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DOE STANDARD

GUIDELINES FOR USE OF PROBABILISTIC SEISMIC HAZARD CURVES AT DEPARTMENT OF ENERGY SITES FOR DEPARTMENT OF ENERGY FACILITIES

U.S. Department of Energy
Washington, D.C. 20585

AREA FACR

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Subject: CHANGE NOTICE #1

This Change Notice has been approved by EH-31 to update references in this document to reflect recently approved DOE Orders and Implementation Guides. It includes 3 pages, an instructions page, a new cover page for the document, and a new "Foreword" page for the orginal document.

Action: Recipients of this Change Notice should take the following actions:

1. Insert the enclosed revised cover page which reflects Change Notice #1, inside the front cover of the original document.

2. Insert the enclosed document page which is the revised "Foreword" statement, prior to the original "Foreword" page and cross out the original "Foreword" paragraphs.

3. Insert this Change Notice page immediately following the revised front cover that was inserted in step 1 above.

FOREWORD

More recent versions of documents referenced by and associated with this technical standard now exist. Specifically,

1. DOE Order 5480.28 has been replaced by DOE Order 420.1, **Facility Safety** and its associated Implementation Guides:

   "Implementation Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Non-nuclear Facilities",

   "Implementation Guide for Nonreactor Nuclear Safety Design Criteria and Explosives Safety Criteria", and

   "Implementation Guide for use with DOE Orders 420 and 470 Fire Safety Program".

2. DOE Standard 1023 is more recent than this technical standard and should be reviewed prior to use of this technical standard. All future Seismic Hazard Curves should be developed using the methods provided in DOE-STD-1023-95.

3. The definitions provided in the Natural Phenomena Hazards (NPH) Implementation Guide take precedence over the definitions provided in this technical standard and in other NPH technical standards.

4. There is an established hierarchy in the set of documents that specify NPH requirements. In this hierarchy, DOE Order 420.1 is the highest authority. The next set of controlling documents are the associated Implementation Guides followed by the set of NPH technical standards. In the event of conflicts in the information provided by these documents, the information provided in the document of higher authority should be utilized (e.g., the definitions provided in the Implementation Guides should be utilized even though corresponding definitions are provided in the NPH technical standards).

5. This technical standard will still apply when DOE Order 420.1 is converted to a rule. In addition, this technical standard will still apply when other referenced DOE Orders such as 5480.23, the SAR Order, 5480.22, the TSR Order, etc. are converted to rules.

ABSTRACT

This Standard is intended to provide guidance in the use of the seismic hazard curves developed by the Lawrence Livermore National Laboratory (LLNL) and the Electric Power Research Institute (EPRI). Experience to-date has shown that application of these methodologies can yield significantly different results. In response to this issue, a Seismic Working Group (SWG) has been formed at the Department of Energy (DOE) Headquarters to coordinate the application of these methodologies within DOE in a consistent manner. The position developed by the SWG and contained in this Standard is intended for immediate use in developing seismic hazard estimates at DOE sites for the evaluation of new and existing, nuclear and non-nuclear DOE facilities. This Standard is needed not only to address the LLNL/EPRI issue but also to assure that state-of-the-art seismic hazard methods are incorporated into DOE standards as soon as possible.

The DOE is currently involved in a joint program with the Nuclear Regulatory Commission and EPRI to evaluate these existing probabilistic seismic hazard methodologies and to develop recommendations for an improved methodology for the 1990's. The final product of this effort is expected to result in more stable hazard estimates and will supersede this Standard in approximately two years.

TABLE OF CONTENTS

Background

The issue of the seismic hazard to be used in safety or risk assessments has recently been raised at a number of Department of Energy (DOE) facilities. One of the technical issues associated with this topic is the existence and use of two different methodologies for the development of seismic hazard curves by Lawrence Livermore National Laboratory (LLNL) and the Electric Power Research Institute (EPRI). Experience to date has shown that application of these methodologies can yield significantly different results. In response to this situation, a Seismic Working Group (SWG) has been formed at DOE Headquarters to coordinate the application of these methodologies within DOE in a consistent manner, and to cooperate in an effort to address the differences between the two methodologies.

The difference between the LLNL and EPRI studies takes on Departmental importance for several reasons: (1) results from these studies are applicable to locations in the Eastern United States (east of 104W) and have been used by a number of DOE sites and contractors; (2) the current usage of these studies is inconsistent from site to site; (3) the Department General Design Criteria (DOE Order 6430.IA) requires that seismic design be evaluated based on probabilistic seismic hazard without explicitly identifying what methodology should be used; and (4) various Departmental organizations are using safety goals to evaluate facility performance and design which can be sensitive to the probabilistic seismic hazard curve used.

The DOE SWG developed several objectives. These objectives are:

1. Develop an understanding of how DOE field offices and support contractors are using the LLNL and EPRI seismic hazard studies;

2. Develop an understanding of what studies have been initiated or completed to investigate the causes of the significant differences between the LLNL and EPRI studies at DOE facility sites;

3. Document the significant differences regarding the use of the LLNL and EPRI studies at the various DOE sites;

4. Provide an interim position regarding how the LLNL and EPRI studies should be used to assess seismic issues for existing and future facility seismic designs; and

5. Provide recommendations regarding efforts to address the differences between the LLNL and EPRI seismic hazard curves that result in more stable estimates of seismic hazard.

Purpose

The purpose of this Standard is to present and implement the fourth objective. This Standard will address the first three objectives by reference as needed. This Standard will be operative for about 2 years. The DOE, in cooperation with the U. S. Nuclear Regulatory Commission (NRC) and EPRI has initiated a seismic hazard program which is expected to result in more stable seismic hazard estimates. This work should be completed within 2 years and the results would be used to develop an updated standard at that time.

This Standard is a revised version of a draft position regarding the LLNL/EPRI seismic hazard curves (DOE, 1992a) which was reviewed by numerous organizations. The DOE SWG has prepared a comment/response document which responds to comments from these organizations. The comment response document explains the changes made to the draft position and is provided as Appendix A.

Applicability

The Standard explicitly applies to all DOE sites east of the about 104W. The Rocky Flats site is excluded from the Standard because the LLNL and EPRI studies did not extend far enough westward to provide the necessary seismic hazard input. The Paducah, Kentucky site is excluded because this site is in close proximity to the New Madrid, Missouri seismic zone which should be modeled as an extended line source. Neither the EPRI nor LLNL studies adequately modeled the New Madrid source in this fashion. The Paducah site has undertaken appropriate probabilistic seismic hazard studies including extended source modeling for New Madrid. Department of Energy sites in the Western United States should be aware of the position, particularly when developing site-specific probabilistic seismic hazard curves.

Department of Energy sites and facilities that are to be licensed by the NRC are exempt from this Standard.

Current Department of Energy Orders and Requirements

The design methods currently being used by DOE are contained in UCRL-15910, "Design and Evaluation Guideline for Department of Energy Facilities Subjected to Natural Phenomena Hazards", the implementing reference in DOE Order 6430.1A, the DOE General Design Criteria. UCRL-15910 is based on the use of probabilistic performance goals for different facility use categories and specifies that the seismic design basis for DOE nonreactor facilities is to be determined using hazard exceedance probabilities.

Currently, a DOE Order is being prepared that will define Natural Phenomena Hazards Mitigation (Draft DOE Order 5480.NPH). Additionally, a set of Natural Phenomena Standards and Guidance Documents will be prepared that will establish more explicit requirements and acceptance criteria for DOE facilities. Department of Energy Standard DOE-STD-1020-92, "Natural Phenomena

Hazards Design and Evaluation Criteria for Department of Energy Facilities" will, when published, supersede UCRL-15910. For the purpose of this standard we will continue to use the UCRL-15910 reference with a parenthetical reference to the future standard. The DOE Natural Phenomena Order and associated documents establish the following requirements:

- The seismic performance goals and the seismic hazard exceedance probabilities will be based on mean probabilistic estimates; and

- Site-specific seismic hazard estimates should be reviewed about every ten years. If new information and/or methods used to compute probabilistic seismic hazard changes then revised probabilistic estimates should be made. In general, the TERA, Inc. seismic hazard curves do not now represent state-of-the-art seismic hazard estimates.

Unfortunately, UCRL-15910 (DOE-STD-1020) is silent in two critical respects. First, there is no specific guidance for DOE sites to complete a probabilistic seismic hazard analysis at set time intervals. As a result the hazard analyses summarized in UCRL-53582, the TERA, Inc. studies, late 1970's vintage, are dated. Considerable research and development efforts in the fields of seismo-tectonics and ground motion estimation since 1980 allow for better modeling of uncertainties in analysis, more accurate determination of the major contributors to seismic hazard, and more confidence in absolute numbers. Additionally, significant amounts of more recent seismic information are available. At some sites the existing TERA, Inc. results appear to be extremely high at the higher probabilities (>IOE-3) to such an extent that results are questionable. This Standard is needed in order to incorporate this more recent information into seismic hazard determination as soon as possible, and to address the concerns with the TERA, Inc. study. Unfortunately, the recent studies that have been completed using the new information are widely divergent in hazard results.

Figure 1 illustrates the issue at hand by showing the median, mean and 85th percentile probabilistic seismic hazard results for the Savannah River Site for, both LLNL and EPRI. Figure 1 shows the extreme difference between the two studies for the mean and 85th percentile and the general consistency between the median results. This leads to the second issue related to UCRL-15910 (DOE-STD-1020), the issue of uncertainty.

UCRL-15910 (DOE-STD-1020) is silent regarding how uncertainty should be factored into the probabilistic performance goal and seismic hazard assessment which directly affects the selection of the peak ground acceleration. While UCRL-15910 (DOE-STD-1020) specifies that the median response spectral shape should be used, it does not explicitly define whether the probabilistically defined peak ground acceleration is associated with a median or mean value, or some other value. The existing TERA, Inc. curves are labeled "best estimate" values which are most closely associated with median values using current approaches. Since the TERA, Inc. values were developed by one team the mean and median are essentially the same from that study. The DOE Eastern United States sites that have updated site specific probabilistic seismic hazard results have had to address the LLNL and EPRI uncertainty issues as well. At present, assessments have been completed inconsistently from site to site. The use of the Standard will provide a consistent approach to clarify these uncertainties.

Format

The discussion provided below is organized as follows: Because there is extensive discussion and evaluation of the existing seismic hazard curves, the seismic hazard position is provided first. The text which follows reviews the existing probabilistic seismic hazard curves, and provides the basis for the development of the specific factors selected for the seismic hazard position.

1.0 SEISMIC HAZARD POSITION

The seismic hazard position described below uses the annual probabilities specified in DOE Order 5480.NPH and UCRL-15910 (DOE-STD-1020).

A: For those sites that have both LLNL and EPRI probabilistic seismic hazard results the recommended approach is to either continue to use the TERA, Inc. seismic hazard values or:

1. Use the peak ground acceleration probabilistic median seismic hazard curves from both the LLNL, without LLNL Expert #5 Attenuation, (hereafter referred to as LLNL-AE5) and EPRI studies.

2. Enter the two studies at the target probability (i.e., at 2×10^{-4}, 1×10^{-3} or 2×10^{-3} per DOE Order 5480.NPH or UCRL-15910 (DOE-STD-1020) and geometrically average the resulting two peak ground accelerations.

3. Multiply the resulting peak ground acceleration by 1.80 for the probabilities of 1×10^{-3} and 2×10^{-3} and 1.65 for the probability of 2×10^{-4} to represent uncertainty in the hazard analysis.

4. Using the peak ground acceleration from 3 above, anchor a median standardized spectral shape such as the median spectral shape defined in NUREG/CR-0098 (Newmark and Hall), or a deterministic site-specific derived median spectral shape. In all cases the spectral shape should be consistent with the rock or soil site conditions at the site in question. The resulting response spectra should be compared to that being used to establish the Design Basis Earthquake (DBE) at each site. If the DBE spectral shape is lower than the NUREG/CR-0098 spectral shape, it is recommended that a site-specific spectral shape be developed.

For those sites who implement a deterministic site-specific spectral shape, information contained in the probabilistic seismic hazard analysis should be used to establish the appropriate magnitude and distance. Interim guidance for the development of deterministic spectral shape is provided in Appendix B. The TERA, Inc. spectral shape shall not be used for future DBE assessments if it is lower than the developed site-specific spectral shape. A DOE Standard is being developed (Draft DOE-STD-1023) that will provide specific criteria which can be used to develop site-specific spectra. The DOE Standard will supersede the interim guidance found in Appendix B. If a modern probabilistic seismic hazard analysis is not available then the NUREG-CR/0098 median spectral shape should be used.

B: For those sites that have only the LLNL or EPRI probabilistic seismic hazard results the recommendation is to use the above factors (in A3 above) on an adjusted median curve as described below. The factor selected to adjust the median is 1.2 (i.e., LLNL median result divided by 1.2) if only LLNL results are available with LLNL-AE5). This factor represents the difference between the LLNL and EPRI median hazard curves at both reactor sites and DOE sites. For sites that have only LLNL results without LLNL-AE5 these median results should be used directly. For a site that would have only EPRI results available (none are known to currently exist) it is recommended that LLNL results be quantified for that site. If this cannot be accomplished, the EPRI median should be multiplied by 1.2 In following the Standard, however, all sites which have both results must use the position developed using both results.

C: The seismic hazard position does not explicitly apply to Probabilistic Risk Assessment (PRA) studies. Probabilistic Risk Assessments being completed should evaluate both LLNL and EPRI hazard curves individually to ensure that there is an adequate seismic understanding of the dominant seismic sequences. Thus, these results should be used in a relative sense. The absolute seismic PRA numbers should not be relied on considering the issues associated with the individual EPRI and LLNL hazard curves.

The advantage of the above approach is that the most stable hazard estimate is used while recognizing the existing uncertainty. The difficulty of this approach relates to how the correction factor is estimated. The correction factor was developed by reviewing the LLNL and EPRI results (fractiles ranging from the 15 percent to 85 percent) for the commercial nuclear power plants in the Eastern United States. This recommendation is thought to represent a reasonable interim solution, and was developed to address the limitations in existing hazard analyses discussed below. The specific value for the correction factor is thought to be conservative in that future work will demonstrate that the mean hazard curves are lower than values recommended by this position. The discussion below also summarizes the development of this factor.

2.0 BASIS FOR RECOMMENDATIONS

2.1 Summary Issues

The discussion provided below is a brief summary of the evaluations that have been completed to date to investigate, in detail, the causes of the significant differences between the LLNL and EPRI seismic hazard methods. It should be noted that detailed evaluations of the differences between the two studies have only been completed at a few sites. This makes it difficult to reach definitive conclusions regarding the generic causes of the differences between the two methods. The reader is referred to the references cited in the discussion below to obtain more detailed discussion regarding the key issues related to the seismic hazard curves.

Three investigators have evaluated in some detail the LLNL and EPRI seismic hazard methods. These investigators are LLNL (Bernreuter, 1987, et al), Jack Benjamin and Associates (McCann, 1991) and Risk Engineering Inc. (McGuire, 1990a, 1990b, 1991). The following are summary issues as a result of these studies. The summary issues are meant to capture key points that the investigators have made.

2.1.1 Lawrence Livermore National Laboratory Summary Issues

- With respect to uncertainty estimates, uncertainty in zonation and ground motion attenuation are, in general, the most significant sources of uncertainty in the LLNL study. When compared to the EPRI results, there appears to be a large difference in the uncertainty estimates associated with the seismicity parameters (both activity rates and slope of the recurrence curve);

- The contribution of the background zone is extremely important for sites in relatively low seismicity regions. Great care should be taken in estimating the seismicity parameters of the zone which contains the site. In some cases the host zone for a given site has no assumed seismicity above magnitude 5.0 in the EPRI study;

- Validation tests show that when using exactly the same input the EPRI and LLNL algorithms give similar results;

- The seismic hazard results are extremely sensitive to the input of LLNL-AE5, particularly for rock site conditions. Lawrence Livermore National Laboratory recognizes that an analysis such as they performed contains certain combinations of assumptions which will lead to estimates that are true outliers. It is LLNL's opinion that this fact makes the mean a relatively poor choice to use to compare the hazard between sites because it is more sensitive to outliers than other estimators, such as the median. Median estimates of seismic hazard appear to be stable estimators of the seismic hazard at a site;

- The number and weights assigned to ground motion models used in the LLNL and EPRI studies are very different. There is a larger number of models encompassing a large range of opinions in the LLNL study compared to the EPRI study; and

- Lawrence Livermore National Laboratory found that the probability of exceedance of a given ground motion value is, in general, close to a lognormal probability distribution. The EPRI distribution of the hazard appears to be skewed strongly toward the low probability of exceedance. A key difference between the two studies relates to differences in the way that the expert opinion was elicited, particularly with respect to uncertainty assessments.

2.1.2 Risk Engineering, Inc. Summary Issues

- Risk Engineering, Inc. found that the uncertainty provided by a given expert in the LLNL study was much larger than the uncertainty provided by the EPRI expert teams. Risk Engineering, Inc. concluded that there were unrealistically large uncertainty bands on seismicity parameters for four of the LLNL seismicity experts, particularly for the Charleston seismic source zone. One seismicity expert (in one extreme case) included a recurrence interval of 20 days for a magnitude greater than 5.0 for the Charleston source. This same expert had an upper end to the recurrence range for magnitude 5.0 of 2290 years, which is longer than the recurrence estimates for the 1886 Charleston event;

- Risk Engineering, Inc. concluded that there was insufficient feedback to allow comparison of the resulting LLNL seismicity expert interpretations with historic seismicity data. In general, the recurrence intervals for all of the LLNL seismicity experts may be anomalously short when compared to historic seismicity;

- Risk Engineering, Inc. has also -found that the EPRI team of Dames and Moore does not fully account for historic seismicity near the Savannah River Site (SRS). One reason for this is the fact that the SRS host source zone was given a low probability of activity. Risk Engineering, Inc. recommended that the Dames and Moore seismic source input not be used to calculate the seismic hazard at SRS;

- Risk Engineering, Inc. has compared the attenuation functions selected by EPRI and the LLNL attenuation experts with available strong motion data in the Eastern North America, and in particular the data generated by the 1988 Saguenay earthquake. They concluded that no individual attenuation function fits the Saguenay observations over the entire distance range of 40 to 200 kilometers. Additionally, they found that the attenuation model selected by LLNL-AE5 is generally inconsistent with observed data; and

- Risk Engineering, Inc. has also criticized the method by which the attenuation model used by LLNL-AE5 was derived. This model was obtained by combining intensity versus amplitude regressions from California and intensity attenuation relationships from Eastern North America. The intensity versus amplitude relationship from California may not be the same in Eastern North America due to differences in ground motion frequency content, duration, and wave type between the two regions. In addition, the substitution process used leads to biased results. Risk Engineering, Inc. has recommended that LLNL-AE5 be deleted from seismic hazard calculations.

2.1.3 Jack Benjamin and Associates Summary Issues

Jack Benjamin and Associates (JBA) developed diagnostic tools to provide a close examination of the factors that contributed the largest percentage to the seismic hazard results. These comparisons showed that differences in the mean hazard result between LLNL and EPRI are controlled by low degree of belief parameter assessments. The overall conclusion of JBA is that the process of expert elicitation and uncertainty evaluation are extremely important. Some of the more important observations are described below.

- The LLNL constant percentile seismic hazard curves are based on 2750 individual seismic hazard curves. The highest curve (1/2750 or .04 percent) contributes 13 percent to the mean hazard curve at Savannah River. This curve is associated with a 1/7.6 chance of exceeding 0.25g annually at the Savannah River Site. This value appears to be extremely high given the historical seismicity in the Southeastern United States. The highest 21 hazard curves (21/2750 or .80 percent) contribute about 50 percent to the mean hazard curve.

- The seismicity parameters associated with some of the highest seismic LLNL hazard curves may be affected by the way that an expert intensity-based recurrence relationship is translated into a magnitude based recurrence relationship. This could result in anomalously high activity rates and/or low recurrence slope ('b') values. Jack Benjamin and Associates concluded that the largest difference between the LLNL and EPRI results were due to difference between the seismicity parameters and upper magnitude cutoffs.

- The LLNL and EPRI attenuation models were compared to a set of empirical Eastern United States data, for peak acceleration and response spectral values. It was found that several attenuation models fit the empirical set at frequencies less than about 5 hertz. LLNL-AE5 fit the data particularly poorly at the low frequencies.

2.2 Lawrence Livermore National Laboratory Draft New Production Reactor Probabilistic Seismic Hazard Results For Savannah River

Lawrence Livermore National Laboratory staff have undertaken a probabilistic seismic hazard study for DOE at the Savannah River Site (LLNL, 1992). Lawrence Livermore National Laboratory staff, recognizing the technical issues related to their earlier work, have attempted to ensure that seismic hazard uncertainties are properly identified and quantified. Draft results from Savannah River when compared to earlier LLNL estimates explicitly show reductions in uncertainty estimates. Such results are likely to have generic implications. The following three issues appear to have the most significant influence on the draft revised Savannah River results.

- LLNL-AE5 has modified the attenuation relationship he had previously selected in the LLNL Eastern United States study. For Savannah River this change is judged to be relatively minor because of the deep soil site conditions. For rock site conditions the revised attenuation relationships is likely to be more significant.

- The characterization of attenuation uncertainty is assessed inconsistently between experts. Lawrence Livermore National Laboratory has identified attenuation uncertainty as a key issue in quantifying mean estimates of seismic hazard. Lawrence Livermore National Laboratory has performed initial sensitivity studies using modified estimates (narrower range) of attenuation uncertainty which results in reduction of mean seismic hazard of about 30 to 50 percent.

- The assessment of uncertainty in earthquake occurrence parameters is treated inconsistently by different experts. Lawrence Livermore National Laboratory is developing diagnostic tools to better determine if seismicity experts have properly quantified earthquake occurrence uncertainty. Preliminary results suggest that some LLNL seismicity experts may over-estimate the range in earthquake occurrence parameters.

Figure 7 discussed later in this Standard shows the original LLNL mean seismic hazard results for the Savannah River Site with and without LLNL-AE5 and preliminary draft results for LLNL study underway for Savannah River. The most recent results show probability reductions in the mean hazard of about 8 at a peak acceleration of about 0.20g. These preliminary results will be used to help establish the appropriate way of containing the LLNL and EPRI seismic hazard curves.

2.3 Seismic Working Group Meeting of March 11, 1991

In addition to the above information, the SWG held a meeting on March 11, 1991, with the specific purpose of obtaining from these three investigators their input related to the causes of the differences between the two studies. Based on the above, the SWG has evaluated these studies and has reached the following conclusions:

- There is a high degree of similarity between the LLNL and EPRI seismic hazard studies ranging from overlap of experts used to general overlap in parameter input from the experts. The key difference between the two studies relates to the topic of uncertainty assessment, particularly "modeling uncertainty" assessment for all input variables. Identified issues relate to the process of expert opinion elicitation, particularly the issues of how and whether experts assess and understand uncertainty;

- The SWG has concluded that the mean seismic hazard curves from the LLNL and EPRI study should not be used as the seismic hazard curve to implement UCRL-15910 (DOE-STD-1020) or as the single seismic hazard curve for probabilistic risk assessments. The work of McCann (1991) demonstrates that the LLNL mean is sensitive to the upper tail of the hazard curve distribution (above about 90th percentile) at the Savannah River Site. Given the location of the mean hazard curve at the sites evaluated by LLNL (LLNL 1989), i.e., generally above the 85th percentile, it is likely that the above conclusion would hold at many locations. The seismic hazard curves at fractiles above about the 85th percentile may not represent realistic seismicity estimates. While the above generic statement is controversial, it is clear that there is doubt regarding these highest fractiles, and this doubt is serious enough at the present time to support the judgement that fractiles above the 85th percentile should not dominate the choice of seismic input;

- The above conclusion may be generally extended to the EPRI study. McGuire (1990a and 1990b) has recommended that, based on comparison to historic seismicity, that some of the EPRI team input could be questioned as underestimating the frequency of earthquakes. Additionally, LLNL (1987) has noted that the process used to include attenuation models is different between the two studies. The EPRI seismic hazard curves were based on holding a ground motion workshop and then selecting three attenuation models while the LLNL results are based on input from several experts. In a relative sense, there is the potential that attenuation uncertainty is underestimated in the EPRI study. These issues degrade confidence in the fractiles below about the 15th percentile and above about the 85th percentile from the EPRI study, which could impact the reliability of the mean;

- There has been concern regarding the ground motion model selected by LLNL-AE5. Lawrence Livermore National Laboratory (1987) has recognized that the input from LLNL-AE5 can dominate the upper fractiles of the hazard results, particularly for rock site conditions. Both McCann (1991) and McGuire (1990a, 1990b and 1991) have expressed two concerns related to LLNL-AE5. The development of the model has been questioned, regarding the assumptions made and the methods used to develop an appropriate intensity based attenuation model for the Eastern United States based on Western ground motion data. Additionally, the model has been compared to existing strong motion data from the East, and questions have been raised regarding how well the model fits the data compared to attenuation models selected by other experts. These two factors suggest that the hazard fractiles from the LLNL study which are dominated by LLNL-AE5 should not be used to define the ground motion. This supports the above assessment that the mean hazard curve from the LLNL study may not be realistic;

- The Uniform Hazard Spectra defined by the LLNL and EPRI studies represents the combination of standard spectral shape models with direct spectral ordinate models. The standard spectral shape is typically based on statistical analysis of large (M>6) earthquakes while the direct spectral ordinate method is based on a specified magnitude and distance. The uncertainty distributions associated with Uniform Hazard Spectra appear to be less stable than the peak acceleration seismic hazard curves. These differences degrade confidence that the Uniform Hazard Spectral shape actually represents equal hazard spectra, and thus they should not be used; and

- The seismic hazard curves which appear to be most stable are the median seismic hazard curves, from both the LLNL and EPRI studies. Additionally, the uncertainty assessment in both studies regarding the difference between the medians and the 15th percentile and 85th percentile should be accounted for in the Standard.

3.0 ASSUMPTIONS

Based on the above conclusions, the following assumptions have been developed by the SWG.

- The Standard should result in a consistent estimate of probabilistic seismic hazard (degree of conservatism) from site to site. The relative consistency from site to site is an important element in implementing the criteria in UCRL 15910 (DOE-STD-1020) (e.g., UCRL 15910 (DOE-STD-1020) performance goals and hazard exceedance probabilities are predicated on the use of consistent hazard estimates).

- Use of either the LLNL and EPRI results should not be to the exclusion of the other. While specific portions of each study have come under question, the studies represent landmarks in the assessment of probabilistic seismic hazard, and should both be used to make seismic decisions.

- Uncertainty should be explicitly incorporated into the selection of the ground motion at a given probability of exceedance.

- The mean seismic hazard curve should be used if the criteria are associated with single value probabilistic seismic hazard input, such as the hazard exceedance probabilities defined in UCRL-15910 (DOE-STD-1020). If there is doubt that existing mean estimates are realistic (as is the case) then a pseudo-mean should be developed. Given the current concerns with both the LLNL and EPRI results the pseudo-mean should not be based on the fractiles below the 15th percentile and above the 85th percentile from either study. The use of mean estimates is incorporated in the DOE Natural Phenomena Hazards Mitigation Order (DOE Order 5480.NPH).

- When available, site specific soil conditions should be explicitly included in the seismic hazard estimates, and in the development of an appropriate response spectra. For soil sites, an explicit determination should be made to assess the potential for site amplification.

4.0 APPROACH SELECTED

As part of determining which approach was best to select, DOE requested that Dr. C. A. Cornell assist in reviewing the existing LLNL and EPRI results at the 69 commercial nuclear power plant sites (NPP). Information in the form of hazard curves and hazard curve ratios (ratio of the 85th percentile to the median, for peak ground acceleration and several response spectral ordinates) was provided to Dr. Cornell and DOE by Risk Engineering Inc. under contract to Martin Marietta Energy Systems, Oak Ridge. This information was reviewed to determine if there were any consistent trends in the uncertainty estimates within the individual LLNL and EPRI studies, and to determine what the trends were between the two studies. Figures 2 and 3 display typical information provided. These figures show the ratio of 85th percentile to the median for 10 hertz spectral frequency for the LLNL and EPRI studies respectively.

Appendix C provides the full set of information on the hazard curve ratios for the peak ground acceleration and the spectral frequencies of 25, 10, 5, 2.5 and 1 hertz. Several levels of ground motion are also shown on each figure. Figures C1 to C6 display the geometric mean of the ratio between the 85th percentile and the median for the EPRI results and the LLNL results with and without LLNL-AE5. Figures C7 through C24 display the entire set of reactor data and the geometric mean, 15th and 85th percentiles of the data. As discussed below, the above data can be used to derive a pseudo-mean correction factor for the seismic hazard curves. Dr. Cornell's report is provided as Appendix D. The more important trends observed are:

- The site-to-site variability in the ratio of 85th/median in both the LLNL and EPRI studies are very similar, for all ground motion cases reviewed. This result is displayed on Figure 4 which shows the ratio for a peak ground acceleration of 0.20g for the NPP sites. The LLNL data shown on Figure 4 includes LLNL-AE5. The range of the above ratio within either the LLNL or EPRI studies is about a factor of 2 to 2.5 for the majority of the NPP sites;

- The difference in the ratio of the 85th/median between the LLNL and EPRI studies is very similar in a wide variety of cases. For peak ground acceleration the difference between LLNL and EPRI is represented by about a factor of 3 to 3.5 with LLNL-AE5 included, falling to about a factor of 2 if LLNL-AE5 is not included. This trend holds true for spectral velocities down to about 2.5 hertz. This trend is displayed on Figure 5 which shows the geometric mean of the ratio of the 85th percentile to the median for peak ground acceleration;

- As shown on Figures 2 through 5 and in Appendix A, the absolute value of the ratio of the 85th/median is drastically different between the two studies. The representative value at a peak ground acceleration of 0.20g is about 3.5 for the EPRI study, and about 7.2 for the LLNL study without LLNL-AE5 and about 11.2 with LLNL-AE5 included. In general, if LLNL-AE5 is excluded, the ratio for the LLNL results decreases by about 20 to 40 percent;

- The value of the ratio of the 85th/median is dependent on the response spectral frequency. The ratio value increases as the spectral frequency decreases, with a more drastic trend observed for the EPRI data. The use of the lower frequency information is complicated by the observation that the attenuation models selected by the LLNL and EPRI studies result in different spectral shapes. As discussed above, some attenuation models provide direct spectral estimates while others are associated with standard spectral shapes such as the Newmark/Hall spectral shape. These two different approaches can be one of the factors which result in larger ratio at the lower frequency; and

- The difference between the LLNL and EPRI median hazard curves is generally less than a factor of 2. This result is displayed on Figure 6 for a peak ground acceleration of 0.20g for the LLNL results including attenuation expert 5. Table 1 also provides summary statistics for the ratio of the medians, broken down by rock and soil site conditions, with and without LLNL-AE5. The largest difference between the LLNL and EPRI medians is for soil sites where the uncertainty in ratios is relatively large. This is thought to reflect differences between the two studies regarding how soil conditions could impact ground motion estimates.

