more practical within the Guidelines product. The methods will include consideration of geotechnical conditions and design of foundations as well as methods for practical assessment of reliability and safety. Modeling strategies will also be developed in this task. The team will keep in mind the limitations of computer applications currently available and anticipated in the future. It will account for the financial investments the design community is able to make in obtaining modeling technology. It will also consider architectural interests in the design process and the engineering limitations that may result.

Personnel: Engineers, Researchers

Priority: Essential
Budget: $1,100,000
Duration: Throughout the project

Task 2.2.6 – Develop analytical predictors of existing building performance

Description:

This effort will proceed in a similar manner to Task 2.2.5, but will focus on existing buildings. The team will research successful examples of retrofit and identify features that should be employed typically. It will quantify uncertainties within the existing built environment.

Personnel: Engineers, Researchers (Material suppliers)

Priority: Optimal
Budget: $650,000
Duration: Throughout the project

Task 2.3 – Develop hazard quantification and prediction methodologies

Description:

The team will develop processes to obtain ground motion information for use in PBSD. It will identify and describe in measurable terms the parameters of ground motion which have the most important effects on buildings. The team will create a standard for characterizing ground motion and will include issues of damping, nonlinearity, duration effects, etc. The team will develop rules for applying ground motion information, to create uniformity of use. Working with members of the earth sciences community, the team will put substantial effort into understanding, quantifying and building a consensus on the effects of edges and basins, soft soils, soil-structure interaction and near-fault ground motion. Similarly, methods to quantify the amount of and consequences of permanent ground displacement will be developed.

Personnel: Engineers, Researchers

Priority: Essential
Budget: $650,000
Duration: Throughout the project

Task 2.4 – Identify uncertainties and develop practical means to assess and increase performance reliability

Task 2.4.1 – Develop means to check and increase reliability

Description:

The team will identify and quantify uncertainties in quantifying seismic hazards, building response and the variability of construction quality. This information will be developed in conjunction with the Risk Management Products, which will focus on the cost implications of these uncertainties. The team will research existing reliability techniques, identifying usable information and gaps. The team will use reliability theory to select and refine the design events and material acceptability. The team will develop simplified methods of reliability analysis, or identify software needs, understandable and usable by engineers. These may include equations, fragility curves for building classes and performance levels, and other tools to help the engineer prepare a design with a defined level of reliability and confidence. The team will also evaluate and reach consensus on appropriate target levels of reliability for specific performance levels (such as life safety or immediate occupancy) and for various building classes and uses.

Personnel: Researchers, Financial interests

Priority: Essential
Budget: $650,000
Duration: 6 years

Task 2.4.2 – Identify methods that optimize constructability, repairability and QA/QC

Description:

The team will evaluate design methodologies focusing on constructability and repairability. The goal will be to identify structural systems that have predictable building performance and can be well controlled in terms of quality. The team will also make a strong effort to identify structural systems that minimize repairability costs following a major event, the goal being to reduce an owner's overall life-cycle costs and downtime.

The team will identify design processes and construction techniques that reduce quality or increase uncertainty in building performance to discourage their use. It will develop specifications and aids to assist designers, owners and contractors in controlling quality during construction. It will develop sample QA/QC programs using existing information where possible.

Personnel: Design professionals, Researchers, Owners, Building officials, Contractors

Priority: Optimal
Budget: $500,000
Duration: 6 years

Task 2.4.3 – Establish a separately funded effort for materials and component testing

Description:

The team will identify separate sources of funding, focusing on materials suppliers, to perform materials testing to fill in gaps in the current state of knowledge. The effort will include evaluating and investigating component performance in terms of quantifiable parameters such as stress, strain, ductility, methods of preparation, etc. The goal is to establish measures of performance that can be used in the analysis and design methodologies described in previous tasks. The team will develop testing protocols for obtaining and cataloguing information.

Personnel: Design professionals, Researchers, Materials suppliers

Priority: Essential
Budget: $400,000 (does not include testing)
Duration: 3 years

Task 2.5 – Establish a program for post earthquake damage assessment

Description:

The team will establish a program by which information can be obtained from existing databases of structural performance. The team will extract relevant information and incorporate it into the study of component and system acceptability criteria. The program will be suitable to extend to future earthquakes, so that current information can continually be updated. The team will research existing building instrumentation efforts and identify knowledge bases that can be accessed to retrieve information. An effort will be made to identify means by which important ground motion information can be extracted from existing and future earthquake records.

Personnel: Design professionals, Government agencies, Researchers, Earth sciences community

Priority: Optimal
Budget: $300,000
Duration: 2 years

Task 2.6 – Prepare documents and reports for use in PBSD Guidelines

Description:

This task will occur at milestones within the research plan developed in Task 2.1.2 and in preparation for each of the Guidelines development phases. The team will gather the technical information and prepare reports and documents for the writers of the Guidelines. Coordination with the RMP and NPP will occur to insure that information is presented in a consistent manner. Once the Guidelines teams have reviewed the work and identified changes or refinements to the research plan, this team will work with the research team for Task 2.1.2 to set out the goals for the next phase of research.

Personnel: Engineers, Researchers, Material suppliers, Building officials, Government agencies

Priority: Essential
Budget: $500,000
Duration: Throughout the project

Challenges

The following list of issues will certainly not encompass all the challenges surrounding the development of the **SPP**, but they should be made a special focus of the development teams.

- *Analysis and modeling*

  It will be important to identify techniques for analysis that can be applied by a broad spectrum of engineering offices. Different methods will need to be calibrated so that results are consistent. Modeling procedures, especially nonlinear methods, will require that software be developed that most designers can obtain and use with reliability and consistency. Academic research has to be translated into formats that can meet the budget and scheduling constraints of design professionals. It may be advisable to collaborate with software houses to develop programs or algorithms based on the procedures.

  Developing consistent approaches for new and existing buildings will also be a challenge.

- *Ground motion*

  Engineers must be able to obtain reliable ground motion information to reduce uncertainty in PBSD design. Error in ground motion assumptions, common in current practice, can quickly overshadow the increased accuracy of the design methodologies. Nonlinear time history analysis has the potential to play a significant role in PBSD. Therefore, procedures for obtaining a robust suite of records suitable for individual sites will be an important part of the overall effort. Understanding the interaction of earthquake sources, travel paths, the site and the structure will also be a difficult challenge.

- *Performance levels and damage states, Acceptability*

  Developing performance indices that are valuable to building stakeholders will be a crucial first step. Engineers may face the challenge of having to develop very specific performance levels and damage states to meet owners' needs.

  Translating elemental damage into global damage will require review of past efforts, research and perhaps significant modeling studies.

