ATC 58-1

Proceedings of

FEMA-sponsored workshop on communicating earthquake risk

ATC Applied Technology Council

Funded by
Federal Emergency Management Agency

Applied Technology Council

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Cover Photo: Building damaged by the 1989 Loma Prieta, California, earthquake. Courtesy of the Earthquake Engineering Research Institute, Oakland, California.

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Proceedings of

FEMA-Sponsored Workshop on Communicating Earthquake Risk

June 18, 2002
Chicago, Illinois

by

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Preface

In September 2001 the Applied Technology Council (ATC) was awarded a contract by the Federal Emergency Management Agency (FEMA) to conduct a long-term project to prepare next-generation Performance-Based Seismic Design Guidelines (ATC-58 Project). The project is to consider and build on the FEMA-349 report, *Action Plan for Performance-Based Seismic Design* (EERI, 2000), which provides an action plan of research and development activities to produce and implement design guidelines that specify how to design buildings having a predictable performance for specified levels of seismic hazard. Ultimately FEMA envisions that the end product from this overall project will be design criteria for performance-based seismic design that could be incorporated into existing established seismic design resource documents, such as the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* (BSSC, 2001), the FEMA 273 *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* (ATC/BSSC, 1997), and its successor document, the FEMA 356 *Prestandard and Commentary for the Seismic Rehabilitation of Buildings* (ASCE, 2000).

The ATC-58 Project is being conducted in several phases, as resources become available. In Phase 1, which commenced in late 2001, ATC developed a management process for the project, identified and engaged key project management and oversight personnel, developed a project Work Plan, commenced development of a report on performance characterization, and conducted two workshops to obtain input on project needs and goals.

Workshop One, the proceedings of which are presented in this document, focused on communicating earthquake risk. Held on June 18, 2002 in Chicago, Illinois, Workshop One was organized to obtain preliminary feedback from a cross section of building stakeholders, including real estate developers, building owners, corporate tenants, lenders, insurers and other interested parties as to how performance-based seismic design guidelines can most usefully deal with issues of earthquake risk. In particular, the workshop dealt with three important issues:

- identification of those aspects of earthquake-related risk that are of most concern to the stakeholders;
- appropriate means to communicate the low-probability but potentially significant consequences of earthquakes; and
- appropriate means to communicate the considerable uncertainties associated with prediction of the effects of earthquakes and the performance of individual affected structures.

The Applied Technology Council gratefully acknowledges the members of the ATC-58 Project Team, who planned and organized the Workshop, and the representatives from a broad range of organizations who participated in the workshop: Daniel Abrams, Daniel Alesch, Randall Berdine, Michel Bruneau, Clifford Carey, Bruce Ellingwood, Mohammed Ettouney, Bruce Hall, Ronald Hamburger, Robert Hanson, Jack Hayes, Robert Hendrickson, Hildo Hernandez, William Holmes, Michael Mahoney, James Malley, Peter May, Ronald Mayes, Jack Moehle, William Moor, Willaim Mott, Christopher Rojahn, Randy Schreitmueller, John P. Scott, Jim Sealy, Debra Stein, Christopher Terzich, Jon Traw, Paul Tucker, Steven Weinryb, and Larry Wong. The affiliations of these individuals are provided in Appendix A, which contains a list of Workshop Attendees. Members of the ATC-58 Project Team, and their respective responsibilities, are identified in the List of Project Participants.

ATC also gratefully acknowledges the financial support provided by the Federal Emergency Management Agency and the guidance and oversight provided by Michael Mahoney (FEMA Project Officer) and Robert Hanson (FEMA Technical Consultant).

Christopher Rojahn
ATC Executive Director

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Executive Summary

The Applied Technology Council, on behalf of the Federal Emergency Management Agency, is engaged in a multi-year project to develop practical and effective design criteria and guidelines to permit performance-based design of buildings to resist the effects of earthquakes. This is known as the ATC-58 project. The goal of this project is to reduce economic costs and life losses associated with earthquakes by permitting buildings to be designed and constructed so that they are reliably capable of providing acceptable and appropriate levels of seismic risk. Simply stated, seismic risk is the potential for experiencing earthquake-related losses. These losses, which can be expressed on the basis of a single facility, system of inter-related facilities, or entire community of facilities can include considerations of life loss, direct economic loss resulting from destruction of property, and indirect economic loss resulting from loss of use of property and business interruption. In order to implement performance-based design, it is necessary for an appropriate level of seismic risk to be selected as the basis for design.

Since the exact time and size of future earthquakes in any region is uncertain, the losses that may be associated with design to any specific criteria is also quite uncertain. Therefore, decision making related to acceptable levels of seismic risk used as the basis for design and construction must often be based on rather complex probabilistic approaches. For this approach to be successful, it is essential that the primary stakeholders, that is individual building owners, tenants, lending institutions, building regulators, and others who do not have formal training in probabilistic risk assessment concepts, be able to understand the levels of risk associated with different criteria choices and that they be able to effectively communicate their choices to the technical community, who is then responsible to implement these choices in the form of completed projects capable of delivering the desired performance. Recognizing this, one of the first tasks being undertaken by the ATC-58 project is the development of a suitable vocabulary, or means of communication of earthquake risk concepts between stakeholders and the building design community.

As an initial step in this process, an invitational workshop was held in Chicago, Illinois on June 18, 2002 to begin a dialogue on acceptable ways to communicate earthquake risk concepts. This workshop was attended by approximately 30 persons, selected from the technical community and a cross section of stakeholder groups, including building owners, corporate risk managers, public agency facility managers, developers, lenders, insurers and attorneys. While no small group could be considered truly representative of the broad range of interests that exist in the community, it was felt that a diverse and broad range of perspectives and interests were included. The information obtained from this workshop will be used by the ATC-58 project, together with information obtained from other sources, to begin formulation of the vocabulary used to communicate earthquake risk and earthquake performance expectations for use in the performance-based design guidelines.

Attendees were asked to consider, through focused presentations, and breakout discussion groups, two basic issues. What are the aspects of seismic risk that are most important to them as an individual stakeholder? What means of measurement of these risks (metrics) are meaningful to them? What is their preferred means of thinking about and communicating the highly uncertain nature of earthquakes and the losses these earthquakes cause?

Participants confirmed that life losses, direct and indirect economic losses are the primary aspects of earthquake of concern. Some stakeholders expressed a strong desire to understand the amount of time that an individual facility affected by an earthquake would be out of service and also to quantify the associated economic losses. Although stakeholders agreed that life safety concerns are important, discussion did not focus on these issues. This may be attributable to several factors including: a potential belief based on recent historic record that life safety risks are already limited, an inherent belief that these would automatically be provided for in any design procedure, or the fact that most participants were selected to represent commercial rather than societal interests.

Although participants were aware that the time of occurrence or location of a specific event is quite uncertain, participants preferred to conceptualize and communicate losses in terms of specific earthquake scenarios, for example, the maximum losses that would occur should a magnitude 7 earthquake be experienced on a specific fault. Probabilistic expressions of loss, particularly, the annual probability that

a loss of a certain type or size would occur were not favorably received. Stakeholders acknowledged that uncertainties exist and felt that "maximum" losses used as a basis for decision making could reasonably have as much as a 10% chance of being exceeded (90% confidence level). Stakeholders also indicated that the concept of confidence associated with an outcome prediction could be favorably communicated in the form of a range of potential outcomes.

Some stakeholders acknowledged that they would implement rigorous cost-benefit type analyses to assist in risk-selection decision making. These stakeholders indicated that there was no unique time window over which such economic outcomes would be considered and that each investment or development opportunity would be evaluated using the time frame most appropriate to that individual decision. Generally, however, time frames that stretched to perhaps a few tens of years were better received than time frames that ran to hundreds or thousands of years.

While the information obtained in this workshop provides valuable insight into the range of views held by various stakeholders, it can not be considered to represent a consensus of the stakeholder community. Additional investigations into the preferred method of risk communication and conceptualization will continue in later phases of the ATC-58 project.

Chapter 1: Introduction

General

This document provides a summary of the proceedings of a Workshop on Communicating Earthquake Risk, held in Rosemont, Illinois on June 18, 2002. This workshop was held as part of the FEMA-funded ATC-58 project to develop performance-based seismic design guidelines. The purpose of the workshop was to obtain preliminary feedback from a cross section of building stakeholders, including real estate developers, building owners, corporate tenants, lenders, insurers and other interested parties as to how performance-based seismic design guidelines can most usefully deal with issues of earthquake risk. In particular, the workshop dealt with three important issues:

- identification of those aspects of earthquake-related risk that are of most concern to the stakeholders;
- appropriate means to communicate the low-probability but potentially significant consequences of earthquakes; and
- appropriate means to communicate the considerable uncertainties associated with prediction of the effects of earthquakes and the performance of individual affected structures.

In addition to providing a summary of the workshop proceedings, this document also provides preliminary interpretation of the data obtained from the workshop and its implications for the development of an approach to characterize building performance as part of the performance-based design guidelines development project. These interpretations were developed by a project task team, known as the Product One Development Team.

Attendees

The Workshop was attended by members of the ATC-58 Project Management Committee, the Project Steering Committee and the Product One Development Team, who served as recorders for the breakout sessions, and representatives of the Federal Emergency Management Agency. In addition the workshop was attended by a select group of invited participants selected to represent specific stakeholder communities. A complete list of attendees is contained in Appendix A. Together, the workshop attendees included representatives of the following stakeholder communities:

- Attorneys
- Building design professionals, including architects and engineers
- Building regulators
- Corporate facilities managers
- Commercial real estate developers
- Commercial lenders
- University facility managers
- Development planning consultants
- Earthquake engineering researchers
- Federal government facility managers
- Healthcare providers
- Property underwriters
- Social scientists

While a number of important stakeholder groups were represented at the workshop, generally, each stakeholder group was represented by only one or two individuals. Therefore, the attendees can not be said to be broadly representative of all interested groups. Also, several important stakeholder groups, notably residential and institutional building owners, and retailers were not represented at all. While on this basis it can not be said that the workshop attendees were truly representative of the cross section of stakeholders that will be affected and influenced by performance-based design, it also must be realized that the collection of stakeholders is so broad and diverse a group that it would be practically impossible to have a truly representative collection of such individuals in any reasonably-sized group. It is believed that this workshop represents one of the first significant attempts to obtain input on issues of acceptable levels of seismic risk used as a basis for design, from other than the technical community, and does provide valuable insight on the perspectives, needs and preferences of the general stakeholder community.

Workshop Format

The workshop included three plenary and two breakout sessions. The first plenary session included a welcome session, introduction of participants, and a presentation on what performance-based seismic design is and why it will be possible to include this approach in the next generation of building codes and design procedures, as opposed to the prescriptive approaches provided in present codes. Then a "typical earthquake scenario," representative of the moderate-magnitude events that affect western U.S. communities frequently, was presented to provoke thought on the types of problems that earthquakes regularly cause. Copies of the slides used as visual aids in the first plenary presentations are contained in Appendix B.

Following the first plenary session, the attendees were broken into three separate discussion groups. Each discussion group convened in a different room. Each member of the discussion groups was asked to read through and respond to questions contained on a discussion guide. These discussion guides, which are presented in Appendix C, together with a list of the assignment of attendees to discussion groups, were designed to facilitate discussion of those aspects of earthquake risk that are of most concern to each of the individual attendees. Attendees were asked to respond to the questions in the discussion guide immediately upon entering the breakout session, without group discussion. After all breakout session attendees had completed the discussion guide exercise, a facilitator lead discussion of the responses and the reasons for these responses. Following discussion, attendees were asked to respond to the questions in the discussion guide a second time.

Following a lunch break, attendees were again convened in plenary session. A brief presentation of the morning breakout session discussions was presented. Then a presentation was made on the issue of uncertainties associated with predicting earthquakes and their affects. This was followed by presentation of a second earthquake scenario, representative of a major event, likely to affect a region one time every few hundred years. The slides used as visual aids in this plenary session are contained in Appendix D.

Following the second plenary session, the attendees were again broken into three individual breakout discussion groups. Afternoon breakout sessions were conducted in a similar manner to the morning sessions. Attendees were asked to read and respond to questions in a discussion guide. This discussion guide was designed to facilitate consideration and discussion of the issues of dealing with the probabilities and uncertainties associated with earthquake occurrence and earthquake loss prediction. As with the morning session, attendees were asked to respond to the questions posed in the discussion guide prior to discussion and again following discussion. Appendix E contains the list of assignment of attendees to individual breakout sessions and the discussion guides used in these sessions.

Following the afternoon breakout sessions there was a concluding plenary session that discussed in a general way how the results of the workshop are intended to be used in the project and the additional opportunities that workshop attendees will have to participate in future project activities.

ATC-58 Project Description and Background

Presently, seismic code requirements are based on "life safety", meaning their goal is to prevent the loss of life or life-threatening injury to building occupants or pedestrians, primarily by preventing building collapse. During a design level earthquake, buildings designed to such codes could suffer significant structural and nonstructural damage, possibly to the point of having to be demolished. However, as long as a building does not collapse during an earthquake or generate large quantities of heavy falling debris, it would have met the intent of current code design requirements. While this may be an acceptable minimum design level for many types of buildings, it is not adequate for certain occupancies, such as critical facilities or buildings where the owner wants to have damage limited to either a repairable level or have the facility functional immediately after an earthquake. As has been vividly demonstrated during recent earthquakes, even well designed buildings conforming to contemporary codes can perform as specified and still be unfit for normal occupancy and use for an extended period of time following an earthquake, resulting from both structural and non-structural damage and the necessary repair operations.

FEMA recently funded the development of an Action Plan by the Earthquake Engineering Research Institute (EERI, 2000) that lays out a roadmap for the development of acceptable design criteria for performance-based seismic design for various levels of seismic hazards for both new and existing buildings. FEMA plans to implement this action plan to guide the development of design criteria that will yield a desired level of building performance, through the ATC-58 project. The plan includes the establishment of a mechanism for characterizing different levels of seismic performance for different seismic hazard conditions and building characteristics as well as quantification of acceptable building performance characteristics. The ultimate goal of performance-based seismic design is the development of building design criteria that would give a building owner or regulator the ability to select a building's expected performance for a specific earthquake hazard.

Ultimately, FEMA envisions that the end product from this overall project will be design criteria for performance-based seismic design that could then be incorporated into existing established seismic design resource documents, specifically the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* (BSSC, 2001) for new construction and the *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* (ATC/BSSC, 1997), and its successor documents, for existing buildings. These resource documents could be implemented on a voluntary basis by individual development teams or could be adopted into the provisions of the building codes and become either an alternative or basic minimum standard for the seismic design and upgrade of buildings.

Chapter 2: Discussion Summary

This section presents a summary of the workshop discussions prepared by the ATC-58 Product One Development Team, consisting of Ronald L. Mayes, James O. Malley, Daniel Alesch and Bruce Ellingwood. Team members Malley, Alesch and May served as recorders during the several breakout discussion sessions.

Summary of Morning Session: What's Important to You?

The morning breakout sessions were focused on eliciting from the attendees those aspects of seismic risk that are of most concern to them, for example protection of life safety versus avoidance of various forms of financial loss, and the relative priority of concern that the attendees assigned to each.

Although discussion during the breakout sessions focused more on the financial and business/occupancy interruption issues of earthquake loss, the project team believes that protection of life safety is a fundamental issue and that this must be the minimum basis for any design, performance-based or not. The project team hypothesized that relatively little attention was paid to life safety in the working group discussions because recent US earthquakes have resulted in very few deaths. Therefore, it is possible that workshop attendees assumed that life safety protection is something that is routinely achieved in the design process and that it was therefore not necessary to discuss this issue further. It is worthy of note that of the workshop attendees, engineers were more focused on protection of life safety and design liability issues whereas economic viability was much more important to other stakeholders.

One question (3A) attempted to elicit an opinion from the attendees as to whether they would be more interested in reducing the overall risk of life threatening injuries by some small percentage, reducing the probable number of lives lost by some small general number, or of reducing the probable number of less serious injuries by some larger number. Responses to these choices are summarized in Table 2-1, below. As can be seen, the attendees overwhelmingly chose reducing the number of lives lost by some defined small number, as opposed to reducing the risk by some percentage or reducing the number of less serious injuries by a large amount.

Table 2-1 Life-Safety Performance Choices (Question 3A, Morning Session)

Percentage of Workshop Participants Choosing the Response	Response Choices
22%	Reducing the probability of the loss of any life by 5 percent
74%	Reducing the number of serious, life-threatening injuries by 20 individuals
4%	Reducing the number of less serious, non-life-threatening injuries by 150 individuals

However, in the opinion of the project team, this was a poorly worded question. Selection of an appropriate answer to this question depends heavily on the number of affected occupants and the building size. Little useful discussion was provoked by this question.

Question 3B attempted to explore the relative importance of different occupancy interruption issues. Specifically, the question sought to determine whether attendees would prefer to spend additional money to reduce the amount of time that a facility would be fully functional, reduce the amount of time that a building would be unavailable for partial occupancy and operation, or reduce the amount of time a building would be unavailable for any occupancy, including retrieval of contents. The responses to this question are summarized in Table 2-2 below.

Table 2-2 Functionality Performance Choices (Question 3B, Morning Session)

Percentage of Workshop Participants Choosing the Response	Response Choices
52%	Reduce the time basic utility services (power, water) are not available (hindering critical operations) by 24 hours
17%	Reduce the time required to secure the facility for safe access to retrieve contents and begin repairs by 36 hours
30%	Reduce the time that it takes to restore full functions by 5 days

Review of the responses clearly shows that the highest priority among the workshop attendees here is the restoration of utility services to permit some beneficial occupancy and use of buildings. Clearly this is more of a regional than building-specific concern. However, it would be important for utility companies to know if a number of businesses have opted for higher performance in their buildings and conversely, the ability of utilities to provide rapid restoration of service should be considered by stakeholders prior to investing in design of facilities to provide either immediate occupancy or operability.

Although only a small number of attendees indicated by vote that it was important to permit building tenants to retrieve contents from a damaged building, the group discussions revealed that a number of stakeholders felt the ability to retrieve contents from a building is quite important.

Question 3C attempted to explore whether participants felt it was more important to limit the repair costs for an individual building, to ensure that an individual building would not experience so much damage it could not be repaired, or to ensure that that the total risk of ruin, that is extreme financial loss, was minimized. Table 2-3 summarizes the response to these choices.

Table 2-3 Repair Performance Choices (Question 3C, Morning Session)

Percentage of Workshop Participants Choosing the Response	Response Choices
35%	Reduce the costs of repairing the structure by 25 percent
35%	Reduce the odds that the earthquake will result in financial insolvency (ruin) by 5 percent
26%	Reduce the losses due to business interruption resulting from earthquake damage and repair operations by 10 percent
4%	Reduce the probability that the facility cannot be repaired by 20 percent

With the exception of ensuring that a building could be practically repaired, for which there was practically no interest, response to these questions was approximately equally split. It is important to note that while there is great interest in protecting against financial ruin and in reducing potential losses due to business interruption, both of these are very tenant-specific. Since many buildings are developed without knowledge either the specific tenant or the type of tenant who will occupy a building, except in rare cases, it will be very difficult to design to minimize the risk of these outcomes.

Question 4A was designed to explore the way the participants preferred to think and communicate about the risk to life safety. Specifically, the question explore expressing this risk in terms of the number of lives that would be lost as a result of adverse performance, the probability that any life would be lost, the probability that more than a given number of lives would be lost, or the mean number of lives lost per year, averaged over many years. Table 2-4 summarizes the results of responses to this question.

Table 2-4 Loss of Life: Information Presentation Choices (Question 4A, Morning Session)

Percentage of Workshop Participants Choosing the Response	Response Choices
22%	Expected number of lives that will be lost
43%	The probability of any loss of life
22%	The probability that the number of lives lost will exceed X (where you specify the threshold level X in advance)
13%	The average number of lives expected to be lost per year

This question provided the first insight into the very poor reception that average annualized losses of any kind received throughout the workshop. In general, there appeared to be a strong preference for communicating the risk of life loss in terms of the probability that any lives would be loss, rather than attempting to predict the probable number of lives that could be lost. Based on the workshop discussions, it was the project team's conclusion that any statement indicating that some specific number of lives would be lost would be politically unacceptable, while statements that allude to the possibility or probability of unspecified life loss are easier to deal with.

Question 4B was designed to explore the way the participants preferred to think and communicate about the risk of financial loss associated with building damage. It explored preferences for measures related to facility repair cost, time that a facility would be out of service and inoperable, total economic losses resulting from damage-related business interruption, and average annualized dollar losses.

Table 2-5 Potential Damage to Facilities: Information Presentation Choices (Question 4B, Morning Session)

Percentage of Workshop Participants Choosing the Response	Response Choices
22%	Probable facility repair cost, expressed as a percentage of the building replacement value
13%	Number of hours or days before full functions can be resumed in the facility
52%	Dollar value of lost business and other costs associated with business interruption
13%	The average annual economic losses per year, expected to occur as a result of earthquakes

As with risks to life, little support was expressed for the use of average annualized loss measures. For this group of participants, there was a clear preference for expressions of loss that focused on the economic loss (dollars) resulting from damage-induced business interruption. It is believed that this preference was expressed because this measure is the most comprehensive with regard to the overall cost impacts, for a single event, though it is not a direct measure of overall cost impacts, as costs associated with building repair are not included in this measure. It is important to note that the engineer can provide estimates or predictions of the probable facility repair cost and even the number of hours that a building may not be fit for occupancy; however, only an owner/operator of a building has the necessary knowledge to calculate likely business interruption costs associate with such occupancy interruption.