Based on the review of this information, the approach selected for the seismic hazard position is as follows: The trends in the ratio of the LLNL/EPRI medians and individual LLNL or EPRI 85th/median can be used to derive a pseudo-mean correction factor. Trends observed are relatively stable, which result in the advantage that a specific correction factor can be derived to result in consistent hazard estimates from site to site. This is thought to be superior to the other approaches in that specific reliance on the LLNL or EPRI 85th percentile hazard curves may not be warranted given their extreme differences, and it is not necessary to derive complex weighing methods to combine the two studies.

The derivation of the specific correction factor is built around the most stable seismic hazard curves, the LLNL and EPRI median curves. A decision was also required regarding the specific spectral frequency and level of ground motion to base the correction factor on. The preferred frequency would be one that shows a high degree of relative stability and be of engineering significance, such as between 2.5 and 10 hertz.

These frequencies were not selected given the above discussion and concerns regarding how the Uniform Hazard Spectrum were derived. Given these issues the decision was made to use the peak ground acceleration.

4.1 Calculation of Correction Factors

Appendix D, provided by Dr. Cornell, describes the specific formulation of the pseudo-mean correction factor. The general steps, using the information at a peak acceleration of 0.20g, are as follows (the number provided for these steps exclude LLNL-AE5): Quantify the difference between LLNL and EPRI for the ratio of the 85th percentile to the median for 0.20g (about 2) and derive a composite 85th/median factor using this value and the EPRI absolute ratio of the 85th/median (composite ratio about 5; a similar result is obtained by calculating the geometric mean of the EPRI and LLNL 85th/median ratios); assume an underlying lognormal distribution and derive a mean/median hazard multiplier (about 3.6); and using this hazard multiplier and representative slopes of seismic hazard curves derive a ratio for mean/median ground motion.

Using the above steps, estimates of the pseudo-mean correction factor were made for the following: Information for the peak acceleration values of 0.1g, 0.2g, and 0.4g; LLNL data that includes and excludes LLNL-AE5; slopes of EPRI and LLNL seismic hazard curves for the nuclear reactor sites; and probability levels and range of median ground motion appropriate for DOE sites. Appendix E provides the data associated the above range of parameters. The following summarized the values selected for the correction factor.

- For the probabilities of 2 x 10^{-3}/yr. and 10^{-3}/yr. associated with UCRL-15910 (DOE-STD-1029) use the LLNL and EPRI slope information for probabilities of 10^{-3} /yr. to 10^{-4}/yr.

- For the probability of 2 x 10^{-4}/yr. associated with UCRL-15910 (DOE-STD-1020) use the LLNL and EPRI slope information for probabilities of 10^{-4}/yr. to 10^{-5}/yr.

- For the probabilities of 2 x 10^{-3}/yr. and 10^{-3} /yr. associated with UCRL-15910 (DOE-STD-1020) use the LLNL and EPRI seismic hazard ratios at a peak acceleration of 0.10g.

- For the probability of 2 x 10^{-4}/yr. associated with UCRL-15910 (DOE-STD-1020) use the LLNL and EPRI seismic hazard ratios at a peak acceleration of 0.20g.

4.2 Seismic Hazard Position: Use of LLNL-AE5

The final issue pertains to the use of LLNL-AE5. Figure 7 displays the existing mean EPRI and LLNL (with and without LLNL-AE5) seismic hazard results and the draft preliminary revised results from LLNL using a reduced range of ground motion uncertainty for the Savannah River Site. All estimates were made using a lower bound magnitude of 5.0. As discussed previously, the revised LLNL mean results are significantly lower than the earlier LLNL results. Also shown in Figure 7 are the results of the LLNL/EPRI correction factor with (Choice 2) and without (Choice 1) LLNL-AE5 taken from Appendix E applied to the Savannah River Site.

The revised LLNL mean results reflect the following changes: (1) the seismicity experts have revised earthquake recurrence parameters (a and b values) to generally more narrow uncertainty distributions; (2) the attenuation experts are explicitly addressing the definition and magnitude of attenuation random uncertainty (one of the uncertainty terms); and (3) LLNL-AE5 has altered his attenuation model. Thus, the revised probabilistic results for Savannah River reflect increased attention to uncertainty assessment for all seismic hazard parameters. The changes made by LLNL-AE5 are expected to be more significant at rock sites where the original LLNL-AE5 input had most impact (Bernreuter, et al, 1987). In general the above noted changes (trends in reduced mean) are judged to be generic and applicable to all sites.

It is the SWGs judgement that Choice 1 more accurately reflects the correction to be applied to the LLNL and EPRI results. Figure 7 shows that for the Savannah River Site that the Choice 1 correction factor (using the existing LLNL results without LLNL-AE5) more accurately reflects the assessment of mean seismic hazard for the revised LLNL results. While the specific degree of uncertainty assessment is likely to change from site to site, the preliminary Savannah River results suggests that the existing LLNL mean hazard results may substantially overestimate the mean hazard, consistent with the previous assessment that the mean hazard curves should not be directly used.

Based on the above, the SWG position is that the pseudo-mean correction factor should be based on using the existing LLNL results without LLNL-AE5. Thus for probabilities associated with low and moderate hazard the correction factor is 1.80 and for high hazard the correction factor is 1.65 (Appendix E).

5.0 EXAMPLES

The approach was used to develop representative peak ground acceleration estimates for five sites which were made available to the SWG; Savannah River, Portsmouth, Oak Ridge, Princeton and Brookhaven. Table 2 shows the peak ground acceleration values for the three probabilities defined in UCRL-15910 (DOE-STD-1020), the actual LLNL and EPRI median, mean and 85th percentile values at these probabilities, and the older TERA, Inc. estimates. Table 3 shows the resulting estimate of the pseudo-mean value, and a comparison to the older TERA, Inc. estimates reported in UCRL-15910 (DOE-STD-1020). Table 3 also shows the recommended approach for Brookhaven and Princeton, sites that only have the LLNL seismic hazard curves.

As shown in Table 3, the recommended values are equal to or lower than the previous estimates provided in UCRL-15910 (DOE-STD-1020). This result is significant when considering that the older hazard curves are labeled "best estimate" values which may be most appropriately correlated with median estimates, considering that TERA, Inc. did not explicitly quantify modeling uncertainty. This would qualitatively suggest that median seismic hazard estimates have decreased since the late 1970's. Tables 2 and 3 also show that if the option selected had directly used the mean or 85th percentile data, the derived pseudo-mean is likely to have been heavily influenced by the LLNL curves. Table 3 also shows that the recommended values are equal to or greater than the EPRI 85th percentile, but significantly lower than the LLNL 85th percentile. Based on the above, it is acceptable for sites in the Eastern United States to continue to use the TERA, Inc. peak acceleration or the values recommended by this Standard.

Table 4 displays the recommended peak horizontal acceleration values in summary fashion. Table 4 also lists the remaining Eastern United States DOE sites. The SWG is unaware of whether LLNL or EPRI data exists for these sites and thus continues to recommend the use of TERA, Inc. results.

The Standard explicitly applies to all DOE sites east of the about 104W. The Rocky Flats Site is excluded from the Standard because the LLNL and EPRI studies did not extend far enough westward to provide the necessary seismic hazard input. The Paducah, Kentucky site is excluded because this site is in close proximity to the New Madrid, Missouri seismic zone which should be modeled as an extended line source. Neither the EPRI or LLNL studies adequately modeled the New Madrid source in this fashion. The Paducah site has undertaken appropriate probabilistic seismic hazard studies including extended source modeling for New Madrid. Department of Energy sites in the Western United States (west of 104W) should be aware of the position, particularly when developing site-specific probabilistic seismic hazard curves and the assessment of uncertainty in deriving mean estimates of seismic hazard.

6.0 FUTURE EFFORTS

In an effort to improve any future probabilistic seismic hazard studies, the SWG requested that a Program Plan for the Evaluation of EPRI and LLNL Seismic Hazard Methodologies and Development of Recommendations for a Consensus Probabilistic Seismic Hazard Methodology for the 1990's be prepared. This proposal has been discussed with the NRC and EPRI with the intent that the work would be supported by the three agencies. The results of this work would include a procedure for estimating the likelihood of earthquake ground motion in the Eastern United States as accepted by the participating government agencies and the electric power industry. The results of this work would replace this Standard. This work was initiated October 1, 1992, and will be completed approximately 24 months from this date. The SWG is also following the ongoing efforts of the NRC regarding potential modifications to the NRC's seismic criteria and regulations. The NRC efforts as they become available will be reviewed to determine if any modifications to this Standard are necessary.

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DEFINITIONS

ATTENUATION: (1) A decrease of signal amplitude during transmission; (2) a reduction in amplitude or energy with or without change of waveform; or (3) the decrease in seismic signal strength with distance which depends not only on geometrical spreading but also may be related to physical characteristics of the transmitting medium causing absorption and scattering.

DAMPING: The reduction in amplitude of an oscillation owing to absorption of energy within a material.

DETERMINISTIC SEISMIC HAZARD ANALYSIS: A deterministic seismic hazard analysis uses one tectonic structure, tectonic province, or capable fault and one attenuation relationship to estimate effects of ground motion at a site.

EUS: Eastern United States sites, east of about longitude 104W in U.S.A. The counterpart is WUS.

EXTENDED SOURCE SEISMIC HAZARD ANALYSIS: A special seismic hazard analysis that considers the extent and orientation of ruptures from large earthquakes in a specific region. The finite-rupture analysis considers multiple alternative interpretations in order to characterize uncertainty in the seismic hazard. (Among DOE sites, Paducah, Kentucky site, as a results of the proximity to potential large earthquakes similar to New Madrid, Missouri earthquakes of 1811 and 1812 has need for such an analysis).

FREE FIELD: Refers to ground motion measurements that are not influenced by manmade structures.

GEOMETRIC MEAN: The geometric mean for a sample of size n - $(X_1 \times X_2 -.. \times X_n)^{1/n}$ versus an arithmetic mean which is $(X_1 + X_2 ..+ X_n)^{1/n}$.

GROUND MOTION: General term referring to the qualitative or quantitative aspects of shaking of the Earth's surface from earthquakes or explosions.

HAZARD (SEISMIC) EXCEEDANCE PROBABILITY: The probability over some period of time that an earthquake will generate a level of ground shaking greater than some specified level.

HERTZ (HZ): A unit of frequency. Expressed in cycles per second.

MEAN: Very briefly the mean is the first moment. It is that value about which the entire empirical distribution could be "balanced."

MEDIAN: The median is any value of' X such that one-half the values are above and one-half below it (it divides the area of the histogram in half).

NATURAL FREOUENCY(IES): The discrete frequency(ies) at which a particular elastic system vibrates when it is set in motion by a single impulse and not influenced by other external forces or by damping. The reciprocal of fundamental period.

PEAK GROUND ACCELERATION: The maximum horizontal component of ground HORIZONTAL acceleration measured in the free field at the ground's surface during an earthquake.

PERFORMANCE GOAL: It is the mean annual probability of exceedance of acceptable behavior limits used as a target to develop natural phenomena hazard mitigation requirements.

PERIOD: The time interval required by one full cycle of wave.

PROBABILISTIC SEISMIC HAZARD ANALYSIS: It is the calculation of probabilities of future earthquake effects (primarily ground shaking) at a site for a specified period of time. All possible tectonic events that could impact the site and the associated ground motions are modeled, taking into account both the likelihood of occurrence, and the uncertainty in input parameters such as seismic source, seismicity, and the attenuation functions.

PSEUDO-MEAN: The (peak ground acceleration) probabilistic mean seismic hazard estimate as developed in this standard based on the fractiles between the 15th percentile and the 85th percentile from the LLNL and EPRI studies.

RESPONSE SPECTRUM: The peak response of a series of simple harmonic oscillators of different natural period when subjected mathematically to a particular ground motion. The response spectrum may be plotted as a curve on tripartite logarithmic graph paper showing the variation of the peak spectral acceleration, displacement, and velocity of the oscillators as a function of vibration period and damping.

SITE AMPLIFICATION: An increase in seismic signal amplitude within some range of frequency as waves propagate through different Earth materials. The amplitude may be decreased in another frequency band.

SITE-SPECIFIC RESPONSE SPECTRA: As opposed to generic response spectra these spectra developed for a specific site taking into consideration the local site conditions and the regional geology and tectonics. The development of these are governed by specific methods and requirements per the prevailing codes and standards.

Table 1

SUMMARY OF LLNL/EPRI RATIO FOR PEAK GROUND ACCELERATION OF 0.20g
MEDIAN SEISMIC HAZARD CURVES

	MEDIAN	MEAN	STD DEV.
ALL NUCLEAR SITES			
with LLNL-AE5	1.67	2.78	2.76
without LLNL-AE5	1.06	1.69	1.71
SOIL SITES			
with LLNL-AE5	1.68	3.59	3.77
without LLNL-AE5	1.24	2.30	2.39
ROCK SITES			
with LLNL-AE5	1.75	2.24	1.60
without LLNL-AE5	1.02	1.29	0.85
ALL SITES EXCEPT GULF COAST			
with LLNL-AE5	1.62	1.99	1.09
without LLNL-AE5	1.01	1.22	0.68

LLNL-AE5 - LLNL Attenuation Expert No. 5

Table 2

Existing Probabilistic Hazard Results For DOE Sites
Peak Horizontal Ground Acceleration (in g's)

Site	Probability (note 1)		
	2x10E-3	1x10E-3	2x10E-4
Savannah River (soil site)			
EPRI	.03, .04, .05	.05, .06, .09	.10, .13, .19
LLNL with LLNL-AE5	.05, .20, .15	.07, .26, .20	.16, .52, .38
LLNL without LLNL-AE5	.15, .13	.05, .20, .18	.13, .40, .33
TERA, Inc. results	.08	.11	.19
Portsmouth (note 4)			
EPRI	.02, .03, .04	.03, .03, .06	.07, .08, .10
LLNL with LLNL-AE5	.02, .16, .15	.05, .22, .20	.10 (note 3)
LLNL without LLNL-AE5	.06, .06	.04, .08, .08	.08, .18, .17
TERA, Inc. results	.08	.11	.17
Oak Ridge (note 4)			
EPRI	.04, .05, .09	.07, .09, .13	.17, .19, .26
LLNL with LLNL-AE5	.07, .30, .24	.10 (note 3)	.22 (note 3)
LLNL without LLNL-AE5	.05, .15, .14	.08, .22, .19	.18, .38, .34
TERA, Inc. results	.15	.19	.32
Princeton (rock site) (note 5)			
LLNL with LLNL-AE5	.06, .17, .19	.08, .23, .26	.19, .50, .48
TERA, Inc.	.13	.16	.27
Brookhaven (soil site) (note 6)			
LLNL with LLNL-AE5	.05, .16, .14	.07, .19, .16	.15, .37, .34
LLNL without LLNL-AE5	.03, .11, .19	.05, .17, .13	.14, .36, .27
TERA, Inc.	.12	.15	.25

*** SEE NOTES AT THE END OF TABLE 3 ***

Table 3

Probabilistic Hazard results For DOE Site Using Standard Position
Peak Horizontal Ground Acceleration (in g's) for Different Probabilities

Site	Probability		
	2x10E-3	1x10E-3	2x10E-4
Savannah River (soil site)			
Avg. of median without LLNL-AE5 times correction factor (note 7)	.05(note 2)	.09	.19
TERA, Inc. results	.08	.11	.19
Portsmouth (note 4)			
Ave. of median without LLNL-AE5 times correction factor (note 7)	.04(note 2)	.06	.12
TERA, Inc. results	.08	.11	.17
Oak Ridge (note 4)			
Ave. of median without LLNL-AE5 times correction factor (note 7)	.08	.13	.29
TERA, Inc. results	.15	.19	.32
Princeton (rock site) (note 5)			
Ave. of median without LLNL-AE5 times correction factor (note 7)	.09	.12	.26
TERA, Inc.	.13	.16	.27

Table 3 cont.

Probabilistic Hazard results For DOE Site Using Standard Position
Peak Horizontal Ground Acceleration (in g's) for Different Probabilities

Site	Probability		
	2x10E-3	1x10E-3	2x10E-4
Brookhaven (soil site) (note 6)			
LLNL median without expert LLNL-AE5 times correction factor (note 7)	.05	.09	.23
TERA, Inc.	.12	.15	.25

Note 1: EPRI and LLNL values shown are median, mean, 85 percent respectively

Note 2: Number shown is EPRI value x correction factor due to lack of LLNL measurable value

Note 3: LLNL results for these fractiles and probabilities were above values provided by site contractor.

Note 4: TERA values for Oak Ridge and Portsmouth assumed soil site conditions while LLNL and EPRI values assumed rock site conditions. Lawrence Livermore National Laboratory personnel believe that for peak acceleration the original TERA values for soil would be the same as if rock has been assumed, thus making comparison consistent.

Note 5: The Princeton site does not have LLNL results available without LLNL-AE5 and does not have available EPRI results. Value recommended is based on LLNL, peak acceleration with LLNL-AE5 divided by 1.2, times the correction factor.

Note 6: The Brookhaven site does not have EPRI results available. Value recommended is based on LLNL peak acceleration without LLNL-AE5 times the correction factor.

Note 7: The correction factor is 1.80 for probabilities more than or equal to 1 x 10E-3 and 1.65 for the probability of 2 x 10E-4.

Table 4

Summary of Recommended Horizontal Peak
Ground Acceleration (in g's)

ANNUAL HAZARD PROBABILITY

SITE	2×10^{-3}	1×10^{-3}	2×10^{-4}	SITE CONDITIONS
Savannah River	.05	.09	.19	Soil
Brookhaven	.05	.09	.23	Soil
Princeton	.09	.12	.26	Rock
Oak Ridge	.08	.13	.29	Rock
Portsmouth	.04	.06	.12	Rock

Summary of Recommended Horizontal Peak Ground
Acceleration Remaining Eastern United States Sites
(those sites which have no LLNL or EPRI results)*

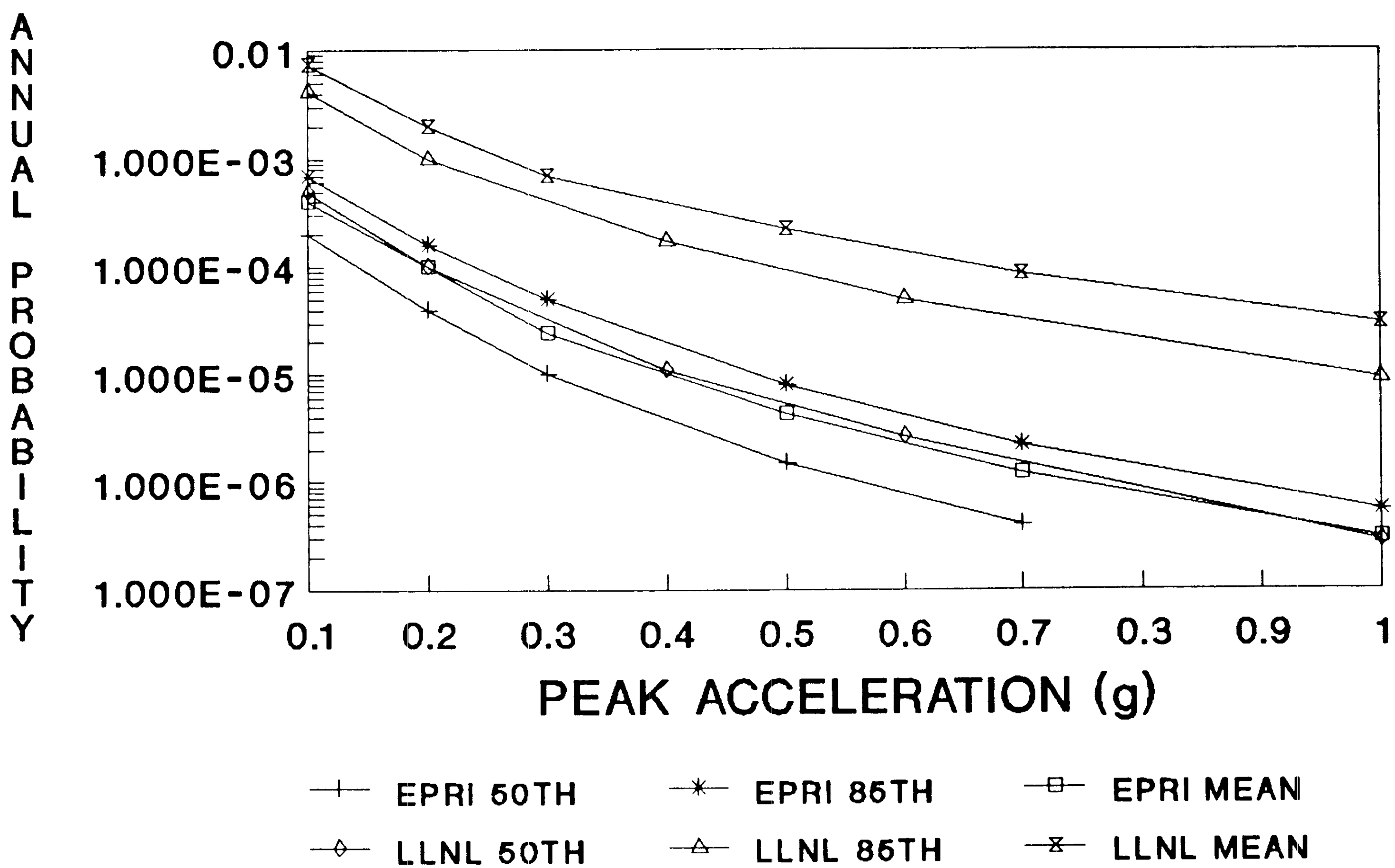
(See table 4-4 of UCRL-15910 for Western United States DOE Sites)

SITE	2×10^{-3}	1×10^{-3}	2×10^{-4}
Bendix Plant	.08	.10	.17
Mound	.12	.15	.23
Pantex	.08	.10	.17
Pinnellas	.04	.05	.09
Argonne	.09	.12	.21

*If a site has available LLNL and EPRI data the recommended position from this standard should be used.

Figure 1

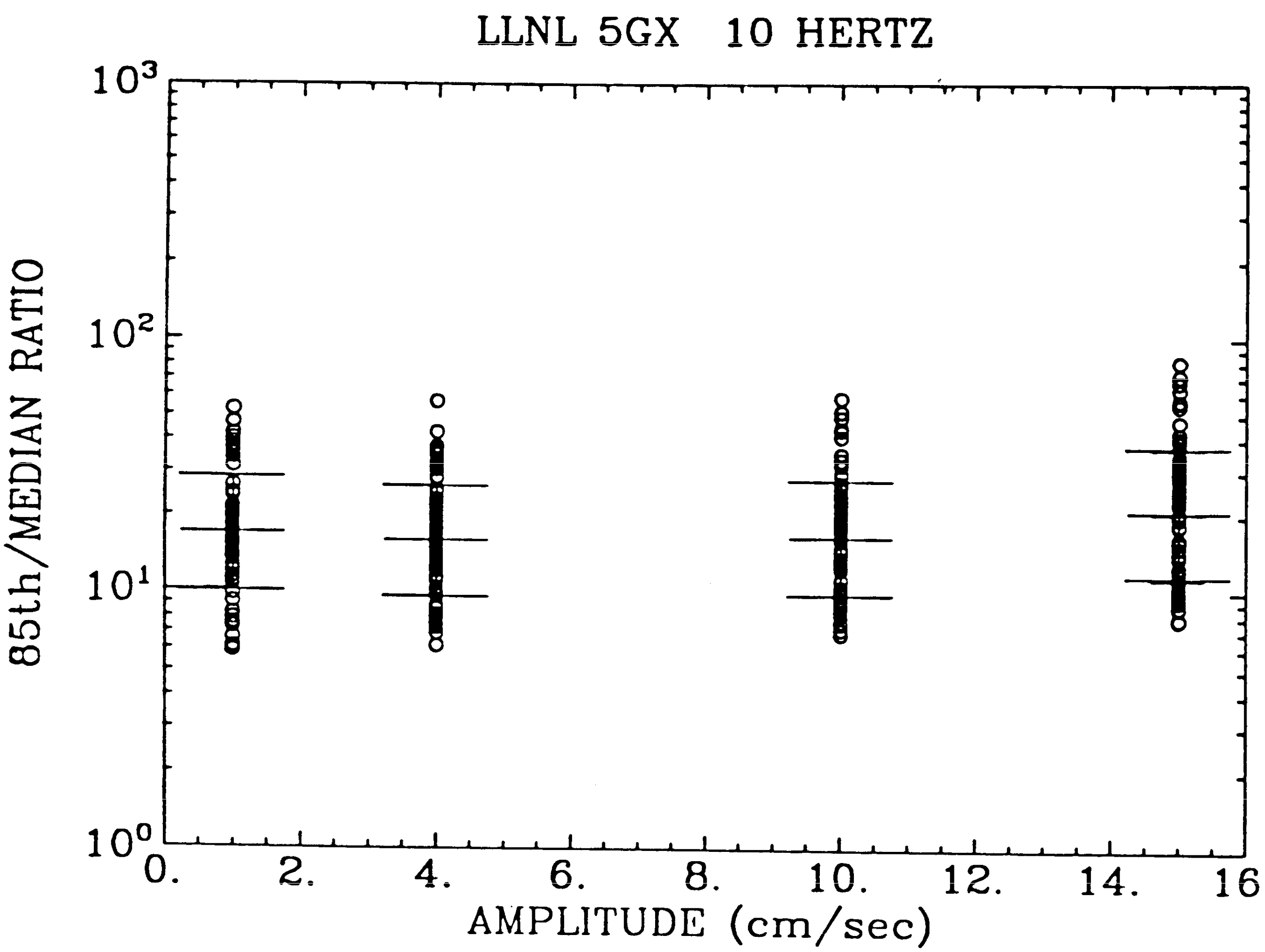
PROBABILISTIC SEISMIC HAZARD COMPARISON
EPRI VS. LLNL SAVANNAH RIVER SITE



LLNL 5 GM EXPERTS

LLNL RATIO OF 85TH/MEDIAN

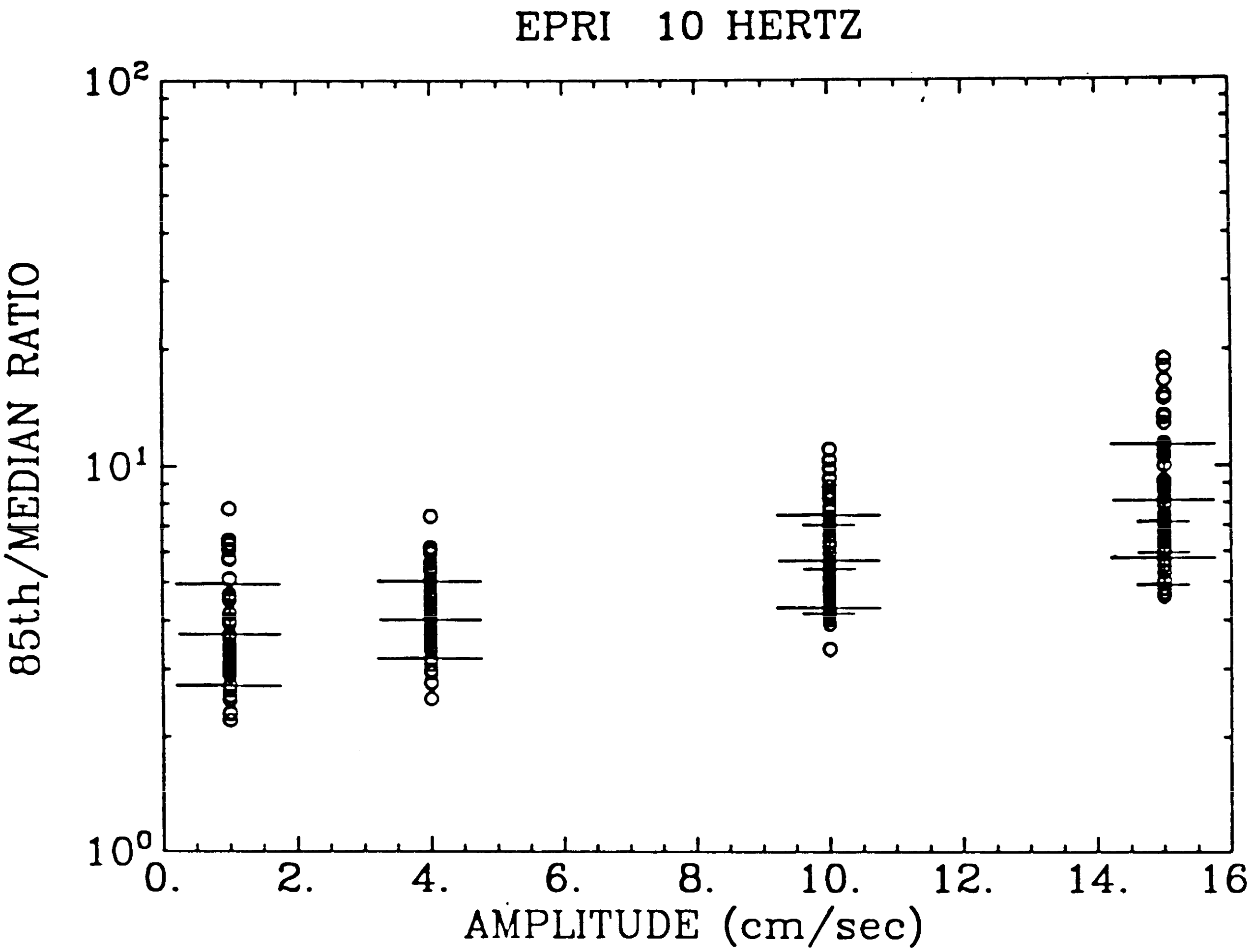
Figure 2



The ratio of 85th/median for 10 hertz spectral velocity from the LLNL probabilistic seismic hazard curves for Eastern United States nuclear power plant sites.
Bars display the geometric mean, 15th percentile and 85th percentile. LLNL 5GX includes LLNL ground motion expert 5.