- *Reliability*

  Quantifying reliability and uncertainty in component behavior will be a challenge due to the relatively small amount of data from past earthquakes and testing. It will also be a challenge to develop reliability methods that can be adopted and applied by design professionals.

- *Data Acquisition*

  Developing a program for extracting performance data from past and future earthquakes will be a logistical and financial challenge. It will take discipline to maintain the program that is established and to make use of the data that are obtained.

PRODUCT 3 - Nonstructural Performance Products

These products will form an important reference component of the PBSD guidelines. They will include information similar to that developed in the Structural Performance Products, but relating to nonstructural building components. They will also include the following concentrations:

- *Prediction of the demands on nonstructural components and the evaluation of their performance under these demands.*

  Just as forces on a structure are developed due to ground shaking and are affected by the interaction between the soil and the structure, nonstructural component demands are developed due to the building shaking and are affected by the interaction between the structure and the components. It will be necessary to study and develop methods by which these demands can be predicted. It will also be important to develop techniques for evaluating the performance of the components under these demands.

- *Testing and certification programs to bring uniformity to the design of manufactured components.*

  More so than buildings, modeling of nonstructural performance is difficult at best and needs to be supplemented with testing. The testing program will have to be broad enough to account for the placement of equipment and contents in different areas within various building types. It will also need to allow certification of equipment and contents bracing for an expected performance objective.

- *Post-earthquake data acquisition and analysis.*

  A detailed plan is needed for acquiring and analyzing performance data from future earthquakes. The nature of this data needs to be defined. Following a major earthquake, the data will be processed and compared to the Guideline provisions. The Guidelines will be modified in future editions by using lessons learned from performance of nonstructural components. This program is considered optimal for the effective development of PBSD.

- *Evaluation of nonstructural components in existing buildings*

  In addition to developing procedures for the installation of nonstructural elements in new buildings, it will be important to devise methods for assessing and increasing the performance of components already installed within existing buildings.

The nonstructural performance products will be developed by a team of design professionals, scientists, equipment manufacturers and researches expert in the behavior of nonstructural components. Testing agencies will be employed as part of the certification program. User groups will be brought in to develop goals and strategies and to assist in the verification process.

Successful development of the NPP will require outside funding of testing. A comprehensive program will cost millions of dollars and will be an ongoing effort. Funding identified herein must be augmented by research dollars provided by industries and manufacturers which have a stake in the performance of nonstructural systems.

Task 3.1 Identify initial parameters and current state of the art

Task 3.1.1 – Identify nonstructural components and their impacts on performance

Description:

The team will identify the various types of nonstructural components and systems that are vulnerable to loss. It will utilize existing efforts in this area. In addition to looking at individual components, a goal will be to understand how the components fit together into systems (i.e. pumps and fans are parts of a chiller system), and what the effects of damage to one component means to the system. Identifying weak links in systems is important. The team will then identify what systems are typically present in various building types, and what the weak links are when considering overall building performance.

Another focus of this task will be to identify the scope of the Nonstructural Performance Products. The team will determine the detail with which issues of design, installation and maintenance of nonstructural components will be evaluated.

Personnel: Design professionals, Material suppliers, Owners

Priority: Essential
Budget: $250,000
Duration: 2 years

Task 3.1.2 – Evaluate effectiveness of current nonstructural and contents installation standards and practice

Description:

With the list of components and systems from task 3.1.1, the team will identify information on performance in past earthquakes. It will catalogue and quantify performance of components and systems by themselves and in relation to overall building performance, in terms of capital and contents loss and down time. The team will compare the effectiveness of different designs of the same components. Issues which play the greatest role in performance will be prioritized (i.e. anchorage design vs. installation quality, equipment ruggedness, etc.). A goal will be to assess the current state of the art and identify gaps in existing knowledge.

Personnel: Design professionals, Material suppliers (Researchers, Owners)

Priority: Essential
Budget: $300,000
Duration: 2 years

Task 3.1.3 – Develop a research plan to advance the state-of-the art

Description:

Once gaps in existing knowledge have been identified, the group will develop a research plan to fill them. The goal will be to develop a road map by which the tasks within this *Action Plan* can be accomplished. The plan will be detailed enough to be used by stakeholders, laying out tasks and schedules. An effort will be made to identify outside sources of funding to augment the budgets assigned to each task with the Plan, considering public and private resources.

Personnel: Researchers, Design professionals, Material suppliers

Priority: Essential
Budget: $150,000
Duration: 1 year

Task 3.2 – Develop analysis and design methodologies

Task 3.2.1 – Quantify nonstructural performance levels

Description:

Working with the performance definitions developed in the **SPP**, the team will quantify nonstructural performance levels using appropriate parameters (drift, damage, loss, business interruption, casualties, etc.).

The goal in this task is to set the performance parameters so that the evaluation and design methodologies developed in later tasks can be targeted to definitive numerical quantities.

Personnel: Design professionals, Researchers, Material suppliers (Government agencies)

Priority: Essential
Budget: $350,000
Duration: Throughout the project

Task 3.2.2 – Develop demand prediction methodologies

Description:

The team will develop processes to calculate the demands on nonstructural components based on their location within various building types. It will identify and describe in measurable terms the parameters that have the most important effects on these demands (height above grade, building stiffness, anchorage, etc.). The goal is to be able to extrapolate from the basic building acceleration, velocity and displacement characteristics, the effects on nonstructural components.

Personnel: Design professionals, Material suppliers, Researchers

Priority: Essential
Budget: $450,000
Duration: Throughout the project

Task 3.2.3 – Develop analytic methodologies for achieving performance levels

Description:

The team will fill in the gaps in existing knowledge identified in earlier tasks. Research will consist primarily of analytical efforts. The team will identify promising new techniques and devote research to making them applicable to the PBSD framework. A forum will be held, bringing together design professionals and manufacturers to discuss design and analysis methodologies.

Following this, a strong effort will be made to develop design and analysis methodologies, consistent with the efforts in the **SPP**.

A focus will be on developing modeling or other techniques to lend consistency to design and analysis. Modeling will account for the range of computer applications currently available and anticipated in the future. It will also account for the financial investments various design engineers are able to make in obtaining modeling technology.

Personnel: Design professionals, Researchers, Material suppliers (Government agencies)

Priority: Essential
Budget: $850,000
Duration: Throughout the project

Task 3.2.4 – Coordinate design and analysis methods with SPP

Description:

The team will compare the design and analysis methods of the **SPP** and **NPP** to ensure that they are compatible and that they lead to the same measures and prediction of performance. The team should check that the level of reliability is similar between the two and that structural and nonstructural performance measures can be combined to form overall performance goals for buildings. The team will also make a focused effort to describe the functions of the **SPP** and **NPP** in relation to the overall goal of PBSD and of the guidelines. A task will be to describe building behavior from both points of view in technical and financial terms and identify where structure and nonstructure overlap or come in conflict.

