USE OF EXPERT ELICITATION AT THE U.S. NUCLEAR REGULATORY COMMISSION

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"Seldom is the development of an answer to a difficult problem the work of any single individual."[1]

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[1] U.S. NUCLEAR REGULATORY COMM'N, OFFICE OF NUCLEAR REGULATORY RESEARCH, NUREG–1624, TECHNICAL BASIS AND IMPLEMENTATION GUIDELINES FOR A TECHNIQUE FOR HUMAN EVENT ANALYSIS (ATHEANA) xxix (2000) (ADAMS Accession No. ML003719212) [hereinafter NUREG-1624]. ADAMS is the NRC's automated document retrieval system and can be accessed by the public at http://wba.nrc.gov:8080/wba/. Information regarding how to use ADAMS is available at http://www.nrc.gov/reading-rm/adams.html. NUREGs, such as the one cited immediately above, are guidance documents issued by the NRC staff and are not binding on either the Commission or licensees. Curators of the Univ. of Mo., CLI-95-8, 41 N.R.C. 386, 397 (1995); U.S. NUCLEAR REGULATORY COMM'N, OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS, DIVISION OF WASTE MANAGEMENT, NUREG–1563, BRANCH TECHNICAL POSITION ON THE USE OF EXPERT ELICITATION IN THE HIGH-LEVEL RADIOACTIVE WASTE PROGRAM 9 (1996) (ML033500190) [hereinafter NUREG-1563] ("BTP's [branch technical positions] are not substitutes for regulations, and compliance with them is not required."). *See also* Int'l Uranium (USA) Corp., CLI-00-1, 51 N.R.C. 9, 19 (2000) ("Like NRC NUREGs and Regulatory Guides, NRC Guidance documents are routine agency policy pronouncements that do not carry the binding effect of regulations."). *But see* Yankee Atomic Elec. Co., CLI-05-15, 61 N.R.C. 365, 375 n.26 (2005) (citation omitted) ("[G]uidance is 'at least implicitly endorsed by the Commission' and therefore 'is entitled to correspondingly special weight.'");

ABSTRACT

Science abounds with unanswerable questions—those for which necessary data or even the necessary scientific methods are simply unavailable. Yet, for a variety of legal and political reasons, many such questions still require an answer. One way the Nuclear Regulatory Commission has cut this Gordian Knot has been through expert elicitation—a formal, highly structured, and well-documented process for obtaining the judgments of multiple experts. Yet, at least within the litigious context of nuclear energy regulation, this useful and creative process has been almost completely ignored by scholars, judges, and even the NRC's own Commissioners. This article examines the Nuclear Regulatory Commission's use of the expert elicitation process and provides an overview of both the process and the history of expert elicitation at the Commission from 1996 forward, and concludes with recommendations for its use of this process in the future. Although these questions, recommendations, topics, and sources are directed specifically to the Nuclear Regulatory Commission, they should also be useful to other agencies that likewise employ expert elicitation as a means of addressing otherwise-unanswerable questions.

Private Fuel Storage, L.L.C., CLI-01-22, 54 N.R.C. 255, 264 (2001) ("Where the NRC develops a guidance document to assist in compliance with applicable regulations, it is entitled to special weight."), *petition for review held in abeyance sub nom.* Devia v. Nuclear Regulatory Comm., 492 F.3d 421 (D.C. Cir. 2007).

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Science abounds with unanswerable questions—those for which necessary data or even the necessary scientific models are simply unavailable. Yet, for a variety of legal and political reasons, some of these unanswerable questions still require answers. Take, for instance, the proposed Yucca Mountain high-level nuclear waste repository—how do you calculate the likelihood of different levels of seismic activity in the Yucca Mountain vicinity over the next 10,000 years?

One way the Nuclear Regulatory Commission (NRC) has cut this Gordian Knot has been through expert elicitation—"a formal, highly structured, and well-documented process for obtaining the judgments of multiple experts."[2] Yet, at least within the litigious context of nuclear energy regulation, this useful and creative process has been almost completely ignored by scholars, judges, and even the NRC's own Commissioners. Only one law-related journal article has directly addressed the use of expert elicitation in the context of nuclear-related technical issues, and that article is now a dozen years old.[3] Likewise, just one Federal court decision refers, even in passing, to this same topic.[4] And until quite recently, expert elicitation has only occasionally garnered the attention of the NRC's own Commissioners. For instance, even to this day, the Commissioners have never referred to the expert elicitation process in their adjudicatory decisions[4a].

This lack of attention at the highest level of the NRC began to change in early 2011, when Commissioner George Apostolakis

[2] NUREG-1563, *supra* note 1, at 3–4, A-1. *Cf.* U.S. NUCLEAR REGULATORY COMM'N, OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS, NUREG–1804, YUCCA MOUNTAIN REVIEW PLAN: FINAL REPORT at p. 3-7 (2003) (ML032030389) [hereinafter NUREG-1804] (defining expert elicitation as "[a] formal process through which expert judgment is obtained."). *See* notes 72-79 and accompanying text for an explanation of the distinctions between "expert elicitation" and "expert judgment."