Question 4C directly explored the preferred method for expressing probable damage repair costs. Choices offered included the absolute cost of repair, expressed in present dollars; cost of repair expressed as a percentage of building replacement cost; the probability that repair costs would exceed some specific amount; the probability that repair costs would be sufficient to lead to financial ruin; and the average annualized expected loss.

Table 2-6 Potential Repair Costs: Information Presentation Choices (Question 4C, Morning Session)

Percentage of Workshop Participants Choosing the Response	Response Choices
39%	Absolute cost, expressed in present dollars, of repairing the facility to bring it back to full functions
17%	Percentage of replacement costs that repair costs will constitute
26%	The probability that the cost of repairs will exceed Y dollars (where you specify the threshold level Y in advance)
4%	“Risk of ruin” – The likelihood that the costs of repair (and other earthquake costs) will lead to financial insolvency
13%	The average annual expected cost of repair and other earthquake-related losses

Interestingly, expressions of probable loss as a percentage of replacement cost, the current most commonly used method of expressing property losses, was not favored by the participants. Rather, there was a strong preference for expression of loss in absolute terms, using present currency values. On the basis of ensuing discussion, the project team believes that the use of an absolute cost expressed in terms of a range of repair costs and a probability based expression of repair costs are not mutually exclusive and should both be considered for use. This will avoid the need to differentiate between stakeholders since both were ranked 1 and 2 with the absolute concept being the higher of the two.

Summary of Afternoon Session: Communicating Probability and Uncertainty

Discussion in the afternoon sessions was intended to expose participant views as to the preferred methods of expressing the uncertain time of occurrence of earthquake and the lack of predictability of exact earthquake effects.

The first question discussed in the afternoon sessions specifically dealt with the preferred way of expressing either the probability that an earthquake will affect a building or the probability that certain consequences of earthquake response (performance) will be experienced. Participants were asked to express a preference for annual probability of experiencing an event, the probability over a period of a number of years that an event will be experienced, the average return period between events of given magnitude, or qualitative expressions of the likelihood of experiencing an event. Table 2-7 summarizes the choices made by participants.

Table 2-7 Ways of Presenting Information about the Likelihood of Seismic Events (Question 1, Afternoon Session)

Percentage of Workshop Participants Choosing the Response	Response Choices
0%	There is a 2 percent chance in any year of a very damaging earthquake
45%	The probability of a very damaging earthquake over the next 20 years is 33 percent
36%	A very damaging earthquake can be expected, on average, once every 50 years
18%	Although the probability in any year of a very damaging earthquake is low, there is a moderately high probability that such an event will occur within the next 20 years

None of the participants preferred to express probability of event occurrence on an annual basis, perhaps resulting from a realization that annual probabilities tend to be small and to lead to a sense of false security. Most participants preferred to express event probability in a quantitative rather than qualitative manner. Slight preference was expressed for statement of probability of event occurrence over an interval of some number of years but strong support was also expressed for statement of probability in terms of mean return periods. Based on discussions, time periods ranging between 20 to 50 years seem to be reasonable for expression of earthquake occurrence probabilities. It is possible that performance objectives relating to life safety protection should be expressed in terms of a somewhat longer time period, perhaps 50 years, and that a 20 year period may be preferable for objectives that relate to financial loss.

Further input on the appropriate time period to use when expressing earthquake probabilities was directly solicited in the second question, that gave participants choices ranging from 5 years to 50 years and also the choice of selecting a different return period for each individual project or transaction. Table 2-8 summarizes the results of responses to these questions.

Nearly half the participants expressed a preference for using a different time window for each decision, depending on the expected life of a particular building or property investment. Of those who indicated a preference for the use of a particular window for expression of event occurrence, 30 and 50 year windows seemed most popular.

The third question explored the preferred method of expressing the probability of earthquake losses, and in particular, life losses. Participants were asked to choose between probable losses per year averaged over many years (annualized loss), an annual probability of experiencing a loss, the probability over a period of years that a loss would be experienced, the probability of experiencing a loss given that a specific event occurred, or the maximum foreseeable loss, should an earthquake occur. Table 2-9 indicates the responses to this question.

Table 2-8 The Timeframe (Number of Years) Most Appropriate to "Planning Horizon" for Making Investments in Facilities? (Question 2, Afternoon Session)

Percentage of Workshop Participants Choosing the Response	Response Choices
0%	5 years
9%	10 years
9%	20 years
18%	30 years
23%	50 years
41%	A different "horizon" for each decision, depending on the expected term of commitment

Table 2-9 Ways of Presenting Information about Potential Loss of Life for a Hypothetical Structure When Fully Occupied (Question 3, Afternoon Session)

Percentage of Workshop Participants Choosing the Response	Response Choices
5%	Over a period of many years, the average expected number of fatalities per year is 1.3.
0%	In any given year there is a 5 percent probability of experiencing one or more earthquake-related fatalities associated with this facility.
36%	In the next 20 years, there is a 25 percent probability of 10 or more earthquake-related fatalities associated with this structure.
50%	If a magnitude 7 earthquake occurs, the expected number of fatalities for this structure is 20.
9%	Given the most severe earthquake likely to occur in the next 100 years, a maximum of fifty lives are expected to be lost in this structure.

Consistent with responses to prior questions, participants showed low preference for annualized expressions of loss as well as annual probabilities of experiencing a loss. Although the insurance industry frequently uses maximum foreseeable losses to characterize risk, there was also little support for this approach among these workshop attendees. By far the strongest support was expressed for an approach that expresses the probable size of the loss, given that a scenario event of given size is experienced. The Project team noted a differentiation between the views of engineers and non-engineer stakeholders. The non-engineer stakeholders had quite a strong preference for Scenario type events whereas engineers preferred the probability based statement. Again these were not believed to be mutually exclusive. The annualized expressions are not recommended for further consideration.

Question 4 also explored participant preference for expressing the probability of losses, however, instead of life losses, this question focused on economic losses. Participants were asked to choose between annualized losses, the probability that a loss exceeding a certain size would be experienced in a specific time frame and the probable maximum loss ever expected to occur. Table 2-10 indicates the responses to this question.

Table 2-10 Ways of Presenting Information about Potential Earthquake Losses (Question 4, Afternoon Session)

Percentage of Workshop Participants Choosing the Response	Response Choices
18%	The annualized expected earthquake-related loss for this facility is $10,000.
55%	The probability of a single earthquake loss exceeding $500,000 in the next 20 years is 33 percent.
27%	The probable maximum loss associated with a major earthquake (expected one time every 500 years) is $6,000,000.

This group of participants expressed a clear preference for expressions of the probability that loss would exceed a given amount in a period of years, which was the second choice for expression of probable life loss. Unfortunately, the first choice for expression of probable life loss, that is the expected number of lives loss given that a scenario event occurs, was not provided as a choice for this question. Therefore, information was not obtained as to whether participants prefer to express financial and life losses in the same terms.

The fifth questions explored participant preference for expression of uncertainty with regard to outcomes associated with earthquake occurrence. Participants were asked to choose between a quantitative expression of the uncertainty associated with a probability estimate, uncertainty expressed as a range of probabilities associated with the event, and a more qualitative expression of uncertainty. Table 2-11 summarizes the response to this question.

Participants indicated a preference for expression of uncertainty in the form of a range of possible bounds on the actual probability of an event. There was also some support for the more rigorous quantitative expression of the uncertainty associated with a probability of event occurrence. Little support was revealed for qualitative statements of uncertainty. Although there was significant participant support for the rigorous expression of uncertainty, the project team felt that the use of multiple probabilities within one expression resulted in excessively complex and potentially confusing statements.

Question 5 similarly explored participant preference for expression of uncertainty, this time with respect to the uncertainty associated with predictions that an economic loss of given size would occur. Choices included a specific quantitative level of confidence, associated with a prediction of loss, a qualitative expression of confidence associated with loss, and a range indicating the bounds on expected losses. Table 2-12 indicates the results of this discussion. Support was split evenly between rigorous quantitative expression of confidence and expression of confidence in the form of a bounding range. As with past questions, there was little support for qualitative expressions of confidence.

Table 2-11 Ways of Communicating Uncertainties about Predictions of Seismic Occurrences (Question 5, Afternoon Session)

Percentage of Workshop Participants Choosing the Response	Response Choices
36%	We are 95 percent confident that there is a 30 percent chance of a magnitude 7.0 or greater earthquake in the next 20 years.
50%	The probability of a magnitude 7.0 or greater earthquake occurring in the next 20 years is between 20 percent and 35 percent.
14%	We are very confident that an earthquake of magnitude 7.0 or greater is at least somewhat likely in the next 20 years.

Table 2-12 Ways of Communicating Uncertainties about the Potential Value of Non-Life Related Earthquake Losses (Question 6, Afternoon Session)

Percentage of Workshop Participants Choosing the Response	Response Choices
41%	We are 90 percent confident that losses from an earthquake for this structure will not exceed $800,000.
14%	We are very confident that losses from an earthquake associated with this structure will not exceed $800,000.
45%	The dollar value of potential losses for this structure are expected to be between $400,000 and $900,000.

The sixth question sought to explore the preferred levels of confidence to use when expressing an expected outcome. Participants were asked to choose between median (50%), 90%, 95% and 99% confidence levels. The results of this discussion are tabulated in Table 2-13. There was almost total support for use of a 90% confidence level, moderate support for use of a 95% confidence level and almost no support for use of other levels. In general, it appeared that use of median levels of confidence were viewed as providing an excessive chance that decisions would be made on poor data, while very high levels of confidence were viewed as excessively conservative. Although not specifically offered as a choice to workshop participants, the project team believes that an 85% confidence level, approximating the statistically significant mean + 1 standard deviation measure, would likely also be acceptable to stakeholders and that this measure may, due to its statistical significance be preferable as an standard level of expression.

Table 2-13 Minimum "Level Of Confidence" in Predictions for Making Decisions About Seismic Improvements for a Hypothetical $2 Million Dollar Investment? (Question 7, Afternoon Session)

Percentage of Workshop Participants Choosing the Response	Response Choices
0%	50 percent confidence in the results for an analysis cost of $25,000, and a possible variation of +/- $500,000 in the value of earthquake related losses.
86%	90 percent confidence in the results for an analysis cost of $50,000 and a possible variation of +/- $200,000 in the value of earthquake related losses.
9%	95 percent confidence in the results for an analysis cost of $75,000, and a possible variation of +/-$100,000 in the value of earthquake related losses.
5%	99 percent confidence in the results for an analysis cost of $200,000, and a possible variation of +/- $50,000 in the value of earthquake related losses.

Appendix A: Workshop Participants

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Consulting Engineer
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New York, New York 10020

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Common System Standards
SBC Services, Inc.
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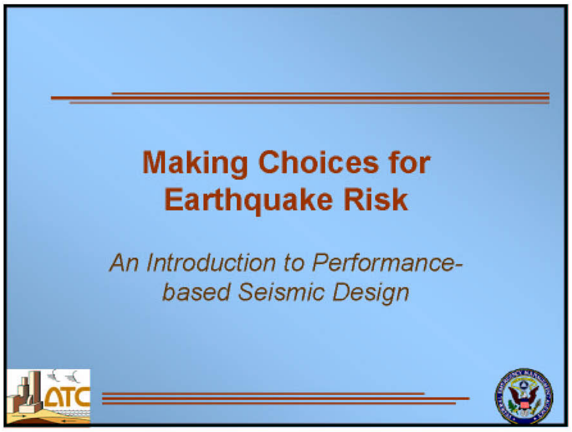
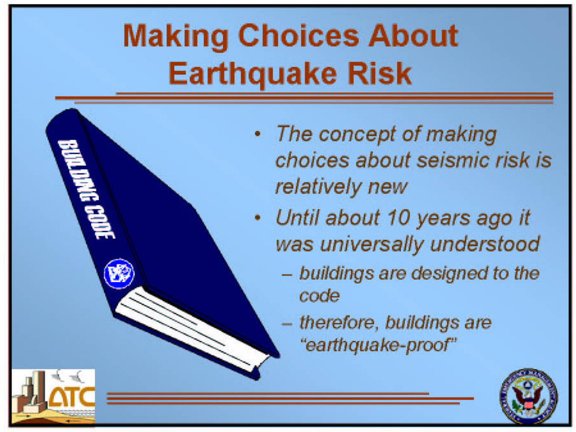
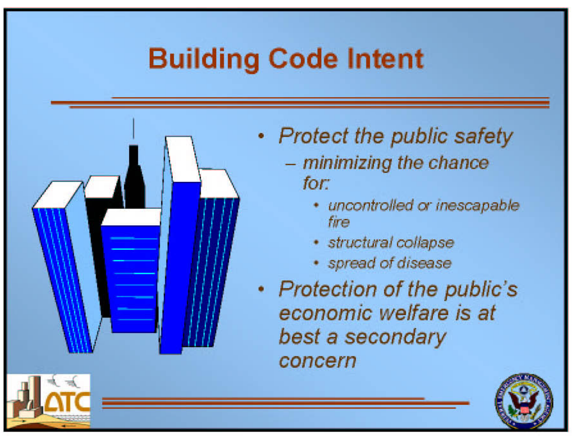
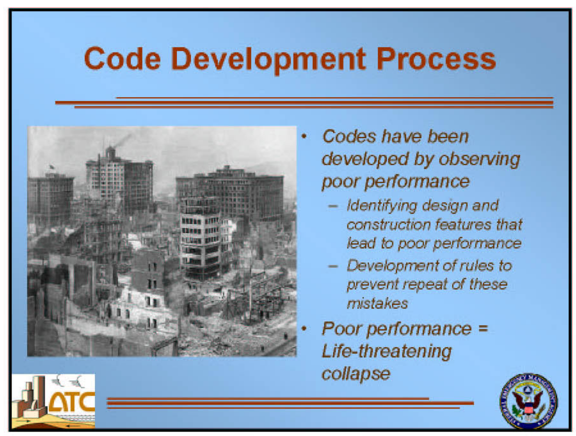
San Ramon, California 94583

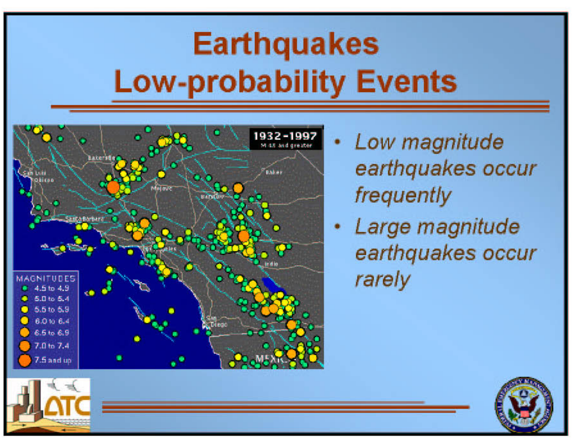
Appendix B: Slides – First Plenary Session

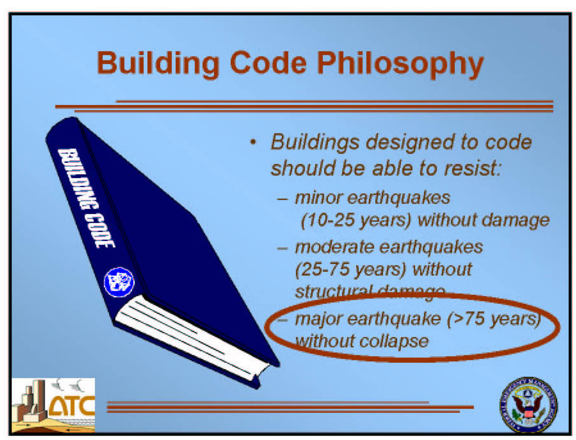


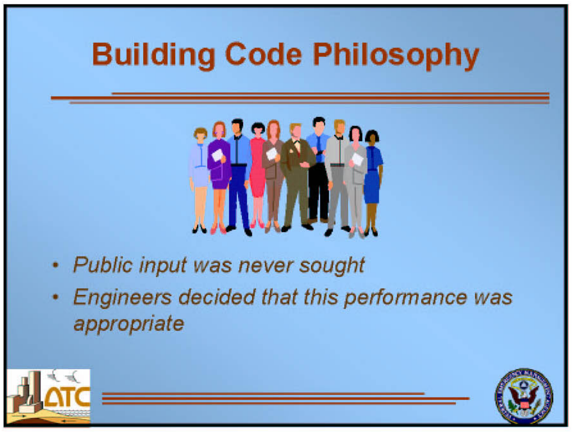


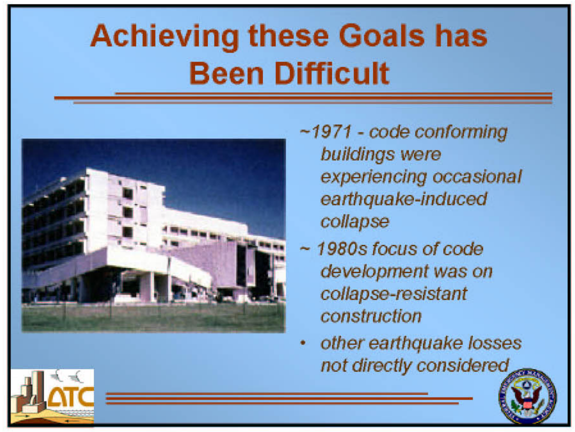


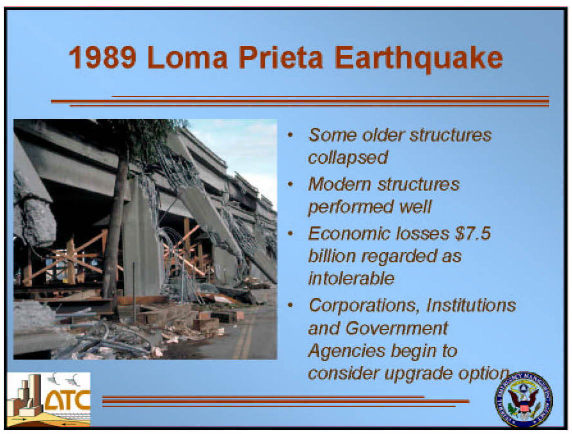


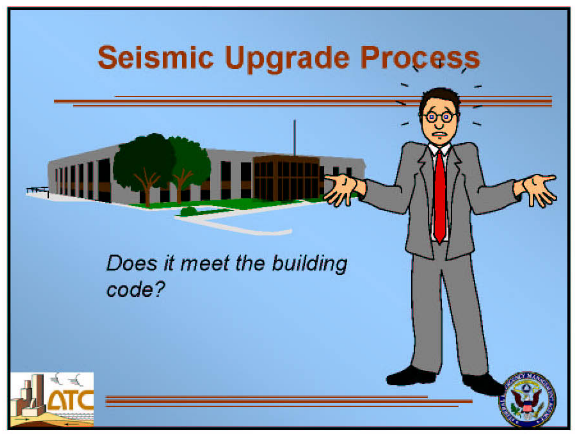





Building Code Philosophy
• Public input was never sought
• Engineers decided that this performance was appropriate
ATC

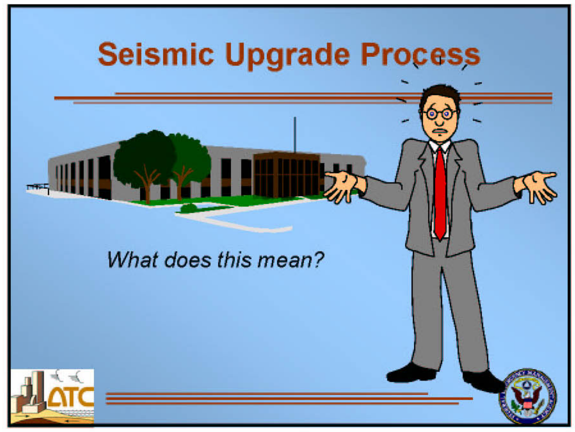

Achieving these Goals has Been Difficult
~1971 - code conforming buildings were experiencing occasional earthquake-induced collapse
~ 1980s focus of code development was on collapse-resistant construction
• other earthquake losses not directly considered
ATC

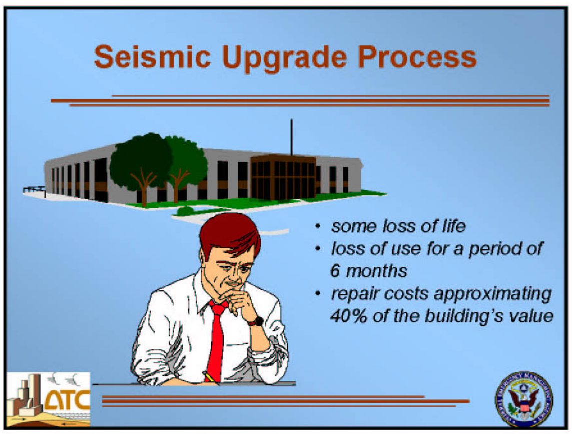

1989 Loma Prieta Earthquake
• Some older structures collapsed
• Modern structures performed well
• Economic losses $7.5 billion regarded as intolerable
• Corporations, Institutions and Government Agencies begin to consider upgrade option
ATC