Personnel: Design professionals, Researchers, Material suppliers

Priority: Essential
Budget: $150,000
Duration: Throughout the project

Task 3.3 – Establish separately funded testing and data collection programs

Task 3.3.1 – Establish comprehensive testing and certification protocols

Description:

The team will catalogue all relevant testing information to date. It will identify gaps in this knowledge with respect to nonstructural component effects on building performance. Research programs will be developed and established to fill these gaps.

A distinction will be made between component "ruggedness:" the ability of the piece of equipment to stay together in a functional black box, and "anchorage:" the ability of the equipment to remain where it was installed.

The team will identify *sources of funding* for extensive testing. These sources will include equipment manufacturers, owners, insurers, government agencies, etc. This may include developing collaborative efforts between equipment buyers and equipment manufacturers, for example. The team will develop a consensus on the technical description of testing protocols. The team will develop a means of obtaining certification of tested equipment for various seismic regions, building types and usage, and locations within buildings. If financially feasible, some testing should be conducted within this task to calibrate certification parameters.

Personnel: Design professionals, Researchers, Material suppliers, Building officials, Government agencies

Priority: Optimal (does not include funds for extensive testing)

Budget: $1,000,000

Duration: 5 years

Task 3.3.2 – Establish a post-earthquake data collection and analysis program

Description:

The team will *establish* a program for collecting nonstructural performance information after an earthquake. This will be coordinated with the efforts in the **SPP**. Existing earthquake performance data will be reviewed for its usefulness and as appropriate will be assembled and catalogued into a database. The team will develop ways to distill and use this information and identify where gaps remain. A workshop will be held to identify the types of information that are the most valuable. The team will develop data collection forms, binders, instructions and databases in preparation for use. It will establish a methodology for creating and maintaining a team of inspectors and will hold seminars on a regular basis to train them. A focus will be to identify how the collected information will be used within the development and refinement of the PBSD Guidelines. The team will identify sources of funding for post-earthquake data collection, so that these groups may be approached in a timely fashion after a damaging event.

Personnel: Design professionals, Researchers, Material suppliers, Building officials, Government agencies

Priority: Optimal
Budget: $300,000
Duration: 2 years

Task 3.3.3 – Establish a program for developing innovative nonstructural design

Description:

The team will *establish* a program for encouraging manufacturer's to develop innovative nonstructural designs that take advantage of the performance-based criteria developed within this project. The team will identify sources of funding to implement this program. Implementation will include offering incentives for use, marketing the program and tracking its success.

Personnel: Design professionals, Material suppliers, Owners, (Government agencies)

Priority: Optimal
Budget: $300,000 (includes only the establishment of the program framework)
Duration: 1 year

Task 3.4 – Develop documents and reports for use in PBSD Guidelines

Description:

This task will occur at milestones within the research plan developed in Task 3.1.3 and in preparation for each of the Guidelines development phases. The team will gather the technical information and prepare reports and documents for the writers of the Guidelines. Coordination with the **RMP** and **SPP** will occur to insure that information is presented in a consistent manner. The team will coordinate verification studies to be run on the analysis and design methodologies. Once the Guidelines teams have reviewed the work and identified changes or refinements to the research plan, this team will work with the research team of Task 3.1.3 to set out the goals for the next phase of research.

Personnel: Design professionals, Researchers, Material suppliers, Building officials, Government agencies

Priority: Essential
Budget: $500,000
Duration: Throughout the project

Challenges

- *Analysis and modeling*

  Developing modeling and analysis techniques for nonstructural systems will be a very challenging effort. The complexity of these systems may overwhelm the capacity of most office computer systems. Reliable methods for estimating the performance of these elements, however, is vital to reaching higher levels of overall building performance. As with the **SPP**, software engineers may need to be consulted and retained to develop programs which can model piping, equipment, ducts, and other elements which have the potential to cause significant loss.

- *Performance levels and damage states*

  Understanding a component's anchorage to the structure is only one half of the challenge of nonstructural systems. Being able to reliably estimate the "ruggedness" of the piece of equipment is also important. A major effort will be required of design professionals and equipment manufacturers to find ways to define equipment fragility and to test for and design ruggedness into equipment.

- *Administration*

  Peer review and plan check of equipment anchorage is a novel concept and will need acceptance from building officials. This will require a major effort to write provisions for their use and to educate and train them on the subject.

- *Education and Incentives, Cost*

  Full scale testing of equipment will prove to be a monumental and very expensive effort that will require funding from multiple sources. Convincing owners and manufacturers to pay for this testing will be a challenge.

  With the idea of certification of equipment will come issues of liability for performance. It will be difficult to convince manufacturers to warrant their equipment and contractors to be responsible for installation. Owners may be able to provide incentives to convince these stakeholders that certification is in their best interests.

- *Data Acquisition*

  As with the **SPP**, similar challenges will be faced in obtaining useful information and maintaining the data collection program.

PRODUCT 4 – Risk Management Products

These products will provide financial information for the Stakeholders' Guide and the PBSD Guidelines. The goal will be to identify cost-benefit and other models by which PBSD can deliver the most benefit to the users. The products will have three main areas of focus:

- *Methodologies for quantifiably defining performance objectives in terms of expected loss, risk and stakeholder tolerance.*

  The work will utilize the efforts of the **SPP** and **NPP**. It will consider issues of damage costs, loss of operation, risk tolerance, etc., with the expectation of obtaining realistic design goals for stakeholders.

  Minimum performance objectives will be established, considering the broader social and economic drivers that affect planning, design and construction decisions. An effort will be made to consider the effects on building performance of elements outside the building envelope, such as infrastructure, utilities and other lifelines.

- *Identifying and minimizing uncertainties in the PBSD process.*

  A key to obtaining wide use of PBSD is developing more reliable and accurate analysis and design methodologies. Uncertainties, error and randomness must be related numerically through reliability measures to the methods developed in the **SPP** and **NPP**. Ways need to be found to minimize these sources of inaccuracy. Risk associated with building performance should be quantified in relation to other activities (such as fire, building maintenance, revenue, etc.). Methods for more accurately identifying risk and reaching acceptable risk levels need to be developed.

- *Developing cost/benefit and other financial analysis models.*

  The philosophy behind PBSD centers on being able to choose from a range of performance objectives, to reliably meet the financial goals and risk tolerance of the stakeholders. Techniques for determining and optimizing cost-benefit ratios and other financial representations of construction are important to achieving implementation. Non-engineering groups need to have a complete understanding of PBSD and its benefits. It is also important for design professionals to understand the concepts of risk management.

An effort will be made to emphasize the broader global planning opportunities that PBSD presents for reducing economic and social losses to communities, regions and states. The RMP should provide the basis for economic and social rating systems for buildings.