[3] *See* Patricia Fleming, *Examining Recent Expert Elicitation Judgment Guidelines: Value Assumptions and the Prospects for Rationality*, 12 RISK: HEALTH, SAFETY AND ENVIRONMENT 107, *passim* (2001) (discussing the NRC's use of expert elicitation at Yucca Mountain). Although other articles in law reviews and law-related journals have alluded to expert elicitation in contexts different from nuclear safety, those articles' references to elicitation were merely incidental to their focus on other topics.

[4] Cook v. Rockwell Int'l Corp., 580 F. Supp. 2d 1071, 1093 (D. Colo. 2006).

[4a] *See generally* U.S. Dep't of Energy (High-Level Waste Repository), LBP-09-29, 70 N.R.C. 1028, 1032 (2009) (citing only NUREG–1563 for guidance on the process of expert elicitation because no adjudicatory decisions discussing expert elicitation were available for citation).

proposed that the agency reexamine its use of expert judgment and expert elicitation.[5] His stated objective was to ensure that the NRC's expert elicitation "incorporates lessons learned from past major studies and is applied consistently in regulatory decision making throughout the Agency."[6] Commissioner Apostolakis explained that expert elicitation could, for instance, "play an important role in the resolution of difficult regulatory challenges including cyber security, digital instrumentation and control, small modular reactors, and material aging issues."[7] He listed three advantages to using expert judgment/elicitation:

> [1: to] promote a more consistent and transparent basis for regulatory decision making . . . [2: to] provide clear and consistent guidance to licensees and staff for both formally utilizing expert judgment and for reviewing licensing actions that are based, at least in part, on expert judgment [and 3: to] improve the efficiency of Agency planning by identifying and prioritizing resources that are commensurate with the significance of the safety or security issue(s) and degree of reliance on expert judgment in the associated regulatory decision making.[8]

Yet he also pointed out that expert elicitation would be inappropriate for some cases, such as those requiring consultation with only a handful of subject-matter experts.[9]

With favorable comments, the other four Commissioners

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[5] Memorandum from Comm'r Apostolakis to Chairman Jaczko, Comm'r Svinicki, Comm'r Magwood & Comm'r Osterdorff, COMGEA-11-0001, Utilization of Expert Judgment in Regulatory Decision Making 3 (Jan. 19, 2011) (ML110200139) [hereinafter COMGEA-11-0001]. This memorandum is an example of a Commissioner-generated "Action Memorandum" (COM), a "written exchange" between Commissioners used as a vehicle for decision-making. U.S. NUCLEAR REGULATORY COMM'N, INTERNAL COMMISSION PROCEDURES, at II-1, II-6 to II-9 (2011), *available at* http://www.nrc.gov/about-nrc/policy-making/internal.html. *See infra* notes 83-90 and accompanying text (explaining the differences between the terms "expert judgment" and "expert elicitation").

[6] COMGEA-11-0001, *supra* note 5, at 1. *See also* SECY-11-0172, Response to Staff Requirements Memorandum COMGEA-11-0001, Utilization of Expert Judgment in Regulatory Decision Making, 1 (Dec. 13, 2011) (ML112020602) [hereinafter SECY-11-0172]. This document is an example of a "SECY Paper" that is provided to the Commission from NRC staff members and contains information on "[p]olicy, rulemaking, and adjudicatory matters, as well as general information" to be considered by the Commission. INTERNAL COMMISSION PROCEDURES, *supra* note 5, at II-1. *See generally id.* at II-1 to II-5.

[7] COMGEA-11-0001, *supra* note 5, at 2.

[8] *Id.* at 3.

[9] *Id.* at 2–3. *See infra* Part II.C.3.e (describing a Department of Energy (DOE) approach lying somewhere between Commissioner Apostolakis' referenced non-use of elicitation when there are only a handful of experts and the typical, full-scale elicitation process).

unanimously supported his request and the five Commissioners collectively issued a directive that the NRC staff prepare a plan to develop such guidance.[10] In responding nine months later, the staff did not immediately comply with the Commissioners' directive but instead recommended that the Commission take no such action at this time, due to both the "relatively high resource implications" of such a project and the satisfactory nature of current NRC guidance regarding expert judgment.[11]

But the Commissioners were unmoved. Commissioner Apostolakis supplemented his earlier explanation as to why the revision of the 1996 guidelines was a wise idea:

> Although a number of different approaches have been used in several NRC-sponsored studies, a structured, agency-wide process with corresponding implementation guidance is currently lacking. Its availability will formalize the utilization of expert judgment, incorporate lessons learned from past NRC studies and ensure that elicitation processes are applied consistently in regulatory decision making throughout the Agency. . . . In cases of lack of experiential evidence, expert judgment methods are employed to produce information regarding the state of knowledge on particular issues. It