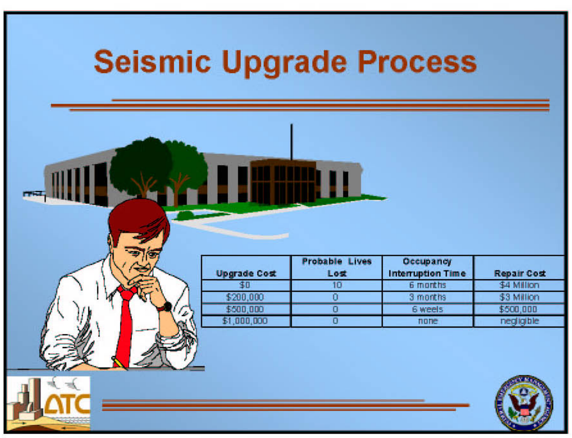

Seismic Upgrade Process
Does it meet the building code?
ATC


Seismic Upgrade Process
No-
ATC

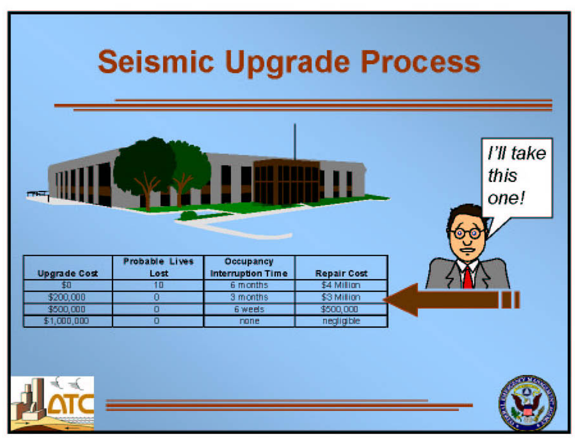

Seismic Upgrade Process
What will happen if we have an earthquake?
ATC







Upgrade Cost	Probable Lives Lost	Occupancy Interruption Time	Repair Cost
$0	10	6 months	$4 Million
$200,000	0	3 months	$3 Million
$500,000	0	6 weels	$500,000
$1,000,000	0	none	negligible



Upgrade Cost	Probable Lives Lost	Occupancy Interruption Time	Repair Cost
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$500,000	0	6 weels	$500,000
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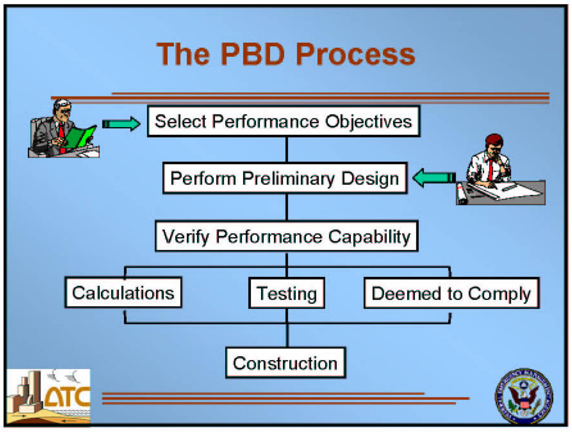
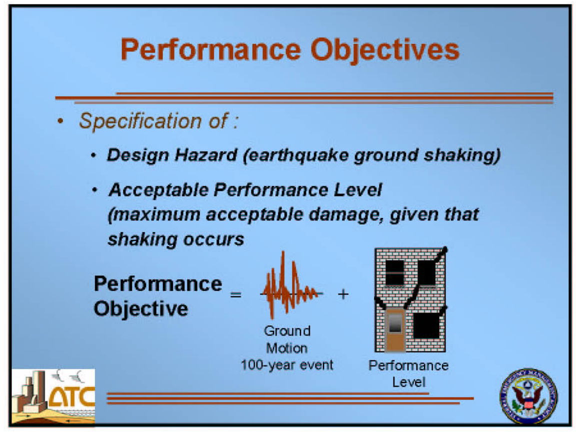
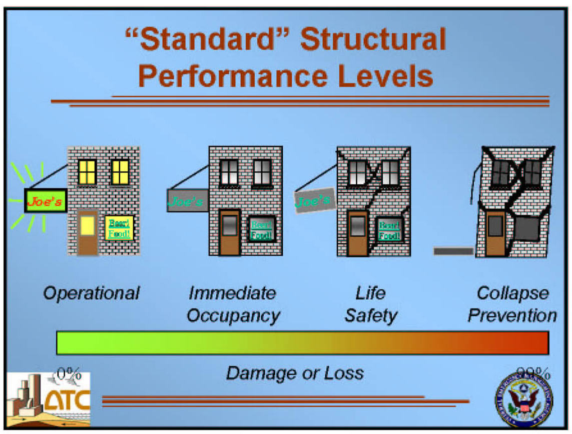
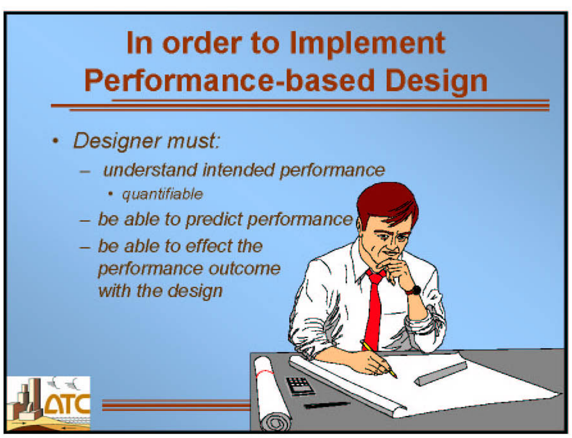

The PBD Process
Select Performance Objectives
Perform Preliminary Design
Verify Performance Capability
Calculations
Testing
Deemed to Comply
Construction
ATC


Performance Objectives
• Specification of :
• Design Hazard (earthquake ground shaking)
• Acceptable Performance Level (maximum acceptable damage, given that shaking occurs
Performance Objective = +
Ground Motion 100-year event
Performance Level
ATC


"Standard" Structural Performance Levels
Operational
Immediate Occupancy
Life Safety
Collapse Prevention
Damage or Loss
ATC


For Performance-based Design to Be Effective
• Owners must understand:
– available options for performance outcomes
– costs associated with these outcomes
– method for selecting between alternatives
ATC


In order to Implement Performance-based Design
• Designer must:
– understand intended performance
• quantifiable
– be able to predict performance
– be able to effect the performance outcome with the design
ATC

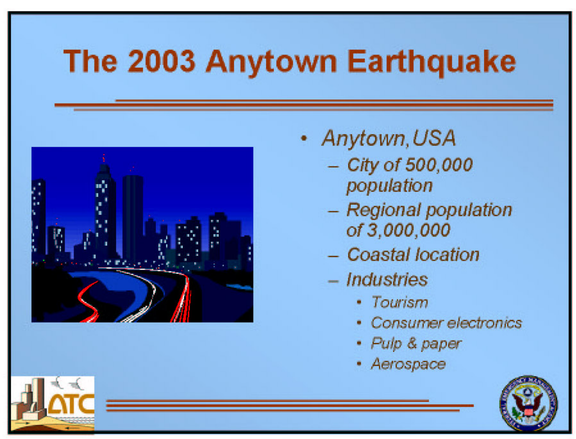

We Need Your Help!
• What consequences of earthquake performance are important to you?
• How important?
• Important enough to spend money to avoid?
ATC

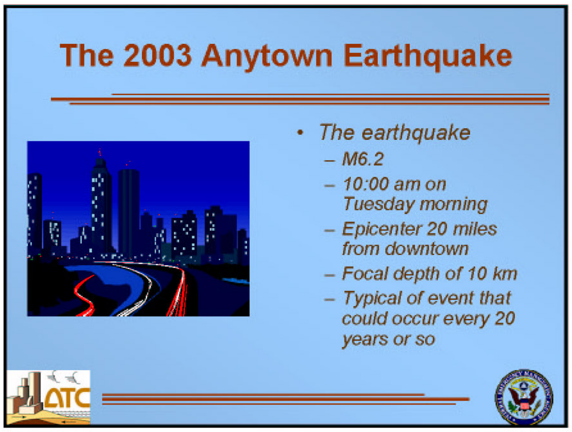

We Need Your Help!
• How do you prefer to measure and discuss these performance issues?

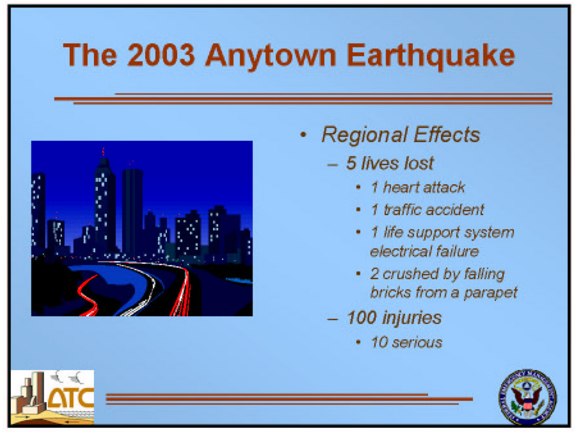

We Need Your Help!
• Prediction of earthquake performance is quite uncertain
– when the next earthquake will occur
– how big it will be
– how much damage it will cause
• How do you prefer to deal with these uncertainties?


This is a first Step
• Today's meeting is an important first step in resolving these issues, but it is not the last step
• Your continued involvement will be welcomed


Earthquake Scenario 1
Workshop on Communicating Earthquake Risk
ATC-58
Development of Performance-Based Seismic Design Guidelines

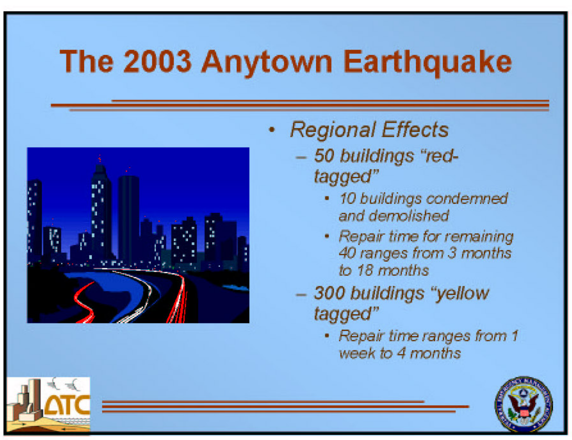

The 2003 Anytown Earthquake
• Anytown, USA
– City of 500,000 population
– Regional population of 3,000,000
– Coastal location
– Industries
• Tourism
• Consumer electronics
• Pulp & paper
• Aerospace

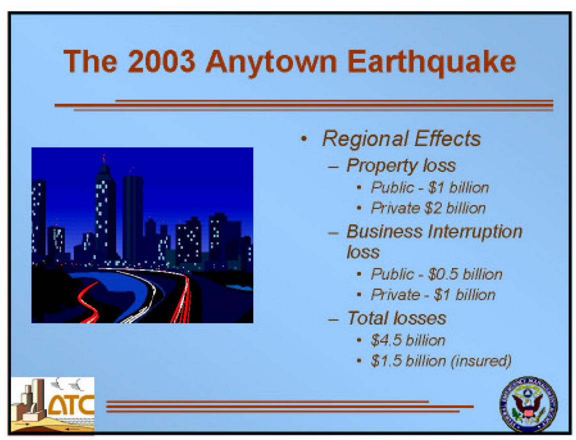

The 2003 Anytown Earthquake
The earthquake
M6.2
10:00 am on Tuesday morning
Epicenter 20 miles from downtown
Focal depth of 10 km
Typical of event that could occur every 20 years or so
ATC


The 2003 Anytown Earthquake
Regional Effects
5 lives lost
1 heart attack
1 traffic accident
1 life support system electrical failure
2 crushed by falling bricks from a parapet
100 injuries
10 serious
ATC


The 2003 Anytown Earthquake
Regional Effects
Electrical power interruption
Region-wide - 4 hours
500,000 customers – 8 hours
100,000 customers – 12 hours
10,000 customers – 24 hours
Water Service
20 line breaks
1,000 customers lost service for 24 hours
ATC

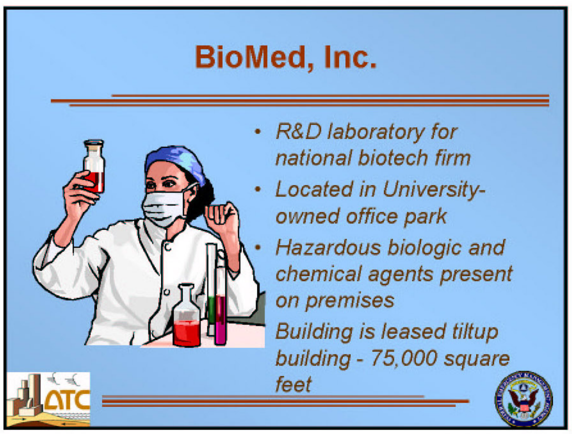

The 2003 Anytown Earthquake
Regional Effects
Commuter Rail
Full service restored in 2 hours
Bridges
3 major river crossings closed for 24 hours for inspection
1 of 3 river crossings closed for 3 weeks for repair
Highways
5 overpass closures in first 12 hours
ATC

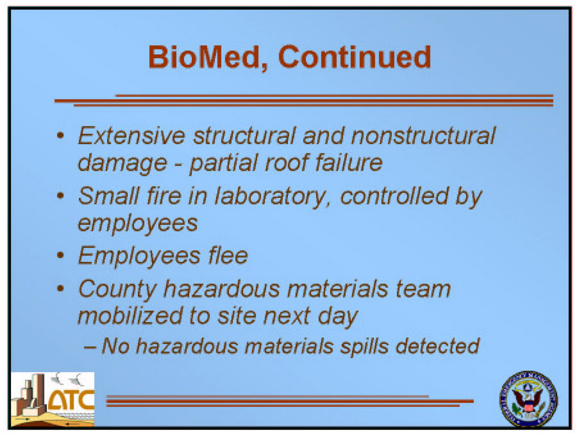

The 2003 Anytown Earthquake
Regional Effects
50 buildings "red-tagged"
10 buildings condemned and demolished
Repair time for remaining 40 ranges from 3 months to 18 months
300 buildings "yellow tagged"
Repair time ranges from 1 week to 4 months
ATC

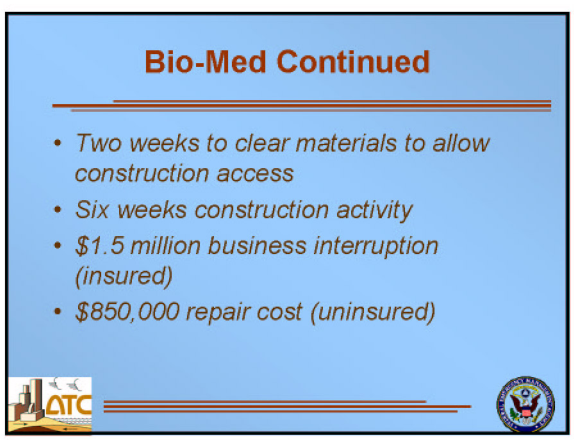

The 2003 Anytown Earthquake
Regional Effects
Property loss
Public - $1 billion
Private $2 billion
Business Interruption loss
Public - $0.5 billion
Private - $1 billion
Total losses
$4.5 billion
$1.5 billion (insured)
ATC


Anytown Coffee Company
• National coffee franchise operation
• Headquarters in 10 story building in CBD
– purchased in 1995 @ $22 million
– 150,000 square feet
– ACC occupies 5 floors, 75,000 square feet
– ground floor - bank branch, ACC outlet
– floors 2-4, multi-tenant commercial
• attorneys, insurance service, accountants
– average population of 700
ATC


Anytown Coffee Company
• Extensive nonstructural damage to office areas
– ceilings and light fixtures fall
– sprinkler lines break - causing flooding damage
• Small fire in ground floor restaurant
• One coronary victim as occupants flee
• Headquarters dormant for 1 week
• Temporary space up and running +2 weeks
• Building repairs
– 6 months, $4 million
– tenants evaporate
• Total Losses
– $7 million
ATC


BioMed, Inc.
• R&D laboratory for national biotech firm
• Located in University-owned office park
• Hazardous biologic and chemical agents present on premises
Building is leased tiltup building - 75,000 square feet
ATC


BioMed, Continued
• Extensive structural and nonstructural damage - partial roof failure
• Small fire in laboratory, controlled by employees
• Employees flee
• County hazardous materials team mobilized to site next day
– No hazardous materials spills detected
ATC


Bio-Med Continued
• Two weeks to clear materials to allow construction access
• Six weeks construction activity
• $1.5 million business interruption (insured)
• $850,000 repair cost (uninsured)
ATC

Appendix C: Participants and Discussion Guides, Morning Breakout Sessions

Participants in Morning Breakout Sessions

Breakout Session 1

Facilitator: Peter May

Recorder: Dan Alesch

Attendees: Debra Stein
Bill Holmes
Michel Bruneau
Bill Mott
Bruce Hall
Clifford Grey
Bob Bachman

Breakout Session 2

Facilitator: Jack Moehle

Recorder: Bruce Ellingwood

Attendees: Robert Hendrickson
Mohammed Ettourney
Jim Sealy
Christopher Terzich
Jack Hayes
Hildo Hernandez

Breakout Session 3

Facilitator: Jon Traw

Recorder: Jim Malley

Attendees: Larry Wong
John Scott
Daniel Abrams
Randall Berdine
William Moore
Stepehn Wenryb
Randy Schreitmuller

ATC-58 Development of Performance-Based Seismic Design Guidelines

What's Important to You?
Discussion Guide

Purpose: The purpose of this exercise is to facilitate a focused discussion of the different choices that are involved when making decisions about seismic risks for buildings or other facilities. Please respond to each of the items as best you can, while keeping in mind your experiences and perspectives about such choices.

Format: There are two places to provide responses for each item. [R1] indicates your response before discussion in the breakout group. [R2] indicates *any change* in your response after discussion in the breakout group. If the response after discussion is the same as before, you need not enter a new choice.

DISCUSSION ITEMS

1. What harms associated with these scenarios do you find most troubling?

[Initial Response – R1]:

1. ____

2. ____

3. ____

2. Please rank the importance of each of the following to you. [Enter rank in the space provided: 1 = most important, 7 = least important before (R1) and after (R2) discussion]:

R1	R2	Impacts to Rank
___	___	Avoiding loss of life.
___	___	Avoiding serious injuries.
___	___	Avoiding the total physical loss of a building or facility
___	___	Avoiding long-term interruption of facility functions or occupancy
___	___	Assuring continuous facility normal-use function or occupancy
___	___	Minimizing repair costs
___	___	Minimizing the potential for financial ruin due to combined effects of business interruption, lost capital, repair costs, and employee costs.

ATC-58 Development of Performance-Based Seismic Design Guidelines

3. Reductions in earthquake risk require investment in the design and construction of a facility in order to provide desired performance characteristics. The following items pose some difficult performance or risk choices, that an owner, tenant or investor may have to make when expending limited available financial resources to develop, lease, or invest in a facility. For each set, choose the one item that you would most likely want to achieve. Assume that the risk reduction outcomes for each set of choices cost approximately the same and are equally achievable.

A. Which of the following would you choose?
(Check one before [R1] and after [R2] discussion)

☐ R1 ☐ R2 Reducing the probability of the loss of any life by 5 percent.

☐ R1 ☐ R2 Reducing the number of serious, life-threatening injuries by 20 individuals.

☐ R1 ☐ R2 Reducing the number of less serious, non life-threatening injuries by 150 individuals.

Why do you make this choice?

B. Which of the following would you choose?
(Check one before [R1] and after [R2] discussion)

☐ R1 ☐ R2 Reduce the time basic utility services (power, water) are not available (hindering critical operations) by 24 hours.

☐ R1 ☐ R2 Reduce the time required to secure the facility for safe access to retrieve contents and begin repairs by 36 hours.

☐ R1 ☐ R2 Reduce the time that it takes to restore full functions by 5 days.

Why do you make this choice?

Discussion Guide – What's Important to You? Page 2

ATC-58 Development of Performance-Based Seismic Design Guidelines

C. Which of the following would you choose?
(Check one before [R1] and after [R2] discussion)

☐ R1 ☐ R2 Reduce the costs of repairing the structure by 25 percent.

☐ R1 ☐ R2 Reduce the odds that the earthquake will result in financial insolvency (ruin) by 5 percent.

☐ R1 ☐ R2 Reduce the losses due to business interruption resulting from earthquake damage and repair operations by 10 percent.

☐ R1 ☐ R2 Reduce the probability that the facility can not be repaired by 20 percent.

Why do you make this choice?

4. Consider different ways of presenting information about earthquake impacts. For each of the following sets of choices, please indicate which one is most meaningful to <u>you</u> for your decision-making.

A. Potential Loss of Life – for a given event or combination of events
(Check one before [R1] and after [R2] discussion)

☐ R1 ☐ R2 Expected number of lives that will be lost.

☐ R1 ☐ R2 The probability of any loss of life.

☐ R1 ☐ R2 The probability that the number of lives lost will exceed X. [where you specify the threshold level X in advance]

☐ R1 ☐ R2 The average number of lives expected to be lost per year.

Why do you make this choice?