Task 4.1 – Quantify performance objectives

Task 4.1.1 – Match performance levels with hazards to develop performance objectives

Description:

The team will take the performance levels and hazards developed in the **SPP**, **NPP** and **RMP** and combine them in order to understand expected performance over measurable and meaningful timespans (building life, a typical mortgage, careers, etc.). The team will select performance objectives for various building types, occupancies, construction eras, etc, and develop performance expectations for these buildings over their lifetimes. A focus will be to define the goals that owners and design professionals can utilize for capital planning and design purposes.

Personnel: Design professionals, Researchers, Owners, Financial interests

Priority: Essential
Budget: $350,000
Duration: 1 year

Task 4.1.2 – Develop minimum performance objectives considering social and economic drivers

Description:

The team will identify the various social and economic drivers that affect decisions about designing to a particular performance objective. The team will evaluate issues of cost, safety, construction duration, building function, etc. and will consider how each affect the various stakeholders. The goal will be to establish a set of minimum performance goals that protect the interests of all the parties involved in the building environment and provide for the protection of the public welfare. The team will discuss minimum performance standards for external elements that affect building performance, such as infrastructure, utilities and lifelines.

Personnel: Design professionals, Researchers, Financial interests, Owners, Building officials, Government agencies

Priority: Essential
Budget: $350,000
Duration: 1 year

Task 4.1.3 – Quantify performance in terms of loss and risk

Description:

The team will develop a set of acceptable risk levels quantified in terms of loss (capital, lives, down time, etc.), considering building type, usage, age or other parameters. It will link performance objectives with these acceptable risk levels. Risk will be defined in agreed upon terminology with varying levels of reliability. The team will define a set of maximum loss thresholds for each performance objective. The Stakeholders' groups will be tapped to provide input. A methodology will be developed to convert loss into financial terminology.

Personnel: Design professionals, Researchers, Financial interests, Owners, (Other stakeholders)

Priority: Essential
Budget: $400,000
Duration: 4 years

Task 4.2 – Develop financial modeling tools

Task 4.2.1 – Develop a research plan to advance current risk evaluation methods

Description:

The team will gather existing information on risk analysis and financial modeling methods and identify gaps in current knowledge. A strong effort will be made to use available information so that future research funding can be most efficiently spent. The current state of the art should not define the scope of this project or limit the direction research might take, but rather allow researchers to avoid unnecessary duplication of effort.

Once gaps in existing knowledge have been identified, the group will develop a research plan to fill them. The goal will be to develop a road map by which the tasks within this *Action Plan* can be accomplished. The plan will be detailed enough to be used by stakeholders, laying out tasks and schedules. An effort will be made to identify outside sources of funding to augment the budgets assigned to each task with the Plan, considering public and private resources.

Personnel: Financial interests, Researchers (Design professionals, Owners)

Priority: Essential
Budget: $150,000
Duration: 1 year

Task 4.2.2 – Develop financial life cycle and damage cost models

Description:

The team will use the structural and nonstructural performance acceptability criteria in the **SPP** and **NPP** to calculate life-cycle and annualized losses relative to each performance objective. Combinations of performance objectives will be evaluated to help users minimize overall life-cycle and damage costs. The team will extrapolate costs for individual buildings, to look at classes of buildings and regional implications for cities, states and the federal government. Costs of repair, business interruption and casualties will also be developed. The goal is to quantify expected losses in a manner that stakeholders can use in long term capital planning. Example applications will be developed. The information developed within this and other tasks should also form the basis for building rating systems, which will integrate structural and nonstructural quality with financial and social performance measures.

Personnel: Researchers, Financial interests, Owners, Government agencies

Priority: Essential
Budget: $650,000
Duration: Throughout the project

Task 4.2.3 – Define cost-benefit relationships for improving performance

Description:

The team will develop tools by which the costs of different retrofit measures (existing buildings) or design criteria (new buildings) can be weighed against the expected reduction in loss and life-cycle costs. A comparison of individual components will be necessary (such as bolting down a wood building vs. bracing sprinkler pipes). The combination of components into design systems will also be considered. Cost-benefit relationships need to be developed in ways that can be calculated by design professionals and are meaningful to owners and financial interests. Cost-benefit ratios should be applicable to individual buildings or portfolios. The goal should be to provide owners with methods for performing economic loss management of their facilities. Efforts will be made to look at how this can be expanded to a regional basis.

Personnel: Design professionals, Researchers, Financial interests, Owners, Government agencies

Priority: Optimal
Budget: $500,000
Duration: Throughout the project

Task 4.2.4 – Calibrate financial models

Description:

The team will develop a series of example applications and will calibrate and compare them against current design techniques. Calibration parameters will include cost, duration, responsibility, liability, etc. The team will establish subgroups to carry out these studies, and will develop a standard reporting method by which the results can be quantitatively compared. If the team decides that the results diverge too significantly from existing methodologies, revisions to the procedures will be made, or a schedule for incremental application of the procedures will be developed. The team will develop methodologies to project costs and other data into the future. In this way, the information can function as a capital planning tool.

Personnel: Design professionals, Researchers, Financial interests

Priority: Essential
Budget: $500,000
Duration: Throughout the project

Task 4.2.5 – Develop cost-effective design strategies

Description:

With information from previous tasks the **SPP** and the **NPP**, the team will develop strategies to improve performance based on building class, usage, location, etc. The team will consider components and systems, identifying which individually and which combinations typically will provide the minimum expected life-cycle cost involving tradeoffs between the initial cost and potential damage costs. The information will be presented in a manner that is usable by engineers for design and will give owners and financial interests a numerical valuation of the money spent. The team may use information obtained in past earthquakes, coupled with testing research previously done.

Personnel: Design professionals, Researchers, Financial interests, Owners

Priority: Optimal
Budget: $500,000
Duration: Throughout the project

Task 4.3 – Educate users about risk management concepts

Description:

The team will establish a program to teach stakeholders about risk management. Representatives of lending agencies, insurance and financial institutions and researchers will write papers and create tools to apply the concepts developed in the above tasks. The team will hold workshops and seminars to discuss this information. The goals for design professionals, contractors, material suppliers and building officials are to recognize that PBSD involves choices about risk, and to be able to use the risk management tools provided in the Guidelines. For building owners, the goal is to bring awareness of how these tools fit in with current risk management techniques they use when purchasing space, making renovations, considering deferred maintenance, etc. A strong effort will be made to identify ways to coordinate current risk analysis techniques used by owners and financial institutions (probable maximum loss, ratings, etc.) with these new tools.