[10] Memorandum from Annette L. Vietti-Cook, Sec'y, to R. W. Borchardt, Exec. Dir. for Operations, Staff Requirements – COMGEA-11-0001 – Utilization of Expert Judgment in Regulatory Decision Making (Mar. 15, 2011) (ML110740304). Regarding the other Commissioners' favorable comments, *see* U.S. NUCLEAR REGULATORY COMM'N, COMMISSION VOTING RECORD: RESPONSE TO STAFF REQUIREMENTS MEMORANDUM COMEGA-11-0001, UTILIZATION OF EXPERT JUDGMENT IN REGULATORY DECISION MAKING (2011) VR-COMGEA-11-0001 (ML110740555) [hereinafter 2011 COMMISSION VOTING RECORD], Response Sheet from Chairman Gregory B. Jaczko (March 2, 2011) ("I appreciate Commissioner Apostolakis making the Commission aware of the increasing importance of expert elicitation . . . , and I agree that the development of guidance to ensure the consistent utilization of expert judgment by the staff is worthwhile."); *id.* at Response Sheet from Comm'r Svinicki (Feb. 28, 2011) ("I approve Commissioner Apostolakis' proposal that the Commission direct the staff to provide a plan for the development of guidance for the application of expert judgment."); *id.* at Response Sheet from Comm'r Magwood (Feb. 22, 2011) ("I agree with Commissioner Apostolakis that the NRC would benefit from formal guidance to assist the staff in choosing the method for obtaining and utilizing expert judgment and support his recommendation for the staff to provide a plan for the development of that guidance."); *id.* at Response Sheet from Comm'r Ostendorff (Feb. 11, 2011) ("I agree with Commissioner Apostolakis' objective to incorporate lessons learned from the use of expert judgment in past major studies. I believe that major lessons learned from across the nuclear sector, if conveyed in a useful and practical manner, could improve the confidence level and consistency of future regulatory decision-making that rely heavily on expert judgment.").

[11] SECY-11-0172, supra note 5, at 7.

> is well known, however, that there is not one universally accepted way to elicit and process expert judgments. What the decision makers need to know is what methods have been used, what has not been done (thus imposing limitations on the results), and, as appropriate, the results of sensitivity studies using alternative methods.[12]

His fellow Commissioners again offered quite favorable comments in support of the re-examination of the 1996 staff guidance document.[13] At this stage, the only point of difference among the Commissioners was the issue of when the staff should begin work on the revised guidance. Commissioner Ostendorff and Chairman Jaczko would instruct the staff to begin the revision as soon as possible, as long as it does not interfere with higher-priority projects[14] "such as implementation of the Fukushima Dai-ichi lessons learned recommendations, completion of fire protection NFPA 805 licensing amendment

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[12] U.S. NUCLEAR REGULATORY COMM'N, COMMISSION VOTING RECORD: RESPONSE TO STAFF REQUIREMENTS MEMORANDUM COMEGA-11-0001, UTILIZATION OF EXPERT JUDGMENT IN REGULATORY DECISION MAKING (FEB. 7, 2012) VR-COMGEA-11-0001 (ML12038A164) [hereinafter 2012 COMMISSION VOTING RECORD], Response Sheet from Comm'r Apostolakis (Jan. 9, 2012).

[13] *See id.* at Response Sheet from Chairman Gregory B. Jaczko (Jan. 30, 2012) (agreeing that "improvements to the existing expert judgment approaches used by the NRC can be made, and that doing so is a worthwhile endeavor."); *Id.* at Response Sheet from Comm'r Svinicki (Jan. 23, 2012) ("I agree with Commissioner Apostolakis, however, that the availability of guidance will ultimately save resources and has the potential to further enhance the transparency of our application of expert judgment, further enhancing the credibility of NRC's technical work."); *Id.* at Response Sheet from Comm'r Magwood (Jan. 13, 2012) ("Expert elicitation is an important tool to help guide regulatory action in cases in which uncertainty exists due to insufficient data. Expert elicitation has been beneficial in areas such as modeling seismic hazard and damage and risk analysis associated with nuclear waste storage. . . . This is an important and timely initiative."); Response Sheet from Comm'r Ostendorff (Jan. 13, 2012) ("I applaud Commissioner Apostolakis for taking this initiative. His approach will further advance our regulatory decision-making with improved guidance, and in a broader sense, advance nuclear safety. . . . A core mission of NRC research is to further the state-of-knowledge in nuclear safety and provide the best available regulatory guidance. Synthesizing diverse practices in the use of expert opinion facilitates knowledge management and is an essential building block to sustain further advancement in the discipline. To this end and with relatively minor resources, this project has the potential to achieve that core research mission.").