ATC-58 Development of Performance-Based Seismic Design Guidelines

B. Potential Damage to Facilities—Downtime and Functionality
(Check one before [R1] and after [R2] discussion)

☐ R1 ☐ R2 Probable facility repair cost, expressed as a percentage of the building replacement value

☐ R1 ☐ R2 Number of hours or days before full functions can be resumed in the facility.

☐ R1 ☐ R2 Dollar value of lost business and other costs associated with business interruption.

☐ R1 ☐ R2 The average annual economic loses per year, expected to occur as a result of earthquakes.

Why do you make this choice?

C. Potential Repair Costs
(Check one before [R1] and after [R2] discussion)

☐ R1 ☐ R2 Absolute cost, expressed in present dollars, of repairing the facility to bring it back to full functions.

☐ R1 ☐ R2 Percentage of replacement costs that repair costs will constitute.

☐ R1 ☐ R2 The probability that the cost of repairs will exceed Y dollars. [where you specify the threshold level Y in advance]

☐ R1 ☐ R2 "Risk of ruin" – The likelihood that the costs of repair (and other earthquake costs) will lead to financial insolvency.

☐ R1 ☐ R2 The average annual expected cost of repair and other earthquake-related losses.

Why do you make this choice?

ATC-58 Development of Performance-Based Seismic Design Guidelines

5. **Are there other considerations not addressed so far that are important for your decision-making about earthquake risks? Please list them:**

   1. ____

   2. ____

   3. ____

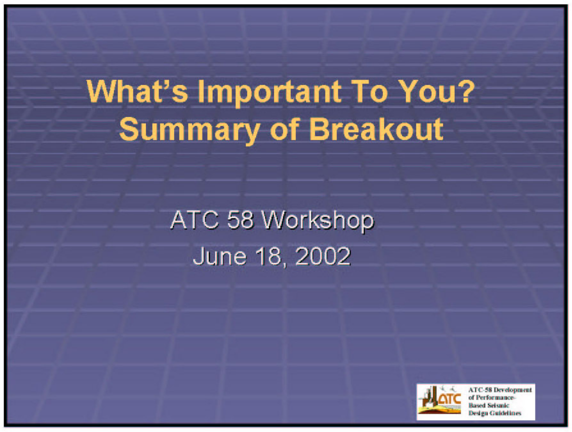
   4. ____

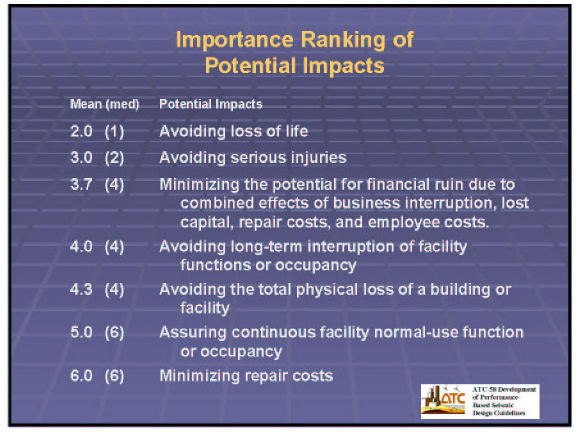
   5. ____

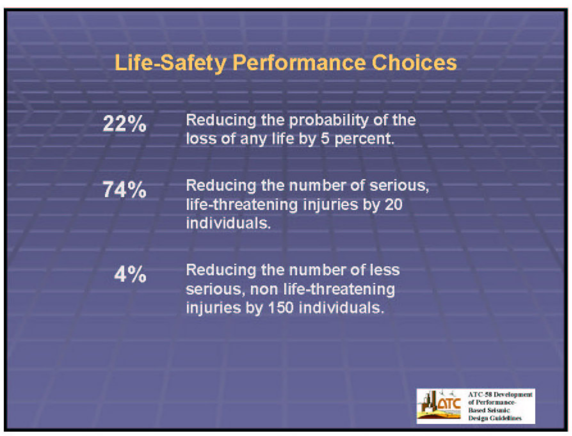
6. **After listening to the discussion in your breakout group are there any other comments you would like to add?**

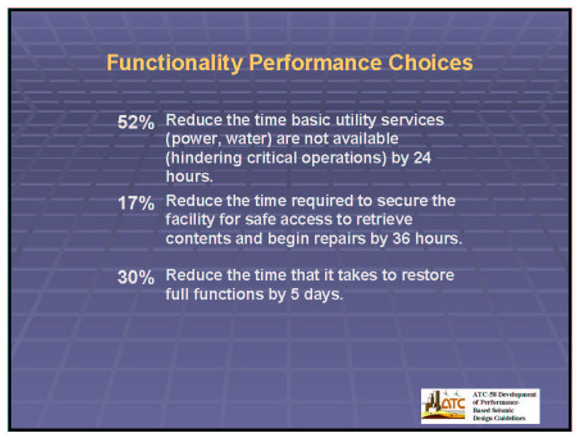
7. **What is your profession/discipline?** ______________________________
   [e.g., Building Official, Corporate Facilities Manager, Corporate Risk Manager, Real Estate Professional, Commercial Lender, Underwriter, etc.]

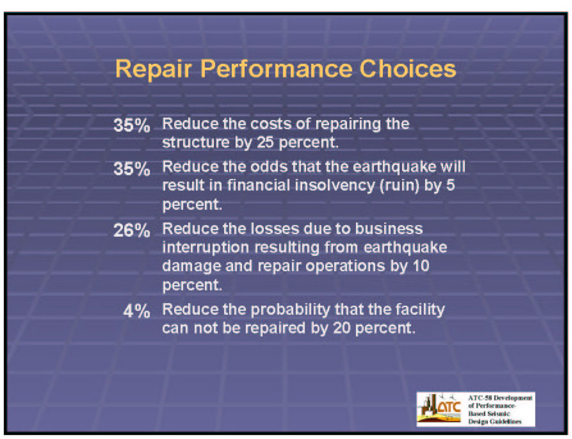
Appendix D: Slides – Second Plenary Session

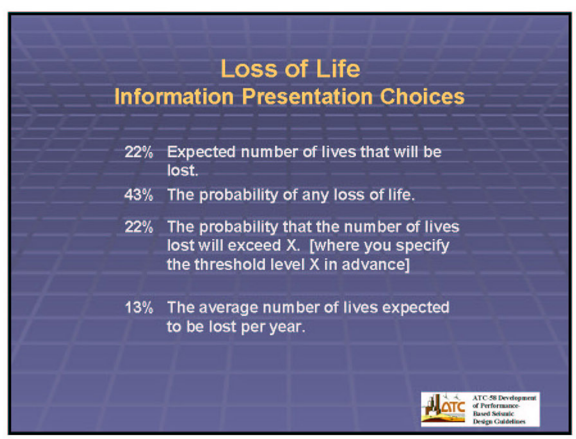


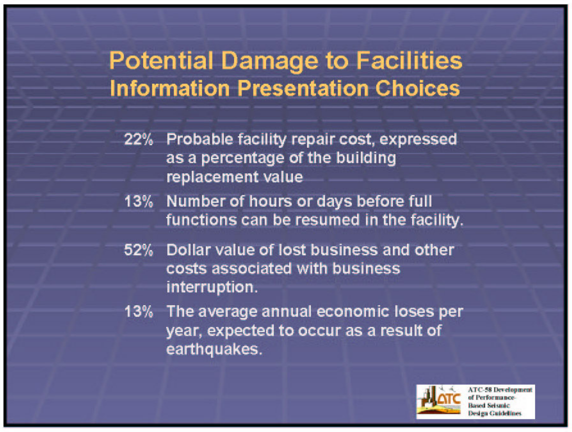


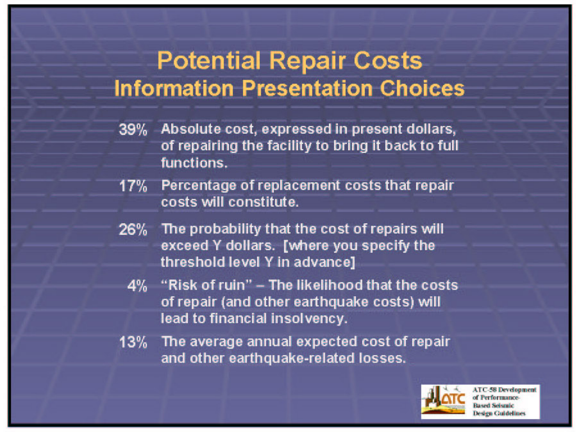


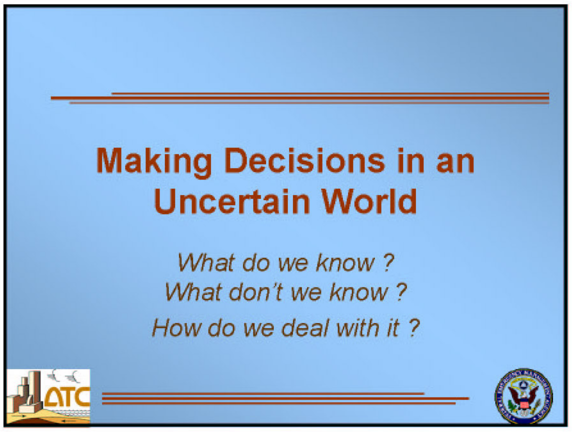


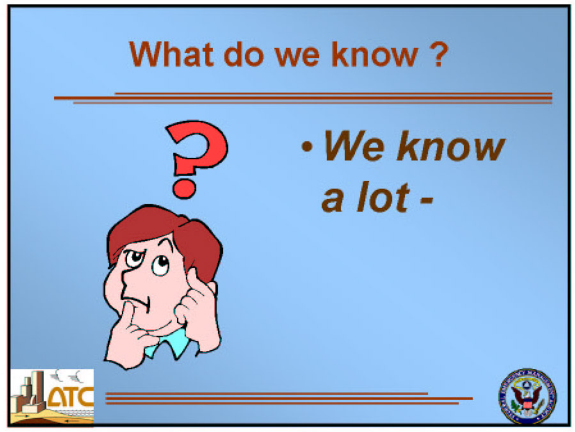


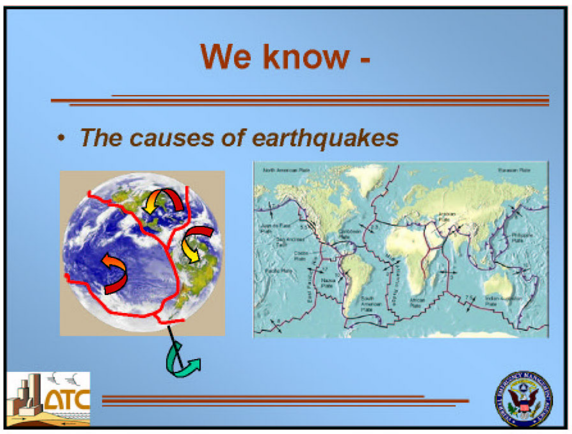


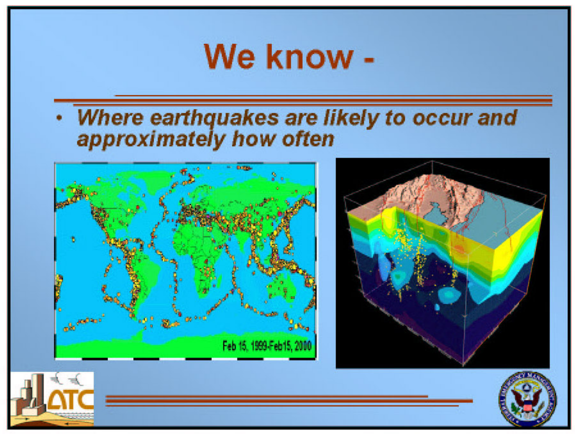

Potential Damage to Facilities
Information Presentation Choices
22% Probable facility repair cost, expressed as a percentage of the building replacement value
13% Number of hours or days before full functions can be resumed in the facility.
52% Dollar value of lost business and other costs associated with business interruption.
13% The average annual economic loses per year, expected to occur as a result of earthquakes.


Potential Repair Costs
Information Presentation Choices
39% Absolute cost, expressed in present dollars, of repairing the facility to bring it back to full functions.
17% Percentage of replacement costs that repair costs will constitute.
26% The probability that the cost of repairs will exceed Y dollars. [where you specify the threshold level Y in advance]
4% "Risk of ruin" – The likelihood that the costs of repair (and other earthquake costs) will lead to financial insolvency.
13% The average annual expected cost of repair and other earthquake-related losses.

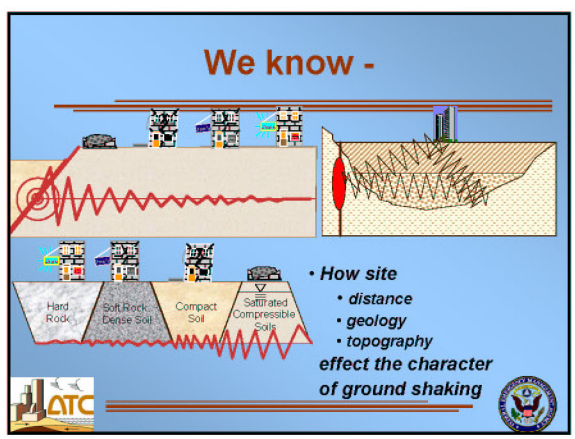

Making Decisions in an Uncertain World
What do we know ?
What don't we know ?
How do we deal with it ?
ATC

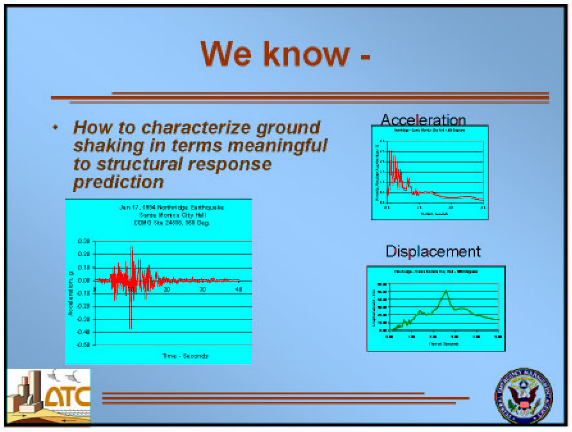

What do we know ?
• We know a lot -
ATC

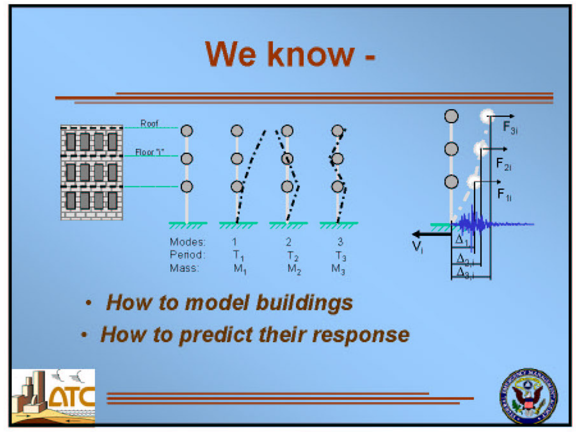

We know -
• The causes of earthquakes
ATC

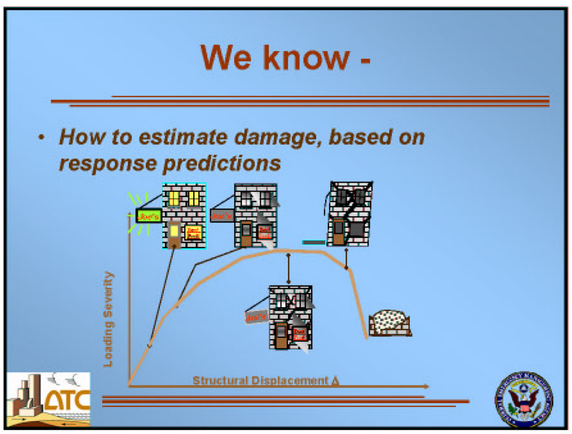

We know -
• Where earthquakes are likely to occur and approximately how often
Feb 15, 1999-Feb15, 2000
ATC


We know -
25 feet
• The types of faulting that can occur, and the type of ground shaking likely to result
ATC

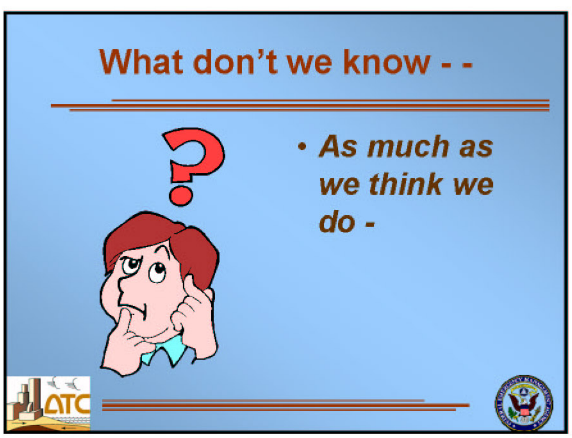

We know -
Hard Rock
Soft Rock Dense Soil
Compact Soil
Saturated Compressible Soils
• How site
• distance
• geology
• topography
effect the character of ground shaking
ATC


We know -
How to characterize ground shaking in terms meaningful to structural response prediction
Acceleration
Displacement
ATC

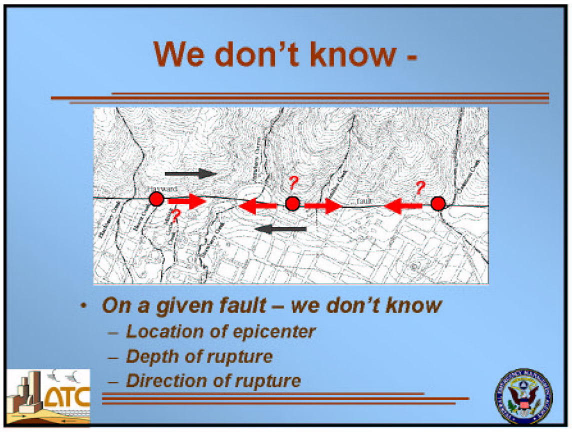

We know -
Roof
Modes: 1 2 3
Period: T_1 T_2 T_3
Mass: M_1 M_2 M_3
F_{3i}
F_{2i}
F_{1i}
V_i
How to model buildings
How to predict their response
ATC

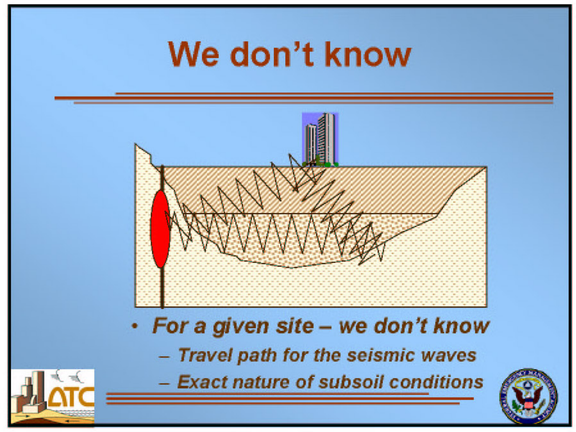

We know -
How to estimate damage, based on response predictions
Loading Severity
Structural Displacement Δ
ATC

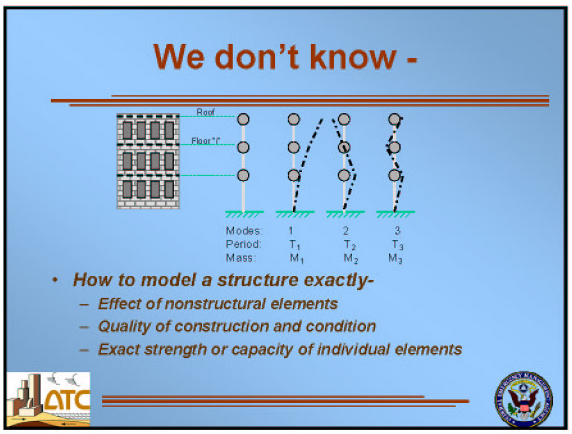

We know -
A great deal !!!
ATC

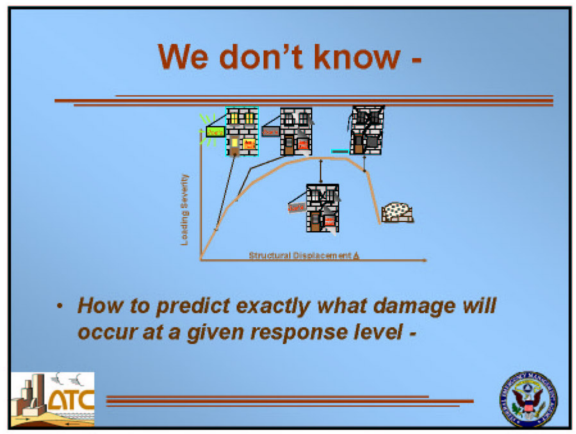

What don't we know - -
As much as we think we do -
ATC

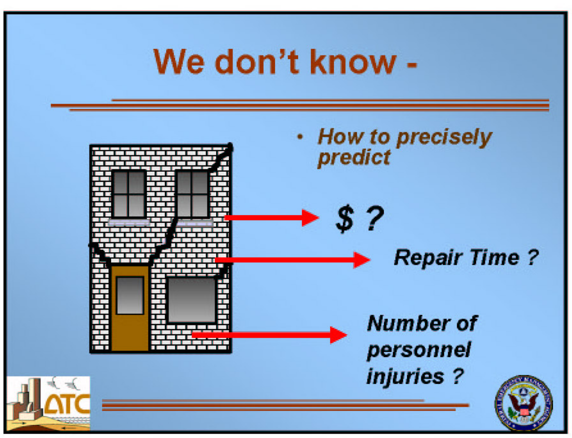

We don't know -
-120° -110° -100° -90° -80° -70°
40°
30°
When the next earthquake will occur-
Where it will occur-
How big it will be-
ATC