EPRI RATIO OF 85TH/MEDIAN

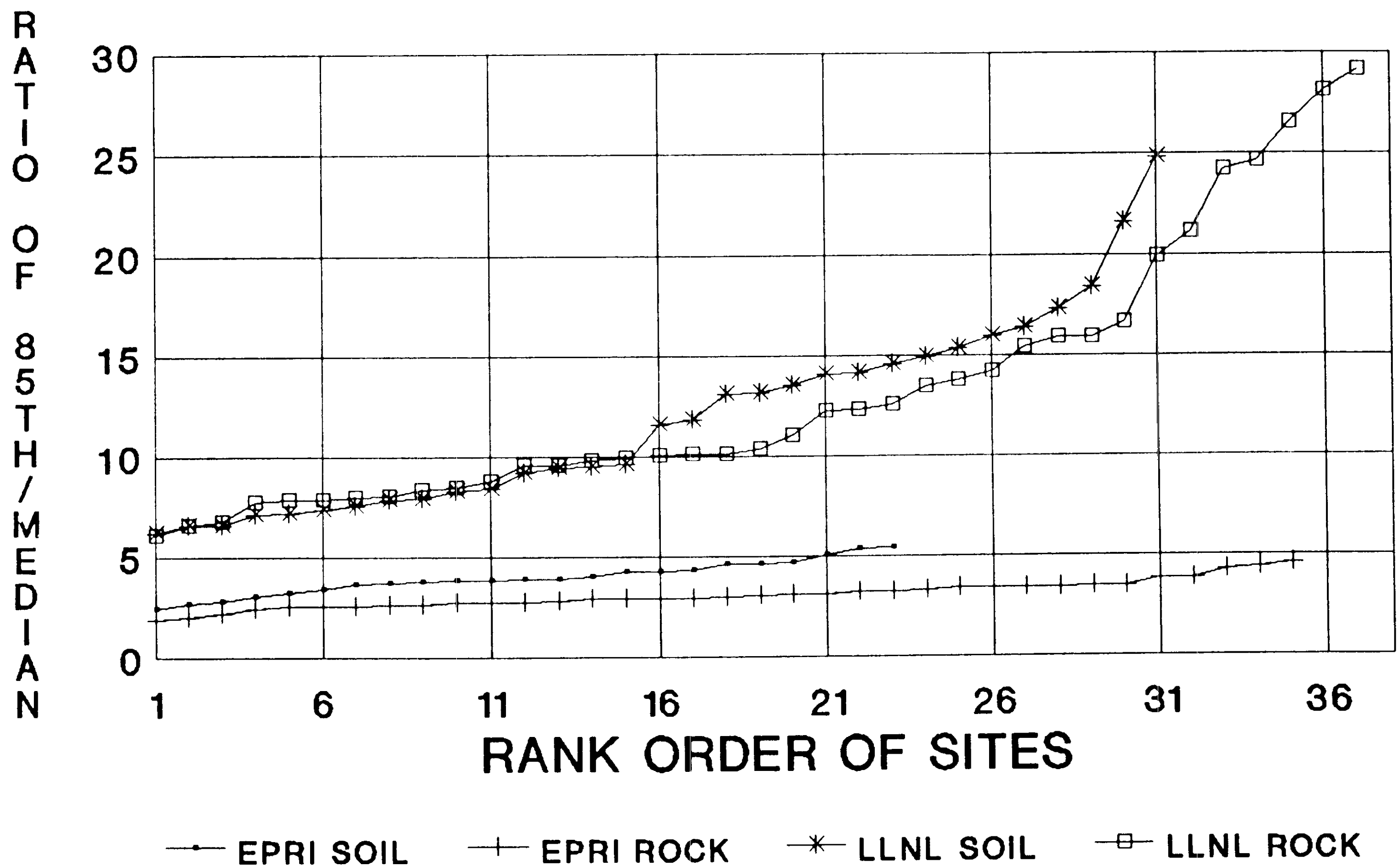
Figure 3



The ratio of 85th/median for 10 hertz spectral velocity from the EPRI probabilistic seismic hazard curves for Eastern United States nuclear power plant sites. Bars display the geometric mean, 15th percentile and 85th percentile.

Figure 4

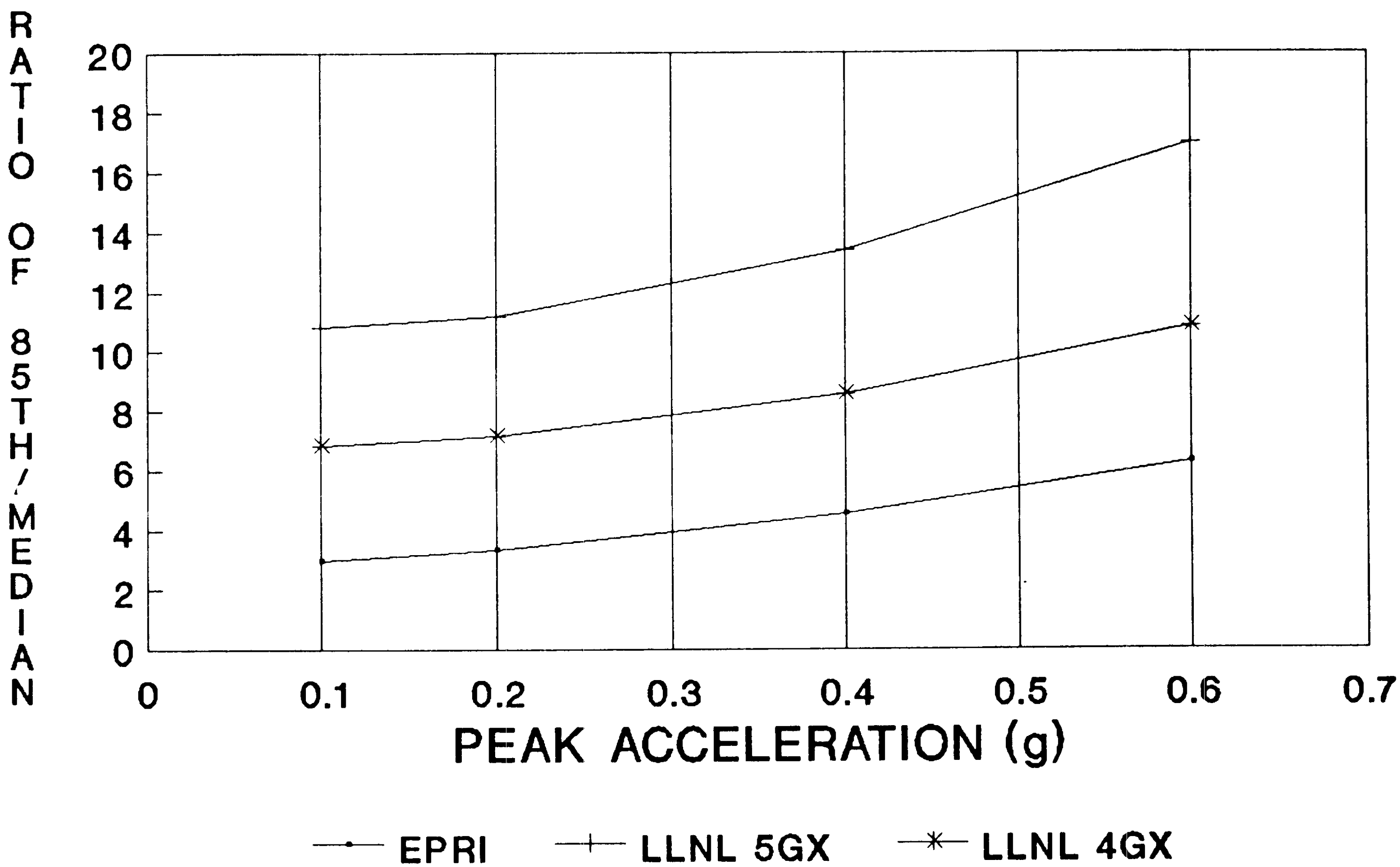
RATIO OF 85TH/MEDIAN LLNL AND EPRI PROBABILISTIC SEISMIC HAZARD CURVES



T A PEAK ACCELERATION OF 0.20g

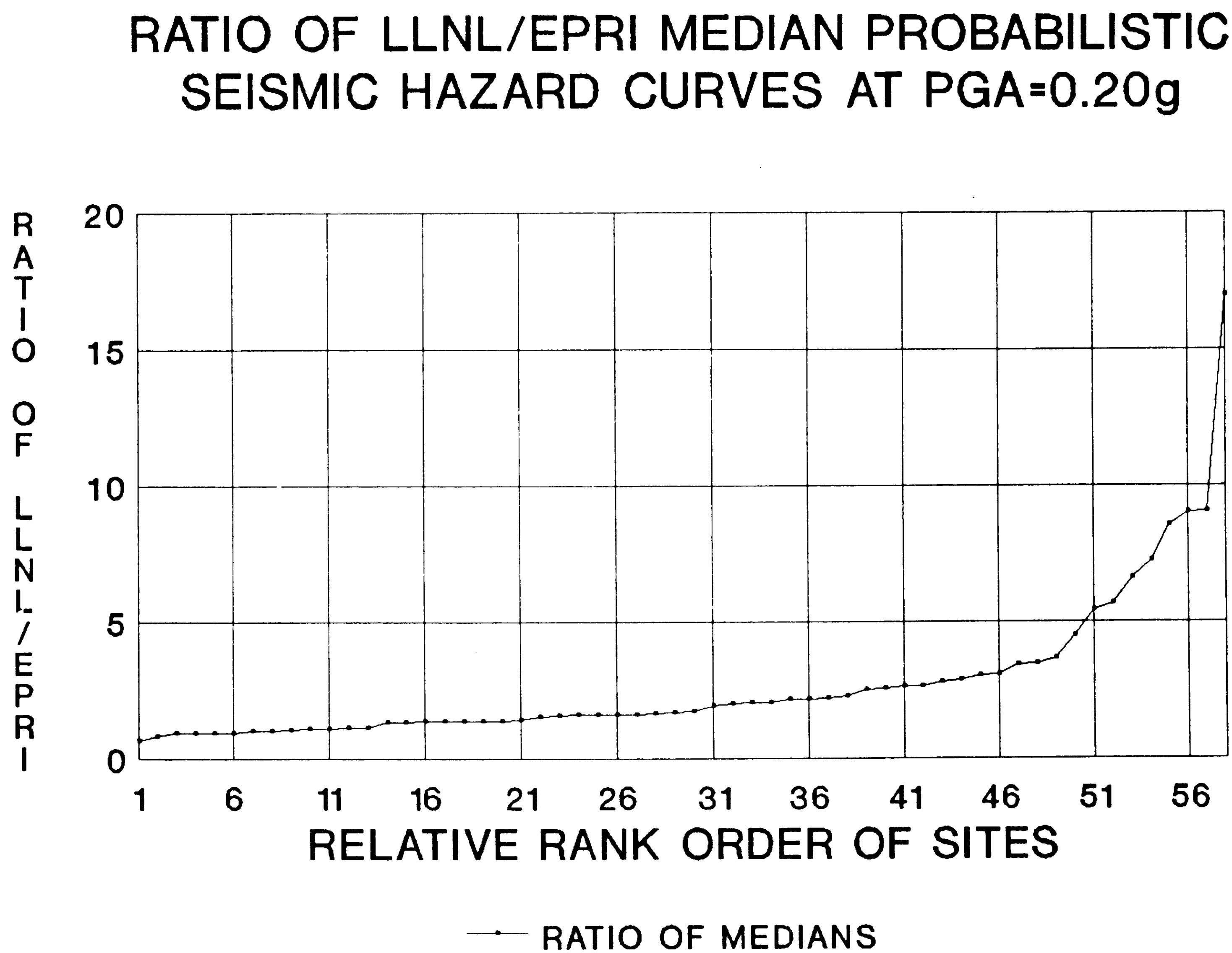
Figure 5

PROBABILISTIC SEISMIC HAZARD RATIOS
GEOM. MEAN OF PGA RATIOS



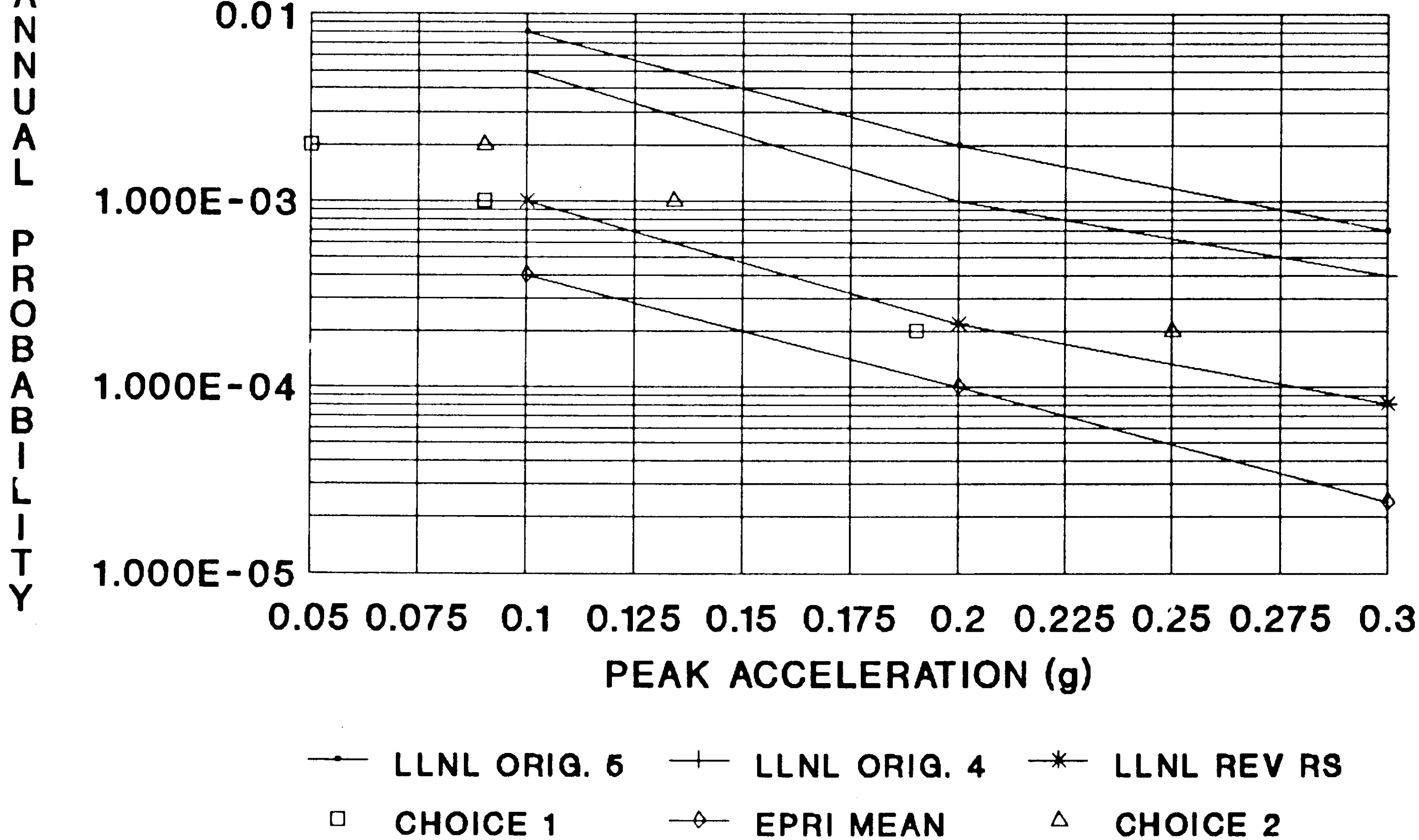
COMPARISON EPRI/LLNL RESULTS

Figure 6



.NL DATA WITH ATTENUATION EXPERT 5

PROBABILISTIC SEISMIC HAZARD COMPARISONS
SAVANNAH RIVER SITE
REVISED LLNL RESULTS COMPARED TO EXISTING LLNL AND EPRI RESULTS



LNL RS = REDUCED ATTENUATION UNCER.

Figure 7

CONCLUDING MATERIAL

Review Activity:
DOE-AL, DP, EH, EM, INEL,
LLNL, NE, NP, NS, NV, OR,
RFP, RW

Preparing Activity:
DOE-DP
Project No. FACR-0005

Appendix A

COMMENT RESOLUTION DOCUMENT ON DRAFT LLNL/EPRI POSITION

Appendix A

COMMENT - RESOLUTION DOCUMENT
Development of a DOE Wide Position Regarding the Use of LLNL and EPRI Probabilistic Seismic Hazard Curves

PART A - COMMENTS

Provided below is the set of comments received from Department of Energy (DOE) organizations who reviewed the Draft Interim Position Regarding the use of Lawrence Livermore National Laboratory (LLNL) and Electric Power Research Institute (EPRI) Seismic Hazard Curves dated March 19, 1992. The comments have been organized using the originating organizations abbreviations. Minor editing of comments has been completed removing reference to attachments that would unnecessarily clutter this document. The consolidated comments are followed by a response document which cross-references the comments.

NS-1

As requested, this memorandum provides the Office of Nuclear Safety's (NS) comments on the DOE Seismic Working Group's (SWG) draft report and interim position on the use of seismic hazard curves. The draft report gives insights and recommendations that go beyond the guidance currently provided by UCRL-15910 for establishing earthquakes for the design and review of DOE facilities. The draft interim position gives innovative and workable criteria for using hazard curves developed from the LLNL and the EPRI methodologies. The SWG intended that LLNL and EPRI seismic hazard curves be used as state-of-the-art replacements for the older TERA, Inc. seismic hazard curves, which are the basis for the recommended earthquake levels in Table 4-4 of UCRL-15910.

Office of Nuclear Safety believes that the draft interim position's general approach for selecting review earthquakes is a rational and practical way to use the LLNL and EPRI hazard curves However, there are newly-discovered technical issues within the draft interim position, and with its use with UCRL-15910, that must be resolved prior to its endorsement by DOE. These issues should be resolved in close coordination with the Office of Environmental Restoration and Waste Managements (EM) development of seismic guidelines for high level waste storage tanks, and the Office of Nuclear Safety Policy and Standards (NE-70's) development of natural phenomena review guidelines (the latter are intended to improve and codify the guidance of UCRL-15910). Because of the use of performance goals by these guidelines and the resulting interrelationship between earthquake selection and structural evaluation criteria, we recommend that the completion of a final version of the SWG's interim position be carefully integrated with EM and NE-70's new structural evaluation criteria.

NS-2

It now appears that the resolution of the technical issues associated with the interim position will likely result in most of the newly selected earthquake values being near the current UCRL-15910 values. Because of this and because of the interim position's limited scope (i.e., it would apply to less than half of the DOE sites for a period less than 24 months), we recommend that continued use of the TERA, Inc. curve values be considered as an alternative to any new interim position.

The limited scope of the draft interim position needs to be clearly recognized. First as stated in the SWG report, it is intended to be used only until research is completed in 18 to 24 months. Secondly, the draft interim position applies to less than half of the DOE sites whose review level earthquakes are now specified in Table 4-4 of UCRL-15910. That is, it does not apply to Paducah, Rocky Flats, or any DOE facility west of, or in, the Rockies. (Unlike the TERA, Inc. hazard curves, the LLNL and EPRI curves were developed only for the Eastern United States.)

The proposed resolutions of issues discussed in comments below seem likely to raise earthquake levels selected by the interim position for higher probability earthquakes. This would result in most of the new earthquake values being near the current UCRL-15910 values. Table 3 of the SWG report now implies that the only significant "benefit" to using the draft interim position (instead of Table 4-4 of UCRL-15910) would be for facilities of moderate hazard or less, but this benefit now appears unreal. Because of this and because of the interim position's limited scope, we recommend that continued use of the TERA, Inc. seismic hazard curve values be considered as an alternative to issuing any new interim position.

NS-3

As discussed in the April 10, 1992, meeting of the Seismic Experts Panel developing criteria for high level waste storage tanks, there is a problem with using UCRL-15910's performance-based criteria with seismic hazard curves whose slopes differ from the TERA, Inc. curves. While the slopes of the TERA, Inc. curves are fairly constant, the slopes of the LLNL and EPRI curves vary over the range of interest. To directly use the current UCRL-15910 structural evaluation criteria, one must make an upwards adjustment to earthquake levels derived by the draft interim position for facilities of moderate hazard or less (i.e., for earthquakes with annual frequencies of 2 x 10-1 and 1 X 10-3). The details of this adjustment have been drafted by the above-mentioned Seismic Expert Panel. These proposed changes should be closely coordinated with any revision to the interim position and the development of NE-70's natural phenomena evaluation guidelines.

NS-4

By introducing a "pseudo-mean correction factor," the draft interim position allows for the use of the median seismic hazard curves, which are more stable than mean seismic hazard curves. We believe the general approach developed by the SWG is rational and practical. However, as noted in the SWG report (in the penultimate paragraph of Page 12), there are recent indications that the factor of 1.65 given in Item A.3 of the position may not be appropriate for earthquakes with annual probabilities of 1 X 10-3 or greater. As with the slope issue, corrections to the pseudo-mean correction factor would also tend to raise the earthquake review levels for facilities not classified as high hazard.

NS-5

The issues discussed above raise a more general concern that, ironically, the seismic criteria developed for lower probability earthquakes (i.e., those less likely to occur) appear to be the most robust. This is probably because of all the attention that the technical community has given to the use of seismic hazard curves for commercial nuclear reactor seismic evaluations. For commercial reactors, annual earthquake probabilities of 1×10^{-3} or greater are of low interest since they are below safe shutdown earthquake levels and do not control risk. The DOE seismic criteria effort needs to be much more focussed towards higher probability earthquakes.

NS-6

Section B of the draft interim position introduces correction factors for cases where only the EPRI or LLNL curves exist. Our calculations indicate that the 1.3 factor for adjusting LLNL medians is too high. The attached table on "Calculation of Earthquake Levels Using DOE SWG Draft Interim Position" shows that this factor underpredicts the results obtained from using both the EPRI and LLNL curves. We recommend that the correction factors given in Section B be re-evaluated considering a wider data base than shown in Table 3, including consideration that these factors may vary with earthquake annual probabilities and could be different for the EPRI and LLNL curves.

NS-7

Part C of the draft interim position (on page 3) provides guidance on developing site-specific spectra. This guidance is somewhat independent from the rest of the material in the SWG's report, and there is very little discussion on the technical basis for Part C. Additional justification should be written if the SWG's report is to be finalized, and the criteria and justification should be incorporated within NE-70's natural phenomena guidelines.

NS-8

Our calculations show two errors in Table 3 of the SWG report. The 2 x 10^{-3} value for Savannah River and the 1 x 10^{-3} values for Portsmouth should both be 0.06 g's, not 0.07g's.

NS-9
Tables 2 and 3 of the SWG report should replace "Tera" with "TERA."

LLNL-1

I am very pleased to see that Dr. C. Allin Cornell, together with R. E. I. were able to identify and quantify clearly the most important stable elements of both EPRI and LLNL studies. I fully endorse the conclusions made by Dr. Cornell and reported in the attachment.

It appears that the essence of the (estimated) seismic hazard has been captured and can be used efficiently for general statement about it in the Eastern United States (EUS).

Considering the fact that the document describes a procedure intended to be applied only during an interim period, after which possibly a more rigorous analysis would be used, I think that the proposed procedure is appropriate.

It is appropriate because it immediately resolves an important engineering problem and it does it by using each of the two sets of inputs (LLNL and EPRI results) with maximum efficiency.

In conclusion, I fully endorse the 4 step procedure to develop a composite estimate of the ground motion at a DOE site using EPRI and LLNL (1989) EUS results.

LLNL-2

The proposed procedure is based on a generalization of the results obtained at sites all over the EUS, it appears to apply well to a large number of sites, hence a large portion of the EUS where the DOE sites are also located. Because the procedure is also based on a variety of assumptions, it appears that some of the selected parameters may not apply very well in some regions.

Once the choice of the median hazard curves was made, the only remaining parameters to be selected in the procedure were:

1. The ratio of mean to median hazard
   rmm

2. The slope (b) of the mean hazard curve in a log-log system of axis.

The assumption of lognormality does not necessarily apply to all the sites in the EUS. In particular, the divergence is maximum for some sites strongly affected by seismic source areas with large upper magnitude cutoff. Ground motion expert 5 tends to increase this effect in the LLNL study. Figure 1 (not shown here), taken from the LLNL., 1989 study, shows an example of hazard histogram for .25g at one site in the southeast, and for a single seismicity expert. Fortunately, this bi-modality shown in Figure 1 for S-expert 1, occurs at different places for the other experts, hence the mixed data, as shown in Figure 2 (not shown here), (mixed over all the S-experts) does not exhibit such a high bi-modality, for this site, and the assumption of lognormality is adequate for the present purpose. (This brings up a side comment, specifically that if one starts removing one or several S-experts from the analysis, the assumption of lognormality becomes poorer and poorer.)

Although I have not had a chance to review the case of all EUS sites, I cannot, at this point, discount the possibility that the lognormality assumption could be grossly wrong in some locations of the EUS.

LLNL-3

The values chosen for rmm are representative of most of the sites in the EUS. There are a few cases, as shown in Figure 4 of the proposed document, for which the LLNL values are drastically different from the selected values. It could be, as it is mentioned in several places in the attachment, that those anomalous values correspond to sites in the Gulf Coast area, where the estimated hazard is very low anyway and leads to large uncertainties. It may also be that the parameter should be region dependent.

LLNL-4

With the selected slope b = 3.5 the variation in the composite mean ground motion ${}^{a}CEL$ at 2 10^{-4} could vary from 1.45 times the EPRI-LLNL composite median ${}^{a}C$ to as much as 2.17 times (see table below).

(using ${}^{a}CEL = {}^{a}C \cdot rmm^{1/b}$)

$rmm = ½ (\log [composite^{85}/median])^2$

85th/median		rmm	${}^{a}CEL/{}^{a}C$
EPRI	LLNL		
3.5	7	3.65	1.45
3.5	23.2	11.2	2.00
3.5	30.0	15.0	2.17

LLNL-5

Slope b.

The slope was selected to be 3.5 after the work of Dr. Robert P. Kennedy.

This parameter exhibits a good stability across studies and across sites. However, it does vary substantially between ground motion levels, and it does vary somewhat, but less, between regions.

For example, I took some very rough estimates of the slope b from the mean hazard curves in the LLNL-EUS study for two hazard levels for 6 sites, arbitrarily chosen.

Milestone	b = 2.3	around 2×10^{-4}	3.8 at 2×10^{-3}
Pilgrim	1.9		3.4
Shearron Harris	2.5		4.3
Calvert Cliffs	3.8		5.4
Browns Ferry	1.0		1.8
Susquehanna	3.2		4.0

These numbers show two things:

1. The slope of b = 3.5 recommended by Dr. Kennedy seems appropriate within the context of the proposed interim procedure for hazard levels around 2×10^{-4}.

2. The slope should be increased for higher hazard levels. A slope of about 4.5 to 5.5 would be appropriate, from the above data (obtained by multiplying 3.5 by the average of the ratios of b at 2×10^{-3} and 2×10^{-4} above.)

LLNL-6

If the interim document is intended to be distributed to all DOE offices for actual engineering use, it would be beneficial to clarify some of the technical language used i.e., geometric mean, ratios, ratios of ratios, etc. A simple graphical display of the procedure would also facilitate a quick understanding.

LLNL-7

We have reviewed the interim position and find it generally acceptable with the comments listed below.

The resolution of LLNL versus EPRI hazard curve methodology is very important since it will affect the guidance for and execution of hazard determination at DOE sites as required by DOE Order 5480.NPH. The interim guidance does not resolve the methodology differences but intends to provide a mechanism to use the results of the LLNL/EPRI studies which were conducted for nuclear power plant sites for the EUS. These results are not generally directly useful for DOE sites. The current results generally must be rerun for the DOE site. Either the EPRI or LLNL algorithms may be used; however, we recommend both be conducted at each site.

Our comments on the interim position are directed at the use of this position by DOE Sites and its compatibility with UCRL-15910. Our comments are as follows.

LLNL-8

Since this position will be used by many sites in the DOE complex it must be very clear to avoid misuse.

1. To use the position, the site must have an EPRI or LLNL hazard curve developed specifically for its location, preferably both. Interpolation from reactor sites is not permitted.

   This must be done by the EPRI approach and the 1989 version of the LLNL approach.

2. If Newmark and Hall spectra (NUREG/CR-0098) are used as the standard median spectral shape they must also be corrected for the EUS, i.e., enriched in higher frequency content.

3. A suggestion for what to do at Paducah, Kentucky, near the New Madrid, Missouri Source Zone may be appropriate.

LLNL-9

When used with the design and evaluation criteria in UCRL-15910, a correction should be made due to the shape of the seismic hazard curves.

> UCRL-15910 adds intentional conservatism based on the shape of the TERA, Inc. hazard curves.
>
> The EPRI and LLNL curves have shapes that are different from the TERA, Inc. curves and need this correction.
>
> This correction has been developed by Dr. Kennedy in his work for DOE/EM on buried waste tanks and is necessary to achieve the performance goals established in UCRL-15910.

LLNL-10

We recommend that Peak Ground Acceleration (PGA) values for DOE sites with moderate and/or high hazard facilities located in the EUS, east of longitude 104W, be computed by both approaches, corrected for curve shape differences, and tabulated by one organization. These should then be reviewed and made available to all DOE sites for their use in design and evaluation. This is much more reliable and cost effective than each site conducting independent studies.

LLNL-11

A marked-up copy of the interim position is also attached. The comments are essentially editorial, but important to avoid misuse.

LLNL-12

In general, we conclude that the interim position is reasonable and attempts to take advantage of the relative strengths of the LLNL and EPRI studies. We do not offer specific recommendations for changes to the document. However, we do have a few relatively minor questions regarding the methodology proposed in the interim position. Clarification of these questions would serve to further strengthen the document.

LLNL-13

A major strength of the interim position is that it explicitly incorporates both of the methodologies, through a geometric averaging of the peak accelerations at the target probability level. Such an approach circumvents the messy problems that could be associated with other schemes for aggregating the results of the two studies (e.g., assigning relative weights, component-level aggregation, etc.). Further, the use of the most stable descriptor of the hazard, the median peak acceleration, also appears to be the most reasonable point for combining the two studies.

It has only been in the past ~5 years that a complete description of the uncertainties in seismic hazard have become nearly as important as the central estimates in Probabilistic Seismic Hazard Analysis for licensing purposes. Perhaps due to the increasing number of probabilistic risk assessments being done for commercial nuclear plants and the probabilistic components of the IPEE program, the state of the practice in seismic hazard analysis is a full description of the seismic hazard and careful attention to characterization of uncertainty.

LLNL-14

The interim position is said to apply to all sites east of about 104W "except for sites within about 50 kilometers of active seismogenic sources, such as the Paducah, Kentucky Site." How is an active seismogenic source defined? Clearly in the example, the Paducah site is near the New Madrid seismic zone.

But what other seismic zones would qualify as being 'seismogenically active.' It appears that the intent is to exclude those sites that lie near anomalously active zones, but the discussion is unclear. If, in fact, those DOE sites that are believed by the SWG to lie near active sources can be explicitly identified in the document, the issue would not be left to the discretion of the sites to identify themselves.

Assuming that one determines that his site lies within 50 km of an active seismogenic source, what happens then? No guidance is given.

LLNL-15

It is not clear to us which sites have both LLNL and EPRI results and which sites only have one or the other. Is there a published list of these? Has seismic hazard actually been calculated at specific DOE sites, or at commercial nuclear power plants nearby? Clarification is needed.