[14] *See id.* at Comments of Comm'r Ostendorff ("[T]he staff should prioritize and resource this work in accordance with the Planning, Budgeting, and Performance Management process . . . ."); *See also id.* at Comments of Chairman Jaczko ("[T]he staff should ensure that this work once started will not displace or impede work of higher safety importance . . . .").

reviews, or resolution of generic issues."[15] Commissioner Magwood expressed similar concerns, but would have the staff report back to the Commission with a "revised plan, schedule, and resource estimate."[16]

The Commissioners ultimately resolved their differences and on February 7, 2012, issued a Staff Requirements Memorandum rejecting the staff's recommendation and instructing it to proceed with the revision of the 1996 guidelines: "The staff should pilot draft guidance in the Level 3 PRA [probabilistic risk assessment] project[17] that will require expert judgment elicitation in areas such as human reliability analysis and severe accident analysis. The pilot process will help inform the guidance and should identify areas for improvement."[18] The Commission further directed the staff to provide various status reports to "leverage their efforts by referencing the existing library of accepted expert elicitation guidance and information," and finally to "consult informally with [other Federal organizations,] . . . . the national laboratory community, and FFRDCs [Federally Funded Research

[15] 2012 COMMISSION VOTING RECORD, *supra* note 12, at Comments of Chairman Jaczko.

[16] *Id.* at Comments of Comm'r Magwood.

[17] In 2011, the Commission directed the NRC staff to "plan for and perform a new full-scope comprehensive site Level 3 PRA for an operating plant." Memorandum from Annette L. Vietti-Cook, Sec'y, to R.W. Borchardt, Exec. Dir. For Operations, Staff Requirements – SECY-11-0089 – Options for Proceeding with Future Level 3 Probabilistic Risk Assessment (PRA) Activities (Sept. 21, 2011) (ML112640419). A "full-scope comprehensive site Level 3 PRA is [defined as] a PRA that includes a quantitative assessment of the public risk from accidents involving all site reactor cores and spent nuclear fuel that can occur during any plant operating state, and that are caused by all initiating event hazards (internal events, fires, flooding, seismic events, and other site-specific external hazards)." Memorandum from R.W. Borchardt to the Commissioners – SECY-11-0089 – Options for Proceeding with Future Level 3 Probabilistic Risk Assessment Activities, 1 n.2 (July 7, 2011) (ML11090A041). Of the three different levels of PRA, a Level 3 PRA provides the "most complete representation of plant risk." Response Sheet from Chairman Gregory B. Jaczko on SECY-11-0089 – Options for Proceeding with Future Level 3 Probabilistic Risk Assessment Activities (Aug. 29, 2011) (ML112500080). The NRC's most recent Level 3 PRA project resulted in the issuance of NUREG-1150 (published in 1990 and discussed briefly in the text accompanying notes 97-100).

[18] Staff Requirements – SECY-11-0172 – Response to Staff Requirements Memorandum COMGEA 11-0001, Utilization of Expert Judgment in Regulatory Decision Making, (Feb. 7, 2012) (ML120380251). *See* NUREG-1563, *supra* note 1, at iii (outlining the NRC's use of expert judgment in 1996 and setting the standard for its use thereafter). *See also* 2012 Commision Voting Record, *supra* note 12, at Commissioner Magwood's vote sheet (Jan. 13, 2012) (listing pre-2012 NRC documents related to expert elicitation).

and Development Centers to learn more about] the views of and practices in place within other organizations."[19]

On June 8, 2012, the NRC Staff provided the Commissioners with a 24-month proposed schedule for the preparation of these guidelines.[20] And on September 13, 2012, the NRC staff informed the Commissioners that it "will use the Level 3 PRA project for the pilot application of staff guidance on expert judgment elicitation."[21] Meanwhile, during that 24-month period, the NRC staff has continued to indicate the relevance of expert elicitation;[22] has continued to refer regularly to elicitations—past, current, and potential;[23] and has even issued a Final Report on a

[19] COMGEA-11-0001, *supra* note 5; 2012 COMMISSION VOTING RECORD, *supra* note 12, at Comments of Comm'r Magwood.

[20] Staff Requirements – SECY-11-0172 – Response to SRM [Staff Requirements Memorandum] COMGEA-11-0001, Utilization of Expert Judgment in Regulatory Decision Making (June 8, 2012) (ML121420096); Revised Project Plan (attached to June 8, 2012 memorandum) (ML121600291). The staff gave itself room for "slippage," stating that it might need to "adjust the completion date . . . to respond to potential changes in available resources or the Level 3 PRA project schedule"—a wise move, given the current political environment. *Id.* at 3.

[21] Potential Uses of the Full-Scope Site Level 3 PRA Project 3 (Sept. 13, 2012) (ML12202B172).