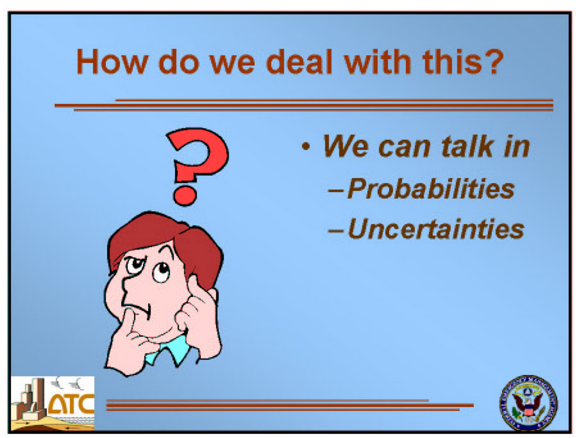

We don't know -
?
?
?
fault
On a given fault – we don't know
– Location of epicenter
– Depth of rupture
– Direction of rupture
ATC

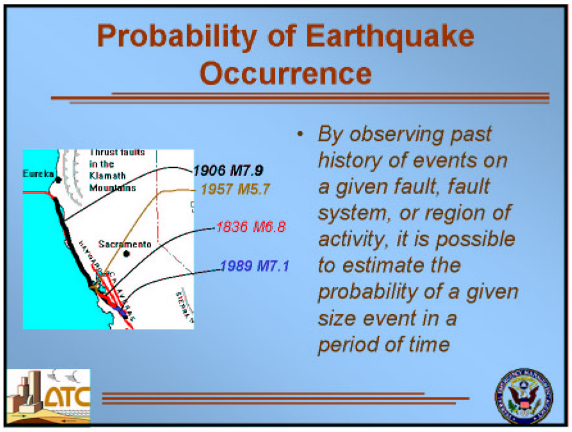

We don't know
For a given site – we don't know
– Travel path for the seismic waves
– Exact nature of subsoil conditions
ATC

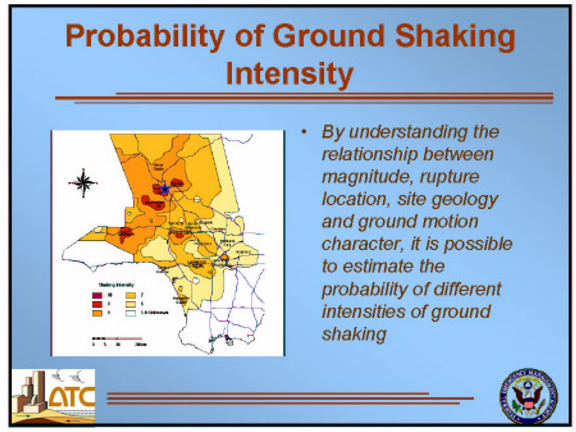

We don't know -
Roof
Floor "i"
Modes: 1 2 3
Period: T1 T2 T3
Mass: M1 M2 M3
How to model a structure exactly-
– Effect of nonstructural elements
– Quality of construction and condition
– Exact strength or capacity of individual elements
ATC

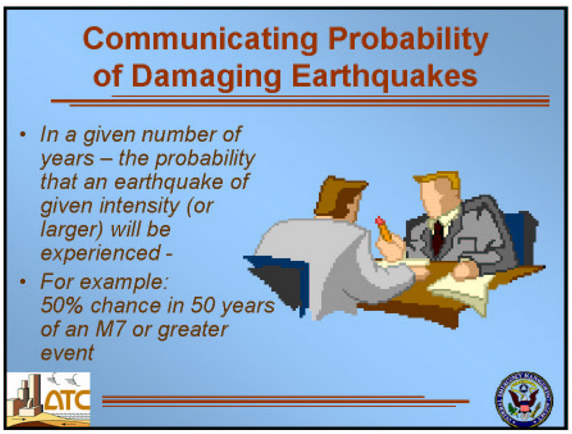

We don't know -
Loading Severity
Structural Displacement Δ
How to predict exactly what damage will occur at a given response level -
ATC


We don't know -
How to precisely predict
$?
Repair Time ?
Number of personnel injuries ?
ATC

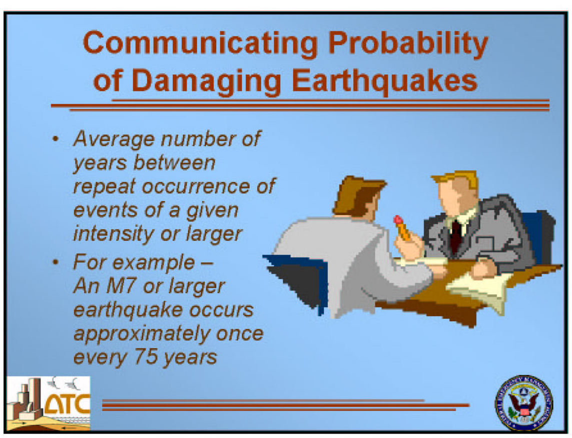

How do we deal with this?
We can talk in
–Probabilities
–Uncertainties
ATC

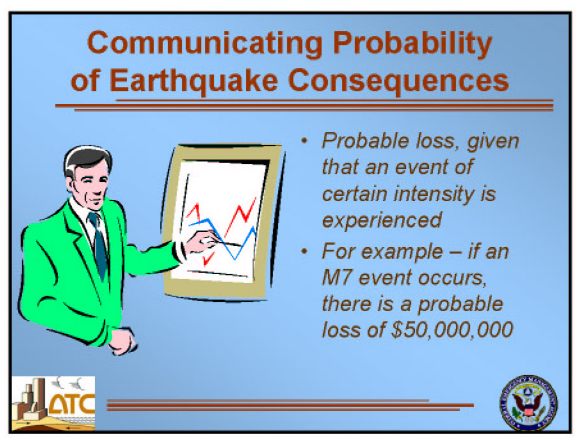

Probability of Earthquake Occurrence
Eureka
Thrust faults in the Klamath Mountains
Sacramento
1906 M7.9
1957 M5.7
1836 M6.8
1989 M7.1
• By observing past history of events on a given fault, fault system, or region of activity, it is possible to estimate the probability of a given size event in a period of time
ATC

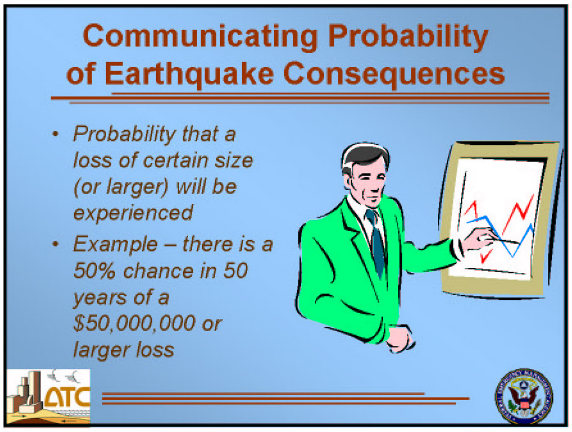

Probability of Ground Shaking Intensity
• By understanding the relationship between magnitude, rupture location, site geology and ground motion character, it is possible to estimate the probability of different intensities of ground shaking
ATC

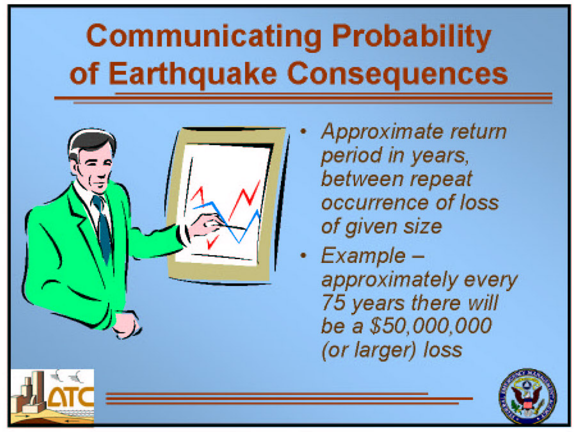

Communicating Probability of Damaging Earthquakes
• In a given number of years – the probability that an earthquake of given intensity (or larger) will be experienced -
• For example: 50% chance in 50 years of an M7 or greater event
ATC

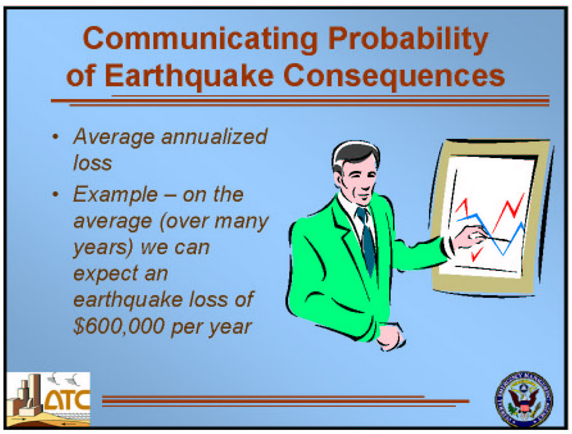

Communicating Probability of Damaging Earthquakes
• Probability in a given year that an event of a certain intensity will be experienced-
• For example – a 1.5% chance per year of experiencing an M7 event
ATC


Communicating Probability of Damaging Earthquakes
• Average number of years between repeat occurrence of events of a given intensity or larger
• For example – An M7 or larger earthquake occurs approximately once every 75 years
ATC

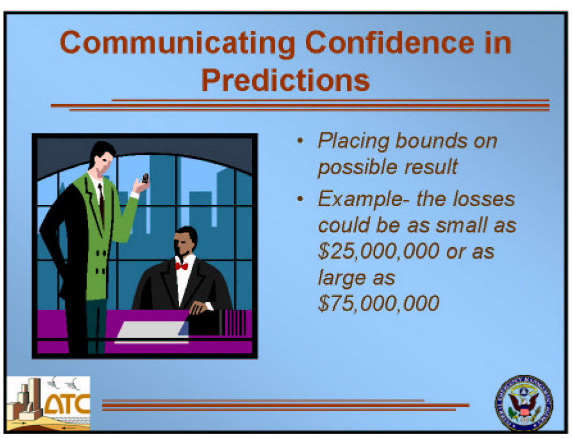

Communicating Probability of Earthquake Consequences
• Probable loss, given that an event of certain intensity is experienced
• For example – if an M7 event occurs, there is a probable loss of $50,000,000
ATC

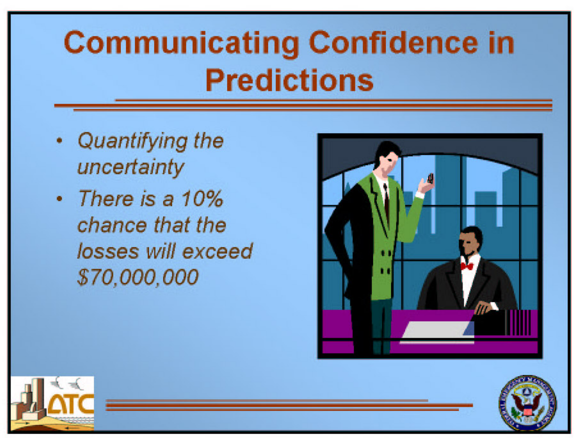

Communicating Probability of Earthquake Consequences
• Probability that a loss of certain size (or larger) will be experienced
• Example – there is a 50% chance in 50 years of a $50,000,000 or larger loss
ATC

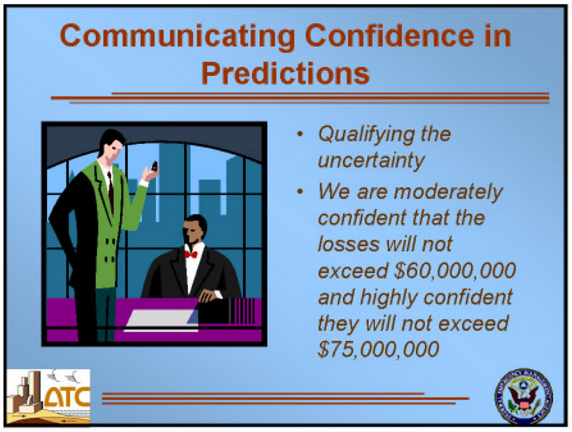

Communicating Probability of Earthquake Consequences
• Approximate return period in years, between repeat occurrence of loss of given size
• Example – approximately every 75 years there will be a $50,000,000 (or larger) loss
ATC

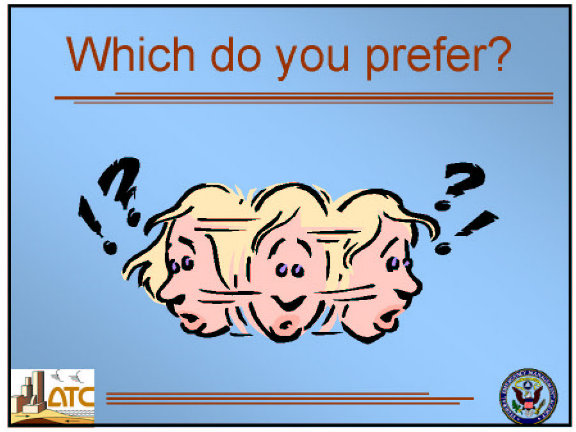

Communicating Probability of Earthquake Consequences
• Average annualized loss
• Example – on the average (over many years) we can expect an earthquake loss of $600,000 per year
ATC

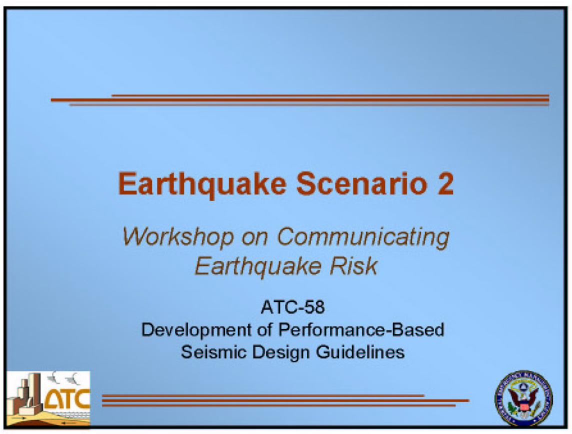

Communicating Confidence in Predictions
• Ignoring the fact that we are uncertain
• Example- the expected losses are $50,000,000
ATC

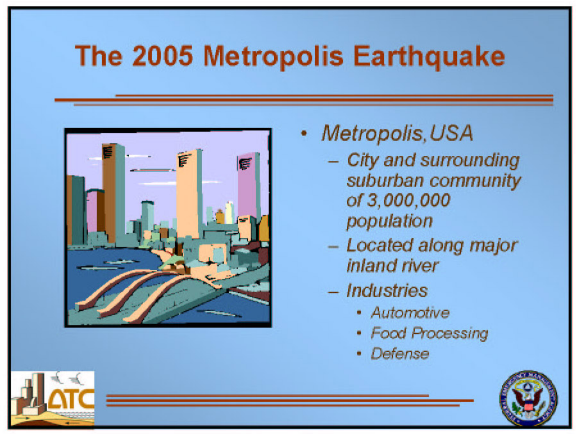

Communicating Confidence in Predictions
• Placing bounds on possible result
• Example- the losses could be as small as $25,000,000 or as large as $75,000,000
ATC

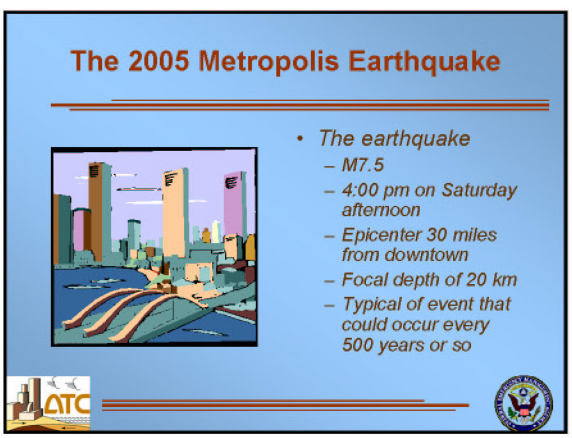

Communicating Confidence in Predictions
• Quantifying the uncertainty
• There is a 10% chance that the losses will exceed $70,000,000
ATC

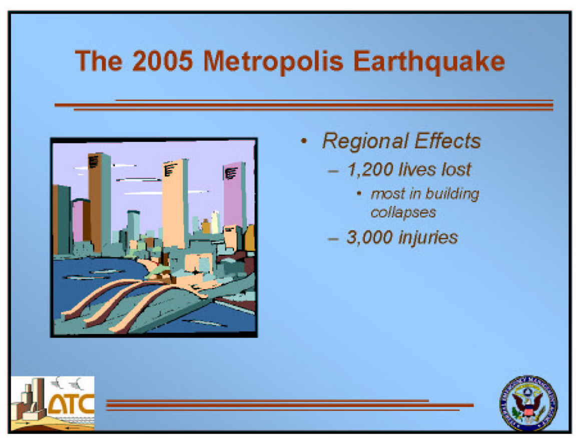

Communicating Confidence in Predictions
• Qualifying the uncertainty
• We are moderately confident that the losses will not exceed $60,000,000 and highly confident they will not exceed $75,000,000
ATC

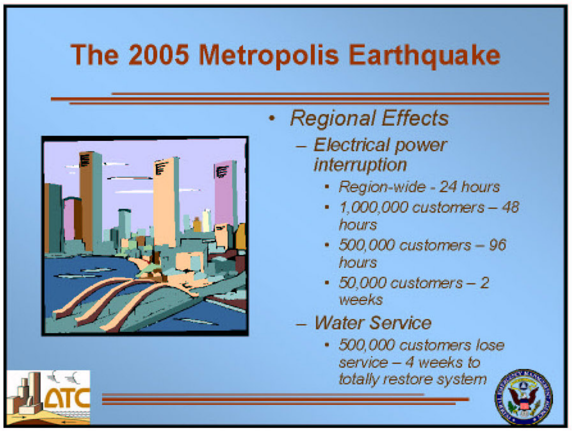

Which do you prefer?
ATC

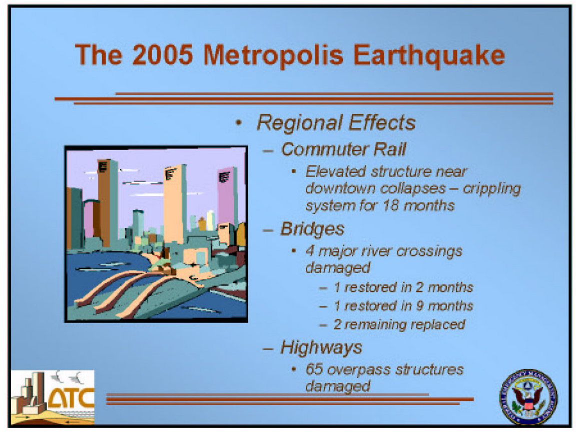

Earthquake Scenario 2
Workshop on Communicating Earthquake Risk
ATC-58
Development of Performance-Based Seismic Design Guidelines
ATC

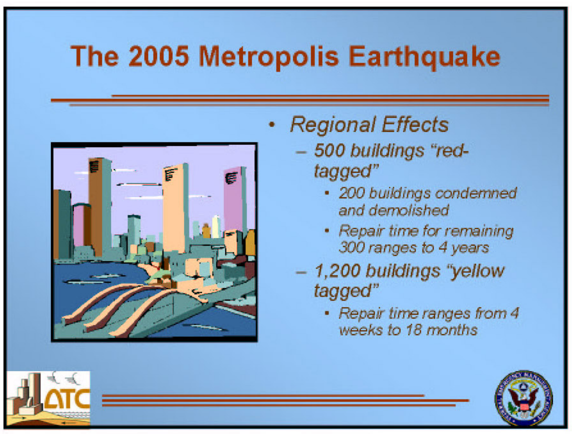

The 2005 Metropolis Earthquake
• Metropolis, USA
– City and surrounding suburban community of 3,000,000 population
– Located along major inland river
– Industries
• Automotive
• Food Processing
• Defense
ATC

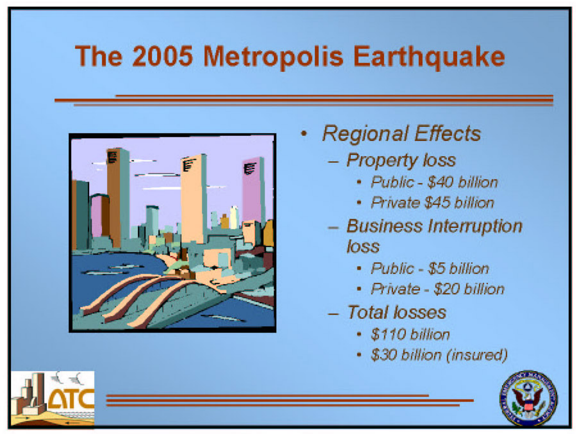

The 2005 Metropolis Earthquake
• The earthquake
– M7.5
– 4:00 pm on Saturday afternoon
– Epicenter 30 miles from downtown
– Focal depth of 20 km
– Typical of event that could occur every 500 years or so
ATC