LLNL-16

It is likely that the assessment of low frequency ground motion hazard based on a mixture of direct spectral ordinate attenuation relationships with average spectral shapes anchored to PGA attenuation relationships is leading to the large variability observed. These differences will be exaggerated at sites where the dominant magnitude is significantly smaller than that associated with the average spectral shapes. The effect is also increased by the difference in frequency content of EUS ground motions represented by some of the more recently developed attenuation relationships compared to spectral shapes based on Western United States (WUS) recordings.

LLNL-17

It might be useful to comment on an alternative approach of establishing "pseudomeans" for each study and then averaging these rather than averaging the standard errors. I do not think that the results are equivalent, though they may be close for the average case considered here. Averaging "pseudo-means" will carry a little more site specific information than averaging the medians, unless global average ratios of the 85th-percentile/median are to be used always.

INEL-1

The Interim Position gives guidance on how to determine peak ground accelerations and spectra based on using numerical adjustments to reconcile the discrepancies in the LLNL and EPRI curves. While this may be mathematically and statistically correct, we question how well these computational results reflect the geological and seismological "real world' data at a particular site. The intent is that this practice will provide enough conservatism. However, what type of comparisons have and will be made on these results with what is known at a particular site? Should the guidance require a comparison to the geological conditions at the site for its intended use? If a comparison is not required, how will these computed numbers be defended to the Defense Nuclear Facilities Safety Board, for example? It appears from the background information presented in the Interim Document that there are problems with the geo-seismological input and treatment of the uncertainties. Having this knowledge, how can numerical manipulations of the LLNL and EPRI curves provide a solid technical basis for seismic design values?

INEL-2

What is the approach to implementing this interim guidance (backfit, implement at Operational Readiness Review stage, in construction, or in current/future design)?

INEL-3

How does one plan for the final guidance two years from now, what does "interim guidance" specifically mean for actions, what selection criteria will be used, and how will the criteria apply to specific projects?

INEL-4

This document does not address which plants this should be applied to, how soon it should be implemented, and how often it should be reviewed. Priorities on which facilities should be addressed first and which category of risk are not addressed. Draft DOE Order 5480.NPH is equally confusing in this respect and also includes deterministic seismic input as well. It points out that one should not do anything hasty when rules change because another change will be following soon.

INEL-5

The SWG has requested that Sandia National Laboratory prepare a "Program Plan for Evaluation of EPRI and LLNL Seismic Hazard Methodologies and Development of Recommendations for a Consensus Probabilistic Seismic Hazard Methodology for the 1990s." We strongly suggest that the recommendations for the probabilistic seismic hazard methodology in this document take into consideration the past experiences of the LLNL and EPRI studies, the studies that are currently being done at Idaho National Engineering Laboratory and other DOE sites, and how seismic hazards assessments have been and are being performed by independent subcontractors (outside of DOE) for the U.S. Nuclear Regulatory Commission (NRC). The resulting document that instructs DOE sites on how to perform the seismic-hazard methodology should be peer-reviewed by a Senior External Event Review Group-type panel, independent of DOE. Also, the documents should be reviewed by the DOE sites as they are being developed. Sandia National Laboratories should not prepare a Program Plan or Probabilistic Seismic Hazard Methodology without having a participant or representative from each DOE site and comments from all those who will have to use and abide by it.

NP-1

As requested, a review of the proposed DOE Interim Position for the use of LLNL and EPRI Probabilistic Seismic Hazard Curves was performed by the Office of New Production Reactors. The Draft Position is consistent with earlier drafts reviewed by Mr. R. C. Burrow of the Office of Modular High-Temperature Gas-Cooled Reactors (NP-60) and Mr. L. V. Ely of the Office of Heavy Water Reactor (NP-40). No essential comments have been identified.

The proposed approach provides consistent guidance for the design of nonreactor facilities, implementing UCRL-15910, "Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards" and DOE Order 6430.1A, "DOE General Design Criteria." The Office of Heavy Water Reactor, DP-40, and the Office of Modular High-Temperature Gas-Cooled Reactors, DP-60, concur with the subject interim position.

NP-2

The interim position regarding the use of the EPRI and LLNL seismic hazard results, when they both exist, as covered under A:, and for the case when only one of them exists, as covered under B: is very clear and could be easily followed. The interim position is supported by the work presented and, indeed, protects the extremes, i.e., below the 15th percentile and above the 85th percentile, where the EPRI/LLNL methodology might be questioned.

NP-3

The case for the sites which choose to develop a deterministic site-specific spectral shape is not so clear and, at best, requires additional explanations. Notwithstanding the question as to why a deterministic, Appendix A type work would have to be established as indicated, the requirement of using the dominant earthquake distance from the probabilistic work needs to be explained. To my knowledge, the probabilistic work defines areas over which an earthquake has an equal probability of occurrence. Thus, guidance has to be provided as to how the location of the dominant earthquake is to be established. Although papers were published discussing this very subject, this interim position which is rather precise in every detail has to specify the method. (As a case in point, an expert could decide to define Charleston as being capable of occurring over an area extending all the way to the New Production Reactor (NPR) site. While this assumption will not result in results too much different than when other assumptions are used, as the area is used to divide by, one has to be told precisely how to use such an input to estimate distance.)

RF-I

The interim position applies to all DOE sites east of 104W but excludes Rocky Flats. No reason is given for excluding Rocky Flats. We appreciate the need for an awareness of the position since existing site specific probabilistic seismic hazard curves are to be reviewed in the near future.

It is interesting to note that when the interim position is applied to Rocky Flats, the High Hazard Zero Period Acceleration (ZPA) would apparently decrease from .219 to .169. This deviation in ZPA levels adds to the need for the planned new site specific seismicity study.

RF-2

As requested, the Systematic Evaluation Program (SEP) has briefly reviewed DOE's interim position with respect to LLNL and EPRI seismic hazard curves. Without detailed review of predecessor documents, SEP has no significant technical comments. The proposed interim methodology appears to adequately .account for differences/uncertainties between the LLNL and EPRI approaches. Systematic Evaluation Program agrees with and strongly supports the DOE/EPRI/NRC joint effort to resolve seismic hazard issues on a "permanent" or better yet, a "renewable" basis.

In SEP's opinion, the following technical issues should be emphasized:

1. Attenuation relationships; and
2. Site soil amplification/deamplification

These issues have the potential and disproportionately large uncertainties both on a regional basis and in site-specific applications.

AL - I

Page 4, Paragraph 3, Last Sentence - This sentence is misstated. University of California Research Laboratory (UCRL-15910) provides two different probabilities, either of which may be used, the performance and exceedance goal probabilities. The sentence should be rewritten to read: "UCRL-15910 allows the use of either performance goal probability or hazard exceedance probability dependent on the design/analysis technique used."

Attached is a copy of a memorandum (J. Schinkle to Albuquerque Field Office (AL) Area Managers) explaining the use of these two probabilities.

The DOE General Design Criteria Manual (DOE Order 6430.1A) requires the consideration of natural phenomena hazards in the design of all new DOE facilities and a comparison of criteria noncompliances for all existing facilities as their Safety Analysis Reports (SARs) are updated. Department of Energy Order 6430.IA requires the use of the UCRL document, "Design and Evaluation Guidelines for DOE Facilities Subjected to Natural Phenomena Hazards, UCRL-15910, June 1990," for these design considerations.

During the January 1992 DOE Natural Phenomena Hazards Workshop, the document's authors reported that a general misinterpretation in the application of UCRL-15910 has been occurring. We are bringing to your attention this clarification on the document's usage to clear up the confusion. Two problems have been found. The first is the use of UCRL-15910 as a facility hazard classification guide. The second is in the selection of the design basis accidents (DBA) to be used in the analyses.

First, the UCRL document is not a hazard classification guide. The facility hazard classification is to be determined independently of UCRL-15910. The AL Waste Management and Operations Surety Division has recommended the use of the Pacific Northwest Laboratory-Lucas (PNL-Lucas) method until specific guidance is issued by DOE Headquarters (HQ). Once the hazard class is determined, the class is used in UCRL-15910 to determine the facility Usage Category. This usage category is used to determine the DBA probabilities of occurrence.

Second, there has been confusion in the interpretation of the DBA occurrence probability. The document presents two different probabilities, the performance goal probability and the exceedance probability. The performance goal probability is lower (less frequent, but higher consequence events) than the hazard exceedance probability (more frequent, but lesser consequences).

There are two ways to approach these probabilities. First, the facility DBA can be based on the event severity corresponding to the nominal performance goal probabilities (median centered approach); that is, basing the nominal design on the performance goal probability without including safety factors. This approach is considered to be controversial and not well understood. Second, it can be based on the traditional conservative approach of using the event severity corresponding to the hazard exceedance probability with all the UCRL-15910 recommended safety factors (higher probability of occurrence, lower consequence event plus safety factors). This latter approach is the one most often used in assessing facilities because it is a better documented and understood approach. Appropriately used, the authors state that either approach is acceptable.

The seismic event performance goal and exceedance probabilities are presented in Table 2-3 (Pages 2-6) and in the table on Page A-2. The wind and tornado probabilities are presented in Table B-3 (Page B-4). Because there is no performance goal probability for flood events, the hazard exceedance probabilities in Table 6-1 (Page 6-2) are used.

UCRL-15910 may be used for facilities at sites without site-specific data. Site-specific data should be used if it is available. The language and discussions in the SARS should reflect the terminology and content used in the UCRL document.

NV-1

The subject document has been reviewed, and we have no comments. Considering the circumstances, the "Interim Position" regarding the use of the LLNL and the EPRI probabilistic seismic hazard curves at DOE sites is a reasonable approach until the issue is resolved in 18 to 24 months.

OR-1

The evaluation to obtain the pseudo-mean peak ground acceleration has been changed to include the LLNL hazard results with expert #5 instead of the LLNL hazard results without expert #5, which were used in the previous draft. We do not recommend using LLNL hazard results with expert #5 included. The guidelines themselves discuss numerous studies which have been performed to justify not using the LLNL results with expert #5 included. The LLNL results with expert #5 for the 85th percentile and the mean are outliers, and should not be used to determine the pseudo-mean peak acceleration in the guidelines. Including expert #5 in the evaluation increases the pseudo-mean peak acceleration about 25-40 percent, which we believe is not appropriate for use with the evaluation requirements defined in UCRL-15910.

The guidelines state that the rationale for including expert #5 "relates to the fact that resulting peak accelerations have a conservative bias, making engineering assessments more stable in that final resolution to the LLNL EPRI issue to 1.5 to 2 years away. If engineering assessments conclude that major upgrades are necessary for existing facilities, an explicit assessment should also be made using the pseudo-mean peak accelerations without LLNL attenuation expert 5."

There are numerous steps in performing seismic evaluations where small extra conservatism has a tendency to be introduced at each step. These extra conservatisms are accumulated through the total evaluation process and can increase the demands 2-3 times or greater in the final evaluation results. The seismic evaluation must also be tied to an overall risk assessment of the facility which could be significantly impacted by these extra conservatisms. Therefore we recommend that extra conservatism not be included this way. We recommend the input parameters for seismic evaluations be determined without a conservative bias, and then evaluate the sensitivity of the input parameters to determine if the evaluation conclusions, and risk assessments are affected. This is the philosophy of the evaluation procedures defined in UCRL-15910.

OR-2

We agree with the additional information on how to develop a deterministic site specific spectral shape. We recommend only the EPRI uniform hazard spectra be used to determine the dominant earthquake parameters for the site-specific spectra shapes because the LLNL uniform hazard spectra are controlled by standard spectral shape models as discussed in the guidelines. Therefore, the LLNL spectra do not actually represent uniform hazard spectra and should not be used to determine the dominant earthquake parameters for the site-specific studies. The guidelines could be improved by including a case study on how to develop the site-specific spectra.

OR-3

The guidelines state that DOE is reviewing the LLNL and EPRI seismic hazard data to determine if the range in slopes used, accurately represents the full range over all probabilities linked to UCRL-15910, and that this review may require a modification to the factor used to obtain the pseudo-mean peak ground acceleration. The guidelines do not discuss the possible modifications, but our review of another draft DOE-HQ document (Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste storage Tanks) raises concern on the impact of the modifications. It appears the seismic hazard results at annual probabilities of 1×10^{-04} and 1×10^{-05} will be used to modify the hazard results at 1×10^{-03}. We have much more confidence in the higher annual probabilities (2×10^{-03} to 1×10^{-03}) than the lower annual probabilities, therefore the lower values should not, be used to modify the higher values.

OR-4

Table 2 in the guidelines is not complete in some instances. The acceleration values which are not specified in Table 2 (footnote #3) of the guidelines are as follows:

Site	Probability	
	1 x 10E-3	2 x 10E-4
Portsmouth		
LLNL (with 5)		0.10 0.40 0.34
Oak Ridge		
LLNL (with 5)	0.10 0.40 0.32	0.22 0.75 0.55

OR-5

We suggest a workshop involving the seismic working group and consultants, DOE field offices, and management and operating (M&O) contractors should be held to discuss the guidelines, due to their growing complexity.

OR-6

We suggest the Oak Ridge site be used as a case study for developing the site specific spectra, since we have already initiated the studies.

EM-1

In general, the interim approach proposed is reasonable for what it is trying to accomplish for the next two years. It is probably conservative with respect to what is likely to result from the final reconciliation of the EPRI and LLNL approaches, especially based on what we know of the improvements being made to the LLNL approach through the hazard studies being performed for the DOE on the NPR program.

Below are two potential alternatives to the DOE interim approach. It is possible that these alternatives were already considered and rejected for one reason or another. We are only stating that there appear to be some as opposed to "essential," but we feel they are worthy of some consideration if none has previously been given.

EM-2

The seismic hazard at a particular site is to a large extent determined by a particular type of earthquake (e.g., magnitude, depth, focal mechanism, etc.) with a particular path. A detailed consideration of these factors in the form of local knowledge would reduce the attenuating model uncertainties. This, plus the fact that for soil sites, even without the Expert 5 of LLNL study, the ratio for peak ground acceleration of 0.20g (LLNL/EPRI) median seismic hazard is high (namely 1.24, according to Table 1 of the interim position) the use of LLNL and EPRI median curves by averaging them and multiplying by a factor 1.65 tends to be too conservative.

For soil sites, the best approach would be to incorporate all local soil conditions, potential for liquefaction, dynamic soil amplification and other such factors and develop the seismic hazard model from basic raw data using proper attenuation models. The median forecasted value of PGA can then be used for scaling the response spectrum shape and site specific median response spectra can be generated.

EM-3

As an alternate to recommendations in the draft "Interim Position" the probabilistic method for EUS, presented in the Army Technical Manual TM-5-810-10-1 Chapter 3, can be used to perform the seismic hazard analysis at the target probability per UCRL-15910 until the results of the study to be conducted by Sandia National Laboratories become available.

RHO-1

The subject guidance document for use of the LLNL and EPRI seismic hazard studies at sites in the EUS sites was reviewed as requested in your April 24, 1992, memorandum. The guidance document was found to be thorough and appropriately conservative. We have no specific criticism or suggested revisions. Though the report does not apply directly to sites in the WUS, there are several conclusions that, if incorporated into specific Orders or requirements, may affect the Hanford Site. These include the incorporation of a consistent approach to uncertainty analysis into the DOE seismic hazard studies of the sites as well as spectral velocity and uniform hazard spectra which have not been determined for the site. The resolution of these differences, if required, would involve additional investigations.

EH-.l

The Office of Safety and Quality Assurance, EH-30, has reviewed the DOE SWG's draft report and interim position on the use of probabilistic seismic hazard curves. The interim position provides a practical approach for using the EPRI and LLNL hazard curves; however, there are technical issues that still remain to be resolved, such as those found as a result of the EM application of reference (2) during the evaluation of underground waste tanks.

EH-2

Existing concerns raised by various reviewers should be adequately resolved by the SWG, for example: (1) how the hazard curve slope factors are determined; and (2) the extent to which the input from expert #5 should be utilized.

EH-3

Because the interim position does not significantly change the peak ground acceleration values from those currently used at the five sites under consideration, other justifications for using the new information should be noted.

EH-4

Recently developed probabilistic ground motion hazard maps stemming from the U.S. Geological Survey (USGS) and other inputs to the National Earthquake Hazard Reduction Program (NEHRP) (1991 Provisions) should be considered. A comparison of the 2E-3 values of the USGS maps with the interim position and the TERA, Inc. values (see attached Table 1) shows a similarity to the TERA, Inc. values given in UCRL-15910, and suggests that the DOE SWG should consider using the NEHRP probability hazard map information in assessing our interim position.

EH-5

Recent information developed by the U.S. Continental Scientific Drilling (CSD) Program may be helpful in resolving some of the uncertainties in the EUS, and may be useful in the development of a "final standard" for both eastern and western DOE locations. Mr. Bill Luth, of the Engineering & Geosciences Division, ER-15, is the DOE lead on this program and should be invited to the SWG to discuss the CSD Cajun Pass findings on fault mechanics, and to identify other technical resources.

EH-6

The development and utilization of Uniform Hazard Spectra can be enhanced by a workshop involving the various DOE sites. The extent to which the NEHRP Uniform Hazard Spectra can be utilized by DOE sites should be included on the agenda.

Table 1

Comparison of Earthquake levels developed by the DOE SWG, March 19, 1992, Draft and those developed by TERA, Inc. (included in UCRL-15910) and the National Earthquake Hazard Reduction Program 1991 Provisions) at the 2E-3 level.

Site	Proposed Interim (1)	TERA (2)	NEHRP 1991 (3) Provisions
Savannah River	0.06	0.08	0.10
Oak Ridge	0.09	0.15	0.10
Brookhaven	0.06	0.12	0.10
Portsmouth	0.03	0.08	0.05
Princeton	0.08	0.13	0.10

(1) Reference 1 of this letter.

(2) UCRL-53582, Rev. 1, Natural Phenomena Hazards Modeling Project: Seismic Hazard Models for Department of Energy Sites, 1984 (Compilation of 25 TERA, Inc. seismic hazard studies)

(3) National Earthquake Hazard Reduction Program Recommended Provisions for the Development of Seismic Regulations for New Buildings, Building Seismic Safety Council 1991.

RW-1

The subject draft interim DOE-wide position on the use of LLNL and EPRI probabilistic seismic hazard curves has been reviewed by the Office of Civilian Radioactive Waste Management (RW-1). The dilemma of using either the LLNL method or the EPRI method for nuclear facility design has been debated since the early 1980's. The draft does a suitable job of combining the separate approaches developed by LLNL and EPRI for probabilistic analysis of seismic hazards for areas east of 104W (the Rocky Mountain front area). Results of the method recommended in the Interim Position appear reasonable for the various exempt sites provided in the report. The correction factors utilized in the Interim Position for recognizing uncertainty are appropriately conservative for this initial effort.

We understand that the Interim Position will be superseded by a final position developed jointly by DOE, the NRC, and EPRI in about 18 to 24 months. It should be clearly noted both in the Interim Position and in the final position that DOE sites that are to be licensed by the NRC (e.g., the Monitored Retrievable Storage facility) will have to follow NRC guidelines and are exempt from the DOE Interim Position and final position to avoid duplicative requirements and/or conflicting results. Statements to this effect are provided in the Memorandum of Agreement between NS and RW, the DOE proposed rule 10 CFR Part 830, "Nuclear Safety Management", and the draft DOE Order 5480.NPH on Natural Phenomena Hazards."

Pursuant to your request, we have provided technical comments and alternative approaches.

RW-2

The use of low frequency ground motion is essential for this procedure, yet it is for low frequencies that the assumptions used by Dr. Cornell break down (P. 5, Para. 1 of his attachment). A critical review might ask why low frequencies are neglected in one procedure and required for another.

RW-3

Earlier discussions indicated that the median curve was the preferred choice, but here the mean is chosen. Some clarification may be necessary.

How is "doubt" determined about the estimate being realistic? Can there be quantitative criteria?

"pseudo-mean" (here and elsewhere in the paper) is too ambiguous as a term and implies falseness. "Adjusted mean" would still be ambiguous but may be a better term.

RW-4

The statement is made that the method of analysis can change if major engineering upgrades are necessary. That would seem to leave the guidelines or the strength of their underlying rationale open to critical questioning.

RW-5

The statement is made that some very low hazard sites do not fit the analysis, and reasons for this inconsistency are discussed in the main paper. Yet it is disconcerting that the basis of the analysis does not work for very low hazards. The inconsistency raises doubts about the applicability of the method for sites with higher risk. I think that these doubts could be reduced if it were shown that the method still works satisfactorily for these very low risk sites by including several in Tables 2 and 3 and adding discussion about why it still works.

RW-6

A brief justification of the 50 km distance would be appropriate, such as, "because ground motion beyond 50 km from an active seismic source is not expected to affect engineering design, even for the largest expected sources," if that is your meaning.

RW-7

The suggestion that western DOE sites should be "aware of the position" needs to be clarified. Reference should be made to existing guidelines for western sites and planned revisions.

RW-8

The statement is made that it is unfortunate that regulations do not give guidance for repeating seismic hazard analysis at set time intervals. Is there an implication here that repeat analyses should be done with attendant implications for facilities built under an earlier analysis? Some method to balance the costs of increasing structural integrity with safety considerations may be necessary.

RW-9

"absolute value" - the adjective is unnecessary if the value is never negative.

RW-10

You are assuming that older hazard curves are correlated with median estimates. Median estimates from LLNL and EPRI being lower only implies that median estimates have decreased if your assumption is true. Thus any meaningful conclusion is unwarranted.

RW-11

The meaning of the second set of three bars is not explained.

RW-12

"i.e." should be "e.g." here and at its several other locations in the text.

RW-13

"has" should be "have"

RW-14

Should "large" be "larger"?

RW-15

"a" should be "at"

RW-16

"note 1" beside "Probability" should be omitted

<u>Summary of Comment Identification</u>

NS	=	Office of Nuclear Safety
LLNL	=	Lawrence Livermore National Laboratory
INEL	=	Idaho National Engineering Laboratory
NP	=	Office of New Production Reactor
RF	=	Rocky Flats Office
AL	=	Albuquerque Field Office
NV	=	Nevada Field Office
OR	=	Oak Ridge Field Office
EM	=	Environmental Restoration and Waste Management
EH	=	Environmental, Safety and Health
RW	=	Office of Civilian Radioactive Waste Management
RHO	=	Hanford Field Office

Appendix A

COMMENT - RESOLUTION DOCUMENT
Development of a DOE Wide Position Regarding the Use of LLNL and EPRI Probabilistic Seismic Hazard Curves

PART B - RESPONSE TO COMMENTS

1. GENERAL RESPONSE
(NS-1, LLNL-1, LLNL-7, LLNL-12, LLNL-13, NP-1, NP-2, RF-2, NV-1, EM-1, RHO-1, EH-1, RW-1)

The general response from comments submitted was positive. Most organizations indicated that a need for this Standard currently exists and that the approach outlined by this position is rational and practical. Indicated strengths of the position include the incorporation of both EPRI and LLNL methodologies, the use of appropriately conservative correction factors and the inclusion of thorough background material.

There do exist newly discovered technical issues within the Standard position, also indicated in the comments, which need to be resolved before final endorsement. The SWG is currently following and participating in the efforts of EM in the development of seismic guidelines for high level waste storage tanks, and the efforts of NE-70 in the development of natural phenomena review guidelines.

A statement has been added to the revised Standard exempting DOE facilities from this Standard that are subject to NRC licensing requirements.

2. USE OF TERA, INC. CURVES OR NEHRP MAP
(NS-2, EH-3, EH-4)

The Standard is recommended for Eastern sites because it gives a more up-to-date representation of seismic hazard and is necessary to incorporate more recent information as soon as possible and to address the concerns with the TERA, Inc. study. In general, the TERA, Inc. seismic hazard curves do not now represent state-of-the-art seismic hazard estimates, particularly with respect to uncertainty assessment and characterization. The Standard recommendations are thought to be conservative in that future work will demonstrate that the mean hazard curves are lower than values recommended.

As shown in Table 3 of the Standard, representative peak ground acceleration values are equal to or lower than the previous estimates from UCRL-15910 (DOE-STD-1020). These results suggest that median seismic hazard estimates have decreased since the late 1970's. Table 3 also shows that the recommended values are equal to or greater than the EPRI 85th but significantly lower than the LLNL 85th.

Due to the results above, the revised Standard recommends for Eastern sites with both the LLNL and EPRI probabilistic seismic hazard results either the continued use of the TERA Inc. seismic hazard values or the use of the approach outlined in the Standard itself.

Comparisons to the NEHRP vibratory ground motion maps have not been completed due to the fact that the seismic hazard data contained in the NEHRP map is relatively old particularly compared to the LLNL and EPRI seismic hazard data, and the NEHRP values are for rock site conditions which are not directly comparable to the LLNL and EPRI results.

3. SLOPE OF HAZARD CURVE
(NS-3, LLNL-4, LLNL-5, LLNL-9, OR-3, EH-2, RW-5)

The slopes of the EPRI and LLNL seismic hazard curves were reviewed as part of developing the revised Standard. This review found that the hazard curve slopes are dependent on probability.

In order to compensate for the differences in slope values at different ground motion levels, separate slope values have been calculated for PGA at various hazard probabilities. A slope value of 2.58 is calculated from a composite ratio of PGA at 10^{-5} to PGA at 10^{-4} and a value of 1.93 is calculated from a composite ratio of PGA at 10^{-4} to PGA at 10^{-3}. Correlating these probability values to those used in UCRL-15910 (DOE-STD-1020), the slope value of 1.93 is used for low hazard and moderate hazard facilities while the slope value of 2.58 is used for high hazard facilities. The revised Standard provides a detailed discussion of this issue.

4. DIFFERENT PROBABILITIES AFFECTING CORRECTION FACTOR
(NS-4, NS-5, LLNL-5, RW-2, RW-5)

In addition to the changes in the slope values mentioned above, the revised Standard also calculates different correction factors for different facility hazard categories (the term hazard category as found in UCRL-15910, (DOE-STD-1020)). Correction factors are calculated at various PGA levels using the different slope values. From Table 2 in the body of the recommendation, median values of ground motion range from .03g to .10g for 10^{-3} and from .07g to .22g for 2×10^{-4} for DOE EUS sites. Therefore, for Low Hazard and Moderate Hazard, a PGA value of .10g is used and for High Hazard facilities, a PGA value of .20g is used. Appendix E to the Standard provides the set of LLNL and EPRI data that was used to develop the correction factors. Appendix E displays the impact of the different probabilities on the various steps used to develop the correction factor. The revised correction factors are 1.80 for Low and Moderate Hazard facilities and 1.65 for High Hazard facilities.

5. FACTOR WHEN ONLY ONE CURVE EXISTS
(NS-6)

For those sites which have only the LLNL or EPRI probabilistic seismic hazard results the recommendation is to use the PGA correction factor on an adjusted median curve. The adjusted median curve is calculated as follows: for sites where only LLNL results are available with attenuation expert #5, these results should be divided by 1.2. This factor represents the difference between the LLNL and EPRI median hazard curves at both reactor and DOE sites. For sites which have only the LLNL results without attenuation expert 5, these median results can be used directly. For a site that would have only EPRI results available (none are known to currently exist) it is recommended that LLNL results be quantified for that site. If this can not be accomplished the EPRI median should be increased by 1.2. Note that this procedure is slightly different from that in the draft version of the Standard, as pointed out by the comments. It was judged that attempting to develop this factor at different probabilities was not warranted by the data available.

6. DEVELOPING SITE SPECIFIC SPECTRA
(NS-7, LLNL-16, NP-3, EM-2, OR-2, OR-6)

Several comments requested enhanced guidance regarding the development of site-specific spectra. Discussion related to this issue has been moved from the body of the Standard into Appendix B. For those sites who choose to develop a deterministic site-specific spectral shape, information contained in the probabilistic seismic hazard analysis should be used to establish the appropriate magnitude and distance. This Standard contains additional information on the development of site-specific spectra (see Appendix B). Department of Energy (NE-70) is developing a standard on developing site-specific spectral shapes (DOE-STD-1023). At present DOE's Oak Ridge office, working with Martin Marietta, is attempting to implement the guidance in Appendix B at Paducah and Portsmouth as test cases. The interim guidance developed in Appendix B considered information in NRC Standard Review plan, Section 2.5.2, on developing site-specific spectra.

7. REGIONAL DEPENDENCY/LOG NORMALITY
(LLNL-2, LLNL-3)

The comments correctly point out that the assumption of log normality may not apply to each individual site's seismic hazard curve. As a matter of practicality the Standard is based on observed general trends versus intensive site specific observations from the LLNL and EPRI results. The full set of data for the ratio of mean to median hazard is provided as Appendix C. One reason that the peak acceleration was used as the ground motion parameter for the Standard was the increased instability of the ratio of mean to median hazard for other estimates of ground motion (response velocity). The actual numerical values chosen for the hazard ratios and slopes were based on all eastern reactor site LLNL and EPRI data as described in Appendix E.

8. GEOGRAPHIC APPLICABILITY
(LLNL-8, LLNL-14, LLNL-15, RF-1, RW-6)

The Standard has been revised to address issues related to geographic applicability and the existence of only one or neither of the LLNL and EPRI hazard curves at DOE sites.

This Standard explicitly applies to all DOE sites east of about 104W. The Rocky Flats Site is excluded from the Standard because the LLNL and EPRI studies did not extend far enough westward to provide the necessary seismic hazard input. The Paducah, Kentucky site is excluded because this site is in close proximity to the New Madrid, Missouri seismic zone which should be modeled as an extended line source. Neither the LLNL or EPRI studies adequately model the New Madrid source in this fashion. The Paducah site has undertaken appropriate probabilistic seismic hazard studies including extended source modeling for New Madrid.

Table 4 has been added to the Standard which displays the recommended position for DOE sites which have existing LLNL and EPRI data. Table 4 also lists the remaining Eastern United States DOE sites. The SWG is unaware of whether LLNL or EPRI data exists for these sites and thus continues to recommend the use of TERA, Inc. results.

The revised Standard continues to suggest using the Newmark and Hall Spectra.

9. RECOMMENDATION BY ONE ORGANIZATION
(LLNL-10)

The purpose of the Standard is to define the acceptable peak acceleration values for DOE EUS sites. The updating of site-specific seismic hazard curves should await the outcome of the joint DOE/NRC/EPRI seismic hazard resolution efforts. For DOE EUS sites which have not calculated the seismic hazard using the LLNL and/or EPRI methods, the TERA, Inc. seismic hazard curves should continue to be used.

10. OTHER WAYS OF DEVELOPING PSEUDO-MEANS
(LLNL-17, EM-3, RW-3)

The comments correctly point out that other approaches could also be developed for combining the LLNL and EPRI results. The establishment of "pseudo-means" for each study separately using the procedure outlined and then averaging these two "pseudo-means" would result in about the same position as that developed in the Standard. The LLNL "pseudo-mean' would be the larger of the two simply reflecting the difference in the

85th/median ratio between LLNL and EPRI. The approach chosen was based on the most stable estimate (the median) and the inclusion of uncertainty based on the fractiles between 15th and 85th percentiles between the two studies.