Personnel: Design professionals, Researchers, Contractors, Material suppliers, Financial interests, Owners, Building officials, Government agencies

Priority: Optimal
Budget: $500,000
Duration: Throughout the project

Task 4.4 – Identify legal implications of PBSD

Description:

The team will contract with attorneys to address the legal implications of moving towards PBSD oriented building codes. The team will develop a list of issues that need to be evaluated, including: liability in the event of unexpected performance, cost allocation, long-term responsibility for the building or components, definitions of terms such as "significant," "reliable," etc. The goal will be to develop strategies to make

PBSD more attractive to stakeholders from a legal standpoint.

Personnel: Attorneys, Design professionals, Financial interests, Owners, Building officials, Government agencies

Priority: Optimal
Budget: $250,000
Duration: 2 years

Task 4.5– Develop documents and reports for use in PBSD Guidelines and Stakeholders' Guide

Description:

This task will occur at milestones within the research plan developed in Task 4.2.1 and in preparation for each of the Guidelines development phases. The team will gather the technical information and prepare reports and documents for the writers of the Guidelines. Coordination with the **SPP** and **NPP** will occur to insure that information is presented in a consistent manner. The team will coordinate verification studies to be run on the analysis and design methodologies. Once the Guidelines teams have reviewed the work and identified changes or refinements to the research plan, this team will work with the research team for Task 4.2.1 to set out the goals for the next phase of research.

Personnel: Design professionals, Researchers, Financial interests, Owners, (Government agencies)
Priority: Essential
Budget: $400,000
Duration: Throughout the project

Challenges

- *Analysis and modeling*

  A major effort will be required to develop financial tools relating costs to structural and nonstructural performance. This will require close collaboration between design professionals and Financial interests.

- *Acceptability*

  It will be important to define acceptable risk. The challenge will be in quantifying stakeholders' tendencies to be either risk adverse or risk tolerant. A key to successful implementation of PBSD is the ability to match a design with the owners' risk tolerance.

  Considering broader social and economic factors affecting a building -- such as a hospital remaining functional to treat injuries within the community, or even of a grocery store being able to provide emergency food supplies after a damaging event -- will complicate the consideration of minimum performance objectives and liability.

- *Data Acquisition*

  A challenge will be to obtain useful information on performance versus loss and performance versus design and construction costs. A major effort may be warranted to cost estimate example designs using the PBSD procedures. This information will be needed to calibrate cost models.

- *Reliability*

  Identifying uncertainties in quantifying costs, damage, hazard and risk will be a major challenge. New methods for integrating engineering design and analysis with financial and social modeling will need to be developed and tested.

PRODUCT 5 – PBSD Guidelines

The Guidelines form the most important product resulting from this project. They distill the information developed in the **SPP**, the **NPP** and the **RMP** into the application document used by design professionals, manufacturers, government agencies and building officials in design and construction. These guidelines can form the basis for the next generation of building codes and earthquake resistant design practice. When implemented, these guidelines should permit economical design that can reliably attain desired seismic performance.

The Guidelines will have to be broad in scope yet deep in level of detail. They need to be usable by a wide range of design professionals. They will focus on:

- *Selecting and quantifying performance objectives, including cost performance.*

  A set of consistent performance levels for new and existing buildings is essential. To be useful and reliable, predictors of structural and nonstructural performance must be characterized in a manner that can be understood by building owners.

- *Defining minimum and standard performance objectives.*

  Although the concept of performance based design permits owners to specify custom objectives for each building, presumably codes will need to have a single set of minimum and standard objectives used for enforcement purposes. These will need to be defined and incorporated into the performance objectives. They should be based on considerations of acceptable risk and should be based on input from multiple stakeholders. In addition, the desired reliability level in achieving these objectives needs to be specified.

- *Characterizing performance and hazard levels consistent with the objective.*

  The performance objectives must be quantified in engineering terms. This includes defining specific acceptable damage levels for various elements, both structural and nonstructural as well as permissible global behavior of the structure itself. Characterization of ground motion will also be important.

- *Performance prediction and evaluation methods.*

  The methods in the guidelines will facilitate design of structures of any configuration for any desired performance and can be used to calibrate building codes for new buildings or develop new codes. Methodologies used for evaluation and retrofit of existing buildings can also be calibrated. Lastly, the financial industry can use the guidelines as a basis to develop methods of ranking the design performance of buildings for underwriting purposes.

- *Means of verification.*

  The various analytical procedures used to evaluate performance and demonstrate acceptability, together with suitable modeling rules and prescriptive requirements on configuration and detailing must be verified. The uncertainty inherent in each of these procedures for buildings of different sizes, types, and configurations, and for different performance levels must be quantified. While a minimum level review is essential, a broad program of verification will be optimal.

- *Procedures for installing and maintaining nonstructural components and contents in buildings.*

  This information will focus on the issues related to installation and maintenance of nonstructural components. Not least among these is the division of responsibilities and liability between the component manufacturer and installer. As the design engineer observes building construction, equipment installation should also be observed for compliance to the manufacturer's specifications.

- *A technical commentary serving as backup for the Guidelines.*

  No matter how well stated in the PBSD Guidelines, the rationale and history behind the provisions will be subject to the interpretation of the engineers and building officials employing them. A comprehensive commentary is necessary to give these users a fuller picture of PBSD and direction when implementing it. The commentary should also include a series of example applications of the guidelines.

The Guidelines will involve major participation from all stakeholders, including design professionals, researchers, manufacturers, owners, financial institutions, building officials and governing agencies. A comprehensive program of verification will require input and involvement from a broad range of users. Technical writers and code officials will also be employed to produce the highest quality document.

The guidelines will be developed in phases. The first, or the 25% phase, will include a basic framework for the Guidelines, to be filled in with research and tools from the **SPP, NPP** and **RMP**. Review by the Guidelines teams at this stage will focus on refining or changing the direction of the technical research efforts for these products. The next phases at 50% and 75% will continue to take information from the technical products and flesh out the Guidelines, again returning comments to refine the research. The 100% phase will consist of final review, formatting, wordsmithing and publication. An important task within the Guidelines product is to develop this phasing further and to coordinate overall efforts with the steering committee.

Task 5.1 – Reach consensus on Guidelines format and development process

Description:

The main goal of this effort will be to reach a consensus on the format of the Guidelines, and to develop a conceptual framework. The team will also establish a procedure for taking the information from the **SPP, NPP** and **RMP** and writing the guideline provisions.