[22] *See*, *e.g.*, Public Meeting Summary: Workshop on Probabilistic Flood Hazard Assessment (PFHA), at 3 (Feb. 28, 2013) (on file with author) ("an expert elicitation strategy similar to the Senior Seismic Hazard Analysis Committee (SSHAC) approach would help address [three technical issues]"); Interim Staff Guidance, Japan Lessons-Learned Project Directorate, JLD-ISG-2012-05: Guidance for Performing the Integrated Assessment for External Flooding (Revision 0) at 70-71 (Nov. 30, 2012) (ML12311A214) (in examining flooding scenarios that involve manual actions, "[i]t may not be possible to collect actual baseline values for some actions, so [e]xpert elicitation techniques may also be used to estimate timing values"); Branch Technical Position on Concentration Averaging and Encapsulation 95 (Rev. 1 2012) (ML121170418) ("[T]he staff believes that expert elicitation may be useful for addressing site-specific intruder analyses for averaging constraints on waste").

[23] *See*, *e.g.*, Memorandum from Dennis Andrukat, Fire Protection Engineer, Fire Protection Branch, Division of Risk Assessment, Office of Nuclear Reactor Regulation, to Alexander R. Klein, Chief, Fire Protection Branch, Division of Risk Assessment, Office of Nuclear Reactor Regulation, Meeting Summary of January 15, 2013 Public Meeting regarding Incorporation of NUREG/CR-7150, Circuit Analysis Results into Fire Protection Interim Guidance, at 2 (Feb. 7, 2013) (ML13024A311) ("Industry stakeholders and NRC staff agreed to work with the NUREG/CR-7150, Volume 2, expert elicitation panel to help determine the classification."); Draft Forecast of Contract Opportunities: Fiscal Year 2013, at 37 (released Jan 31, 2013) (ML13032A407) (referring to a potential contract opportunity involving expert elicitation); Workshop on Probabilistic Flood Hazard Assessment (PFHA): Program [Agenda] 8 (Jan. 29 - 31, 2013) (ML13024A242) (listing as one of the questions a panel would address: "Is expert elicitation a viable approach" for probabilistic flood hazard assessment);

joint expert elicitation jointly sponsored by the NRC and the Electric Power Research Institute (EPRI).[24]

This article provides an overview of both the process and the history of expert elicitation at the NRC from 1996[25] to its current time in the limelight.[26] First, it will address in detail the definition and elements of expert elicitation, and will draw attention to major issues and challenges associated with this process. Second, it will examine specific NRC experiences with expert elicitations—both conducting its own and reviewing those of DOE. And finally, it will set out the advantages and

Transcript of Hearing, Advisory Committee On Reactor Safeguards (ACRS), Reliability And PRA Subcommittee (Jan. 16, 2013) (ML13035A148), at 34 (Ms. Xing: "next week—we are going to have an expert elicitation workshop for listening to IEEE"), 37 ("hopefully, by the end of March [2013], . . . we [will] finish expert elicitation"); NUREG-1921 EPRI/NRC-RES Fire Human Reliability Analysis Guidelines: Final Report, p. 4-24, p. 4-43, p. 6-9, pp. C-3, C-8, C-11, C-22 (July 2012) (ML12216A104) (referring to the earlier ATHEANA expert elicitation); Draft Report for Comment, Electrical Cable Test Results and Analysis During Fire Exposure (ELECTRA-FIRE): A Consolidation of Three Major Fire-Induced Circuit and Cable Failure Experiments Performed Between 2001 and 2011, NUREG-2128, xiii, 6-2 (June 2012) (ML12166A028) (citing a 2002 expert elicitation concerning actuation of cable fires). *See also* Advisory Committee on Reactor Safeguards, Review and Evaluation of the Nuclear Regulatory Commission Safety Research Program: A Report to the U.S. Nuclear Regulatory Commission, NUREG-1635 (Vol. 10) (Oct. 2012) (ML12311A417), at 15 (expert elicitation studies are underway to examine "effective methods for failure (fault) modes and effects analysis (FMEA) for regulatory assurance for complex logic in DI&C systems."), 20 ("a structured PRA expert elicitation process will examine the available data and develop conditional probabilities and uncertainties for various ac and dc circuit failure modes that may be caused by fire-induced cable damage").

[24] Final Report, Joint Assessment of Cable Damage and Quantification of Effects from Fire (JACQUE-FIRE) (NUREG/CR-7150, Vol. 1; EPRI 1026424) (Oct. 2012) (ML12313A105).