The 2005 Metropolis Earthquake
• Regional Effects
– 1,200 lives lost
• most in building collapses
– 3,000 injuries
ATC


The 2005 Metropolis Earthquake
• Regional Effects
– Electrical power interruption
• Region-wide - 24 hours
• 1,000,000 customers – 48 hours
• 500,000 customers – 96 hours
• 50,000 customers – 2 weeks
– Water Service
• 500,000 customers lose service – 4 weeks to totally restore system
ATC


The 2005 Metropolis Earthquake
• Regional Effects
– Commuter Rail
• Elevated structure near downtown collapses – crippling system for 18 months
– Bridges
• 4 major river crossings damaged
– 1 restored in 2 months
– 1 restored in 9 months
– 2 remaining replaced
– Highways
• 65 overpass structures damaged
ATC


The 2005 Metropolis Earthquake
• Regional Effects
– 500 buildings “red-tagged”
• 200 buildings condemned and demolished
• Repair time for remaining 300 ranges to 4 years
– 1,200 buildings “yellow tagged”
• Repair time ranges from 4 weeks to 18 months
ATC


The 2005 Metropolis Earthquake
• Regional Effects
– Property loss
• Public - $40 billion
• Private $45 billion
– Business Interruption loss
• Public - $5 billion
• Private - $20 billion
– Total losses
• $110 billion
• $30 billion (insured)
ATC


Broadway Department Stores
• National Retailer
• Metropolis Division
– flagship store / distribution center in downtown
• historic building on Main Street
• marginally profitable
ATC


Broadway Department Stores
• 5 regional suburban locations at malls
• 3 main competitors
• Competition on
– Convenience
– Price
ATC


Broadway Department Stores
BROADWAY
• Damage
• Regional stores
– 3 undamaged
– 2 moderately damaged
• 1 week business interruption
• losses ~ $2,000,000
ATC


Broadway Department Stores
• Downtown store-
– Extensive damage and partial collapse
• 5 customer fatalities
• 2 employees injured (1 seriously)
• building red-tagged
• estimated repair cost $20 million
• estimated repair time 18 months
– Building stabilized but not reopened
ATC


Oak Grove Apartments
• 7 building, 120 unit apartment complex
– 6- 20 unit buildings, 2 story apartments over garage
– 1 - club / admin building
– owned by REIT
– constructed 1980 @ $8 million
ATC


Oak Grove Continued
• 3 Apartment blocks damaged near collapse
• 2 Apartment blocks experience soil failure and heavy settlement damage
• 5 tenants injured
• Building Official "red-tags" entire complex
• Tenants unable to retrieve property
• Oak Grove declares total loss, though club building and 1 apartment block OK
ATC

Appendix E: Participants and Discussion Guides, Afternoon Breakout Sessions

Participants in Afternoon Breakout Sessions

Facilitator: Peter May

Recorder: Dan Alesch

Attendees: Debra Stein
Mohammed Ettourney
John Scott
Daniel Abrams
Bill Mott
Hildo Hernandez

Breakout Session 2

Facilitator: Jack Moehle

Recorder: Bruce Ellingwood

Attendees: Larry Wong
Bill Holmes
Randall Berdine
Bruce Hall
William Moore
Steven Wenryb

Breakout Session 3

Facilitator: Jon Traw

Recorder: Jim Malley

Attendees: Robert Hendrickson
Jim Sealy
Michel Bruneau
Christopher Terzich
Robert Bachman
Clifford Grey
Randy Screitmuller

ATC-58 Development of Performance-Based Seismic Design Guidelines

How Should Low Probability Events and Uncertainties Associated with these Events Be Communicated?

Discussion Guide

Purpose: The purpose of this exercise is to facilitate a focused discussion of decisions involving uncertain seismic risks for buildings and other facilities, given that neither the precise timing of the next earthquake nor the precise effects on any specific facility can be predicted. Please respond to each of the items as best you can, while keeping in mind your experiences and perspectives about such choices.

Format: There are two places to provide responses for each item. [R1] indicates your response before discussion in the breakout group. [R2] indicates *any change* in your response after discussion in the breakout group. If the response after discussion is the same as before, you need not enter a new choice.

DISCUSSION ITEMS

I. COMMUNICATING PROBABILISTIC OUTCOMES

1. Consider the following ways of presenting information about the likelihood of seismic events. Which do you find to be the most helpful?
(Check one before [R1] and after [R2] discussion)

☐ R1 ☐ R2 There is a 2 percent chance in any year of a very damaging earthquake.

☐ R1 ☐ R2 The probability of a very damaging earthquake over the next 20 years is 33 percent.

☐ R1 ☐ R2 A very damaging earthquake can be expected, on average, once every 50 years.

☐ R1 ☐ R2 Although the probability in any year of a very damaging earthquake is low, there is a moderately high probability that such an event will occur within the next 20 years.

Why do you make this choice? What is difficult about this choice?

ATC-58 Development of Performance-Based Seismic Design Guidelines

2. In general, what timeframe – number of years – is most appropriate to your "planning horizon" for thinking about such possibilities with respect to investments in facilities?
(Check one before [R1] and after [R2] discussion)

- ☐ R1 ☐ R2 5 years
- ☐ R1 ☐ R2 10 years
- ☐ R1 ☐ R2 20 years
- ☐ R1 ☐ R2 30 years
- ☐ R1 ☐ R2 50 years
- ☐ R1 ☐ R2 A different "horizon" for each decision, depending on the expected term of commitment.

Why do you choose this "planning horizon"? What factors affect your "planning horizon" for any given facility?

3. Consider the following ways of presenting information about potential loss of life for a hypothetical structure when fully occupied. Which do you find to be the most helpful?
(Check one before [R1] and after [R2] discussion)

- ☐ R1 ☐ R2 Over a period of many years, the average expected number of fatalities per year is 1.3.
- ☐ R1 ☐ R2 In any given year there is a 5 percent probability of experiencing one or more earthquake-related fatalities associated with this facility.
- ☐ R1 ☐ R2 In the next 20 years, there is a 25 percent probability of 10 or more earthquake-related fatalities associated with this structure.
- ☐ R1 ☐ R2 If a magnitude 7 earthquake, occurs, the expected number of fatalities for this structure is 20.
- ☐ R1 ☐ R2 Given the most severe earthquake likely to occur in the next 100 years, a maximum of fifty lives are expected to be lost in this structure.

ATC-58 Development of Performance-Based Seismic Design Guidelines

Why do you make this choice? What is difficult about this choice?

4. Consider the following ways of presenting information about potential earthquake losses (i.e. dollar value of lost business, repair costs, employee costs). Which do you find to be the most helpful?
(Check one before [R1] and after [R2] discussion)

☐ R1 ☐ R2 The annualized expected earthquake-related loss for this facility is $10,000.

☐ R1 ☐ R2 The probability of a single earthquake loss exceeding $500,000 in the next 20 years is 33 percent.

☐ R1 ☐ R2 The probable maximum loss associated with a major earthquake (expected one time every 500 years) is $6,000,000.

Why do you make this choice? What is difficult about this choice?

II. COMMUNICATING UNCERTAINTIES

5. Consider the following ways of communicating uncertainties about predictions of seismic occurrences. Which do you find to be the most helpful?
(Check one before [R1] and after [R2] discussion)

☐ R1 ☐ R2 We are 95 percent confident that their is a 30 percent chance of a magnitude 7.0 or greater earthquake in the next 20 years.

☐ R1 ☐ R2 The probability of a magnitude 7.0 or greater earthquake occurring in the next 20 years is between 20 percent and 35 percent.

☐ R1 ☐ R2 We are very confident that an earthquake of magnitude 7.0 or greater is at least somewhat likely in the next 20 years.

ATC-58 Development of Performance-Based Seismic Design Guidelines

Why do you make this choice? What is difficult about this choice?

6. Consider the following ways of communicating uncertainties about the potential value of non-life related earthquake losses. Which do you find to be the most helpful?
(Check one before [R1] and after [R2] discussion)

☐ R1 ☐ R2 We are 90 percent confident that losses from an earthquake for this structure will not exceed $800,000.

☐ R1 ☐ R2 We are very confident that losses from an earthquake associated with this structure will not exceed $800,000.

☐ R1 ☐ R2 The dollar value of potential losses for this structure are expected to be between $400,000 and $900,000.

Why do you make this choice? What is difficult about this choice?

7. What minimum "level of confidence" in predictions would you insist upon for making decisions about seismic improvements for a hypothetical $2 million dollar investment?
(Check one before [R1] and after [R2] discussion)

☐ R1 ☐ R2 50 percent confidence in the results for an analysis cost of $25,000, and a possible variation of +/- $500,000 in the value of earthquake related losses.

☐ R1 ☐ R2 90 percent confidence in the results for an analysis cost of $50,000 and a possible variation of +/- $200,000 in the value of earthquake related losses.

☐ R1 ☐ R2 95 percent confidence in the results for an analysis cost of $75,000, and a possible variation of +/-$100,000 in the value of earthquake related losses.

☐ R1 ☐ R2 99 percent confidence in the results for an analysis cost of $200,000, and a possible variation of +/-$50,000 in the value of earthquake related losses.

ATC-58 Development of Performance-Based Seismic Design Guidelines

Why do you make this choice? What is difficult about this choice?

III. OTHER CONSIDERATIONS

8. After listening to the discussion in your breakout group about thinking about probabilities and uncertainties are there any other comments you would like to add?

9. What is your profession/discipline? ___________________________
[e.g., Building Official, Corporate Facilities Manager, Corporate Risk Manager, Real Estate Professional, Commercial Lender, Underwriter, etc.]

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Applied Technology Council Projects and Report Information

One of the primary purposes of Applied Technology Council is to develop resource documents that translate and summarize useful information to practicing engineers. This includes the development of guidelines and manuals, as well as the development of research recommendations for specific areas determined by the profession. ATC is not a code development organization, although several of the ATC project reports serve as resource documents for the development of codes, standards and specifications.

Applied Technology Council conducts projects that meet the following criteria:

1. The primary audience or benefactor is the design practitioner in structural engineering.
2. A cross section or consensus of engineering opinion is required to be obtained and presented by a neutral source.
3. The project fosters the advancement of structural engineering practice.

Brief descriptions of completed ATC projects and reports are provided below. Funding for projects is obtained from government agencies and tax-deductible contributions from the private sector.

ATC-1: This project resulted in five papers that were published as part of *Building Practices for Disaster Mitigation, Building Science Series 46*, proceedings of a workshop sponsored by the National Science Foundation (NSF) and the National Bureau of Standards (NBS). Available through the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22151, as NTIS report No. COM-73-50188.

ATC-2: The report, *An Evaluation of a Response Spectrum Approach to Seismic Design of Buildings*, was funded by NSF and NBS and was conducted as part of the Cooperative Federal Program in Building Practices for Disaster Mitigation. Available through the ATC office. (Published 1974, 270 Pages)

ABSTRACT: This study evaluated the applicability and cost of the response spectrum approach to seismic analysis and design that was proposed by various segments of the engineering profession. Specific building designs, design procedures and parameter values were evaluated for future application. Eleven existing buildings of varying dimensions were redesigned according to the procedures.

ATC-3: The report, *Tentative Provisions for the Development of Seismic Regulations for Buildings* (ATC-3-06), was funded by NSF and NBS. The second printing of this report, which includes proposed amendments, is available through the ATC office. (Published 1978, amended 1982, 505 pages plus proposed amendments)

ABSTRACT: The tentative provisions in this document represent the results of a concerted effort by a multi-disciplinary team of 85 nationally recognized experts in earthquake engineering. The provisions serve as the basis for the seismic provisions of the 1988 and subsequent issues of the *Uniform Building Code* and the *NEHRP Recommended Provisions for the Development of Seismic Regulation for New Buildings*. The second printing of this document contains proposed amendments prepared by a joint committee of the Building Seismic Safety Council (BSSC) and the NBS.

ATC-3-2: The project, "Comparative Test Designs of Buildings Using ATC-3-06 Tentative Provisions", was funded by NSF. The project consisted of a study to develop and plan a program for making comparative test designs of the ATC-3-06 Tentative Provisions. The project report was written to be used by the Building Seismic Safety Council in its refinement of the ATC-3-06 Tentative Provisions.

ATC-3-4: The report, *Redesign of Three Multistory Buildings: A Comparison Using ATC-3-06 and 1982 Uniform Building Code Design Provisions*, was published under a grant from NSF. Available through the ATC office. (Published 1984, 112 pages)

ABSTRACT: This report evaluates the cost and technical impact of using the 1978 ATC-3-06 report, *Tentative Provisions for the Development of Seismic Regulations for Buildings*, as amended by a joint committee of the Building Seismic Safety Council and the National Bureau of Standards in 1982. The evaluations are based on studies of three existing California buildings redesigned in accordance with the ATC-3-06 Tentative Provisions and the 1982 *Uniform Building Code*. Included in the report are recommendations to code implementing bodies.

ATC-3-5: This project, "Assistance for First Phase of ATC-3-06 Trial Design Program Being Conducted by the Building Seismic Safety Council", was funded by the Building Seismic Safety Council to provide the services of the ATC Senior Consultant and other ATC personnel to assist the BSSC in the conduct of the first phase of its Trial Design Program. The first phase provided for trial designs conducted for buildings in Los Angeles, Seattle, Phoenix, and Memphis.

ATC-3-6: This project, "Assistance for Second Phase of ATC-3-06 Trial Design Program Being Conducted by the Building Seismic Safety Council", was funded by the Building Seismic Safety Council to provide the services of the ATC Senior Consultant and other ATC personnel to assist the BSSC in the conduct of the second phase of its Trial Design Program. The second phase provided for trial designs conducted for buildings in New York, Chicago, St. Louis, Charleston, and Fort Worth.

ATC-4: The report, *A Methodology for Seismic Design and Construction of Single-Family Dwelling*s, was published under a contract with the Department of Housing and Urban Development (HUD). Available through the ATC office. (Published 1976, 576 pages)

ABSTRACT: This report presents the results of an in-depth effort to develop design and construction details for single-family residences that minimize the potential economic loss and life-loss risk associated with earthquakes. The report: (1) discusses the ways structures behave when subjected to seismic forces, (2) sets forth suggested design criteria for conventional layouts of dwellings constructed with conventional materials, (3) presents construction details that do not require the designer to perform analytical calculations, (4) suggests procedures for efficient plan-checking, and (5) presents recommendations including details and schedules for use in the field by construction personnel and building inspectors.

ATC-4-1: The report, *The Home Builders Guide for Earthquake Design*, was published under a contract with HUD. Available through the ATC office. (Published 1980, 57 pages)

ABSTRACT: This report is an abridged version of the ATC-4 report. The concise, easily understood text of the Guide is supplemented with illustrations and 46 construction details. The details are provided to ensure that houses contain structural features that are properly positioned, dimensioned and constructed to resist earthquake forces. A brief description is included on how earthquake forces impact on houses and some precautionary constraints are given with respect to site selection and architectural designs.

ATC-5: The report, *Guidelines for Seismic Design and Construction of Single-Story Masonry Dwellings in Seismic Zone 2*, was developed under a contract with HUD. Available through the ATC office. (Published 1986, 38 pages)

ABSTRACT: The report offers a concise methodology for the earthquake design and construction of single-story masonry dwellings in Seismic Zone 2 of the United States, as defined by the 1973 *Uniform Building Code*. The Guidelines are based in part on shaking table tests of masonry construction conducted at the University of California at Berkeley Earthquake Engineering Research Center. The report is written in simple language and includes basic house plans, wall evaluations, detail drawings, and material specifications.

ATC-6: The report, *Seismic Design Guidelines for Highway Bridges*, was published under a contract with the Federal Highway

Administration (FHWA). Available through the ATC office. (Published 1981, 210 pages)

ABSTRACT: The Guidelines are the recommendations of a team of sixteen nationally recognized experts that included consulting engineers, academics, state and federal agency representatives from throughout the United States. The Guidelines embody several new concepts that were significant departures from then existing design provisions. Included in the Guidelines are an extensive commentary, an example demonstrating the use of the Guidelines, and summary reports on 21 bridges redesigned in accordance with the Guidelines. In 1991 the guidelines were adopted by the American Association of Highway and Transportation Officials as a standard specification.

ATC-6-1: The report, *Proceedings of a Workshop on Earthquake Resistance of Highway Bridges*, was published under a grant from NSF. Available through the ATC office. (Published 1979, 625 pages)

ABSTRACT: The report includes 23 state-of-the-art and state-of-practice papers on earthquake resistance of highway bridges. Seven of the twenty-three papers were authored by participants from Japan, New Zealand and Portugal. The Proceedings also contain recommendations for future research that were developed by the 45 workshop participants.

ATC-6-2: The report, *Seismic Retrofitting Guidelines for Highway Bridges*, was published under a contract with FHWA. Available through the ATC office. (Published 1983, 220 pages)

ABSTRACT: The Guidelines are the recommendations of a team of thirteen nationally recognized experts that included consulting engineers, academics, state highway engineers, and federal agency representatives. The Guidelines, applicable for use in all parts of the United States, include a preliminary screening procedure, methods for evaluating an existing bridge in detail, and potential retrofitting measures for the most common seismic deficiencies. Also included are special design requirements for various retrofitting measures.

ATC-7: The report, *Guidelines for the Design of Horizontal Wood Diaphragms*, was published under a grant from NSF. Available through the ATC office. (Published 1981, 190 pages)

ABSTRACT: Guidelines are presented for designing roof and floor systems so these can function as horizontal diaphragms in a lateral force resisting system. Analytical procedures, connection details and design examples are included in the Guidelines.

ATC-7-1: The report, *Proceedings of a Workshop on Design of Horizontal Wood Diaphragms*, was published under a grant from NSF. Available through the ATC office. (Published 1980, 302 pages)

ABSTRACT: The report includes seven papers on state-of-the-practice and two papers on recent research. Also included are recommendations for future research that were developed by the 35 workshop participants.

ATC-8: This report, *Proceedings of a Workshop on the Design of Prefabricated Concrete Buildings for Earthquake Loads*, was funded by NSF. Available through the ATC office. (Published 1981, 400 pages)

ABSTRACT: The report includes eighteen state-of-the-art papers and six summary papers. Also included are recommendations for future research that were developed by the 43 workshop participants.

ATC-9: The report, *An Evaluation of the Imperial County Services Building Earthquake Response and Associated Damage*, was published under a grant from NSF. Available through the ATC office. (Published 1984, 231 pages)

ABSTRACT: The report presents the results of an in-depth evaluation of the Imperial County Services Building, a 6-story reinforced concrete frame and shear wall building severely damaged by the October 15, 1979 Imperial Valley, California, earthquake. The report contains a review and evaluation of earthquake damage to the building; a review and evaluation of the seismic design; a comparison of the requirements of various building codes as they relate to the building; and conclusions and recommendations pertaining to future building code provisions and future research needs.

ATC-10: This report, *An Investigation of the Correlation Between Earthquake Ground Motion and Building Performance*, was funded by the U.S. Geological Survey (USGS). Available through the ATC office. (Published 1982, 114 pages)

ABSTRACT: The report contains an in-depth analytical evaluation of the ultimate or limit capacity of selected representative building framing types, a discussion of the factors affecting the seismic performance of buildings, and a summary and comparison of seismic design and seismic risk parameters currently in widespread use.

ATC-10-1: This report, *Critical Aspects of Earthquake Ground Motion and Building Damage Potential*, was co-funded by the USGS and the NSF. Available through the ATC office. (Published 1984, 259 pages)

ABSTRACT: This document contains 19 state-of-the-art papers on ground motion, structural response, and structural design issues presented by prominent engineers and earth scientists in an ATC seminar. The main theme of the papers is to identify the critical aspects of ground motion and building performance that currently are not being considered in building design. The report also contains conclusions and recommendations of working groups convened after the Seminar.

ATC-11: The report, *Seismic Resistance of Reinforced Concrete Shear Walls and Frame Joints: Implications of Recent Research for Design Engineers*, was published under a grant from NSF. Available through the ATC office. (Published 1983, 184 pages)

ABSTRACT: This document presents the results of an in-depth review and synthesis of research reports pertaining to cyclic loading of reinforced concrete shear walls and cyclic loading of joints in reinforced concrete frames. More than 125 research reports published since 1971 are reviewed and evaluated in this report. The preparation of the report included a consensus process involving numerous experienced design professionals from throughout the United States. The report contains reviews of current and past design practices, summaries of research developments, and in-depth discussions of design implications of recent research results.

ATC-12: This report, *Comparison of United States and New Zealand Seismic Design Practices for Highway Bridges*, was published under a grant from NSF. Available through the ATC office. (Published 1982, 270 pages)

ABSTRACT: The report contains summaries of all aspects and innovative design procedures used in New Zealand as well as comparison of United States and New Zealand design practice. Also included are research recommendations developed at a 3-day workshop in New Zealand attended by 16 U.S. and 35 New Zealand bridge design engineers and researchers.