Personnel: Design professionals, Researchers, Material suppliers, Contractors, Financial interests, Owners, Building officials, Government agencies

Priority: Essential
Budget: $150,000
Duration: 1 year

Task 5.2 – Develop design and analysis provisions

Task 5.2.1 – Develop systematic design and analysis processes

Description:

Using the analysis and design methodologies defined in the **SPP** and **NPP**, the team will create design and analysis processes that take a building through concepts into final design, identifying major steps along the way. Procedures will be developed for new and retrofit conditions. The team will develop minimum performance objectives to be included in the standards based on the economic and social drivers developed in the **RMP.** A focus will be on developing modeling guidelines to lend consistency to the design and analysis process. The team will work closely with the verification team in Task 5.3, to ensure that the provisions are tested and are acceptable. This team will be responsible for suggesting refinements or changes to the technical product research as necessary to accommodate the provisions. A goal should be to minimize this as much as possible, to maintain the schedule and budget. The committees will write the provisions using consistent and appropriate language, figures, equation styles, procedures for implementation, etc.

Personnel: Design professionals, Researchers, Material suppliers, Building officials, Government agencies, (Financial interests)

Priority: Essential
Budget: $1,200,000
Duration: Throughout the project

Task 5.2.2 – Write a technical commentary to support the Guidelines

Description:

The team will write a technical commentary to support the information in the PBSD Guidelines. It will develop the format of the commentary to track the outline of the Guidelines. The goal of the commentary is to give specific background on the development of the procedures within the Guidelines and to explain the concepts in technical terms. It should also contain many references to allow users to obtain additional guidance. The team will consider the advantages of discussing the broader implications of decisions that were made in the Guidelines (financial, political, based on reliability, etc.). The team will have the commentary reviewed for accuracy by a panel of experts set up by the Steering Committee. This panel will include members of the **SPP, NPP** and **RMP** teams.

Personnel: Design professionals, Researchers,

Priority: Essential
Budget: $500,000
Duration: 2 years

Task 5.2.3 – Develop administrative guidelines for building officials

Description:

The team will establish administrative provisions for the use of PBSD by building officials. It will detail the process by which buildings, including structural and nonstructural components, are reviewed, plan checked and field inspected. The team will also develop tools for building officials to ease the burden of reviewing PBSD design. The team will consider the benefits of third party plan check and peer review and other means of streamlining the process while maintaining quality

Personnel: Design professionals, Owners, Building officials, Government agencies

Priority: Optimal
Budget: $200,000
Duration: 1 year

Task 5.3 – Implement a verification program

Task 5.3.1 – Run examples to check accuracy of provisions

Description:

The team will establish subgroups to verify the accuracy of the design and analysis procedures. The subgroups will create and test a series of parametric examples. The team will set up a means by which the results of the testing can be checked for accuracy and acceptability. The team will identify and make necessary changes in the procedures in cooperation with the technical product teams.

Personnel: Design professionals, Researchers, Building officials,

Priority: Essential
Budget: $600,000
Duration: Throughout the project

Task 5.3.2 – Compare resulting designs and costs against current methodologies

Description:

The team will evaluate the effects of the resulting guidelines on each of the major stakeholders, looking at costs, level of effort and responsibility. A series of example applications will be developed and compared against current design techniques. The various methods that are developed will be calibrated against each other. Calibration will consider at least: the effort to implement, resulting performance and expected construction costs. Information from the **RMP** will be incorporated into the calibration study. The team will establish subgroups to carry out these studies, and will develop a standard reporting method by which the results can be quantitatively compared. If the team decides that the results diverge too significantly from existing methodologies, revisions to the procedures will be made, or a schedule for incremental application of the procedures will be developed.

Personnel: Design professionals, Researchers, Financial interests

Priority: Essential
Budget: $400,000
Duration: Throughout the project

Task 5.4 – Develop procedures for quality control during construction

Description:

The team will write a set of guidelines for maintaining quality during construction. Information on reliability and uncertainty developed in the **SPP** and **NPP** will be used to evaluate the various stages of construction. The team will address such issues as material fabrication and inspection, installation, testing, uniformity in construction practices, field changes, etc. The goal is to provide a clear statement about the need for a high level of construction quality, and to provide standard procedures to attain this quality. It may be desirable to permit different levels of quality control based on expected performance or on building usage, etc.

Personnel: Design professionals, Contractors, Material Suppliers, Owners, Building officials

Priority: Optimal
Budget: $300,000
Duration: 2 years

Task 5.5 – Develop a plan for verifying nonstructural component design and installation

Description:

The team will develop a standard format for checking the adequacy of nonstructural component and system design, manufacture and installation. Much like peer review and inspection procedures for the structure, this system will be designed to track nonstructural elements through a similar process. The team will establish a system for identifying and training qualified inspectors and reviewers. The team will use the information developed in the **NPP** to make easier reevaluation of existing components and determine expected performance.

Personnel: Design professionals, Contractors, Material suppliers, Building officials

Priority: Optimal
Budget: $300,000
Duration: 2 years

Task 5.6 – Publish guidelines and create an adoption process

Description:

The team will set up milestone deliverables at 25%, 50%, 75% and 100% and will describe the content to be included in each. It will establish and implement a final review and adoption process. A peer review procedure will be established at each milestone. A technical writing team will be created and a consensus reached on the style and voice of the guidelines. The Guidelines will be written and reviewed. A small team of reviewers will focus on the presentation of the information, both graphically and textually.

Personnel: Design professionals, Researchers, Material suppliers, Financial interests, Owners, Building officials, Government agencies

Priority: Essential
Budget: $600,000
Duration: Throughout the project

Task 5.7 – Develop a means for future revisions

Description:

After the guidelines are completed, the team will assess the project and identify future goals, research efforts, etc. that will build upon the work completed. The team will write a framework for the next generation of PBSD related projects. The goal of the task is to provide a plan for the continuing evolution of PBSD. The team will establish a procedure for updating the guidelines

Personnel: Design professionals, Researchers, Government agencies

Priority: Optimal
Budget: $150,000
Duration: 1 year

Challenges

- *Analysis and modeling*

  Developing general methods for design and performance prediction will be a challenge when considering varying performance objectives. The procedures must be relatively easy to implement yet still provide higher reliability than current design methodologies and be reasonably economical.

  Procedures for nonstructural design and analysis will have to be greatly expanded from current standards. This will require a major effort on the part of the product team.

  Because modeling will play a more significant role in PBSD design than it currently does, standards for computer aided design will be necessary. These standards need to insure consistency while allowing creative flexibility.

- *Reliability*

  The incorporation of reliability methods into design procedures will be a challenge. Design professionals will need to begin to think in terms of probability, uncertainty and risk. Quantifying these terms in relation to traditional structural engineering concepts will be difficult but important.

- *Administration*

  As with any adoption process, acceptance from the stakeholders will be one of the most difficult challenges. It will require political and diplomatic skill to bring each of the parties into enthusiastic agreement. The teams should consider using professional facilitators and negotiators to build a strong consensus about the PBSD Guidelines and their use.

- *Example applications*

  It will be a challenge to develop realistic, understandable examples of the application of the guidelines that will achieve sellable conclusions and encourage the use of PBSD.