[25] Although this article cites and briefly discusses several pre-1996 elicitations or elicitation-related documents, the issuance of two documents in 1996 makes that year a logical starting point for this examination of expert elicitation: (i) the completion of the first of DOE's voluminous elicitation reports and (ii) the NRC staff's issuance of its definitive guidance on elicitation. *See* GEOMATRIX CONSULTANTS INC. & TRW, PROBABILISTIC VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, NEVADA 1-1 (1996) (ML003743285) [hereinafter VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN] ("To ensure that a wide range of perspectives was considered in the hazard analysis, individual judgments were elicited from members of an expert panel."); NUREG-1563, *supra* note 1 (providing guidance on the use of expert judgment for the NRC). Relevant portions of this guidance are reproduced in the Appendix, *infra.*

[26] *See* COMGEA-11-0001, *supra* note 5 (outlining the Commission's current objective of uniformity in the use of expert judgment).

disadvantages of expert elicitation, present a series of questions and recommendations for the NRC's consideration regarding how to refine its own version of elicitation, and provide a separate series of suggested topics and sources for further research. Although these questions, recommendations, topics and sources are directed specifically to the NRC, they should also be useful to other agencies, such as the Environmental Protection Agency, which are likewise using, or considering the use of, expert elicitation as a means of addressing otherwise-unanswerable questions.

I. WHAT IS EXPERT ELICITATION

As noted above, the NRC staff has defined "expert elicitation" as "a formal, highly structured, and well-documented process for obtaining the judgments of multiple experts."[27] The NRC has used this process in a variety of situations, such as rulemaking, adjudication, and technical analysis not associated with

[27] NUREG-1563, *supra* note 1, at A-1. The NRC staff has described expert elicitation as a "well-recognized technique for quantifying phenomenological knowledge when modeling approaches or data are insufficient." 1 U.S. NUCLEAR REGULATORY COMM'N, NUREG-1829, ESTIMATING LOSS-OF-COOLANT ACCIDENT (LOCA) FREQUENCIES THROUGH THE ELICITATION PROCESS v (2008) (Vol. 1: ML080630013; Vol. 2: ML081060300) [hereinafter 1 NUREG-1829 and 2 NUREG-1829, respectively]. *See also* 1 NUREG-1829 at xv (reiterating that expert elicitation is a well-recognized technique "when data or modeling approaches are insufficient"); *Id.* at p. 1-10 ("Expert elicitation is a formal process for providing quantitative estimates of the frequencies of physical phenomena when the required data is sparse and when the subject is too complex to adequately model. [Elicitation is particularly useful where] scientific uncertainty about [the issue under consideration] is so large that, in the absence of adequate data, validated models or computer codes cannot be developed."); Notice of Availability of Draft Report for Comment: "Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process," NUREG-1829, 70 Fed. Reg. 57,901, 57,902 (Supplemental Proposed Rule Oct. 4, 2005) (describing expert elicitation as "well-recognized for quantifying phenomenological knowledge when data or modeling approaches are insufficient"); Risk-Informed Changes to Loss-of-Coolant Accident Technical Requirements, 74 Fed. Reg. 40,006, *passim* (Supplemental Proposed Rule Aug. 10, 2009) (discussing the expert elicitation process used in a rulemaking proceeding); Notice of Public Workshop on Draft Report for Comment: "Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process," NUREG-1829, 70 Fed. Reg. 62,352, 62,352 (Oct. 31, 2005) (describing use of expert elicitation for developing "LOCA frequency estimates"); Jennifer Kuzma et al., *Evaluating Oversight Systems for Emerging Technologies: A Case Study of Genetically Engineered Organisms*, 37 J.L. MED. & ETHICS 546, 554 (2009) ("Expert elicitation is an evidence gathering methodology in the face of high uncertainty and little information.").

rulemaking or adjudication.[28] The NRC staff's principle guidance document regarding expert elicitation is NUREG-1563, which specifically addresses DOE's use of the expert elicitation process to support the *Yucca Mountain* application but, according to the staff, would be equally applicable to any future DOE application for another high-level radioactive waste repository site.[29] In NUREG-1563, the staff states that the process is appropriate under any of the following circumstances:

> (a) Empirical data are not reasonably obtainable, or the analyses are not practical to perform;
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> (b) Uncertainties are large and significant to a demonstration of compliance;
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> (c) More than one conceptual model can explain, and be consistent with, the available data; or
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> (d) Technical judgments are required to assess whether bounding assumptions or calculations are appropriately conservative.[30]

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[28] In addition, the Commission has twice cited an expert elicitation by the Electric Power Research Institute (EPRI) in *Federal Register* notices seeking comments on generic communications addressing fire safety issues. *See* Proposed Generic Communication; Post-Fire Safe-Shutdown Circuit Analysis Spurious Actuations, 70 Fed. Reg. 60,859, 60,859 (Oct. 19, 2005); Proposed Generic Communication; Clarification of Post-Fire Safe-Shutdown Circuit Regulatory Requirements, 70 Fed. Reg. 25,622, 25,623 (May 13, 2005) These two NRC documents refer to ELEC. POWER RESEARCH INST., REPORT NO. 1006961, SPURIOUS ACTUATION OF ELECTRICAL CIRCUITS DUE TO CABLE FIRES: RESULTS OF AN EXPERT ELICITATION (2002) [hereinafter EPRI Report].