The probabilistic method in the Army Technical Manual uses relatively old probabilistic results developed by the USGS. As discussed in the response to previous comments, the LLNL and EPRI results represent improvements in seismic hazard characterization, particularly the quantification of modeling uncertainty.

11. EDITORIAL COMMENTS
(NS-8, NS-9, LLNL-6, LLNL-11, OR-4, RW-9, RW-11 - RW-16)
Reflected in revised Standard.

12. CLARIFY UCRL-15910 (DOE-STD-1020)
(AL-1)

This comment addresses issues currently present in UCRL-15910 (DOE-STD-1020) which have been misinterpreted in their use. The first is the issue of hazard classification. The comments correctly state that UCRL-15910 (DOE-STD-1020) is not a hazard classification document. The hazard classification is to be determined independently of UCRL-15910 (DOE-STD-1020). Secondly, there has been confusion in the interpretation of the DBA occurrence probability, as UCRL presents both a performance goal probability and an exceedance probability.

Currently, a DOE Order is being prepared that will define Natural Phenomena Design Requirements (Draft DOE Order 5480.NPH). Additionally, a set of Natural Phenomena Standards and Guidance Documents will be prepared that will establish more explicit requirements and acceptance criteria for DOE facilities. This set of documents will supersede UCRL-15910. The new hierarchy of design requirements, starting with a revised DOE Order 6430.1A, "General Design Criteria," will provide a clear definition and source of hazard classification as well.

The revised Standard provides further detail on this subject.

13.. EXCLUDING ATTENUATION EXPERT-5
(OR-1, EH-2, RW-4)

Comments were received which questioned the use of LLNL studies which include LLNL-AE5. Concerns which have been previously expressed by various sources in regard to the accuracy of LLNL-AE5 are included in the Standard.

In addition, Figure 7 displays the existing mean EPRI and LLNL (with and without LLNL-AE5) seismic hazard results and the draft preliminary revised results from LLNL using a reduced range of ground motion uncertainty for the Savannah River Site. This figure shows that the revised LLNL mean results are significantly lower than the earlier LLNL results. Also shown in Figure 7 are the results of the LLNL\EPRI correction factor with (Choice 2) and without (Choice 1) LLNL-AE5. It appears that for the Savannah River Site that the Choice 1 correction factor (using the existing LLNL results without LLNL-AE5) will more accurately reflect the assessment of mean seismic hazard when future probabilistic results are finalized.

While the specific degree of uncertainty assessment is likely to change from site to site, the preliminary Savannah River results suggest that the existing LLNL mean hazard results may substantially overestimate the mean hazard, consistent with the previous assessment that the mean hazard curves should not be directly used. Based on this information, the SWG position is that the pseudo-mean correction factor should be based on the existing LLNL results without LLNL attenuation expert 5.

14. WORKSHOP
(OR-5, EH-6)

Comments have indicated that a workshop on the development and utilization of this Standard would be beneficial. This workshop would include the seismic working group and consultants, DOE field offices, and M&O contractors. We plan to have this workshop although the specific date has not been selected.

15. NEW INFORMATION
(EH-5)

Recent information developed by the CSD Program may be helpful in resolving some of the uncertainties in the EUS, and may be useful in the development of a "final standard" for both eastern and western DOE locations. We agree that a summary should be provided to SWG and passed on to contractors as appropriate.

16. CORRELATION OF MEDIAN ESTIMATES
(RW-10)

The older TERA, Inc. curves are best correlated with median hazard estimates because they were based on "best-estimate" values without the explicit quantification of modeling uncertainty. In any case Table 3 indicates that the TERA, Inc. values are conservative compared to the Standard position values.

17. ACCOUNTING FOR SITE CONDITIONS
(INEL-1, RW-7, RW-8)

Comments correctly state that site geological conditions need to be considered in seismic analysis. There is a guidance document being developed to address seismic hazard data criteria needed, currently entitled "Guidance for Geotechnical Studies." This document was written by Defense Programs for the Systematic Evaluation Program and is being provided to the Office of Nuclear Energy to turn into a DOE Standard (DOE-STD-1022).

The final position to be developed through the DOE/NRC program is likely to more explicitly require geologic/seismic justification of expert input. In addition, draft DOE Order 5480.NPH provides clarification on time intervals for reviewing seismic hazard work.

18. USE OF THE STANDARD
(INEL-2, INEL-5)

The Standard should be used now to define ground motion in any ongoing efforts for both new and existing facilities. Draft Order 5480.NPH defines evaluation for existing facilities using backfit and this approach should be used to determine how to implement the Standard to existing facilities. The Standard does currently define geographic applicability (see response 8). In addition, a set of Natural Phenomena Standards and Guidance Documents will be prepared that will establish more explicit requirements and acceptance criteria for DOE facilities. This DOE guidance on seismic hazard will be reviewed by all sites.

In about 2 years this Standard approach will be replaced by a final standard or incorporated into a standard being prepared to support 5480.NPH. Evaluations of new and existing facilities continuing from that point will use the final position, which is expected to further lower design acceleration values.

Currently, DOE is proceeding with the NRC and EPRI on a joint program to develop a final position which includes more stable seismic hazard estimates. This effort will utilize a group of senior technical specialists who are well recognized experts in Geosciences, Ground Motion and Expert Elicitation.

Appendix B

INTERIM GUIDANCE FOR THE DEVELOPMENT OF DETERMINISTIC SPECTRAL SHAPE

Appendix B

INTERIM GUIDANCE FOR THE DEVELOPMENT OF DETERMINISTIC SPECTRAL SHAPE

UCRL-15910 (DOE-STD-1020) specifies that median response spectral shapes should be associated with the Design Basis earthquake (DBE). UCRL-15910 (DOE-STD-1020) states that the spectral shapes recommended by TERA, Inc. can be used for the DBE. The TERA, Inc. spectral shapes, like the TERA, Inc. probabilistic hazard curves, are relatively old and do not represent the current state-of-the-art. Site-specific spectral shapes can be used to determine if the TERA spectral shape is unconservative. The discussion provided below provides guidance regarding the development of site specific spectral shapes. The Office of Nuclear Energy is developing a Department of Energy (DOE) Standard related to DBE response spectra which will supersede the interim guidance provided below (Draft Standard DOE-STD-1023).

For, those sites who choose to develop a deterministic site-specific spectral shape, information contained in the probabilistic seismic hazard analysis should be used to establish the appropriate magnitude and distance. This will require that the dominant earthquake source(s), magnitude(s) and distance(s) be determined. Such an analysis should be completed for both the peak ground acceleration and for a lower frequency best associated with the maximum spectral velocity (in the 1 to 5 hertz frequency range). Thus, this will require the use of the Uniform Hazard Spectra. The recommended steps to complete this analysis are outlined below:

1. At the probability of interest (i.e., 2 x 10E-4 for high hazard facilities) determine the dominant magnitudes (M's) and distances (R's) for peak ground acceleration (PGA) and maximum spectral velocity (MSV). For example:

   PGA: M(l); R(l)
   MSV: M(2); R(2)

   It is recommended that the stability of the M:R combinations be assessed at other probabilities (such as 5 to 10 times lower than the probability of interest) given the issues raised with the Uniform Hazard Spectra, which are described in the text of the Standard.

   Both Lawrence Livermore National Laboratory and Risk Engineering Incorporated have available methods (codes) which can be used to determine the dominant M and R.

2. Develop the (deterministic) median response spectra for each M:R combination: For example M(I)R(l) median spectra and M(2)R(2) median spectra. Guidance can be found in U.S. Nuclear Regulatory Commission

Standard Review Plan, Section 2.5.2 regarding methods to develop site-specific spectral shapes. The development of median response spectra should address the issue of appropriate frequency range for ground motion in the Eastern United States.

3. Scale the spectra for each M:R combination to the corresponding ground motion parameter value associated with the appropriate annual probability from UCRL-15910 (DOE-STD-1020). For example, scale the median spectra for M(l):R(l) to the PGA with the appropriate annual probability (e.g., 2 x 10E-4 for high hazard facilities), and scale the M(2):R(2) spectra to the MSV with the same annual probability.

    Note that the scaling to the MSV may be problematic in that the appropriate value of the MSV is questionable. The correction factors of 1.8 and 1.65 are not applicable to the MSV. If this approach is selected, justification should be provided for the MSV value selected.

4. Envelope the two resulting spectra to create a single response spectrum.

The steps above are thought to represent one approach to developing site-specific spectra for use with probabilistic peak accelerations. The DOE is evaluating this approach for technical adequacy. Other approaches may also be proposed and will be evaluated by DOE for technical adequacy. At present DOE's Oak Ridge Office, working with Martin Marietta, is attempting to implement the above interim guidance at Paducah and Portsmouth as test cases.

The engineer/designer may either use the above single envelope spectra or analyze twice, one for each M:R combination, using the more conservative result for design purposes.

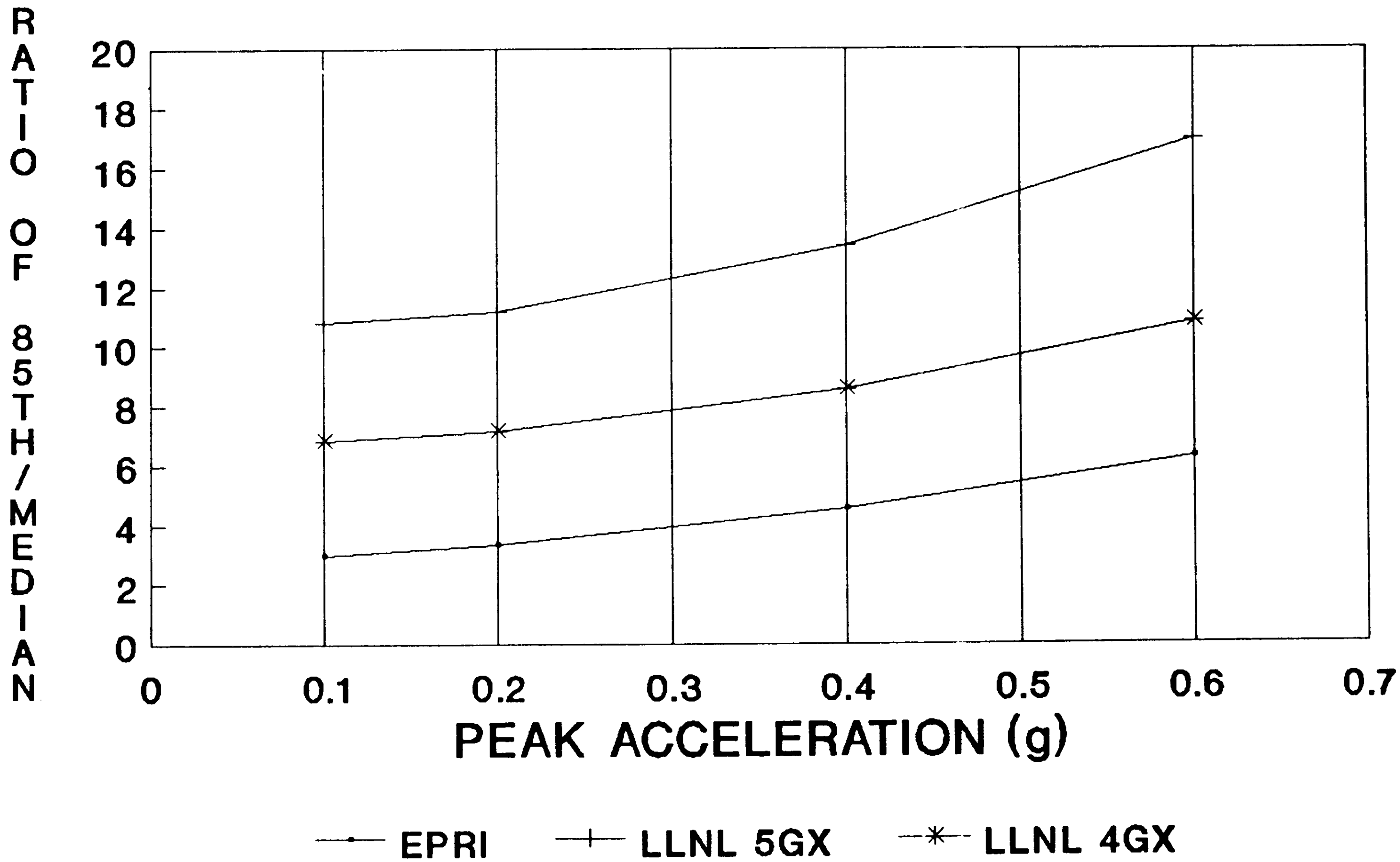
Appendix C

FIGURES SHOWING THE INFORMATION PROVIDED BY RISK ENGINEERING, INC. REGARDING THE HAZARD CURVES RATIOS FOR THE NUCLEAR POWER PLANT SITES.

Figures C1 to C6: The geometric mean of the ratio between the 85th percentile and the median for the Electric Power Research Institute results and the Lawrence Livermore National Laboratory (LLNL) results with and without LLNL-AE5.

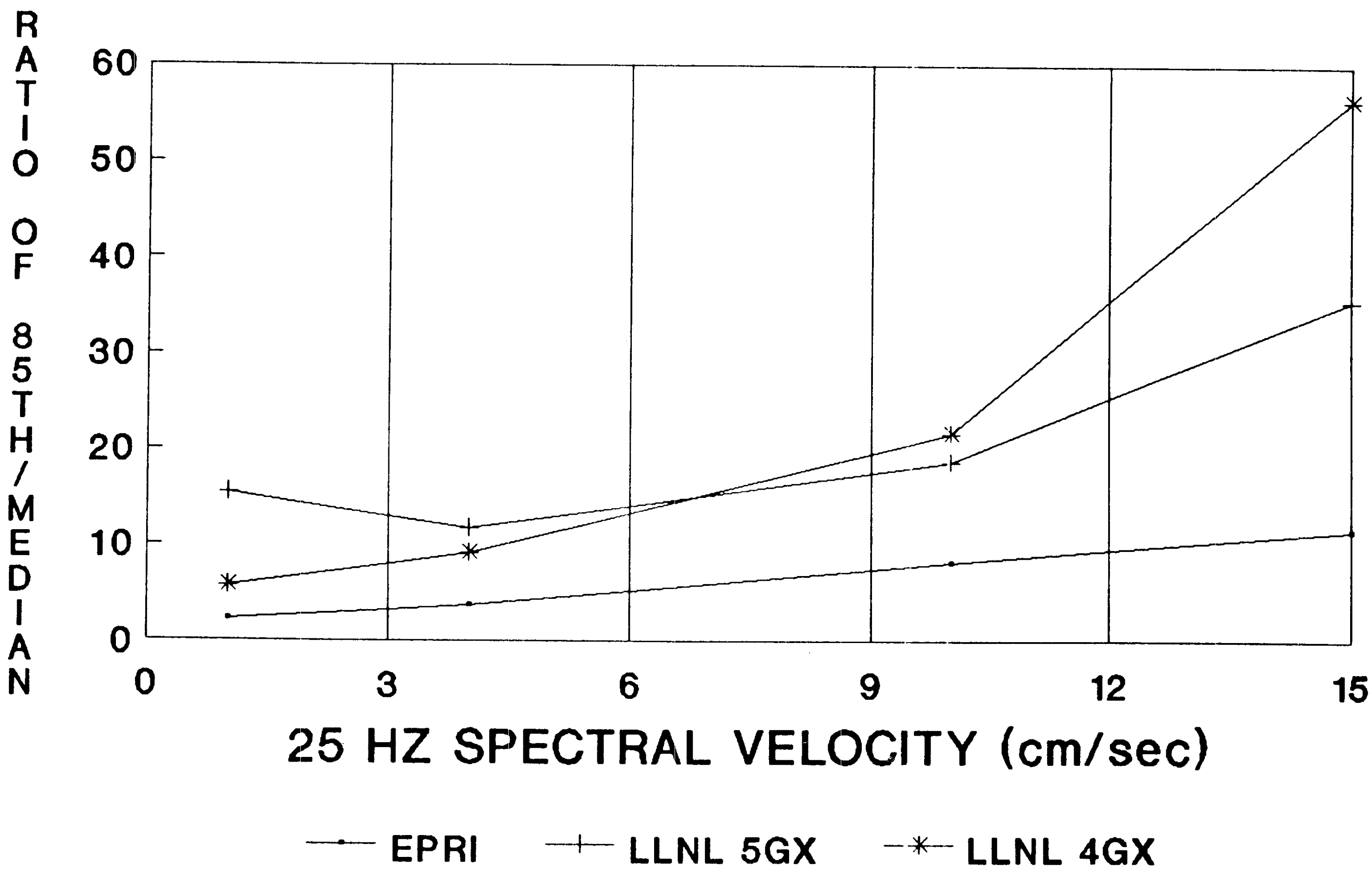
Figures C7 to C24: The entire set of reactor data and the geometric mean, 15th and 85th percentiles of the data. Each circle represents the data for a nuclear power plant site. Bars display the geometric mean, 15th percentile and 85th percentile. Lawrence Livermore National Laboratory 5 GX includes LLNL-AE5 while LLNL 4 GX excludes LLNL-AE5.

PROBABILISTIC SEISMIC HAZARD RATIOS
GEOM. MEAN OF PGA RATIOS



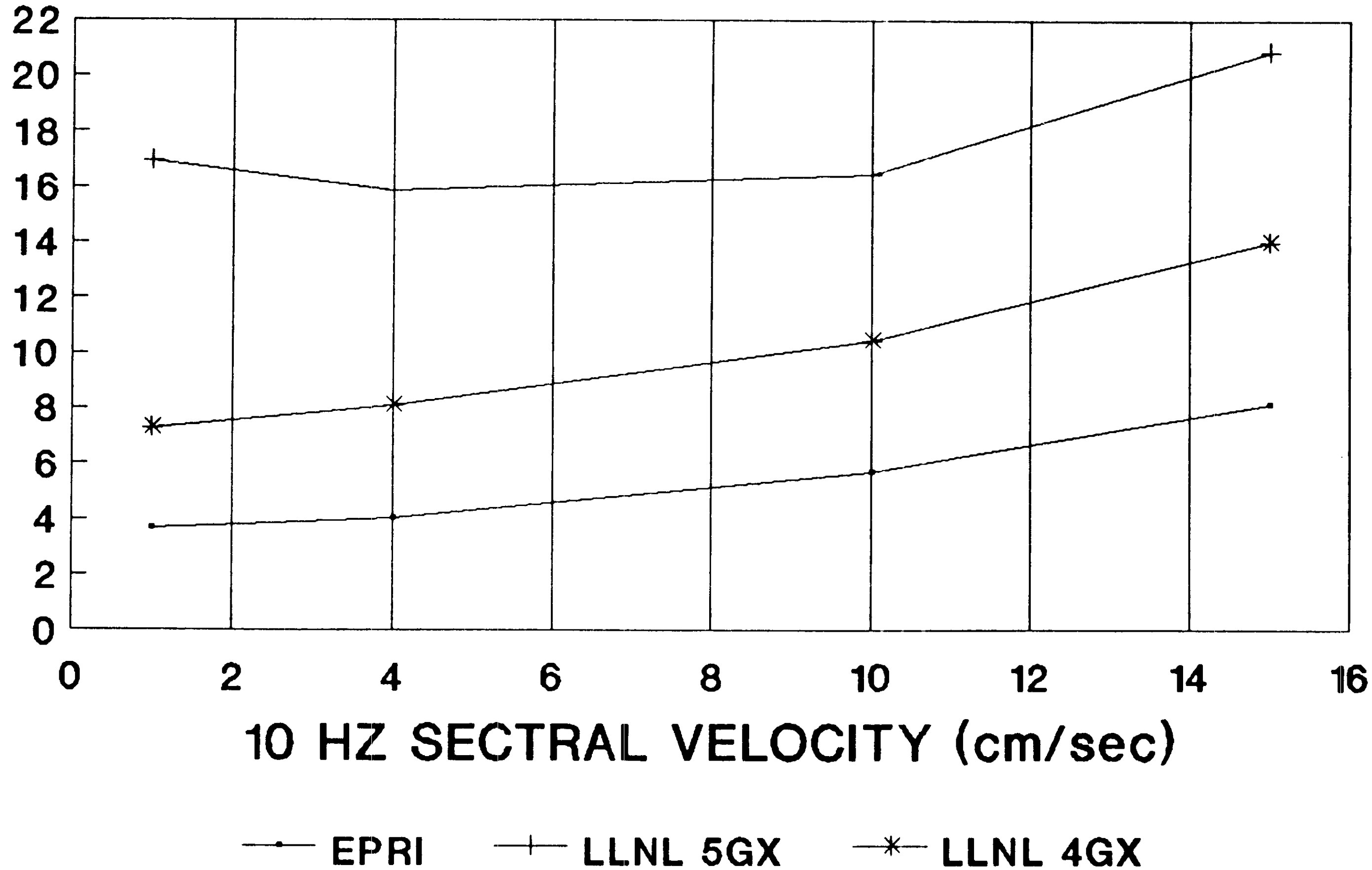
COMPARISON EPRI/LLNL RESULTS

PROBABILSITIC SEISMIC HAZARD RATIOS
GEOM. MEAN OF 25HZ VEL. RATIOS



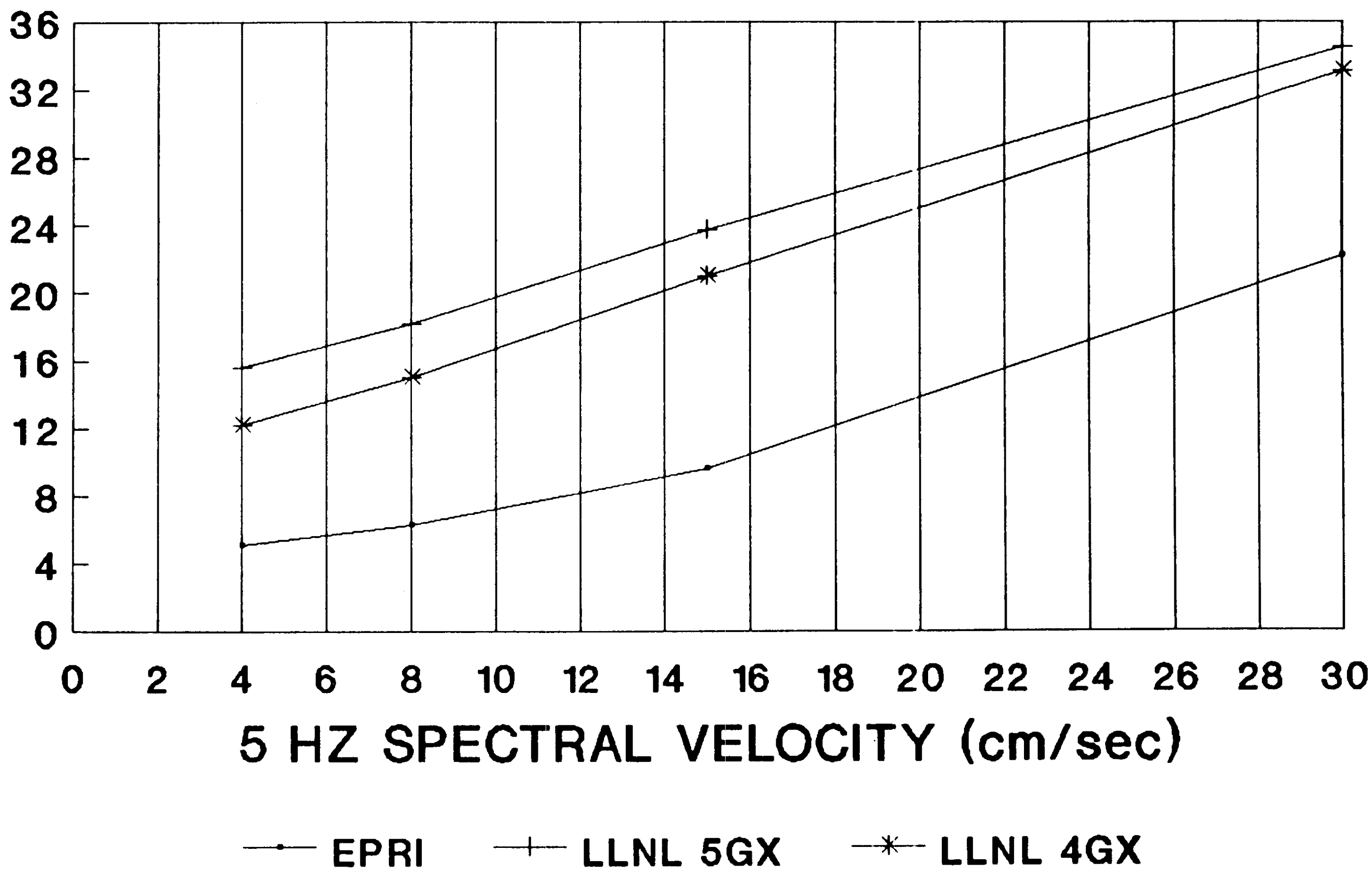
COMPARISON EPRI/LLNL RESULTS

PROBABILISTIC SEISMIC HAZARD RATIOS
GEOM. MEAN OF 10HZ VEL. RATIOS

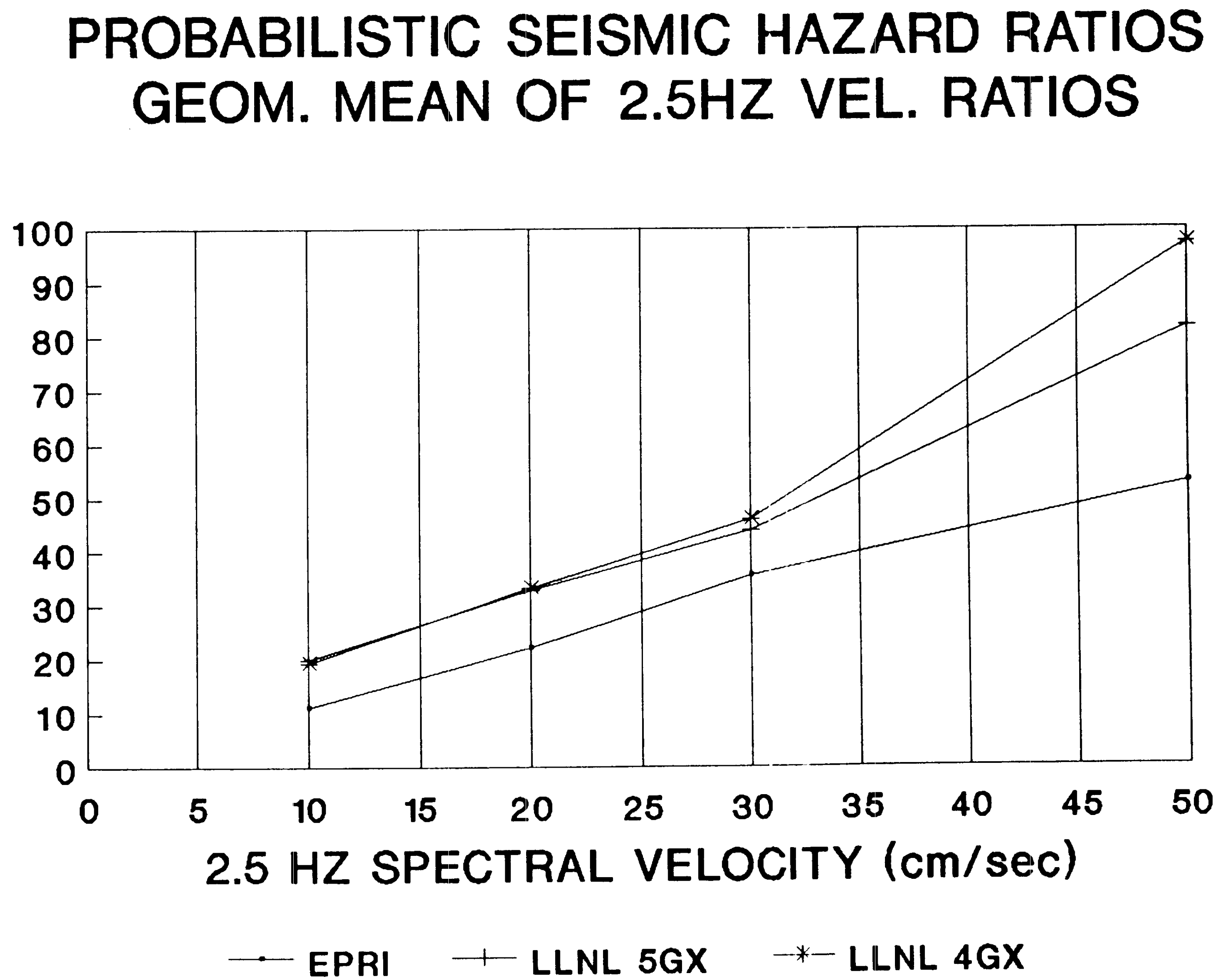


IISON EPRI/LLNL RESULTS

PROBABILISTIC SEISMIC HAZARD RATIOS
GEOM. MEAN OF 5HZ VEL. RATIOS



RISON EPRI/LLNL RESULTS



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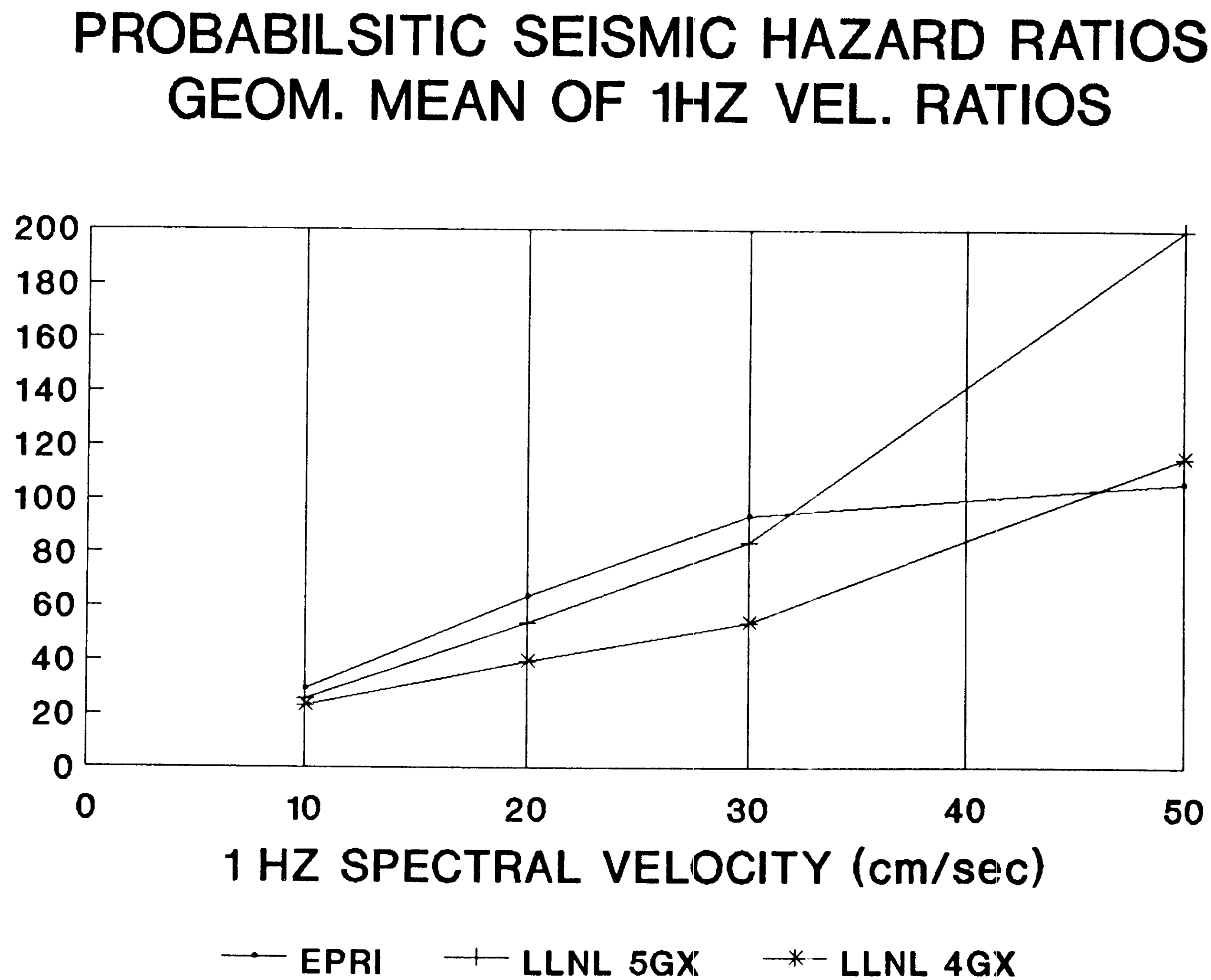
DOE-STD-1024-92