PRODUCT 6 – Stakeholders' Guide

The Stakeholders' Guide will serve to educate the non-engineering audience about the benefits of PBSD. It will be their reference and planning tool much as the PBSD Guidelines serve a similar purpose for the engineering community. The Guide needs to be written in a non-technical style, and emphasize graphic presentation. The financial information should be presented in a way that will be useful to owners and financial professionals. It needs to communicate the concept and application of PBSD to these primary stakeholders. It will include the following components:

- *Background on codes and performance based design.*

  The Guide should give background on the history of code development and the reasons for moving toward performance based design. It should describe in general terms the principles of PBSD and its benefits over current methods. The goal is to show stakeholders that this move is necessary and that performance based design standards are in their financial and business interests.

- *Financial and other benefits of using PBSD.*

  Tables, charts, equations, examples and text, should convey the advantages and appropriate uses of PBSD in terms of financial and other models. Adoption will require that the document include the issues that stakeholders see as concerns and benefits. It will need to specify and quantify these benefits and provide a mechanism for making incremental changes to current practice.

- *Guidance for implementing PBSD.*

  The owner and financial professionals need to be guided through the process of implementing PBSD. Much more than in current practice these stakeholders will form an integral part of the design team. They must assist in making decisions about the direction of a project and be involved throughout its implementation.

- *Example applications of PBSD*

  The guide will contain example applications of the guidelines, covering structural and nonstructural design, and financial planning issues. The examples will contain technical information for the design professionals as well as nontechnical information for building owners and financial interests.

Task 6.1 – Define content and format of Stakeholders' Guide

Description:

The team will convene a series of workshops with stakeholder representatives to create the format and content of the Stakeholders' Guide. The team will determine the level of complexity of the information and equations presented. The goal is to layout the format for the guide so that it is usable to a non-technical audience. A strong effort will be made to involve owners and financial representatives, as these will be the primary users of the information. Another goal is to be able to quantify the level of effort that will be required of these groups in the planning, design and construction processes, in terms of cost and time. A consensus about the style of presentation will also be reached.

Personnel: Design professionals, Researchers, Financial interests, Owners, Contractors, Material suppliers, Building officials, Government agencies, Legal professionals

Priority: Essential
Budget: $150,000
Duration: 1 year

Task 6.2 Present and explain financial modeling techniques

Description:

The team will present and explain the financial modeling tools developed in the Guidelines and the Risk Management Products. In the same manner as the Guidelines these tools should be presented with different levels of complexity, so that the user can employ the most appropriate to a specific situation. The technical and financial research will have been done as part of the **RMP**. In this task the goal is to provide descriptions of and practical ways to employ these tools.

Personnel: Design professionals, Researchers, Financial interests, Owners

Priority: Essential
Budget: $300,000
Duration: Throughout the project

Task 6.3 – Describe the design and construction process

Description:

As with the Guidelines, the team will develop a road map to move from the concept stage to completion of construction, identifying major steps along the way. Retrofit and new design will be considered. The responsibilities and qualifications of each of the stakeholders (including owners and design professionals) throughout the design and construction process will be identified and described. The team will review these responsibilities and evaluate their effects on the groups. The team will prepare the information using language, figures, equation styles, procedures for implementation, etc., consistent with the Guidelines. The team will consult with legal professionals to evaluate possible changes in liability.

Personnel: Design professionals, Owners, Financial interests, Building officials, Government agencies, Legal professionals

Priority: Optimal
Budget: $250,000
Duration: 2 years

Task 6.4 – Develop examples for the guide

Description:

The team will develop a series of examples for the financial and engineering application of PBSD, which will serve as teaching and reference tools. The team will set up a verification means and check the examples for accuracy and acceptability. The examples will include photographs and other graphic aids to increase understanding of the process.

Personnel: Design professionals, Researchers, Financial interests, Owners

Priority: Essential
Budget: $400,000
Duration: 2 years

Task 6.5 – Develop a plan to maintain or monitor the designed performance objective

Description:

The team will identify maintenance needs for nonstructural components, based on type, function, age, etc. It will develop a program that owners can follow, similar to deferred maintenance or tenant improvement, for maintaining the performance quality of existing equipment. A similar program will be developed to maintain and monitor the overall structural performance goals of a building throughout its life, accounting for changes in occupancy, advancements in the state of the art, structural modifications, etc. This information will be published as part of the Stakeholders' Guide. The team will prepare educational material to inform owners, contractors, and others about the procedures for maintaining a building's designed performance.

Personnel: Design professionals, Contractors, Manufacturers, Owners

Priority: Optimal
Budget: $250,000
Duration: 1 year

Task 6.6 – Publish the stakeholders' guide

Description:

The team will set up milestone deliverables at 25%, 50%, 75% and 100% and will describe the content to be included in each. It will establish a final review and adoption process. The team will also include a nontechnical background and history of the PBSD process and of current code evolution. The goal will be to show the non-engineering audience the need for PBSD and the expected changes with respect to the current design and construction practice. A peer review procedure will be established at each milestone. A writing team will be created and a consensus reached on the style and voice of the guide. A small team of reviewers will focus on the presentation of the information, both graphically and textually. This group will have the responsibility, along with the steering committee of ensuring that the presentation compliments the Guidelines themselves.

Personnel: Design professionals, Financial interests, Owners, Government agencies, Outside experts in information outreach

Priority: Essential
Budget: $400,000
Duration: Throughout the project

Task 6.7 – Develop a means for future revisions

Description:

The team will set up dates for considering revisions to the Guide and a procedure for doing so.

Personnel: Design professionals, Owners, Financial interests, Government agencies

Priority: Optimal
Budget: $100,000
Duration: 1 year

Challenges

- *Cost*

  Turning PBSD into a reality will require substantial investments of time and money by all stakeholders. Stakeholders will need to be convinced that spending money up front will be in their long-term financial interests. Lessons should be taken from other successful efforts, or from other countries such as Japan.

- *Administration*

  The Stakeholders' Guide will need to function well with the PBSD Guidelines. Owners and other non-engineering stakeholders will primarily use the former while design professionals will use the latter. Each, however, must lead to complimentary results that meet the needs of all parties. Close collaboration of both teams will be important. This will present special challenges for each because of the differences in their training and expertise.

- *Education and Incentives*

  A focus of the Guide will be to make the concepts of risk and reliability understandable to all parties. PBSD incorporates reliability-based design, a concept that design professionals often only consider peripherally. Owners and Financial interests, however, use risk management on a regular basis. It will be a challenge to communicate to design professionals that uncertainty must be included in their design approaches, and to convince owners that there are limits on what can be known or anticipated regarding building performance.