ATC-12-1: This report, *Proceedings of Second Joint U.S.-New Zealand Workshop on Seismic Resistance of Highway Bridges*, was published under a grant from NSF. Available through the ATC office. (Published 1986, 272 pages)

ABSTRACT: This report contains written versions of the papers presented at this 1985 workshop as well as a list and prioritization of workshop recommendations. Included are summaries of research projects being conducted in both countries as well as state-of-the-practice papers on various aspects of design practice. Topics discussed include bridge design philosophy and loadings; design of columns, footings, piles, abutments and retaining structures; geotechnical aspects of foundation design; seismic analysis techniques; seismic retrofitting; case studies using base isolation; strong-motion data acquisition and interpretation; and testing of bridge components and bridge systems.

ATC-13: The report, *Earthquake Damage Evaluation Data for California*, was developed under a contract with the Federal Emergency Management Agency (FEMA). Available through the ATC office. (Published 1985, 492 pages)

ABSTRACT: This report presents expert-opinion earthquake damage and loss estimates for industrial, commercial, residential, utility and transportation facilities in California. Included are damage probability matrices for 78 classes of structures and estimates of time required to restore damaged facilities to pre-earthquake usability. The report also describes the inventory information essential for estimating economic losses and the methodology used to develop loss estimates on a regional basis.

ATC-13-1: The report, *Commentary on the Use of ATC-13 Earthquake Damage Evaluation Data for Probable Maximum Loss Studies of California Buildings*, was developed with funding from ATC's Henry J. Degenkolb Memorial Endowment Fund. Available through the ATC office. (Published 2002, 66 pages)

ABSTRACT: This report provides guidance to consulting firms who are using ATC-13 expert-opinion data for probable maximum loss (PML) studies of California buildings. Included are discussions of the limitations of the ATC-13 expert-opinion data, and the issues associated with using the data for PML studies. Also included are three appendices containing information and data not included in the original ATC-13 report: (1) ATC-13 model building type descriptions, including methodology for estimating the expected performance of standard, nonstandard, and special construction; (2) ATC-13 Beta damage distribution parameters for model building types; and (3) PML values for ATC-13 model building types.

ATC-14: The report, *Evaluating the Seismic Resistance of Existing Buildings*, was developed under a grant from the NSF. Available through the ATC office. (Published 1987, 370 pages)

ABSTRACT: This report, written for practicing structural engineers, describes a methodology for performing preliminary and detailed building seismic evaluations. The report contains a state-of-practice review; seismic loading criteria; data collection procedures; a detailed description of the building classification system; preliminary and detailed analysis procedures; and example case studies, including nonstructural considerations.

ATC-15: The report, *Comparison of Seismic Design Practices in the United States and Japan*, was published under a grant from NSF. Available through the ATC office. (Published 1984, 317 pages)

ABSTRACT: The report contains detailed technical papers describing design practices in the United States and Japan as well as recommendations emanating from a joint U.S.-Japan workshop held in Hawaii in March, 1984. Included are detailed descriptions of new seismic design methods for buildings in Japan and case studies of the design of specific buildings (in both countries). The report also contains an overview of the history and objectives of the Japan Structural Consultants Association.

ATC-15-1: The report, *Proceedings of Second U.S.-Japan Workshop on Improvement of Building Seismic Design and Construction Practices*, was published under a grant from NSF. Available through the ATC office. (Published 1987, 412 pages)

ABSTRACT: This report contains 23 technical papers presented at this San Francisco workshop in August, 1986, by practitioners and researchers from the U.S. and Japan. Included are state-of-the-practice papers and case studies of actual building designs and information on regulatory, contractual, and licensing issues.

ATC-15-2: The report, *Proceedings of Third U.S.-Japan Workshop on Improvement of Building Structural Design and Construction Practices*, was published jointly by ATC and the Japan Structural Consultants Association. Available through the ATC office. (Published 1989, 358 pages)

ABSTRACT: This report contains 21 technical papers presented at this Tokyo, Japan, workshop in July, 1988, by practitioners and researchers from the U.S., Japan, China, and New Zealand. Included are state-of-the-practice papers on various topics, including braced steel frame buildings, beam-column joints in reinforced concrete buildings, summaries of comparative U. S. and Japanese design, and base isolation and passive energy dissipation devices.

ATC-15-3: The report, *Proceedings of Fourth U.S.-Japan Workshop on Improvement of Building Structural Design and Construction Practices*, was published jointly by ATC and the Japan Structural Consultants Association. Available through the ATC office. (Published 1992, 484 pages)

ABSTRACT: This report contains 22 technical papers presented at this Kailua-Kona, Hawaii, workshop in August, 1990, by practitioners and researchers from the United States, Japan, and Peru. Included are papers on postearthquake building damage assessment; acceptable earth-quake damage; repair and retrofit of earthquake damaged buildings; base-isolated buildings, including Architectural Institute of Japan recommendations for design; active damping systems; wind-resistant design; and summaries of working group conclusions and recommendations.

ATC-15-4: The report, *Proceedings of Fifth U.S.-Japan Workshop on Improvement of Building Structural Design and Construction Practices*, was published jointly by ATC and the Japan Structural Consultants Association. Available through the ATC office. (Published 1994, 360 pages)

ABSTRACT: This report contains 20 technical papers presented at this San Diego, California workshop in September, 1992. Included are papers on performance goals/acceptable damage in seismic design; seismic design procedures and case studies; construction influences on design; seismic isolation and passive energy dissipation; design of irregular structures; seismic evaluation, repair and upgrading; quality control for design and construction; and summaries of working group discussions and recommendations.

ATC-16: This project, "Development of a 5-Year Plan for Reducing the Earthquake Hazards Posed by Existing Nonfederal Buildings", was funded by FEMA and was conducted by a joint venture of ATC, the Building Seismic Safety Council and the Earthquake Engineering Research Institute. The project involved a workshop in Phoenix, Arizona, where approximately 50 earthquake specialists met to identify the major tasks and goals for reducing the earthquake hazards posed by existing nonfederal buildings nationwide. The plan was developed on the basis of nine issue papers presented at the workshop and workshop working group discussions. The Workshop Proceedings and Five-Year Plan are available through the Federal Emergency Management Agency, 500 "C" Street, S.W., Washington, DC 20472.

ATC-17: This report, *Proceedings of a Seminar and Workshop on Base Isolation and Passive Energy Dissipation*, was published under a grant from NSF. Available through the ATC office. (Published 1986, 478 pages)

ABSTRACT: The report contains 42 papers describing the state-of-the-art and state-of-the-practice in base-isolation and passive energy-dissipation technology. Included are papers describing case studies in the United States, applications and developments worldwide, recent innovations in technology development, and structural and ground motion issues. Also included is a proposed 5-year research agenda that addresses the following specific issues: (1) strong ground motion; (2) design criteria; (3) materials, quality control, and long-term reliability; (4) life cycle cost methodology; and (5) system response.

ATC-17-1: This report, *Proceedings of a Seminar on Seismic Isolation, Passive Energy Dissipation and Active Control,* was published under a grant from NCEER and NSF. Available through the ATC office. (Published 1993, 841 pages)

ABSTRACT: The 2-volume report documents 70 technical papers presented during a two-day seminar in San Francisco in early 1993. Included are invited theme papers and competitively selected papers on issues related to seismic isolation systems, passive energy dissipation systems, active control systems and hybrid systems.

ATC-18: The report, *Seismic Design Criteria for Bridges and Other Highway Structures: Current and Future***,** was developed under a grant from NCEER and FHWA. Available through the ATC office. (Published, 1997, 151 pages)

ABSTRACT: Prepared as part of NCEER Project 112 on new highway construction, this report reviews current domestic and foreign design practice, philosophy and criteria, and recommends future directions for code development. The project considered bridges, tunnels, abutments, retaining wall structures, and foundations.

ATC-18-1: The report, *Impact Assessment of Selected MCEER Highway Project Research on the Seismic Design of Highway Structures***,** was developed under a contract from the Multidisciplinary Center for Earthquake Engineering Research (MCEER, formerly NCEER) and FHWA. Available through the ATC office. (Published, 1999, 136 pages)

ABSTRACT: The report provides an in-depth review and assessment of 32 research reports emanating from the MCEER Project 112 on new highway construction, as well as recommendations for future bridge seismic design guidelines. Topics covered include: ground motion issues; determining structural importance; foundations and soils; liquefaction mitigation methodologies; modeling of pile footings and drilled shafts; damage-avoidance design of bridge piers, column design, modeling, and analysis; structural steel and steel-concrete interface details; abutment design, modeling, and analysis; and detailing for structural movements in tunnels.

ATC-19: The report, *Structural Response Modification Factors* was funded by NSF and NCEER. Available through the ATC office. (Published 1995, 70 pages)

ABSTRACT: This report addresses structural response modification factors (R factors), which are used to reduce the seismic forces associated with elastic response to obtain design forces. The report documents the basis for current R values, how R factors are used for seismic design in other countries, a rational means for decomposing R into key components, a framework (and methods) for evaluating the key components of R, and the research necessary to improve the reliability of engineered construction designed using R factors.

ATC-20: The report, *Procedures for Postearthquake Safety Evaluation of Buildings*, was developed under a contract from the California Office of Emergency Services (OES), California Office of Statewide Health Planning and Development (OSHPD) and FEMA. Available through the ATC office (Published 1989, 152 pages)

ABSTRACT: This report provides procedures and guidelines for making on-the-spot evaluations and decisions regarding continued use and occupancy of earthquake damaged buildings. Written specifically for volunteer structural engineers and building inspectors, the report includes rapid and detailed evaluation procedures for inspecting buildings and posting them as “inspected” (apparently safe, green placard), “limited entry” (yellow) or “unsafe” (red). Also included are special procedures for evaluation of essential buildings (e.g., hospitals), and evaluation procedures for nonstructural elements, and geotechnical hazards.

ATC-20-1: The report, *Field Manual: Postearthquake Safety Evaluation of Buildings*, was developed under a contract from OES and OSHPD. Available through the ATC office (Published 1989, 114 pages)

ABSTRACT: This report, a companion Field Manual for the ATC-20 report, summarizes the postearthquake safety evaluation procedures in a brief concise format designed for ease of use in the field.

ATC-20-2: The report, *Addendum to the ATC-20 Postearthquake Building Safety Procedures* was published under a grant from the NSF and funded by the USGS. Available through the ATC office. (Published 1995, 94 pages)

ABSTRACT: This report provides updated assessment forms, placards, including a revised yellow placard (“restricted use”) and procedures that are based on an in-depth review and evaluation of the widespread application of the ATC-20 procedures following five earthquakes occurring since the initial release of the ATC-20 report in 1989.

ATC-20-3: The report, *Case Studies in Rapid Postearthquake Safety Evaluation of Buildings,* was funded by ATC and R. P. Gallagher Associates. Available through the ATC office. (Published 1996, 295 pages)

ABSTRACT: This report contains 53 case studies using the ATC-20 Rapid Evaluation procedure. Each case study is illustrated with photos and describes how a building was inspected and evaluated for life safety, and includes a completed safety assessment form and placard. The report is intended to be used as a training and reference manual for building officials, building inspectors, civil and structural engineers, architects, disaster workers, and others who may be asked to perform safety evaluations after an earthquake.

ATC-20-T: The *Postearthquake Safety Evaluation of Buildings Training CD* was developed by FEMA to replace the 1993 ATC-20-T Training Manual that included 160 35-mm slides. Available through the ATC office. (Published 2002, 230 PowerPoint slides with Speakers Notes)

ABSTRACT: This Training CD is intended to facilitate the presentation of the contents of the ATC-20 and ATC-20-2 reports in a 4½-hour training seminar. The Training CD contains 230 slides of photographs, schematic drawings and textual information. Topics covered include: posting system; evaluation procedures; structural basics; wood frame, masonry, concrete, and steel frame structures; nonstructural elements; geotechnical hazards; hazardous materials; and field safety.

ATC-21: The report, *Second Edition, Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*, was developed under a contract from FEMA. Available through the ATC office, or from FEMA by contacting 1-800-480-2520, as *FEMA 154 Second Edition*. (Published 2002, 161 pages)

ABSTRACT: This report describes a rapid visual screening procedure for identifying those buildings that might pose serious risk of loss of life and injury, or of severe curtailment of community services, in case of a damaging earthquake. The screening procedure utilizes a methodology based on a "sidewalk survey" approach that involves identification of the primary structural load-resisting system and its building material, and assignment of a basic structural hazards score and performance modifiers based on the observed building characteristics. Application of the methodology identifies those buildings that are potentially hazardous and should be analyzed in more detail by a professional engineer experienced in seismic design. In the Second Edition, the scoring system has been revised and the *Handbook* has been shortened and focused to ease its use.

ATC-21-1: The report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation*, *Second Edition*, was developed under a contract from FEMA. Available through the ATC office, or from FEMA by contacting 1-800-480-2520, as *FEMA 155 Second Edition*. (Published 2002, 117 pages)

ABSTRACT: Included in this report is the technical basis for the updated rapid visual screening procedure of ATC-21, including (1) a summary of the results from the efforts to solicit user feedback, and (2) a detailed description of the development effort leading to the basic structural hazard scores and the score modifiers.

ATC-21-2: The report, *Earthquake Damaged Buildings: An Overview of Heavy Debris and Victim Extrication*, was developed under a contract from FEMA. (Published 1988, 95 pages)

ABSTRACT: Included in this report, a companion volume to the ATC-21 and ATC-21-1 reports, is state-of-the-art information on (1) the identification of those buildings that might collapse and trap victims in debris or generate debris of such a size that its handling would require special or heavy lifting equipment; (2) guidance in identifying these types of buildings, on the basis of their major exterior features, and (3) the types and life capacities of equipment required to remove the heavy portion of the debris that might result from the collapse of such buildings.

ATC-21-T: The report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards Training Manual* was developed under a contract with FEMA. Available through the ATC office. (Published 1996, 135 pages; 120 slides)

ABSTRACT: This training manual is intended to facilitate the presentation of the contents of the ATC-21 report (*First Edition*). The training materials consist of 120 slides and a companion training presentation narrative coordinated with the slides. Topics covered include: description of procedure, building behavior, building types, building scores, occupancy and falling hazards, and implementation.

ATC-22: The report, *A Handbook for Seismic Evaluation of Existing Buildings (Preliminary)*, was developed under a contract from FEMA. Available through the ATC office. (Originally published in 1989; revised by BSSC and published as FEMA 178: *NEHRP Handbook for the Seismic Evaluation of Existing Buildings* in 1992, 211 pages; revised by ASCE for FEMA and published as FEMA 310: *Handbook for the Seismic Evaluation of Buildings – a Prestandard* in 1998, 362 pages, available from FEMA by contacting 1-800-480-2520)

ABSTRACT: The ATC-22 handbook provides a methodology for seismic evaluation of existing buildings of different types and occupancies in areas of different seismicity throughout the United States. The methodology, which has been field tested in several programs nationwide, utilizes the information and procedures developed for the ATC-14 report and documented therein. The handbook includes checklists, diagrams, and sketches designed to assist the user.

ATC-22-1: The report, *Seismic Evaluation of Existing Buildings: Supporting Documentation*, was developed under a contract from FEMA and is available as the FEMA 175 report by contacting 1-800-480-2520. (Published 1989, 160 pages)

ABSTRACT: Included in this report, a companion volume to the ATC-22 report, are (1) a review and evaluation of existing buildings seismic evaluation methodologies; (2) results from field tests of the ATC-14 methodology; and (3) summaries of evaluations of ATC-14 conducted by the National Center for Earthquake Engineering Research (State University of New York at Buffalo) and the City of San Francisco.

ATC-23A: The report, *General Acute Care Hospital Earthquake Survivability Inventory for California, Part A: Survey Description, Summary of Results, Data Analysis and Interpretation*, was developed under a contract from the Office of Statewide Health Planning and Development (OSHPD), State of California. Available through the ATC office. (Published 1991, 58 pages)

ABSTRACT: This report summarizes results from a seismic survey of 490 California acute care hospitals. Included are a description of the survey procedures and data collected, a summary of the data, and an illustrative discussion of data analysis and interpretation that has been provided to demonstrate potential applications of the ATC-23 database.

ATC-23B: The report, *General Acute Care Hospital Earthquake Survivability Inventory for California, Part B: Raw Data*, is a companion document to the ATC-23A Report and was developed under the above-mentioned contract from OSHPD. Available through the ATC office. (Published 1991, 377 pages)

ABSTRACT: Included in this report are tabulations of raw general site and building data for 490 acute care hospitals in California.

ATC-24: The report, *Guidelines for Seismic Testing of Components of Steel Structures*, was jointly funded by the American Iron and Steel Institute (AISI), American Institute of Steel Construction (AISC), National Center for Earthquake Engineering Research (NCEER), and NSF. Available through the ATC office. (Published 1992, 57 pages)

ABSTRACT: This report provides guidance for most cyclic experiments on components of steel structures for the purpose of consistency in experimental procedures. The report contains recommendations and companion commentary pertaining to loading histories, presentation of test results, and other aspects of experimentation. The recommendations are written specifically for experiments with slow cyclic load application.

ATC-25: The report, *Seismic Vulnerability and Impact of Disruption of Lifelines in the Conterminous United States*, was developed under a contract from FEMA. Available through the ATC office. (Published 1991, 440 pages)

ABSTRACT: Documented in this report is a national overview of lifeline seismic vulnerability and impact of disruption. Lifelines considered include electric systems, water systems, transportation systems, gas and liquid fuel supply systems, and emergency service facilities (hospitals, fire and police stations). Vulnerability estimates and impacts developed are presented in terms of estimated first approximation direct damage losses and indirect economic losses.

ATC-25-1: The report, *A Model Methodology for Assessment of Seismic Vulnerability and Impact of Disruption of Water Supply Systems*, was developed under a contract from FEMA. Available through the ATC office. (Published 1992, 147 pages)

ABSTRACT: This report contains a practical methodology for the detailed assessment of seismic vulnerability and impact of disruption of water supply systems. The methodology has been designed for use by water system operators. Application of the methodology enables the user to develop estimates of direct damage to system components and the time required to restore damaged facilities to pre-earthquake usability. Suggested measures for mitigation of seismic hazards are also provided.

ATC-26: This project, U.S. Postal Service National Seismic Program, was funded under a contract with the U.S. Postal Service (USPS). Under this project, ATC developed and submitted to the USPS the following interim documents, most of which pertain to the seismic evaluation and rehabilitation of USPS facilities:

ATC-26 Report, *Cost Projections for the U. S. Postal Service Seismic Program* (completed 1990)

ATC-26-1 Report, *United States Postal Service Procedures for Seismic Evaluation of Existing Buildings (Interim)* (Completed 1991)

ATC-26-2 Report, *Procedures for Post-disaster Safety Evaluation of Postal Service Facilities (Interim)* (Published 1991, 221 pages, available through the ATC office)

ATC-26-3 Report, *Field Manual: Post-earthquake Safety Evaluation of Postal Buildings (Interim)* (Published 1992, 133 pages, available through the ATC office)

ATC-26-3A Report, *Field Manual: Post Flood and Wind Storm Safety Evaluation of Postal Buildings (Interim)* (Published 1992, 114 pages, available through the ATC office)

ATC-26-4 Report, *United States Postal Service Procedures for Building Seismic Rehabilitation (Interim)* (Completed 1992)

ATC-26-5 Report, *United States Postal Service Guidelines for Building and Site Selection in Seismic Areas (Interim)* (Completed 1992)

ATC-28: The report, *Development of Recommended Guidelines for Seismic Strengthening of Existing Buildings, Phase I: Issues Identification and Resolution*, was developed under a contract with FEMA. Available through the ATC office. (Published 1992, 150 pages)

ABSTRACT: This report identifies and provides resolutions for issues that will affect the development of guidelines for the seismic strengthening of existing buildings. Issues addressed include: implementation and format, coordination with other efforts, legal and political, social, economic, historic buildings, research and technology, seismicity and mapping, engineering philosophy and goals, issues related to the development of specific provisions, and nonstructural element issues.

ATC-29: The report, *Proceedings of a Seminar and Workshop on Seismic Design and Performance of Equipment and Nonstructural Elements in Buildings and Industrial Structures*, was developed under a grant from NCEER and NSF. Available through the ATC office. (Published 1992, 470 pages)

ABSTRACT: These Proceedings contain 35 papers describing state-of-the-art technical information pertaining to the seismic design and performance of equipment and nonstructural elements in buildings and industrial structures. The papers were presented at a seminar in Irvine, California in 1990. Included are papers describing current practice, codes and regulations; earthquake performance; analytical and experimental investigations; development of new seismic qualification methods; and research, practice, and code development needs for specific elements and systems. The report also includes a summary of a proposed 5-year research agenda for NCEER.

ATC-29-1: The report, *Proceedings of a Seminar on Seismic Design, Retrofit, and Performance of Nonstructural Components*, was developed under a grant from NCEER and NSF. Available through the ATC office. (Published 1998, 518 pages)

ABSTRACT: These Proceedings contain 38 technical papers presented at a seminar in San Francisco, California in 1998. The paper topics include: observed performance in recent earthquakes; seismic design codes, standards, and procedures for commercial and institutional buildings; seismic design issues relating to industrial and hazardous material facilities; design analysis, and testing; and seismic evaluation and rehabilitation of conventional and essential facilities, including hospitals.