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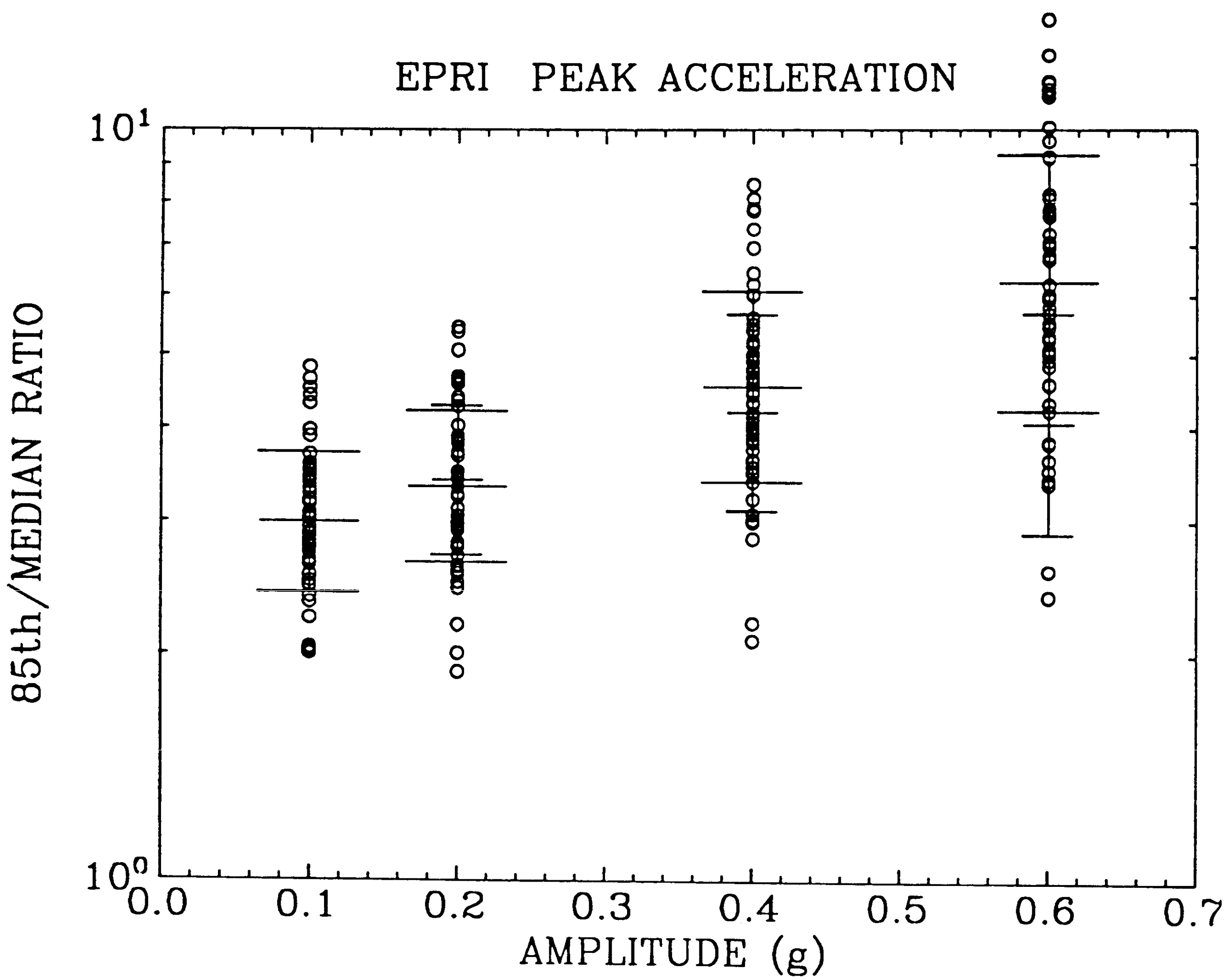
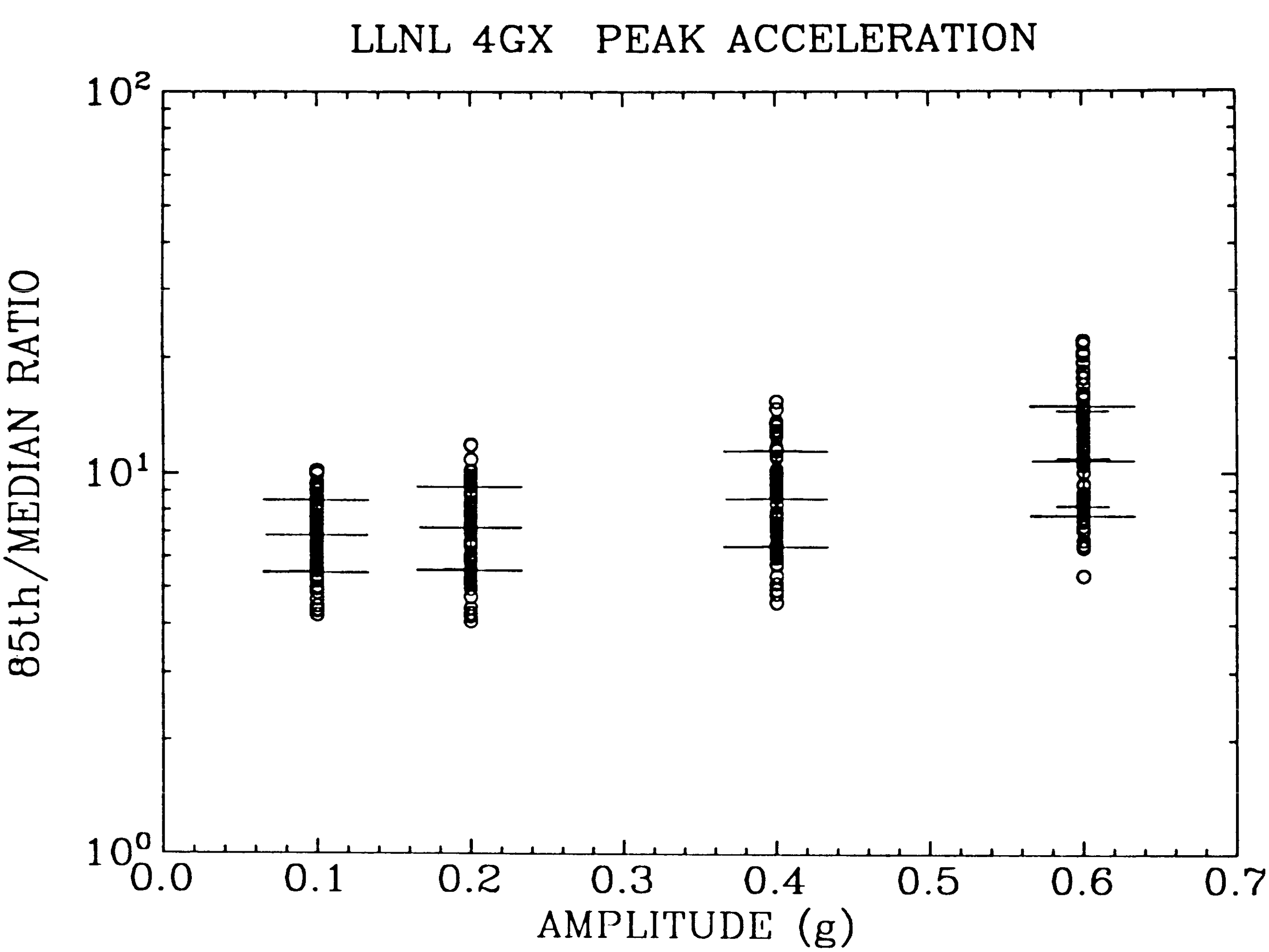
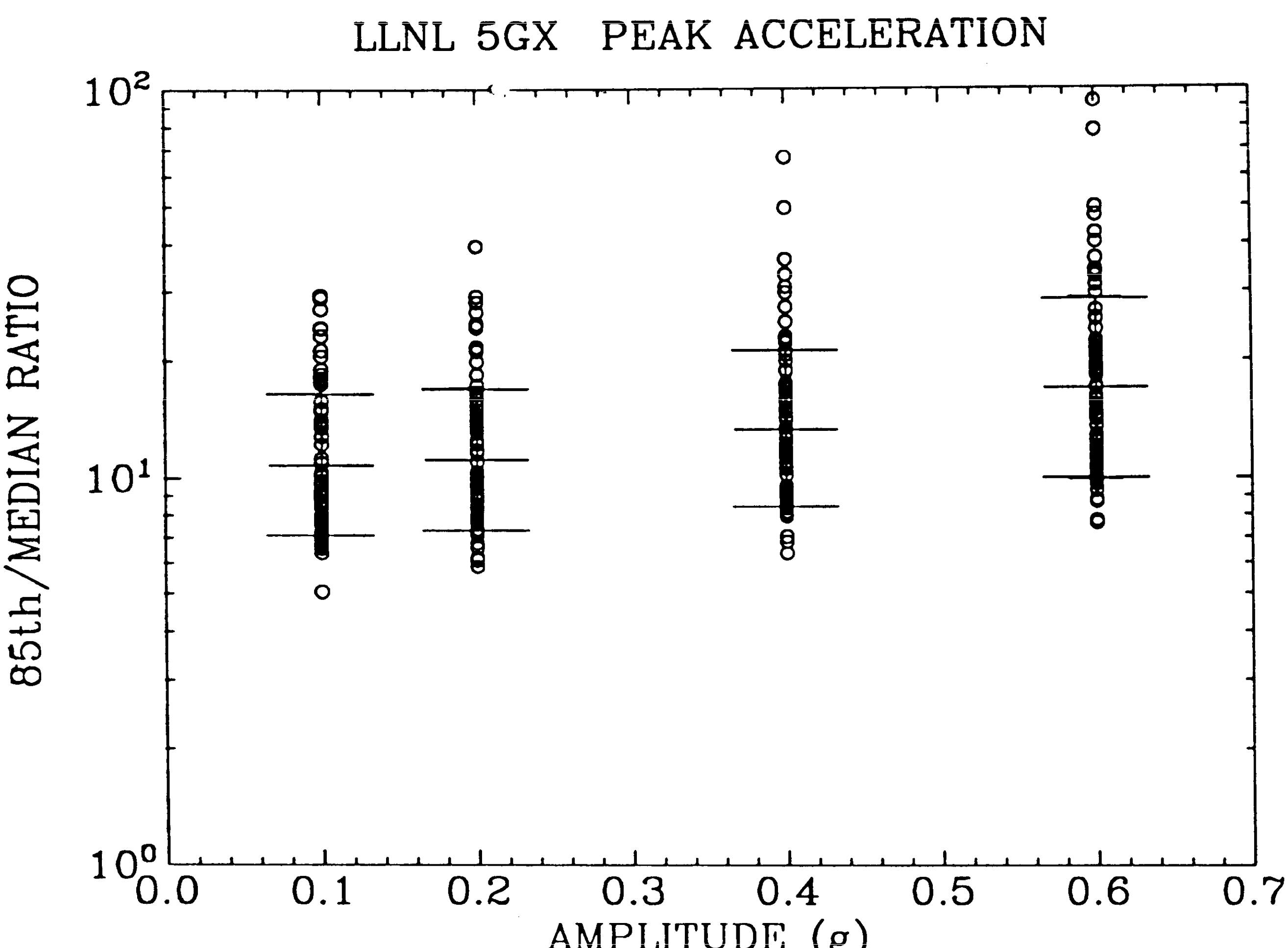
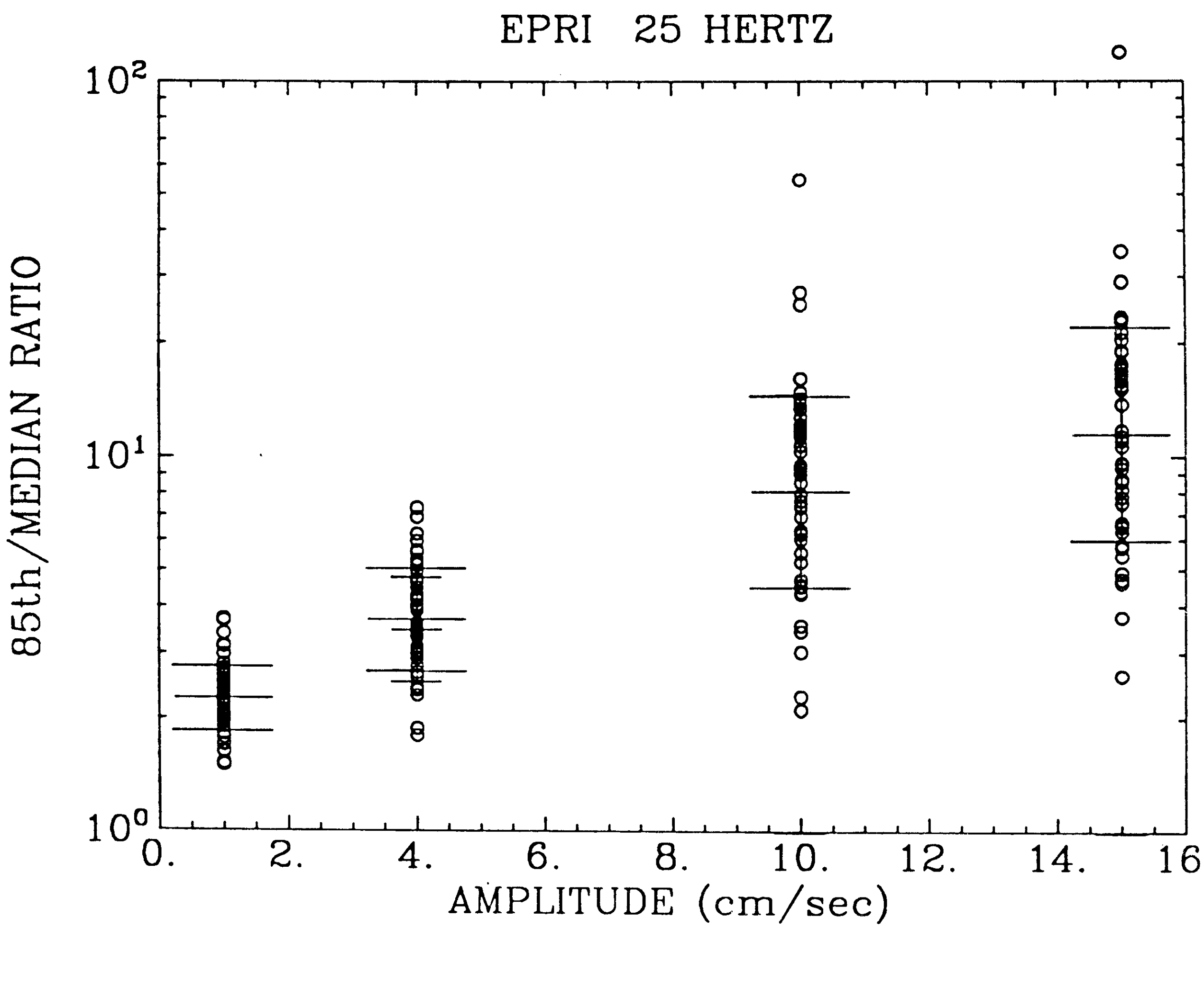
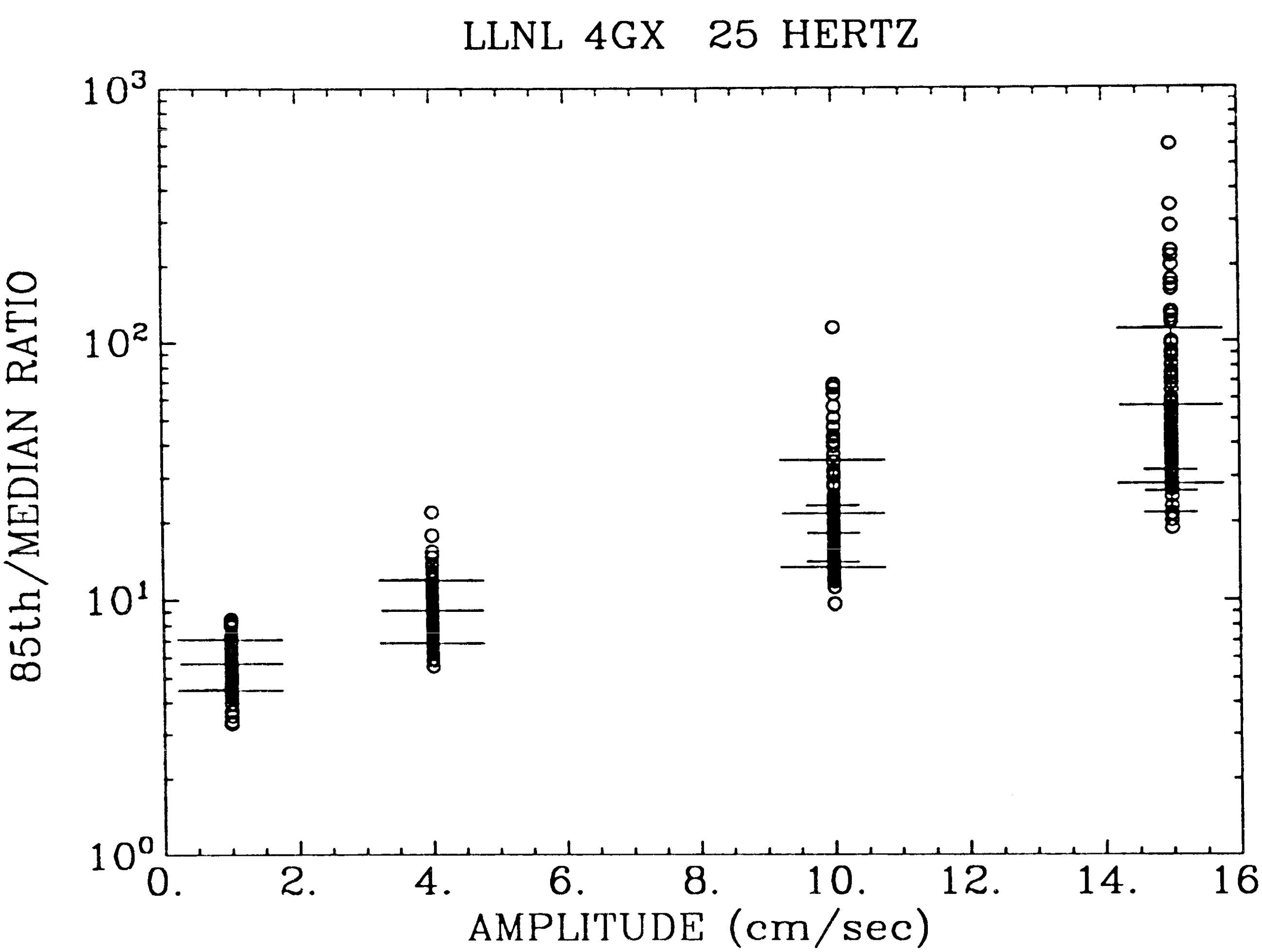
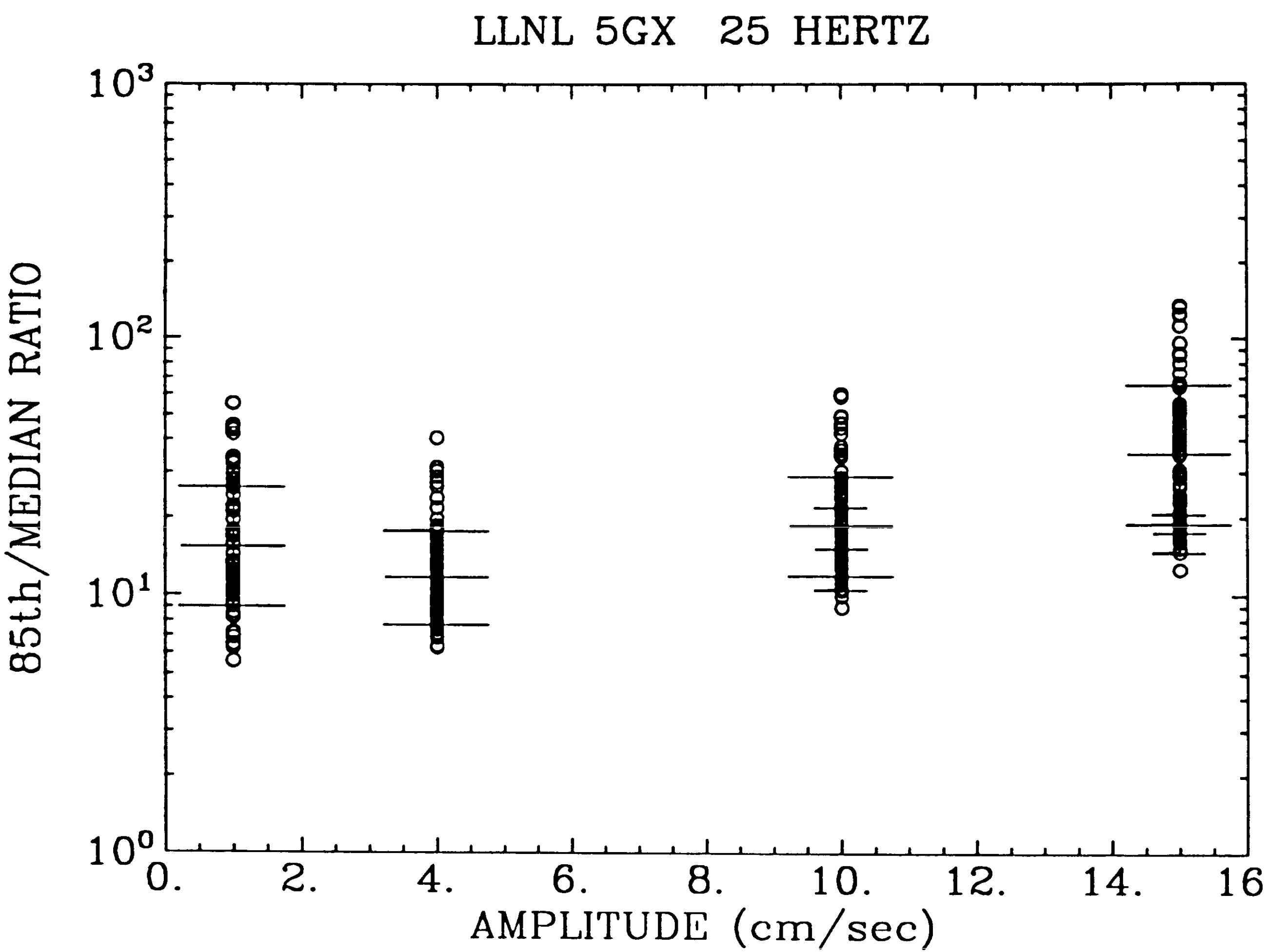

EPRI PEAK ACCELERATION
10^1
10^0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
AMPLITUDE (g)
85th/MEDIAN RATIO

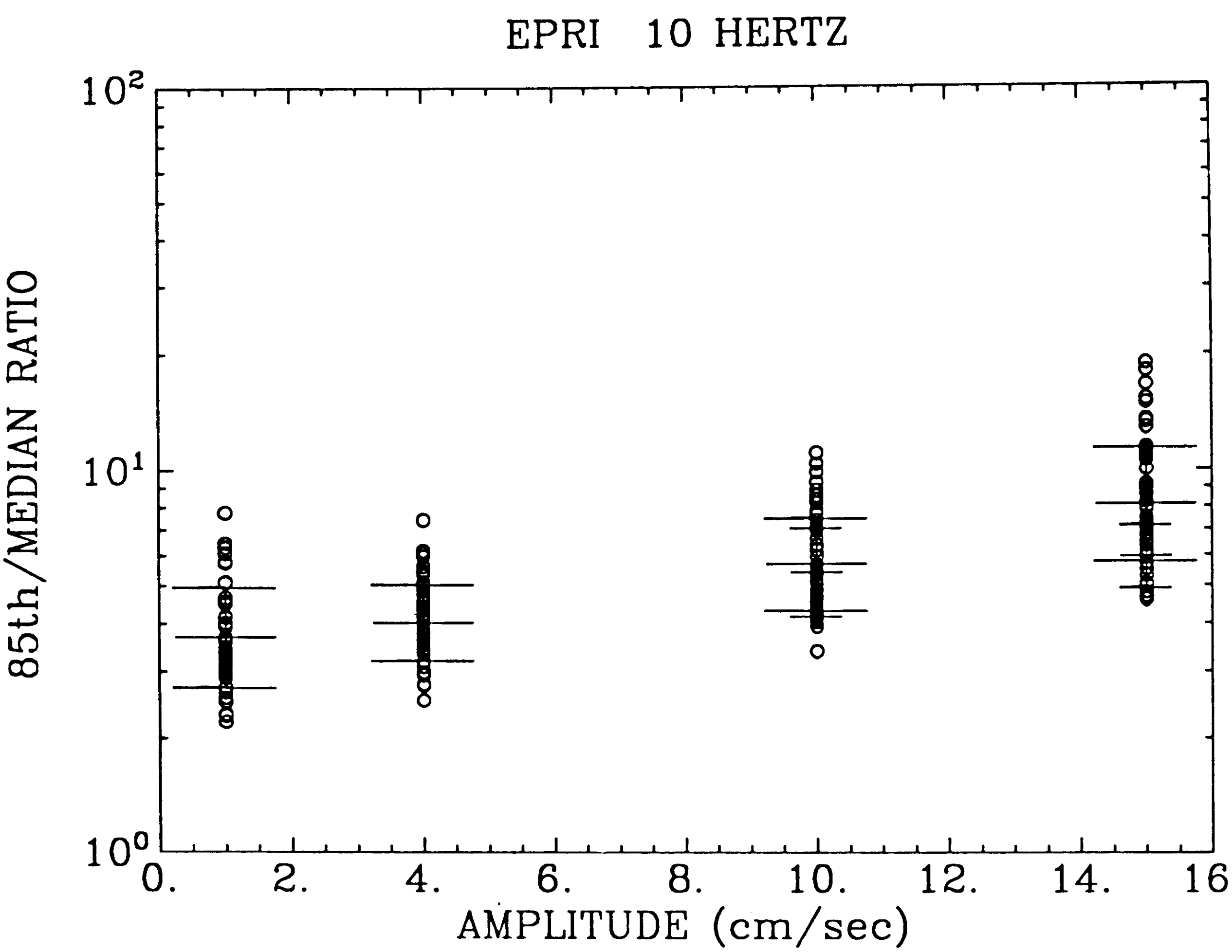

LLNL 4GX PEAK ACCELERATION
10^2
10^1
10^0
85th/MEDIAN RATIO
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
AMPLITUDE (g)

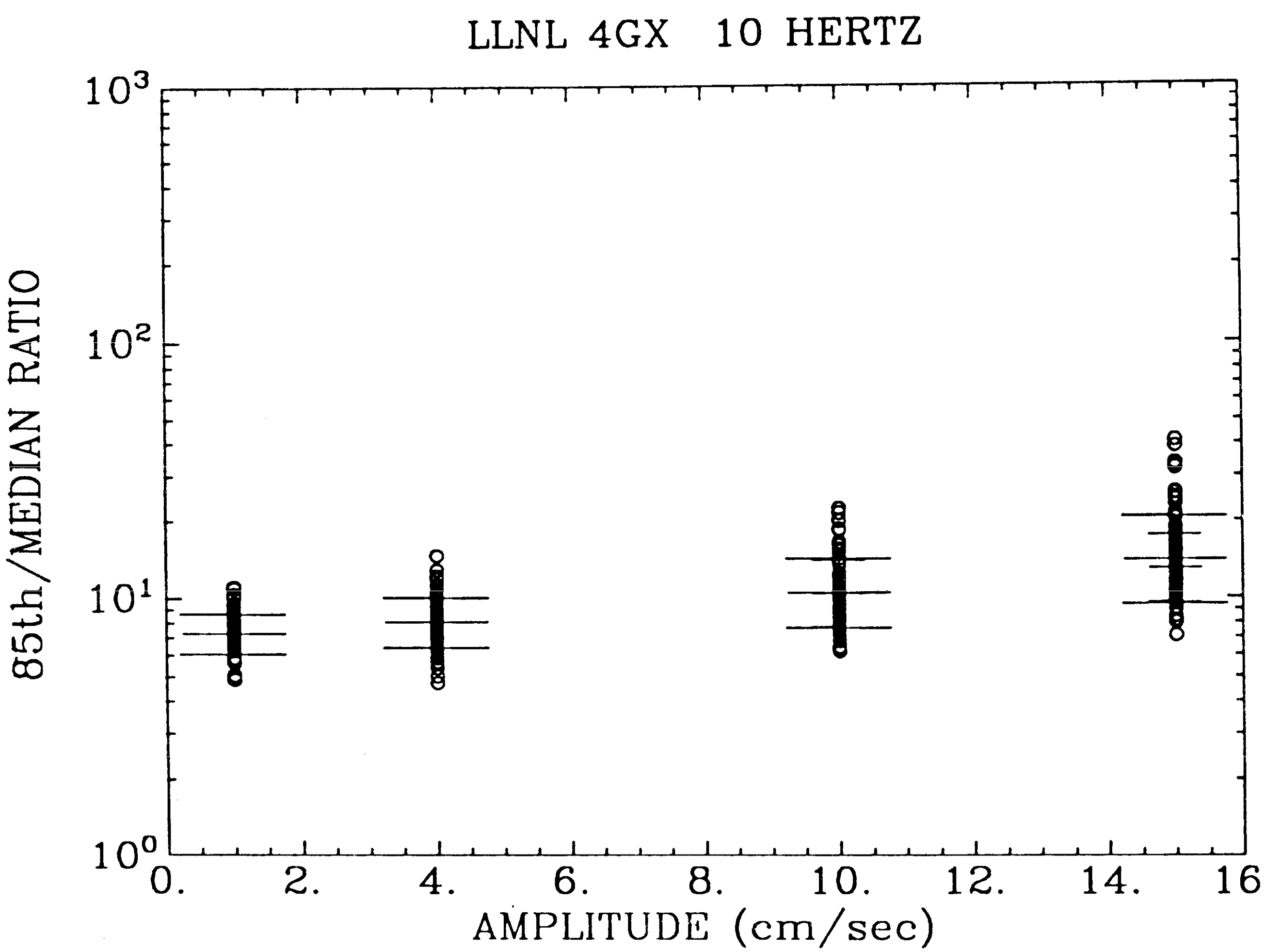

LLNL 5GX PEAK ACCELERATION
10^2
10^1
10^0
85th/MEDIAN RATIO
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
AMPLITUDE (g)