[29] NUREG-1563, *supra* note 1, at D-6. ("[I]t is the staff's view that [the expert elicitation guidance to the Yucca Mountain Project] would apply, generically, to any potential repository licensed by NRC."). Although expert elicitation had been used in several prior instances in the context of nuclear regulation (*see infra* parts II.A and II.B), NUREG-1563 was the first formal NRC guidance document on the subject; in drafting NUREG-1563, the NRC staff drew upon those prior instances as well as various NRC resource documents to help formulate its position statements. *See* Availability of Final Branch Technical Position on the Use of Expert Elicitation in the High-Level Waste Program, 61 Fed. Reg. 67,354, 67,355 (Dec. 20, 1996) (referencing the lack of a formal "guidance" document on the use of expert elicitation and relying on its previous use in other NRC programs for guidance); Availability of Draft Branch Technical Position on the Use of Expert Elicitation in the High-Level Waste Program, 61 Fed. Reg. 7568, 7569 (Feb. 28, 1996) (citing the lack of agency guidance on the use of expert elicitation).

[30] NUREG-1563, *supra* note 1, at 15; NUREG-1804, *supra* note 2, at 2.5-61. As Professor Sheila Jasanoff observes in the analogous context of environmental regulation, "[i]n the absence of techniques for formally assessing expert judgments, decisionmakers might be forced either to wait for nearly unattainable levels of objective scientific proof or to demand, under political pressure, that pollution sources prove the safety of their emissions as a precondition of operating." SHEILA JASANOFF, THE FIFTH BRANCH: SCIENCE

The first of these appears most frequently in the NRC's and DOE's discussions of expert elicitation.[31] The staff provides three examples of this circumstance:

> (i) the site characteristics important to waste isolation would be irreversibly compromised by extensive data collection in such a way that could potentially disqualify the site; (ii) it is infeasible or impossible to collect data over the temporal or spatial scales appropriate to adequately address a particular issue; and (iii) the cost of collecting the comprehensive suite of data may be prohibitive.[32]

The staff emphasized that the customary modes of "acquisition and analysis of physical data should be the *primary* manner in which licensing information is collected,"[33] but acknowledged that "many considerations may preclude the collection of such information necessary for licensing."[34] When such considerations are present, expert elicitation or other forms of expert judgment[35] may be used "to complement and supplement the data obtained" through more traditional means.[36] In the same guidance

ADVISORS AS POLICYMAKERS 273 n.50 (1990).

[31] *See* NUREG-1563, *supra* note 1, at 5–6, 12, 20 (suggesting the use of expert judgment where empirical data is unavailable).

[32] *See id.* at 21. *See id.* at 20–22 (elaborating on the instances where expert judgment would be necessary due to the lack of empirical data).

[33] *Id.* at 2 (emphasis added). Expert elicitation should be used only "when other means of obtaining requisite data or information have been thoroughly considered and it has been concluded that such means are not[, without more,] practical to implement." *Id.* at 1, 19.

[34] *Id.* at 2.

[35] For an explanation of the differences between these two terms, *see infra* text accompanying notes 83-90.

[36] NUREG-1563, *supra* note 1, at 1. *See also* GEOMATRIX CONSULTANTS INC. & TRW, WASTE FORM DEGRADATION AND RADIONUCLIDE MOBILIZATION EXPERT ELICITATION PROGRAM p. 2-2 (1998) (ML003757634) [hereinafter Waste Form Expert Elicitation] ("[E]xpert judgment is not a substitute for data; it is the process by which data are evaluated and interpreted."); GEOMATRIX CONSULTANTS INC. & TRW, SATURATED ZONE FLOW AND TRANSPORT EXPERT ELICITATION PROJECT p. 2-2 (1997) (same) (ML120480324) [hereinafter 1997 Saturated Zone Flow Expert Elicitation]; IVAN G. WONG & J. CARL STEPP, PROBABILISTIC SEISMIC HAZARD ANALYSES FOR FAULT DISPLACEMENT AND VIBRATORY GROUND MOTION AT YUCCA MOUNTAIN, NEVADA p. 2-2 (1998) (ML032130141) [hereinafter Seismology Expert Elicitation]. For examples of non-nuclear projects that use expert elicitation in conjunction with other modes of data collection, *see* Kuzma, *supra* note 27, at 572 ("Through evaluation in three different ways (interviews, quantitative expert elicitation, and historical literature analysis), we were able to critically examine GEOs oversight and more broadly generate hypotheses about relationships among features and outcomes of oversight."); Jordan Paradise et al., *Evaluating Oversight of Human Drugs and Medical Devices: A Case Study of the FDA and Implications*

document, NUREG-1563, the staff announced its expectation that DOE would consider "cost, schedule, resource availability, and other programmatic factors" when determining whether it could obtain the needed information through more preferable means than expert elicitation.[37]