Interrelation of Products

It is important to consider the six products as interrelated. It will not be possible to develop PBSD by isolating each as an independent project. This section describes some of the necessary relationships between the products and identifies key crossover lines between the various product teams.

The Technical Reference Products

The **SPP, NPP** and **RMP** will contain the bulk of the research, analysis and testing necessary to develop PBSD guidelines. Generally, these efforts will be developed concurrently throughout the project. However, there are some important commonalties that should be developed first, including:

- *Development of performance levels and global acceptability criteria.*

  This is necessary to establish a common basis for analysis and the development of the standards. Prior to the start of focused research, the three teams should reach a consensus on the definitions of performance and acceptability.

- *Hazard quantification and prediction.*

  The identification of hazard parameters impacts all three products and should be consistent between them. Researchers and design professionals developing this information will to some extent be working concurrently with the structural, nonstructural and risk teams. Before these teams make assumptions regarding hazard evaluation and characteristics, however, agreement on these issues is needed. This will require greater interaction between design professionals and scientists.

- *Reporting methodologies.*

  Each product should report information in a consistent manner, to make the eventual synthesis into the Guidelines and Stakeholders' Guide easier. Reporting formats should be developed at the beginning of the project. Milestones should be put in place to compare progress and track that basic assumptions are consistent between the groups. It will be the function of the steering committee to make sure that each team is meeting its schedule. However, several members of the technical product teams will likely be part of the Guidelines teams as well. Conflicts about fundamental goals and reporting styles may create problems in the development of the Guidelines.

The End Use Products

The PBSD Guidelines and the Stakeholders' Guide are the products that will ultimately be used to implement PBSD. They need to compliment and supplement each other, not duplicate information, and work toward the same overall goal. To this end, both teams working together should perform several tasks.

➢ *Set goals with stakeholders.*

While each product will be developed for somewhat different audiences, many of the goals will be the same. Each of the goals identified by the stakeholders should be accounted for in one or both of the products. Stakeholders' forums should be held with the product teams early on and regularly throughout the project, to make sure that no important goal is missed.

➢ *Develop document outlines.*

To insure that these products do not miss information or undesirably duplicate it, the outlines for each should be developed in a unified setting. Planning sessions should be held to make sure that both will be compatible.

➢ *Coordinate example applications.*

Because of the tight overall project schedule, much of the efforts for these two products will be done concurrently. At the point when the Guidelines are technically complete, the two teams should meet to agree on the content and style of the examples to be included in the Stakeholders' Guide.

Hand over between the Technical and End Use Products

The project schedule requires that work be done in a manner that moves forward quickly. Obviously, developing accurate, reliable and acceptable information is of utmost importance. The quality of the products should not be sacrificed to meet the schedule. However, since the consensus process typically involves compromise and reevaluation, valuable time may be lost if the end use products are begun before substantial progress is made on the technical products. To make the hand over more efficient the following tasks should be performed:

➢ *Convene technical acceptance workshops.*

Before the process of distilling the technical products into the end use products at each phase (25%, 50%, 75% and 100%) begins, review should be implemented to "sign-off" on the former. A representative group of stakeholders needs to come to agreement that significant research has been completed and that there is enough information to begin developing the Guidelines. If substantial research is needed during the writing of the guidelines, this could snowball, causing reworking of all the technical products. This is to be avoided.

➢ *Check that the technical products are on the right track:*

At milestones during the technical product development, the members of the end use product teams should confirm that the right information is being produced to facilitate development of the guidelines. To this end, early in the development of the technical products these teams need to prepare outlines of the end use products, so that they or the steering committee can see that work is moving on the right track.

Development of Education Program

Two keys to the success of the education program will be having valuable information published in an understandable and exciting way, and recruiting experts to present this information. It may be unrealistic to assume that the members of the product development teams will be most suited to lead these efforts.

➢ *Translate technical material into easy to understand educational and promotional material.*

The team responsible for developing the education program will meet with representatives from the other product development teams to identify material which would be useful. They will work together to prepare technically accurate information while at the same time, keeping the product beneficiaries in mind. The representatives will review material developed by the team for accuracy.

➢ *Recruit and train experts to present educational material*

The education teams will identify people who are gifted in presenting and teaching, and have a strong knowledge of the PBSD products. These people may not be members of the other product development teams. If this is so, the teachers will need to have close interaction with the product team members to fully understand the concepts that need to be conveyed. The team will develop teaching and presentation programs and train the teachers on presentation methods. The teachers will eventually receive feedback from the seminars they give. The education team will use this information to refine the program.

An effort should be made to bring the concepts of PBSD into universities, so students in engineering, architecture and construction management programs will be familiar with and embrace PBSD concepts when they enter their professions.

Conclusion

Few lives have been lost in major American seismic events, in buildings designed under modern codes. The economic losses in recent earthquakes, however, have put a strain on communities, owners, lenders, insurers, governments and building users. It must be said, too, that none of these events have been of a level that would typically be considered catastrophic. Temblors with a magnitude similar to the 1812 New Madrid or 1906 San Francisco earthquakes will likely result in losses that are several times larger than anything previously experienced if they occur in a densely populated area.

There has been much miscommunication between design professionals, owners and financial institutions about the performance that buildings built to modern codes are expected to deliver. This has led to higher than appropriate expectations by owners.

Owners, however, must be able to make reliable financial decisions about a building's seismic performance. Their long-term capital planning strategies require that seismic risk be translated into meaningful, quantifiable terms. Engineers need ways to design buildings with a predictable level of performance that can be adjusted to meet the owner's needs.

Performance based seismic design represents a bold new strategy for reducing earthquake losses. It focuses on the economic goals of building stakeholders and integrates financial modeling with the latest engineering research. This *Action Plan* lays out a rational, cost-effective and achievable program for establishing and implementing PBSD in a manner that will benefit each of the groups with a stake in the built environment.

The organization of this project around six "products" insures that the critical areas of research and implementation are addressed. It breaks the overall effort into manageable units and produces valuable, self-contained material at regular intervals. It brings together a diversity of opinions, interests and expertise to produce robust and widely acceptable guidelines. The products themselves will rely upon various media to most effectively disseminate information.

The tasks within each product are designed to address the major challenges that will arise, and provide clear guidance for the development teams. Establishing a steering committee and education program insures that administration and promotion of the project are top priorities.

The budget and schedule are both ambitious. However, flexibility is built into each product by recommending essential and optimal funding levels. Tasks are devoted to *finding* sources of major funding for long term research, testing and education efforts, with the intention of spreading these costs throughout the stakeholder community.

The process of building design and construction must undergo a significant change if it is to meaningfully reduce the potential for disastrous earthquake losses. This *Action Plan* represents a major step towards fulfilling the potential of PBSD and reaping its benefits.

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