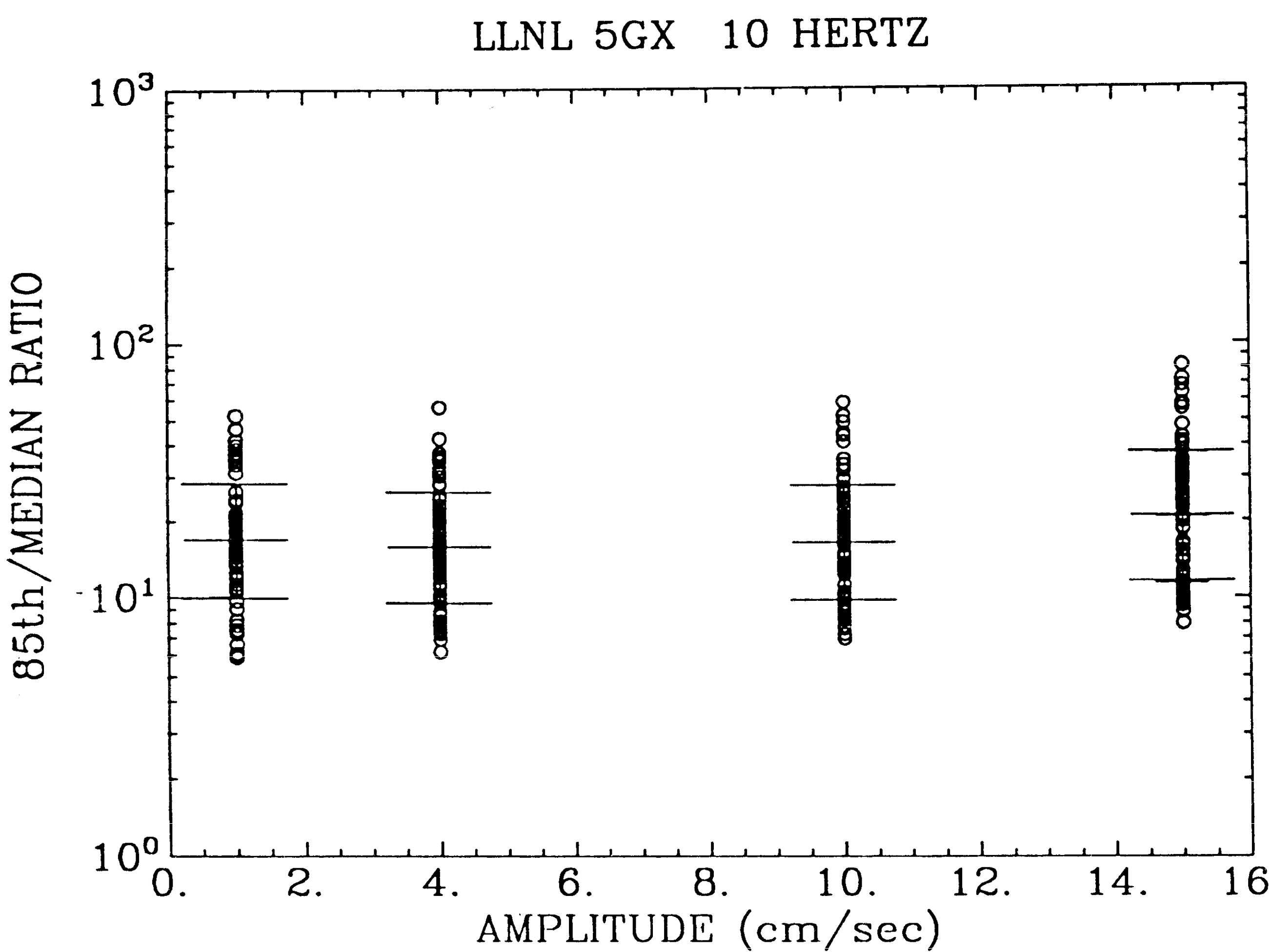

EPRI 25 HERTZ
10²
10¹
10⁰
85th/MEDIAN RATIO
0.
2.
4.
6.
8.
10.
12.
14.
16.
AMPLITUDE (cm/sec)

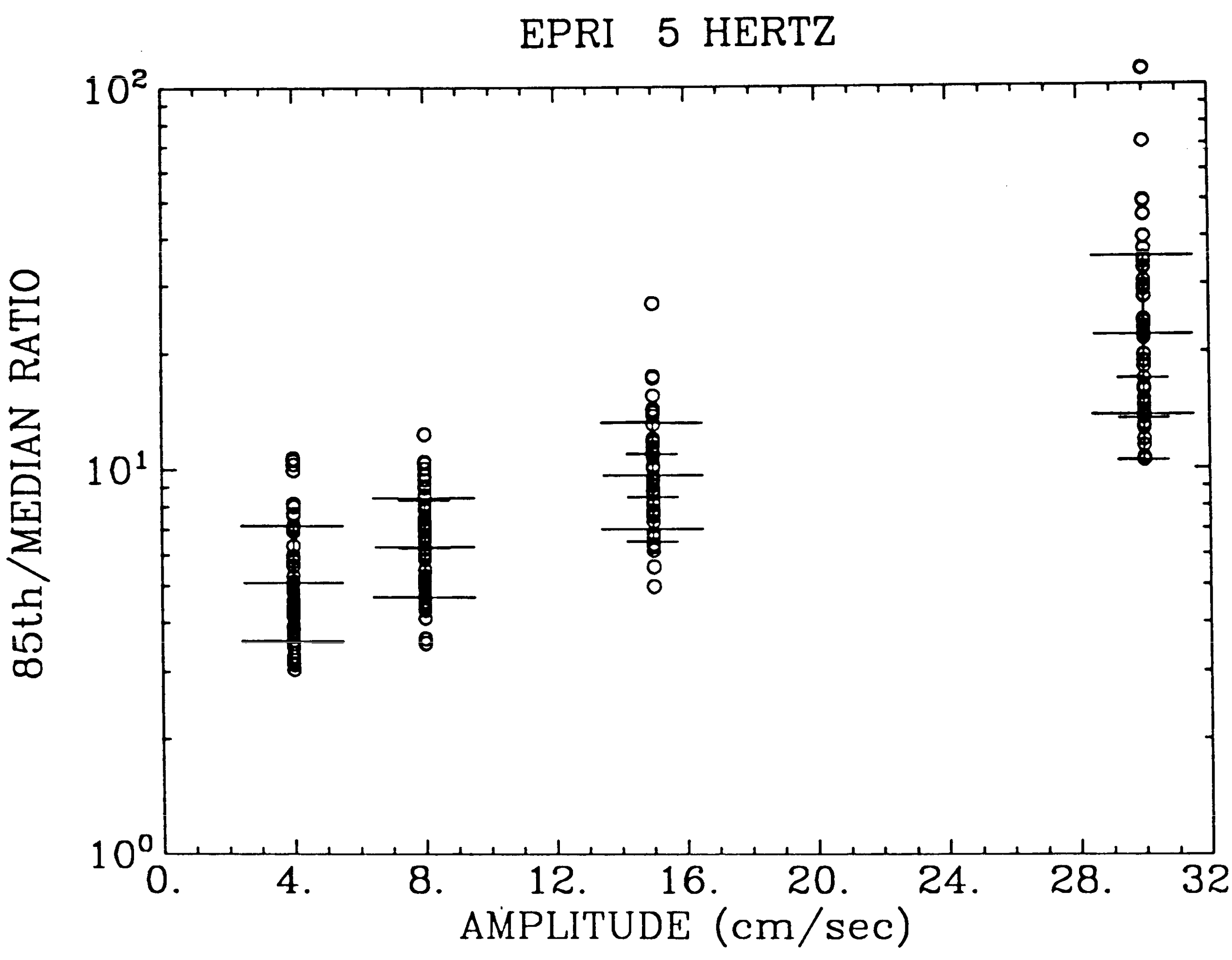

LLNL 4GX 25 HERTZ
85th/MEDIAN RATIO
AMPLITUDE (cm/sec)
10^3
10^2
10^1
10^0
0.
2.
4.
6.
8.
10.
12.
14.
16.

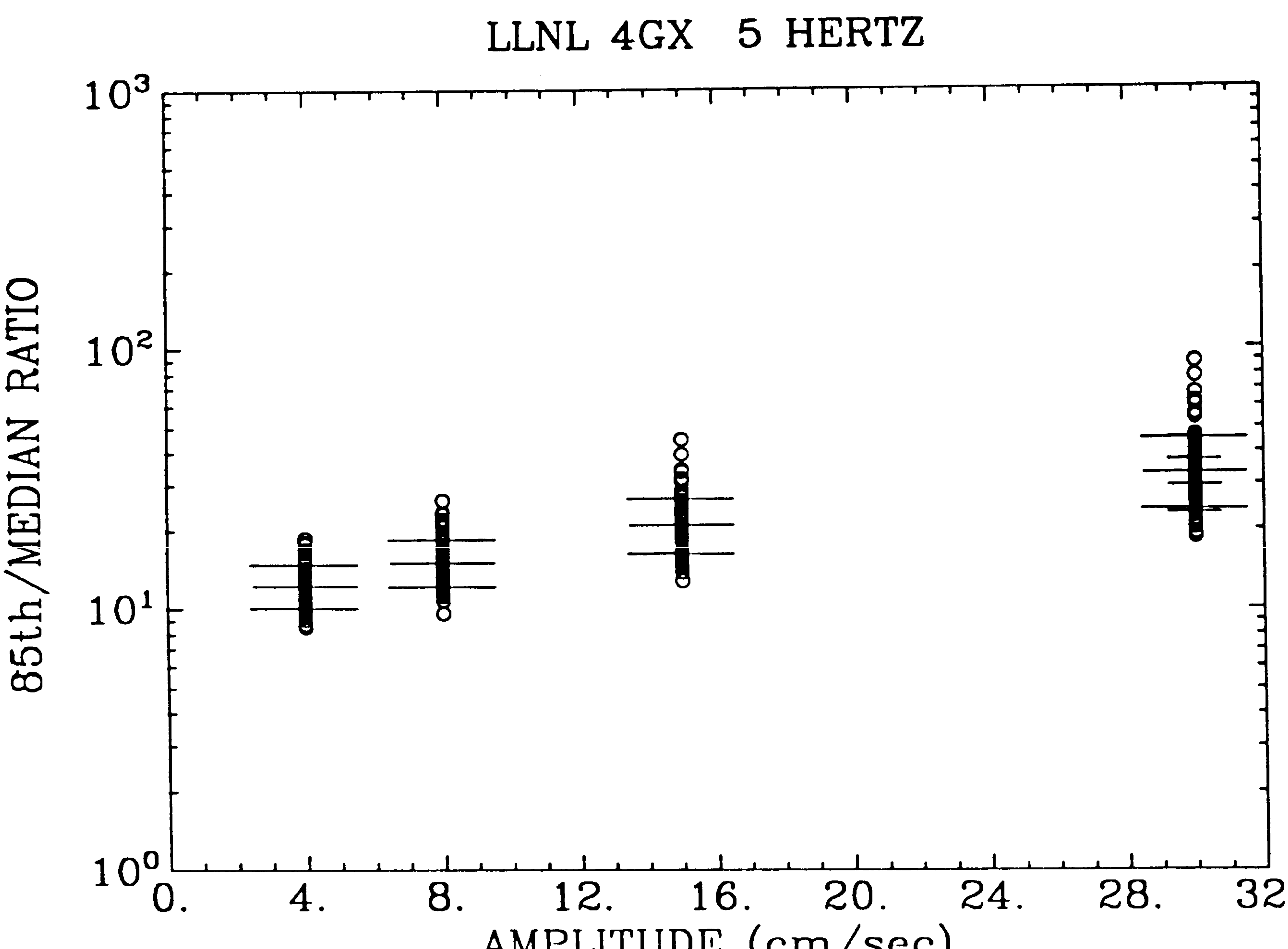

LLNL 5GX 25 HERTZ
85th/MEDIAN RATIO
AMPLITUDE (cm/sec)
10³
10²
10¹
10⁰
0.
2.
4.
6.
8.
10.
12.
14.
16.

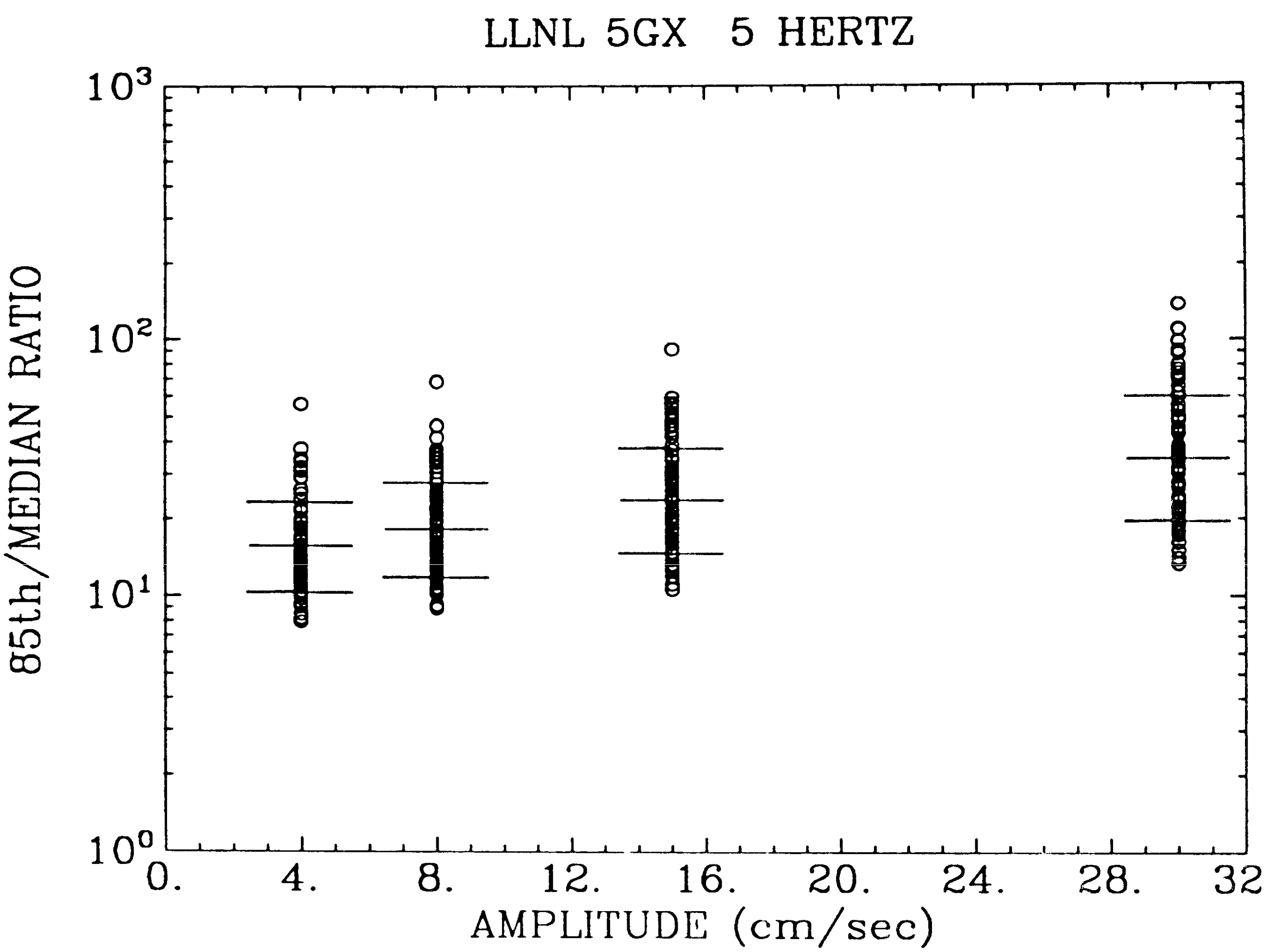

EPRI 10 HERTZ
10^2
10^1
10^0
85th/MEDIAN RATIO
0.
2.
4.
6.
8.
10.
12.
14.
16.
AMPLITUDE (cm/sec)

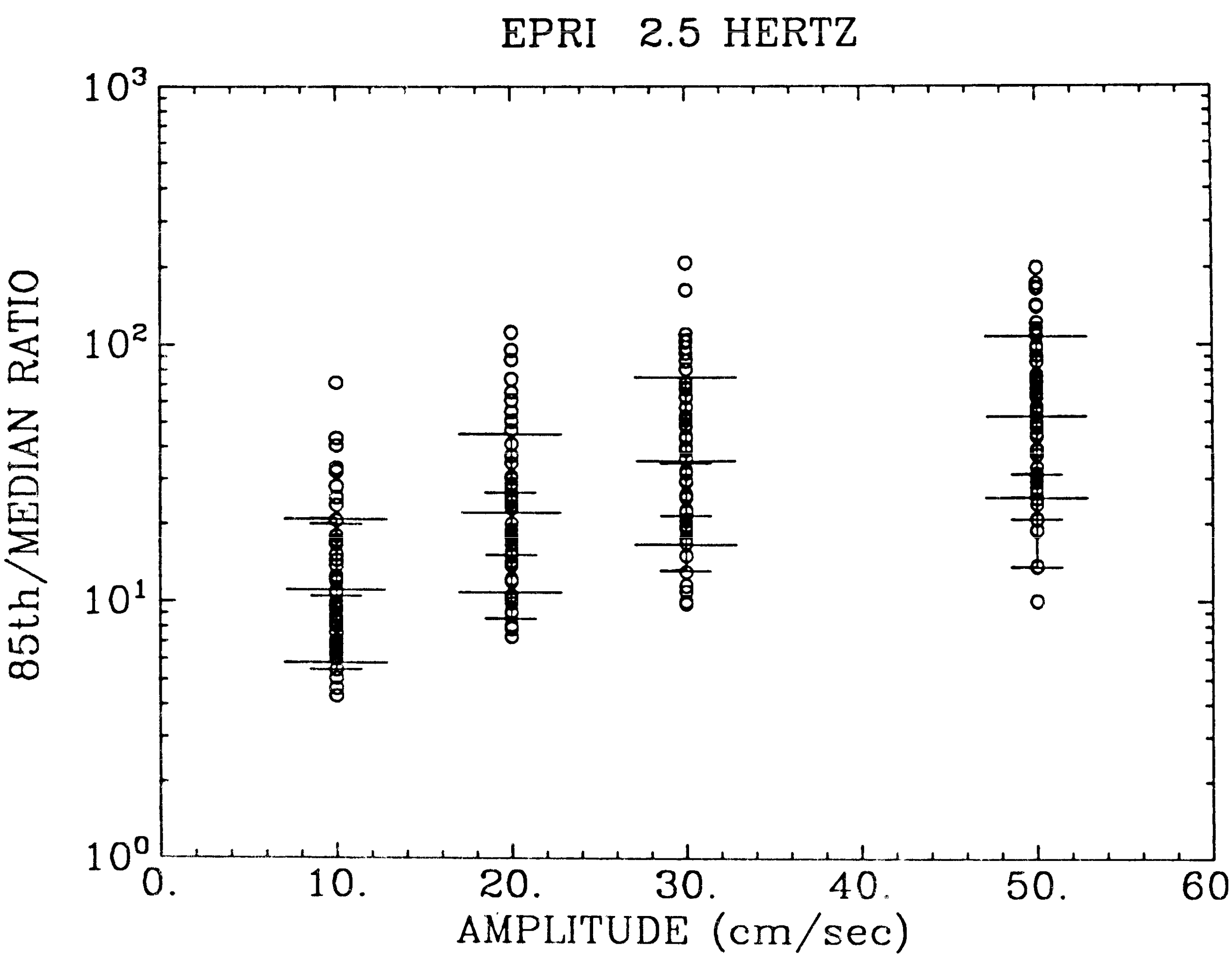

LLNL 4GX 10 HERTZ
85th/MEDIAN RATIO
10³
10²
10¹
10⁰
0.
2.
4.
6.
8.
10.
12.
14.
16.
AMPLITUDE (cm/sec)

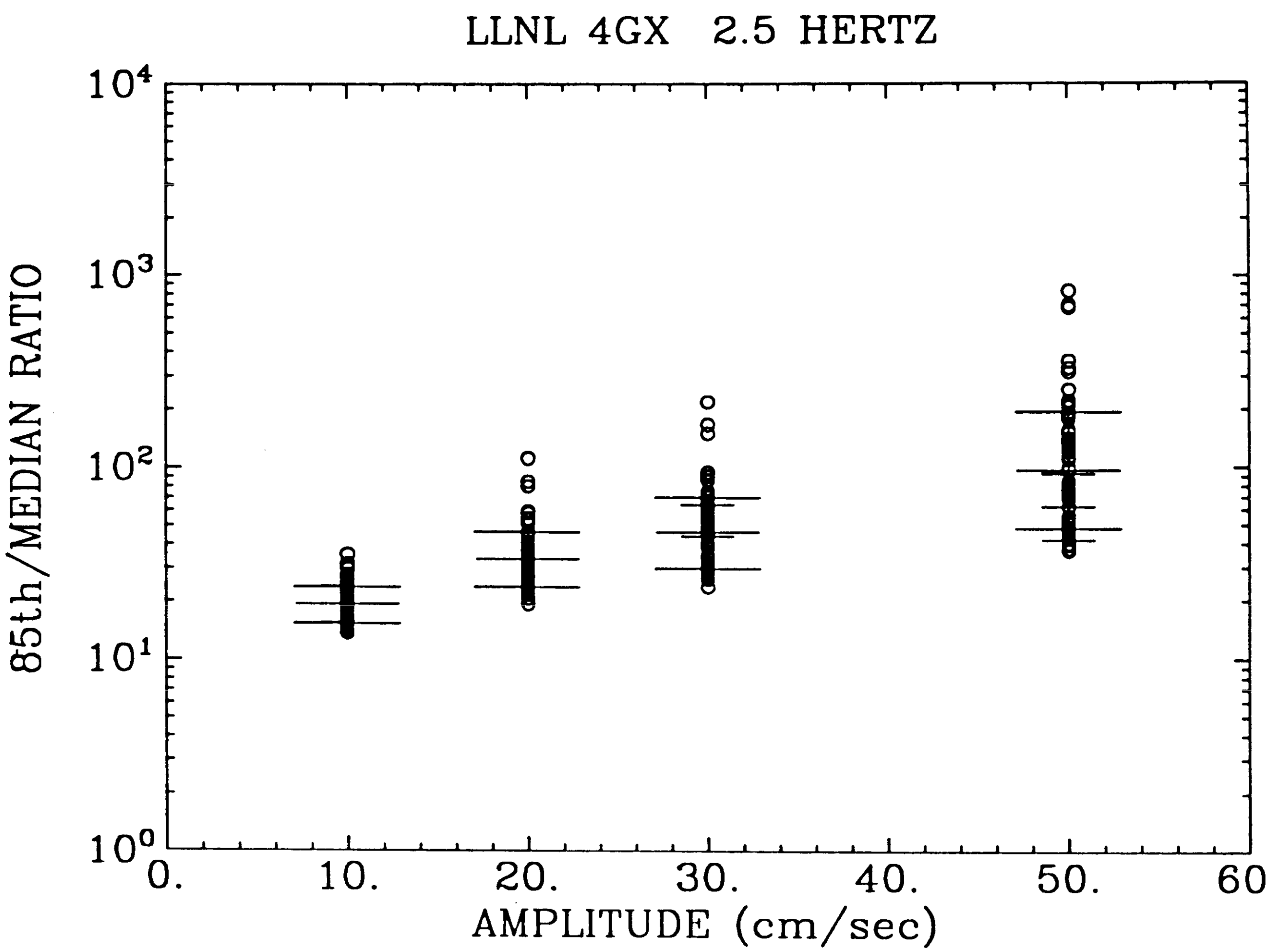

LLNL 5GX 10 HERTZ
85th/MEDIAN RATIO
10^3
10^2
10^1
10^0
0.
2.
4.
6.
8.
10.
12.
14.
16.
AMPLITUDE (cm/sec)

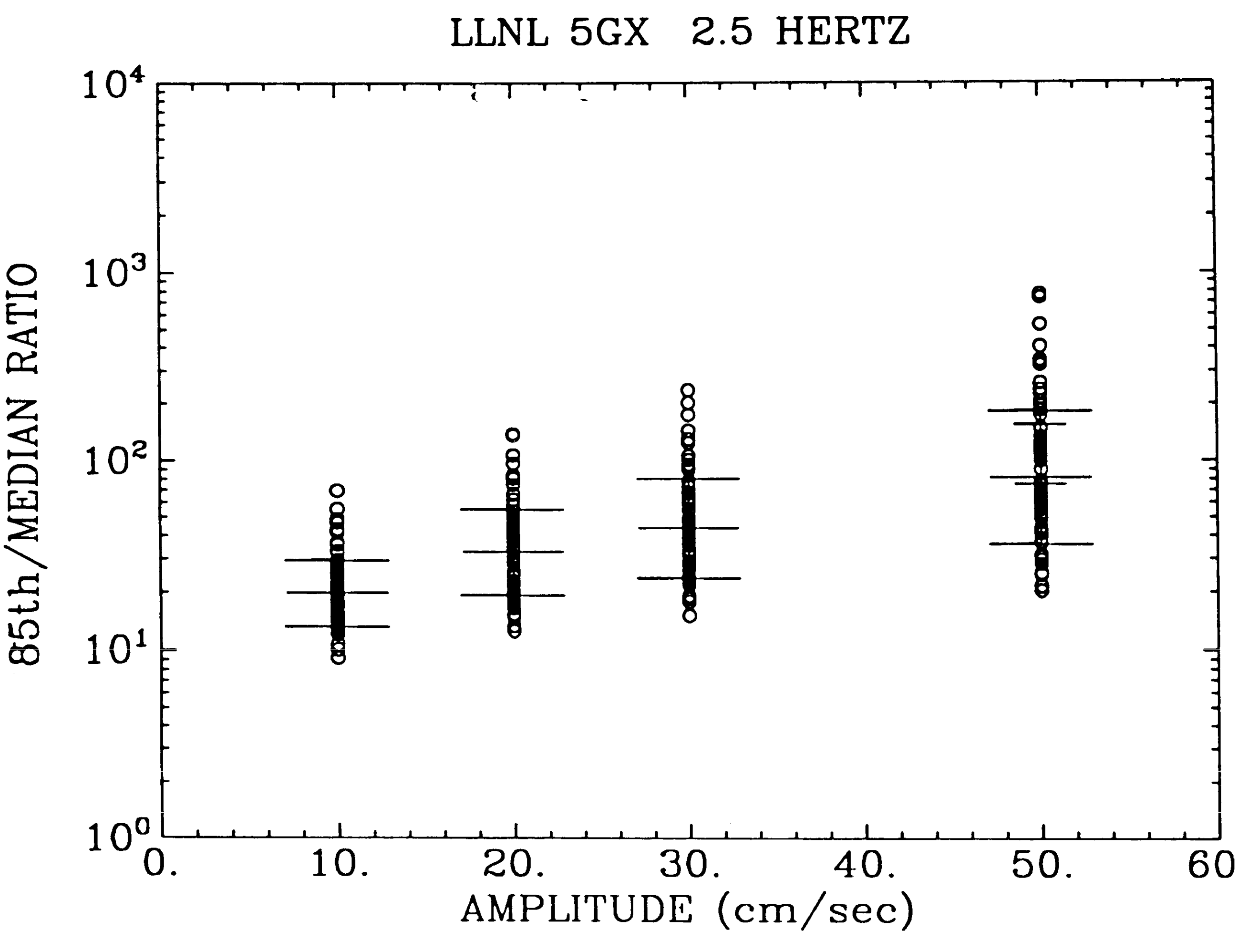

EPRI 5 HERTZ
10^2
10^1
10^0
85th/MEDIAN RATIO
0.
4.
8.
12.
16.
20.
24.
28.
32.
AMPLITUDE (cm/sec)