ATC-30: The report, *Proceedings of Workshop for Utilization of Research on Engineering and Socioeconomic Aspects of 1985 Chile and Mexico Earthquakes*, was developed under a grant from the NSF. Available through the ATC office. (Published 1991, 113 pages)

ABSTRACT: This report documents the findings of a 1990 technology transfer workshop in San Diego, California, co-sponsored by ATC and the Earthquake Engineering Research Institute. Included in the report are invited papers and working group recommendations on geotechnical issues, structural response issues, architectural and urban design considerations, emergency response planning, search and rescue, and reconstruction policy issues.

ATC-31: The report, *Evaluation of the Performance of Seismically Retrofitted Buildings*, was developed under a contract from the National Institute of Standards and Technology (NIST, formerly NBS) and funded by the USGS. Available through the ATC office. (Published 1992, 75 pages)

ABSTRACT: This report summarizes the results from an investigation of the effectiveness of 229 seismically retrofitted buildings, primarily unreinforced masonry and concrete tilt-up buildings. All buildings were located in the areas affected by the 1987 Whittier Narrows, California, and 1989 Loma Prieta, California, earthquakes.

ATC-32: The report, *Improved Seismic Design Criteria for California Bridges: Provisional Recommendations,* was funded by the California Department of Transportation (Caltrans). Available through the ATC office. (Published 1996, 215 pages)

ABSTRACT: This report provides recommended revisions to the current *Caltrans Bridge Design Specifications* (BDS) pertaining to seismic loading, structural response analysis, and component design. Special attention is given to design issues related to reinforced concrete components, steel components, foundations, and conventional bearings. The recommendations are based on recent research in the field of bridge seismic design and the performance of Caltrans-designed bridges in the 1989 Loma Prieta and other recent California earthquakes.

ATC-32-1: The report, *Improved Seismic Design Criteria for California Bridges: Resource Document,* was funded by Caltrans. Available through the ATC office. (Published 1996, 365 pages; also available on CD-ROM)

ABSTRACT: This report, a companion to the ATC-32 Report, documents pertinent background material and the technical basis for the recommendations provided in ATC-32, including potential recommendations that showed some promise but were not adopted. Topics include: design concepts; seismic loading, including ARS design spectra; dynamic analysis; foundation design; ductile component design; capacity protected design; reinforcing details; and steel bridges.

ATC-33: The reports, NEHRP Guidelines for the Seismic Rehabilitation of Buildings (FEMA 273), NEHRP Commentary on the Guidelines for the Seismic Rehabilitation of Buildings (FEMA 274), and Example Applications of the NEHRP Guidelines for the Seismic

Rehabilitation of Buildings (FEMA 276), were developed under a contract with the Building Seismic Safety Council, for FEMA. Available through FEMA by contacting 1-800-480-2520 (Published 1997, Guidelines, 440 pages; Commentary, 492 pages; Example Applications, 295 pages.) FEMA 273 and portions of FEMA 274 have been revised by ASCE for FEMA as FEMA 356 Prestandard and Commentary for the Seismic Rehabilitation of Buildings. Available through FEMA by contacting 1-800-480-2520 (Published 2000, 509 pages)

ABSTRACT: Developed over a 5-year period through the efforts of more than 60 paid consultants and several hundred volunteer reviewers, these documents provide nationally applicable, state-of-the-art guidance for the seismic rehabilitation of buildings. The FEMA 273 *Guidelines* contain several new features that depart significantly from previous seismic design procedures used to design new buildings: seismic performance levels and rehabilitation objectives; simplified and systematic rehabilitation methods; methods of analysis, including linear static and nonlinear static procedures; quantitative specifications of component behavior; and procedures for incorporating new information and technologies, such as seismic isolation and energy dissipation systems, into rehabilitation.

ATC-34: The report, *A Critical Review of Current Approaches to Earthquake Resistant Design***,** was developed under a grant from NCEER and NSF. Available through the ATC office. (Published, 1995, 94 pages)

ABSTRACT: This report documents the history of U. S. codes and standards of practice, focusing primarily on the strengths and deficiencies of current code approaches. Issues addressed include: seismic hazard analysis, earthquake collateral hazards, performance objectives, redundancy and configuration, response modification factors (*R* factors), simplified analysis procedures, modeling of structural components, foundation design, nonstructural component design, and risk and reliability. The report also identifies goals that a new seismic code should achieve.

ATC-35: This report, *Enhancing the Transfer of U.S. Geological Survey Research Results into Engineering Practice* was developed under a cooperative agreement with the USGS. Available through the ATC office. (Published 1994, 120 pages)

ABSTRACT: The report provides a program of recommended "technology transfer" activities for the USGS; included are recommendations pertaining to management actions, communications with practicing engineers, and research activities to enhance development and transfer of information that is vital to engineering practice.

ATC-35-1: The report, *Proceedings of Seminar on New Developments in Earthquake Ground Motion Estimation and Implications for Engineering Design Practice*, was developed under a cooperative agreement with USGS. Available through the ATC office. (Published 1994, 478 pages)

ABSTRACT: These Proceedings contain 22 technical papers describing state-of-the-art information on regional earthquake risk (focused on five specific regions—Northern and Southern California, Pacific Northwest, Central United States, and northeastern North America); new techniques for estimating strong ground motions as a function of earthquake source, travel path, and site parameters; and new developments specifically applicable to geotechnical engineering and the seismic design of buildings and bridges.

ATC-35-2: The report, *Proceedings: National Earthquake Ground Motion Mapping Workshop*, was developed under a cooperative agreement with USGS. Available through the ATC office. (Published 1997, 154 pages)

ABSTRACT: These Proceedings document the technical presentations and findings of a workshop in Los Angeles in 1995 on several key issues that affect the preparation and use of national earthquake ground motion maps for design. The following four key issues were the focus of the workshop: ground motion parameters; reference site conditions; probabilistic versus deterministic basis, and the treatment of uncertainty in seismic source characterization and ground motion attenuation.

ATC-35-3: The report, *Proceedings: Workshop on Improved Characterization of Strong Ground Shaking for Seismic Design,* was developed under a cooperative agreement with USGS. Available through the ATC office. (Published 1999, 75 pages)

> ABSTRACT: These Proceedings document the technical presentations and findings of a workshop in Rancho Bernardo, California in 1997 on the Ground Motion Initiative (GMI) component of the ATC-35 Project. The workshop focused on identifying needs and developing improved representations of earthquake ground motion for use in seismic design practice, including codes.

ATC-37: The report, *Review of Seismic Research Results on Existing Buildings*, was developed in conjunction with the Structural Engineers Association of California and California Universities for Research in Earthquake Engineering under a contract from the California Seismic Safety Commission (SSC). Available through the Seismic Safety Commission as Report SSC 94-03. (Published, 1994, 492 pages)

> ABSTRACT: This report describes the state of knowledge of the earthquake performance of nonductile concrete frame, shear wall, and infilled buildings. Included are summaries of 90 recent research efforts with key results and conclusions in a simple, easy-to-access format written for practicing design professionals.

ATC-38: This report, *Database on the Performance of Structures near Strong-Motion Recordings: 1994 Northridge, California, Earthquake*, was developed with funding from the USGS, the Southern California Earthquake Center (SCEC), OES, and the Institute for Business and Home Safety (IBHS). Available through the ATC office. (Published 2000, 260 pages, with CD-ROM containing complete database).

> ABSTRACT: The report documents the earthquake performance of 530 buildings within 1000 feet of sites where strong ground motion was recorded during the 1994 Northridge, California, earthquake (31 recording sites in total). The project required the development of a suitable survey form, the training of licensed engineers for the survey, the selection of the surveyed areas, and the entry of the survey data into an electronic relational database. The full database is contained in the ATC-38 CD-ROM. The ATC-38 database includes information on the structure size, age and location; the structural framing system and other important structural characteristics; nonstructural characteristics; geotechnical effects, such as liquefaction; performance characteristics (damage); fatalities and injuries; and estimated time to restore the facility to its pre-earthquake usability. The report and CD also contain strong-motion data, including acceleration, velocity, and displacement time histories, and acceleration response spectra.

ATC-40: The report, *Seismic Evaluation and Retrofit of Concrete Buildings*, was developed under a contract from the California Seismic Safety Commission. Available through the ATC office. (Published, 1996, 612 pages)

> ABSTRACT: This 2-volume report provides a state-of-the-art methodology for the seismic evaluation and retrofit of concrete buildings. Specific guidance is provided on the following topics: performance objectives; seismic hazard; determination of deficiencies; retrofit strategies; quality assurance procedures; nonlinear static analysis procedures; modeling rules; foundation effects; response limits; and nonstructural components. In 1997 this report received the Western States Seismic Policy Council "Overall Excellence and New Technology Award."

ATC-41 (SAC Joint Venture, Phase 1): This project, Program to Reduce the Earthquake Hazards of Steel Moment-Resisting Frame Structures, Phase 1, was funded by FEMA and conducted by a Joint Venture partnership of SEAOC, ATC, and CUREe. Under this Phase 1 program SAC prepared the following documents:

> SAC-94-01, *Proceedings of the Invitational Workshop on Steel Seismic Issues, Los Angeles, September 1994* (Published 1994, 155 pages, available through the ATC office)

> SAC-95-01, *Steel Moment-Frame Connection Advisory No. 3* (Published

1995, 310 pages, available through the ATC office)

SAC-95-02, *Interim Guidelines: Evaluation, Repair, Modification and Design of Welded Steel Moment-Frame Structures* (FEMA 267 report) (Published 1995, 215 pages, available through FEMA by contacting 1-800-480-2520)

SAC-95-03, *Characterization of Ground Motions During the Northridge Earthquake of January 17, 1994* (Published 1995, 179 pages, available through the ATC office)

SAC-95-04, *Analytical and Field Investigations of Buildings Affected by the Northridge Earthquake of January 17, 1994* (Published 1995, 2 volumes, 900 pages, available through the ATC office)

SAC-95-05, *Parametric Analytical Investigations of Ground Motion and Structural Response, Northridge Earthquake of January 17, 1994* (Published 1995, 274 pages, available through the ATC office)

SAC-95-06, *Surveys and Assessment of Damage to Buildings Affected by the Northridge Earthquake of January 17, 1994* (Published 1995, 315 pages, available through the ATC office)

SAC-95-07, *Case Studies of Steel Moment Frame Building Performance in the Northridge Earthquake of January 17, 1994* (Published 1995, 260 pages, available through the ATC office)

SAC-95-08, *Experimental Investigations of Materials, Weldments and Nondestructive Examination Techniques* (Published 1995, 144 pages, available through the ATC office)

SAC-95-09, *Background Reports: Metallurgy, Fracture Mechanics, Welding, Moment Connections and Frame systems, Behavior* (FEMA 288 report) (Published 1995, 361 pages, available through FEMA by contacting 1-800-480-2520)

SAC-96-01, *Experimental Investigations of Beam-Column Subassemblages, Part 1 and 2* (Published 1996, 2 volumes, 924 pages, available through the ATC office)

SAC-96-02, *Connection Test Summaries* (FEMA 289 report) (Published 1996, available through FEMA by contacting 1-800-480-2520)

ATC-41-1 (SAC Joint Venture, Phase 2): This project, Program to Reduce the Earthquake Hazards of Steel Moment-Resisting Frame Structures, Phase 2, was funded by FEMA and conducted by a Joint Venture partnership of SEAOC, ATC, and CUREe. Under this Phase 2 program SAC has prepared the following documents:

SAC-96-03, *Interim Guidelines Advisory No. 1 Supplement to FEMA 267 Interim Guidelines* (FEMA 267A Report) (Published 1997, 100 pages, and superseded by FEMA-350 to 353.)

SAC-99-01, *Interim Guidelines Advisory No. 2 Supplement to FEMA-267 Interim Guidelines* (FEMA 267B Report, superseding FEMA-267A). (Published 1999, 150 pages, and superseded by FEMA-350 to 353.)

FEMA-350, *Recommended Seismic Design Criteria for New Steel Moment-Frame Buildings*. (Published 2000, 190 pages, available through FEMA: 1-800-480-2520)

FEMA-351, *Recommended Seismic Evaluation and Upgrade Criteria for Existing Welded Steel Moment-Frame Buildings*. (Published 2000, 210 pages, available through FEMA: 1-800-480-2520)

FEMA-352, *Recommended Postearthquake Evaluation and Repair Criteria for Welded Steel Moment-Frame Buildings*. (Published 2000, 180 pages, available through FEMA: 1-800-480-2520)

FEMA-353, *Recommended Specifications and Quality Assurance Guidelines for Steel Moment-Frame Construction for Seismic Applications*. (Published 2000, 180 pages, available through FEMA: 1-800-480-2520)

FEMA-354, *A Policy Guide to Steel Moment-Frame Construction*. (Published 2000, 27 pages, available through FEMA: 1-800-480-2520)

FEMA-355A, *State of the Art Report on Base Materials and Fracture*. Available from the ATC office. (Published 2000, 107 pages; available on CD-ROM through FEMA: 1-800-480-2520)

FEMA-355B, *State of the Art Report on Welding and Inspection*. Available from the ATC office. (Published 2000, 185 pages; available on CD-ROM through FEMA: 1-800-480-2520)

FEMA-355C, *State of the Art Report on Systems Performance of Steel Moment Frames Subject to Earthquake Ground Shaking*. Available from the ATC office. (Published 2000, 322 pages; available on CD-ROM through FEMA: 1-800-480-2520)

FEMA-355D, *State of the Art Report on Connection Performance*. Available from the ATC office. (Published 2000, 292 pages; available on CD-ROM through FEMA: 1-800-480-2520)

FEMA-355E, *State of the Art Report on Past Performance of Steel Moment-Frame Buildings in Earthquakes*. Available from the ATC office. (Published 2000, 190 pages; available on CD-ROM through FEMA: 1-800-480-2520)

FEMA-355F, *State of the Art Report on Performance Prediction and Evaluation of Steel Moment-Frame Structures*. Available from the ATC office. (Published 2000, 347 pages; available on CD-ROM through FEMA: 1-800-480-2520)

ATC-43: The reports, *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Basic Procedures Manual* (FEMA 306), *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Technical Resources* (FEMA 307), and *The Repair of Earthquake Damaged Concrete and Masonry Wall Buildings* (FEMA 308), were developed for FEMA under a contract with the Partnership for Response and Recovery, a Joint Venture of Dewberry & Davis and Woodward-Clyde. Available on CD-ROM through ATC; printed versions available through FEMA by contacting 1-800-480-2520 (Published, 1998, *Evaluation Procedures Manual*, 270 pages; *Technical Resources*, 271 pages, *Repair Document*, 81 pages)

ABSTRACT: Developed by 26 nationally recognized specialists in earthquake engineering, these documents provide field investigation techniques, damage evaluation procedures, methods for performance loss determination, repair guides and recommended repair techniques, and an in-depth discussion of policy issues pertaining to the repair and upgrade of earthquake damaged buildings. The documents have been developed specifically for buildings with primary lateral-force-resisting systems consisting of concrete bearing walls or masonry bearing walls, and vertical-load-bearing concrete frames or steel frames with concrete or masonry infill panels. The intended audience includes design engineers, building owners, building regulatory officials, and government agencies.

ATC-44: The report, *Hurricane Fran, North Carolina, September 5, 1996: Reconnaissance Report***,** was funded by the Applied Technology Council. Available through the ATC office. (Published 1997, 36 pages)

ABSTRACT: Written for an intended audience of design professionals and regulators, this report contains information on hurricane size, path, and rainfall amounts; coastal impacts, including storm surges and waves, forces on structures, and the role of erosion; the role of beach nourishment in reducing wave energy and crest height; building code requirements; observations and interpretations of damage to buildings, including the effect of debris acting as missiles; and lifeline performance.

ATC-48 (ATC/SEAOC Joint Venture Training Curriculum): The training curriculum, *Built to Resist Earthquakes, The Path to Quality Seismic Design and Construction for Architects, Engineers, and Inspectors*, was developed under a contract with the California Seismic Safety Commission and prepared by a Joint Venture partnership of ATC and SEAOC. Available through the ATC office (Published 1999, 314 pages)

ABSTRACT: Bound in a three-ring notebook, the curriculum contains training materials pertaining to the seismic design and retrofit of wood-frame buildings, concrete and masonry construction, and nonstructural components. Included are detailed, illustrated, instructional material (lessons) and a series of multi-part Briefing Papers and Job Aids to facilitate improvement in the quality of seismic design, inspection, and construction.

ATC-51: The report, *U.S.-Italy Collaborative Recommendations for Improved Seismic Safety of Hospitals in Italy*, was developed under a contract with Servizio Sismico Nazionale of Italy (Italian National Seismic Survey). Available through the ATC office. (Published 2000, 154 pages)

ABSTRACT: Developed by a 14-person team of hospital seismic safety specialists and regulators from the United States and Italy, the report provides an overview of hospital seismic risk in Italy; six recommended short-term actions and four recommended long-term actions for improving hospital seismic safety in Italy; and supplemental information on (a) hospital seismic safety regulation in California, (b) requirements for nonstructural components in California and for buildings regulated by the Office of U. S. Foreign Buildings, and (c) current seismic evaluation standards in the United States.

ATC-51-1: The report, *Recommended U.S.-Italy Collaborative Procedures for Earthquake Emergency Response Planning for Hospitals in Italy*, was developed under a second contract with Servizio Sismico Nazionale of Italy (Italian National Seismic Survey, NSS). Available through the ATC office. (Published 2002, 120 pages)

ABSTRACT: The report addresses one of the short-term recommendations — planning for emergency response and postearthquake inspection — made in the first phase of the ATC-51 project, and considers both current practices for emergency response planning in the United States and available NSS information and regulations pertaining to hospital emergency response planning in Italy. The report contains: (1) descriptions of current procedures and concepts for emergency response planning in the United States and Italy, (2) an overview of relevant procedures for both countries for evaluating and predicting the seismic vulnerability of buildings, including procedures for postearthquake inspection, (3) recommended procedures for earthquake emergency response planning and postearthquake assessment of hospitals, to be implemented through the use of a Postearthquake Inspection Notebook and demonstrated through the application on two representative hospital facilities; and (4) recommendations for emergency response training, postearthquake inspection training, and the mitigation of seismic hazards.

ATC-52: The project, "Development of a Community Action Plan for Seismic Safety (CAPSS), City and County of San Francisco", was conducted under a contract with the San Francisco Department of Building Inspection. Under Phase I, completed in 2000, ATC defined the tasks to be conducted under Phase II, a multi-year ATC effort scheduled to commence in 2001. The Phase II tasks include: (1) development of a reliable estimate of the size and nature of the impacts a large earthquake will have on San Francisco; (2) development of technically sound consensus-based guidelines for the evaluation and repair of San Francisco's most vulnerable building types; and (3) identification, definition, and ranking of other activities to reduce the seismic risks in the City and County of San Francisco.

ATC-53: The report, *Assessment of the NIST 12-Million-Pound (53 MN) Large-Scale Testing Facility*, was developed under a contract with NIST. Available through the ATC office. (Published 2000, 44 pages)

ABSTRACT: This report documents the findings of an ATC Technical Panel engaged to assess the utility and viability of a 30-year-old, 12-million pound (53 MN) Universal Testing Machine located at NIST headquarters in Gaithersburg, Maryland. Issues addressed include: (a) the merits of continuing operation of the facility; (b) possible improvements or modifications that would render it more useful to the earthquake engineering community and other potential large-scale structural research communities; and (c) identification of specific research (seismic and non-seismic) that might require the use of this facility in the future.

ATC-R-1: The report, *Cyclic Testing of Narrow Plywood Shear Walls,* was developed with funding from the Henry J. Degenkolb Memorial Endowment Fund of the Applied Technology Council. Available through the ATC office (Published 1995, 64 pages)

ABSTRACT: This report documents ATC's first self-directed research program: a series of static and dynamic tests of narrow plywood wall panels having the standard 3.5-to-1 height-to-width ratio and anchored to the sill plate using typical bolted, 9-inch, 5000-lb. capacity hold-down devices. The report provides a description of the testing program and a summary of results, including comparisons of drift ratios found during testing with those specified in the seismic provisions of the 1991 *Uniform Building Code*. The report served as a catalyst for changes in code-specified aspect ratios for narrow plywood wall panels and for new thinking in the design of hold-down devices. It also stimulated widespread interest in laboratory testing of wood-frame structures.

ATC Design Guide 1: The report, *Minimizing Floor Vibration***,** was developed with funding from ATC's Henry J. Degenkolb Memorial Endowment Fund. Available through the ATC office. (Published, 1999, 64 pages)

ABSTRACT: Design Guide 1 provides guidance on design and retrofit of floor structures to limit transient vibrations to acceptable levels. The document includes guidance for estimating floor vibration properties and example calculations for a variety of currently used floor types and designs. The criteria for acceptable levels of floor vibration are based on human sensitivity to the vibration, whether it is caused by human behavior or machinery in the structure.

ATC TechBrief 1: The ATC TechBrief 1, *Liquefaction Maps*, was developed under a contract with the United States Geological Survey. Available free of charge through the ATC office. (Published 1996, 12 pages)

ABSTRACT: The technical brief inventories and describes the available regional liquefaction hazard maps in the United States and gives information on how to obtain them.

ATC TechBrief 2: The ATC TechBrief 2, *Earthquake Aftershocks − Entering Damaged Buildings*, was developed under a contract with the United States Geological Survey. Available free of charge through the ATC office. (Published 1996, 12 pages)

ABSTRACT: The technical brief offers guidelines for entering damaged buildings under emergency conditions during the first hours and days after the initial damaging event.

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