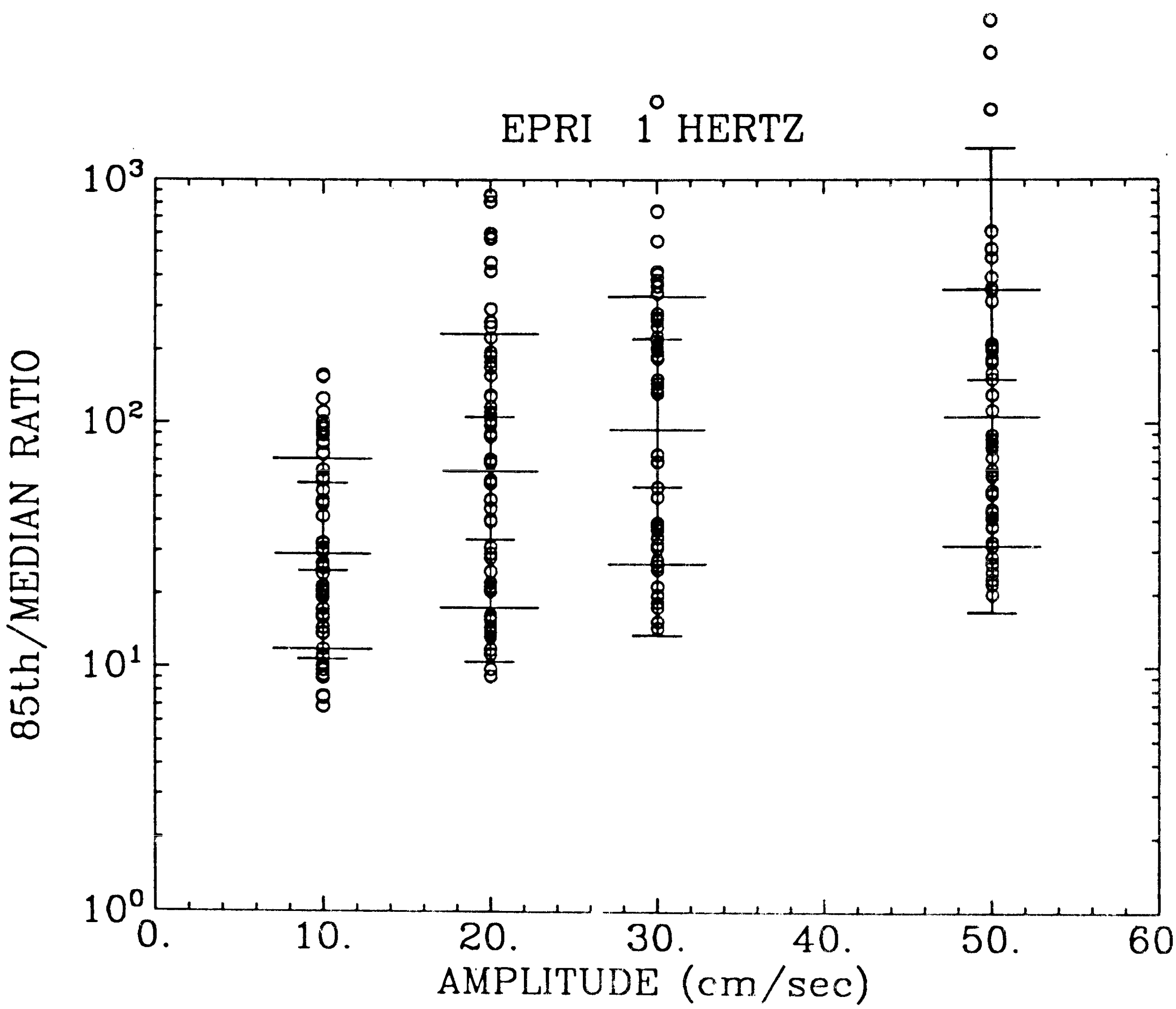

LLNL 4GX 5 HERTZ
85th/MEDIAN RATIO
10^3
10^2
10^1
10^0
0.
4.
8.
12.
16.
20.
24.
28.
32.
AMPLITUDE (cm/sec)


LLNL 5GX 5 HERTZ
10^3
10^2
10^1
10^0
85th/MEDIAN RATIO
0.
4.
8.
12.
16.
20.
24.
28.
32.
AMPLITUDE (cm/sec)

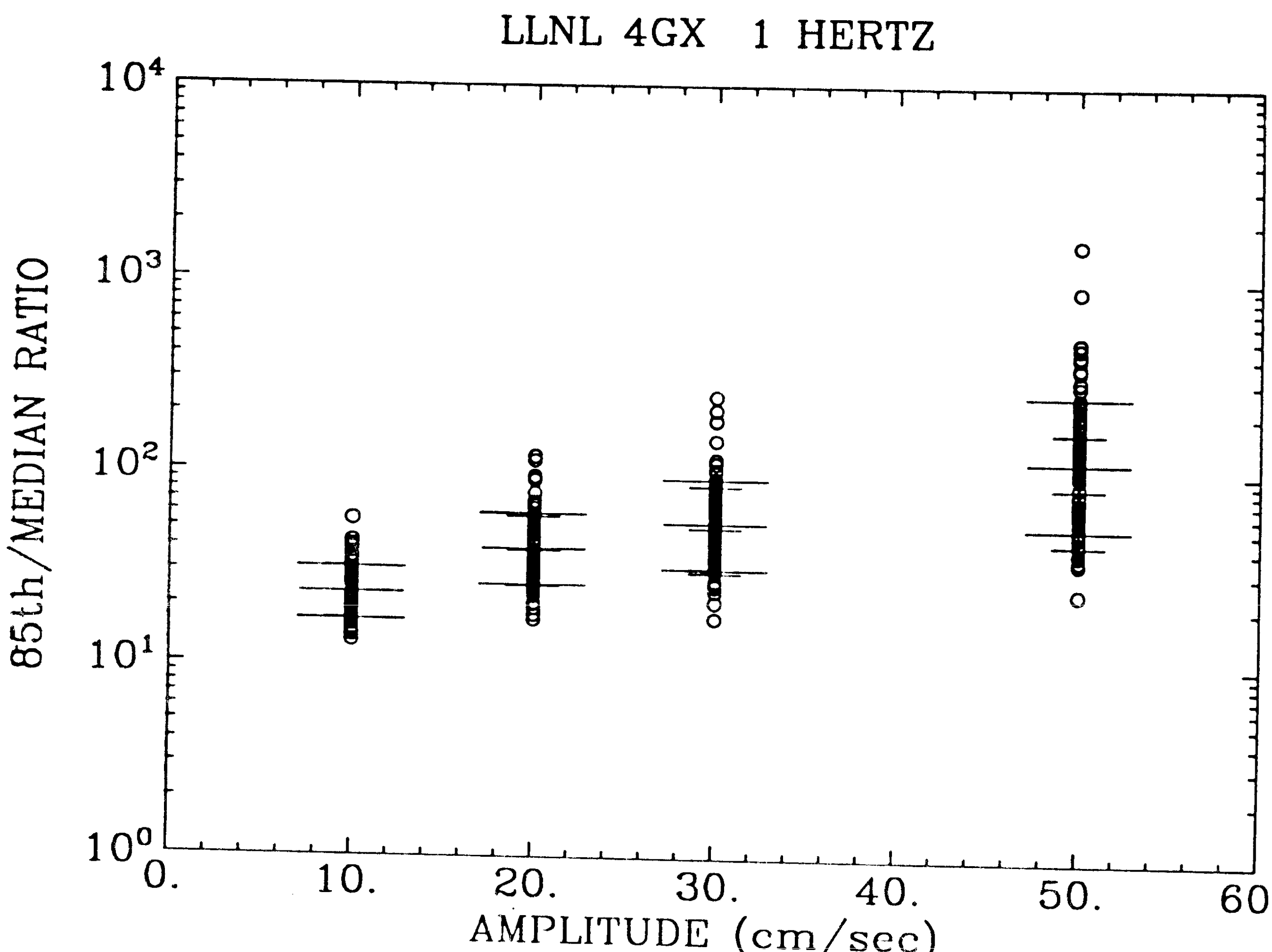

EPRI 2.5 HERTZ
85th/MEDIAN RATIO
10^3
10^2
10^1
10^0
0.
10.
20.
30.
40.
50.
60.
AMPLITUDE (cm/sec)

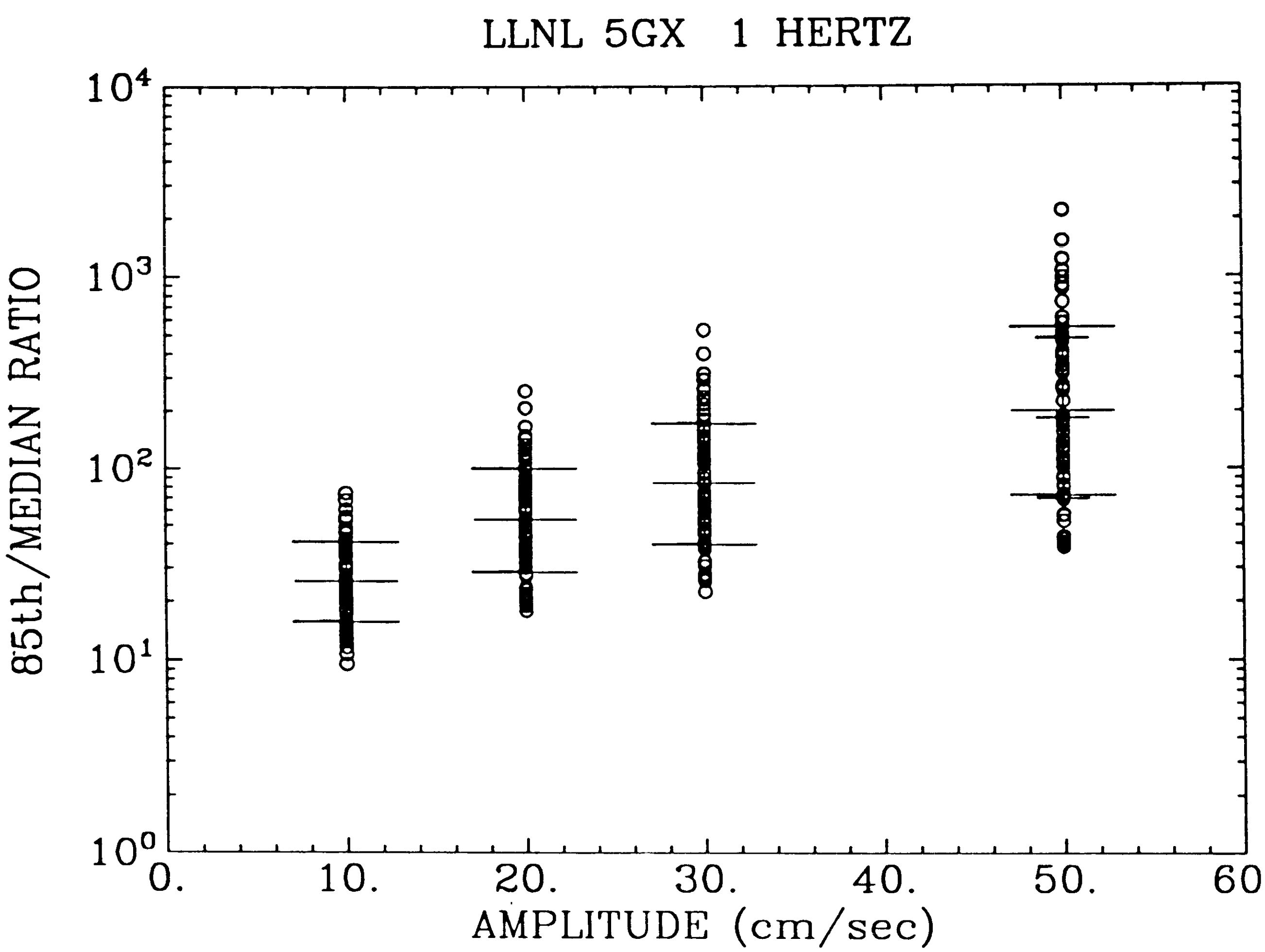

LLNL 4GX 2.5 HERTZ
85th/MEDIAN RATIO
10⁴
10³
10²
10¹
10⁰
0.
10.
20.
30.
40.
50.
60.
AMPLITUDE (cm/sec)


LLNL 5GX 2.5 HERTZ
85th/MEDIAN RATIO
10^4
10^3
10^2
10^1
10^0
0.
10.
20.
30.
40.
50.
60.
AMPLITUDE (cm/sec)



EPRI 1 HERTZ
10^3
10^2
10^1
10^0
85th/MEDIAN RATIO
0.
10.
20.
30.
40.
50.
60.
AMPLITUDE (cm/sec)


LLNL 4GX 1 HERTZ
85th/MEDIAN RATIO
10⁴
10³
10²
10¹
10⁰
0.
10.
20.
30.
40.
50.
60.
AMPLITUDE (cm/sec)


LLNL 5GX 1 HERTZ
10^4
10^3
10^2
10^1
10^0
85th/MEDIAN RATIO
0.
10.
20.
30.
40.
50.
60.
AMPLITUDE (cm/sec)

Appendix D

AN INTERIM RECOMMENDATION FOR DOE USE OF THE LLNL AND EPRI HAZARD CURVES

An Interim Recommendation for DOE Use of the LLNL and EPRI Hazard Curves

C. Allin Cornell
September, 1991

A Report to
J. K. Kimball

For reasons well described in the DOE Seismic Working Group document[1]. "Use of the LLNL and EPRI Probabilistic Seismic Hazard Curves: Interim Position", it is desirable to establish a straight-forward procedure to use the most dependable, stable information provided by both of the two large-scale, state-of-the-art regional seismic hazard analyses conducted by Lawrence Livermore National Laboratory for the Nuclear Regulatory Commission and by the Electric Power Research Institute for the Seismicity Owners Group, a set of electric utilities operating nuclear power plants, in the U. S.

Based on a comparison of results at some 70 EUS sites it is clear that the two studies produce hazard results that are quite similar in terms of their central or median estimates, but quite different in their estimates of the uncertainty about this central estimate, as evidenced by major differences in their 15 percentile, 85 percentile, and mean[2] estimates. Nonetheless there are certain stable trends in these differences. These will be discussed below. This stability suggests that it is feasible to establish a simple procedure for combining the results of the two studies that can be considered applicable at all sites.

For use with UCRL-15910 and DOE's Interim Position document, the objective here is to provide a ground motion measure associated with a prescribed target mean hazard level, e.g., 2×10^{-4}. The procedure will make use of the more consistent, stable parts of the LLNL and EPRI studies, primarily their median hazard estimates. In addition, in order to reflect the uncertainty-induced difference between the median estimate and the higher mean hazard estimate, an additional factor will be developed to modify the median-based estimate. This factor is based on the observed consistencies within and between the studies (e.g., site-to-site, frequency-to-frequency, etc.), coupled with a simple averaging approach.

Some Observed Differences and Consistencies. The "data" used for this study were primarily median and 85 percentile hazard estimates for 70 sites produced both by LLNL and by EPRI for PGA and spectral velocities (at 25, 10, 5, 2.5, and 1 hertz) at a range of

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[1] This report is designed to serve as an attachment to that report, avoiding duplication of text, figures, and tables.

[2] In this case the mean *is* a measure of the degree of uncertainty. The reason is simple. In analyses of rare events, e.g., in the 10^{-3} to 10^{-5} range, it is common that the mean estimate is much larger than the median, e.g., of the order of the 85 percentile, because the uncertainty band spreads over two or more decades and, although often quite symmetrical with respect to the log probability, it is skewed strongly right (upward) on an arithmetic scale.

amplitudes. (These results were prepared by Risk Engineering Inc., under contract to Martin-Marietta Energy Systems, for DOE.)

Let us look first at the "inconsistencies". Figures 2 and 3 in the Interim Position report are typical raw ratios of 85 percentile to median estimates of the hazard for 4 amplitudes of 10 hertz spectral velocity at 70 sites. Note the major differences between the LLNL and EPRI ratios. Nonetheless, the site-to-site variability in these ratios is relatively small; the (indicated) standard deviations are perhaps only 15% to 30% of the median ratio in the amplitude range of primary interest. As shown in Figure 4 of the Interim Position report, this site-to-site variability is explainable in part by soil vs. rock site effects, and a few high "outlier" sites (which contribute significantly to the computed standard deviations) are very often (in the case of EPRI, at least) sites with comparatively very low median hazards estimates, e.g., in the Gulf Coast. Based on this observation of relatively small site-to-site variability in the ratios, we focus on simply the geometric mean (over sites) ratio of 85th percentile to median hazard.

Figures A-1 through A-6 (Interim Position Report) show these ratios versus amplitude for PGA and for several spectral velocities for three cases EPRI, LLNL 4GX and LLNL 5GX ("4GX" and "5GX" is a commonly used notation for LLNL results that contain 4 and 5 ground motion experts, respectively. In the former case, Expert 5 is excluded, for reasons discussed in the Interim Position Report.) We observe, first, that

(1) these ratios are very different among the three cases; herein lies our problem, of course. The LLNL results imply larger estimated uncertainty in the estimates.

(2) the ratios increase rapidly as the frequency decreases (for reasons not yet completely understood, but related in part to the wide divergence among low frequency spectral velocity predictions associated with broad-band prediction schemes versus "random vibration" ground motion prediction schemes).

(3) there is a mild upward trend in the ratios with amplitude; it is stronger for lower frequencies.

On the other hand, with care we can find a somewhat more consistent and helpful picture. First, let us restrict our attention to amplitudes consistent with pga levels in order of 0.2g or less. We shall find these levels are typical of the values of interest for DOE "high hazard" facilities ($2x10^{-4}$ mean annual probability of exceedance) in the EUS. The corresponding spectral velocity levels are roughly 2 cm/sec, 6 cm/sec, 12 cm/sec, 25 cm/sec, 25 cm/sec for 25, 10, 5, 2.5, and 1 hertz respectively. Second, we focus attention on the 4GX results of LLNL (for reasons discussed in the Interim Position Report). Then, under these restriction, we observe:

(1) the ratios are about equal for the PGA and 10 hertz ground motion parameters, having a value of about 3.0 to 4.5 for EPRI and 7 to 9 for LLNL. This suggests that the high frequency end of the spectrum is rather consistently estimated whether via PGA or via the 10 hertz spectral velocity.

(2) the ratio of the ratios, i.e., the ratio of the LLNL ratio (4GX) to the EPRI ratio is very consistent, namely about 2 over the entire frequency range, but

especially from PGA down to 2.5 hertz, where (at the amplitude levels listed above) the ratio is (7/3.5) = 2.0, (6/2.5) = 2.4, (9/4.5) = 2.0, (18/8) = 2.25, and (38/18) = 2.1 for PGA, 25 hertz, 10 hertz, 5 hertz, and 2.5 hertz respectively[3].

We shall use these consistent ratios in the recommendations below.

Next look at the most positive part of the LLNL versus EPRI comparison, the central or median estimates of hazard. These are graphed (for 0.2g PGA) in Figure 4 of the Interim Position Report, and statistics are reported in Table 1 of that document. The conclusion is that these results are remarkably consistent. (A very few sites are shown with a ratio of median hazards of 5 or more; these are predominantly very low hazard Gulf Coast sites). The typical ratio of 2 is, recall, between hazards in the 10^{-3} to 10^{-4} range; this is a difference of only 0.3 in the exponent. (Or, as we shall see below, a factor of only about 20% in the associated PGA.) the implication is that the average (simple or geometric) median hazard at a given PGA or the average PGA at a given (median) hazard is a good representation of both of the studies. In different words, the study-to-study variability in the results is small, particularly in comparison to the uncertainty (as measured by, say, the ratio of 85 percentile to median hazard, where typical values are 4 to 8, as we have seen above). Further, the site-to-site variability in this ratio is relatively small (Table 1, Interim Position Report), imply that this simple conclusion can be accepted for all sites.

Recommended Interim Procedure. Based on the observations above the following procedure is recommended for developing from the two studies, a ground motion spectrum associated with a specified mean hazard level.

Step (1) Focus on the PGA as the ground motion *level* parameter. As seen above the 85/median hazard ratios are consistent at the highest frequencies for the amplitudes of prime interest. There are strong technical reasons to prefer a spectral ordinate for this level or scaling parameter (rather than the PGA), but residual concerns discussed above about the effect of major differences in the ground motion estimation schemes for spectral ordinates, plus tradition, lead us to adopting here the PGA. (The 10 hertz spectral velocity would appear to work equally well and with the same numerical conclusions.)

Step (2) Enter the two studies' median hazard curves for the PGA at the site, at the target hazard level (e.g., 2×10^{-4}). Take the (geometric[4]) average of the two PGA levels. This represents the "dual-study composite" PGA associated with a median hazard equal to the target level. This will be multiplied a factor to

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[3]For the 5GX, the ratios are very similar (about 2) for 5 and 2.5 hertz; they are 1 (surprisingly) for lower frequencies, but they are unfortunately considerably higher (13/3.5) = 3.7 and (16/4.5) = 3.6 for higher frequency cases: PGA and 10 hertz, respectively. The 25 hertz case appears anomalously high.

[4]The two values will virtually always be close enough that the simple average will give almost the same answer.

adjust it to reflect the mean hazard. This factor is found as follows. It is the same value for all sites.

Step (3) Find a composite 85 percentile/median factor by taking the (geometric) average of these ratios from the EPRI and LLNL-4GX results above. Recall that these ratios consistently have a ratio of 2 in the higher frequencies; therefore the geometric average will be $\sqrt{2}$ times the lower (EPRI) 85 percentile/median ratio. The EPRI ratio (for PGA) is 3.0 to 3.5 for amplitudes of 0.2g or less. Let us use the higher value, 3.5, for all amplitudes. The representative, composite factor for 85 percentile/median hazard is, therefore, $\sqrt{2}$ x 3.5 or 5. Note that the simple average would be very similar ((3.5 + 2 x 3.5)/2 = 5.2). This step is the key one in the proposed procedure. It is a major decision to base this "uncertainty factor" on the results for the high frequency end of the spectrum. The decision is based on the concerns already expressed about the extreme values at the low frequency end, plus the generally greater consistency within and between studies at the high frequency end. It is hoped that future studies will permit us to improve upon this step.

Step (4) Find the corresponding mean/median hazard factor. For this step we assume an underlying lognormal distribution for simplicity (LLNL has verified that their uncertainty distributions over hazard are well represented by a lognormal distribution). It is easily shown[5] that for a lognormal distribution a ratio of 85 percentile/median of x implies a mean/median ratio of $\exp\{½(\ln x)^2\}$ or here $\exp\{½(\ln 5)^2\} = 3.6$.

Step (5) Find the PGA multiplier corresponding to this hazard mean/median multiplier. It is well known (based on theory and observation) that hazard curves plot approximately linearly on log-log paper, at least over the range of interest here, i.e., hazard ratios of an order of magnitude or less. This implies H is proportional to y^{-b}, in which H is hazard, y is ground motion level and b is the slope on log-log paper. It follows that for a mean/median hazard ratio of x (e.g., the ratio 3.6 above), the corresponding ratio of ground motion values is $(x)^{1/b}$, e.g., for a mean/median hazard ratio of 3.6 and a b of 3.5, the ratio of corresponding PGA values is $(3.6)^{1/3.5} = 1.44$. This factor should be used to adjust upward the "composite" PGA found in Step 2 above; the lower PGA value is associated with the median estimate of the hazard and the larger value is associated with the mean estimate of the hazard. The slopes of hazard curves in the EUS fall in a relatively narrow range for a given hazard level. This fact has been confirmed by several investigators. R.P. Kennedy suggests that in the 10^{-3} to 10^{-5} hazard range

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[5]Because 85 percentile = (median) $\exp\{\sigma_{\ln H}\}$ and mean = (median) $\exp\{½\sigma_{\ln H}\}$ in which $\sigma_{\ln H}$ is the standard deviation of the log hazard. Solving the first equation for $\sigma_{\ln H}$ in terms of the ratio 85 percentile/median and substituting into the second equation yields the desired mean/median ratio.

this slope[6] varies at most from 3.7 to 2.9. Over this range of b values, the factor above ranges from 1.4 to 1.55, for the suggested hazard ratio of 3.6. We conclude that due to the insensitivity of these results to the observed site-to-site variations, it is satisfactory to simply adopt a single factor, say 1.5 for all cases. In this case, Step 2 is followed immediately by:

Step 3 (revised; replacing Steps 3, 4, and 5 above): Multiply the "composite" PGA corresponding to the median target probability of exceedance by 1.5 to obtain the "composite" PGA corresponding to the target mean probability of exceedance.

Examples of applying this proposed procedure are given in Table 2 of the Interim Position Report.

Note that if LLNL 5GX were to be used as a basis, rather than 4GX, the results change as follows:

The LLNL/EPRI ratio of 2 increases to about 3.7 (see footnote 3). The geometric mean of the two ratios increases from 5 to $(\sqrt{3.7})(3.5)$ or 6.7. The mean/median factor increases from 3.6 to $\exp\{½(\ln 6.7)^2\} = 6.1$. The corresponding factor on the PGA increases from 1.5 to, say, $(6.1)^{1/3.3} = 1.7$.

Finally, it is recommended that this PGA value be used, at least as an interim basis, simply as the "ZPA" (zero period acceleration) at which to anchor either a standard broad band spectral shape, such as that in NUREG 0098, or a site-specific spectral shape (developed by any of several familiar means, properly allowing for local soil conditions). It is suggested that this be a median spectral shape (where median refers to the median of a sample of shapes from a representative suite of ground motion records.) It might be argued that, because this median shape is not being anchored to a spectral ordinate obtained from the seismic hazard analysis but rather to a PGA, it therefore fails to capture the record-to-record variability in the S_v/PGA ratio (D.A.F.) (or "peak-to-valley" variability within a typical rough spectrum). This variability is included in spectral velocity hazard analyses, but when combined with the larger PGA variability the net effect is only a small increase.

[wplet2\doe.rpt]

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[6]Kennedy specifies the slope through the ratio of the PGA at 10^{-5} hazard to the PGA at 10^{-3} hazard, a ratio he calls a_5/a_c. His suggested range for EUS is within 3.5 to 5.0. It is easily shown that $a_5/a_c = (0.01)^{-1/b}$ or $b = 2/\log_{10}(a_5/a_c)$.

Appendix E

OUTLINE OF STEPS TO DEVELOP PSEUDO-MEAN CORRECTION FACTOR

Appendix E

OUTLINE OF STEPS TO DEVELOP PSEUDO-MEAN CORRECTION FACTOR

Development of Pseudo-Mean Correction Factor Following A. Cornell Approach for Peak Acceleration. LLNL 5 represents LLNL hazards results with LLNL-AE5 while LLNL 4 represents LLNL hazard results without LLNL-AE5.

1. Ratio of 85th/median at .2g

	EPRI = 3.34	LLNL 5 - 11.17	LLNL 4 = 7.18

From Figure C1 and McGuire (geometric mean of 85th/median ratio from reactor sites) and from Figures C7 - C9.

at .1g	EPRI - 2.99	LLNL 5 = 10.82	LLNL 4 = 6.84
at .4g	EPRI = 4.55	LLNL 4 = 13.38	LLNL 4 = 8.58

---

2. Take Geometric Average of the above ratios

at .2g	EPRI/LLNL5 Ratio = $(3.34 * 11.17)^{½}$ = 6.11
	EPRI/LLNL4 Ratio = $(3.34 * 7.18)^{½}$ = 4.90
at .1g	EPRI/LLNL5 Ratio = $(2.99 * 10.82)^{½}$ = 5.69
	EPRI/LLNL4 Ratio = $(2.99 * 6.84)^{½}$ = 4.52
at .4g	EPRI/LLNL5 Ratio = $(4.55 * 13.38)^{½}$ = 7.80
	EPRI/LLNL4 Ratio = $(4.55 * 8.58)^{½}$ = 6.25

These are composite LLNL/EPRI 85th/median ratios.

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3. From Cornell if x = 85th/median ratio then mean/median = $e^{½ (\ln x)**2}$

		x	mean/median
at .2g	EPRI/LLNL 5	6.11	5.14
	EPRI/LLNL 4	4.90	3.54
at .1g	EPRI/LLNL 5	5.69	4.53
	EPRI/LLNL 4	4.52	3.12
at .4g	EPRI/LLNL 5	7.80	8.25
	EPRI/LLNL 4	6.25	5.36

These are composite LLNL/EPRI mean/median ratios.

4. From Cornell to translate mean/median hazard ratio to ground motion.

$GM_{ratio} = y^{-1/b}$ where b = slope of hazard curve.

y = mean/median hazard ratio.

We have tabulated ground motion ratios at different probabilities.

From Cornell	$A5/A3 = (.01)^{-1/b}$	b = 2/log (A5/A3)
	$A5/A4 = (.1)^{-1/b}$	b = 1/log (A5/A4)
	$A4/A3 = (.1)^{-1/b}$	b = 1/log (A4/A3)

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5. Summary of Hazard Curves Slope.

A5/A4 = pga at 10^{-5}/pga at 10^{-4}

A4/A3 = pga at 10^{-4}/pga at 10^{-3}

		# of sites	median	mean	r
LLNL	A5/A4	16	2.32	2.28	.18
EPRI	A5/A4	58	2.47	2.61	.54
LLNL	A4/A3	53	2.64	2.64	.19
EPRI	A4/A3	58	3.90	4.12	.93

To arrive at composite estimate use only sites that have both LLNL and EPRI.

Composite	A5/A4	Sites = 13	n=26	mean = 2.44	r = .39
Composite	A4/A3	Sites = 48	n=96	mean = 3.30	r = .91

Compare to geometric average of individual LLNL + EPRI.

Composite A5/A4 = $(2.28 * 2.61)^{-1/2}$ = 2.44

Composite A4/A3 = $(2.64 * 4.12)^{-½}$ = 3.30

Values are the <u>same</u>.

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6. From composite A5/A4 and A4/A3 calculate b at

A5/A4 b = 1/log (2.44) = 2.58
A4/A3 b = 1/log (3.30) = 1.93

7. Take b's from #6 and plug into equation in #4 using the mean/median hazard ratios in #3.

		from #3 mean/median hazard	A5/A4 "b"	A4/A3 "b"	A5/A4 GM_I	A4/A3 GM_I
at .2g	EPRI/LLNL5	5.14	2.58	1.93	1.89	2.34
	EPRI/LLNL4	3.54	2.58	1.93	1.63	1.93
at .1g	EPRI/LLNL5	4.53	2.58	1.93	1.80	2.19
	EPRI/LLNL4	3.12	2.58	1.93	1.55	1.80
at .4g	EPRI/LLNL5	8.25	2.58	1.93	2.26	2.98
	EPRI/LLNL4	5.36	2.58	1.93	1.92	2.39

where GM_r = ground motion ratio (#4)

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8. Cross-complete ground motion ratios to UCRL-15910 (DOE-STD-1020) Hazard Exceedance Prob. & Perf. Prob.

Low Haz. (PC-2)	$Prob_H = 10^{-3}$	$Prob_P = 5 \times 10^{-4}$
Mod. Haz. (PC-3)	$Prob_H = 10^{-3}$	$Prob_P = 10^{-4}$
High Haz. (PC-4)	$Prob_H = 2 \times 10^{-4}$	$Prob_P = 10^{-5}$

Low and moderate should be based on A4/A3. High should be based on A5/A4.

$_H$ = hazard

$_P$ = performance

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9. What ground motion levels should correction be based on? What <u>median</u> levels of ground motion represent DOE sites at above prob.

SEE TABLE 2

at 10^{-2} median ranges from 0.03 to .10g.

at 2×10^{-4} median ranges from 0.07 to .22g.

Note trend from #7 the lower the "g" value the smaller ground motion ratio.

Thus for low and moderate hazard, use .10g values from #7 at A4/A3.

For high hazard use .20g values from #7 at A5/A4.

10. Summary correction factors (GM_r)

without LLNL-AE5	Low and moderate	= 1.80
	High	= 1.63*
with LLNL-AE5	Low and moderate	= 2.19
	High	= 1.89

* This value has been rounded for actual use and is referred to in the body of the standard as 1.65.

CONCLUDING MATERIAL

Review Activities	Preparing Activity
DP	DP-62
NE	
EM	
NP	Project Number
NS	FACR-0005
ER	
EH	