The NRC staff also emphasized the importance of transparency to the expert elicitation process, i.e., the ability of someone outside the process (i) to see all the relevant information that led to the elicitation's conclusions, (ii) to follow all communications amongst the panel members during their deliberations so that the outsider can understand the basis for the conclusions, (iii) to see how the panel used those same conclusions to reach the ultimate outcome of the elicitation, and (iv) to understand why the license applicant chose to use expert judgment rather than the more objective information-gathering methods.[38] Such transparency should, according to the staff, enhance both its own and the public's confidence in DOE's high-level waste program.[39]

The expert elicitation process, as outlined in NUREG-1563, is comprised of nine formal steps:

1. Definition of objectives
2. Selection of experts
3. Refinement of issues and problem definition
4. Assembly and dissemination of basic information
5. Pre-elicitation training

for Nanobiotechnology, J.L. MED. & ETHICS 598, 598 (2009) (referring to the use of "a method of expert elicitation . . . combined with the existing literature, case law, and regulations"); Jae-Young Choi & Gurumurthy Ramachandran, *Review of the OSHA Framework for Oversight of Occupational Environments*, 37 J.L. MED. & ETHICS 633, 635 (2009) (referring to the "review of the relevant literature, historical analysis, group consensus, and quantitative expert and stakeholder elicitation"); Susan M. Wolf et al., *Gene Therapy Oversight: Lessons for Nanotechnology*, 37 J.L. MED. & ETHICS 659, 671 (2009) (referring to a combination of "expert elicitation [and] literature review").

[37] NUREG-1563, *supra* note 1, at 19. The NRC staff lists more preferable means: "gathering additional field or labogratory data . . . undertaking additional theoretical analyses[,] . . . [and] altering the compliance demonstration strategy" in order to lessen or remove the need to resolve an issue that would otherwise be a subject for which expert elicitation would be necessary. *Id.* at 20.

[38] *See id.* at 19 (suggesting that documentation be provided with expert judgments so as to allow "external examination of what the judgments were, how the judgments were arrived at (their basis), how the judgments were used, and why the judgments were used instead of obtaining objective information (e.g., obtaining the needed data).").

[39] *See id.* at 20.

6. Elicitation of judgments
7. Post-elicitation feedback
8. Aggregation of judgments
9. Documentation[40]

The NRC staff, however, did not consider these nine steps as carved in stone.[41] Rather, the staff intended that they constitute merely a "general framework" that could be "customized or revised" to suit the needs of the elicitation at issue.[42] The staff in

[40] *Id.* at 15–18, 22–30. The NRC staff's general description of its proposed expert elicitation protocol is included as the Appendix to this article. More recently, the staff published two brief outlines of the nine steps. NUREG-1804, *supra* note 2, at pp. 2.5-62 to 2.5-65. For slight variations on the nine-step approach, *see* U.S. NUCLEAR REGULATORY COMM'N, NUREG/CR-6372, RECOMMENDATIONS FOR PROBABILISTIC SEISMIC HAZARD ANALYSIS: GUIDANCE ON UNCERTAINTY AND USE OF EXPERTS, vol. 1, at 41–48 (1997) (ML080090003) [hereinafter NUREG/CR-6372] (listing seven steps); *id.* at 70–78 (listing seven steps plus peer review); *id.* at 106–14 (listing only six steps). The staff describes the approaches of NUREG-1563 and NUREG/CR-6372 as "very similar" and "essentially the same." U.S. NUCLEAR REGULATORY COMM'N, NUREG-2107, TECHNICAL EVALUATION REPORT ON THE CONTENT OF THE U.S. DEPARTMENT OF ENERGY'S YUCCA MOUNTAIN REPOSITORY LICENSE APPLICATION pp. 20-1 to 20-2 (2011) (ML111990436) [hereinafter NUREG-2107].
In *Yucca Mountain*, DOE described how it implemented each of these nine steps in its expert elicitations regarding volcanology, seismology, and hydrology. *See* U.S. DEP'T OF ENERGY, OFFICE OF CIVILIAN RADIOACTIVE WASTE MGMT., DOE/RW-0573, YUCCA MOUNTAIN REPOSITORY LICENSE APPLICATION: SAFETY ANALYSIS REPORT pp. 5.4-3 to 5.4-12 (2008) (ML081560572, ML090710110) [hereinafter SAR]. Specifically, see the descriptions regarding the expert elicitations on volcanology (§ 5.4.1), seismology (§ 5.4.2), and hydrology (§ 5.4.3).
The sections of the SAR cited in this article are found in five separate documents, each of which has a different ADAMS Accession Number. Chapter 2, Introduction is found at ML090700898; Chapter 2, Part 2 is found at ML090700908; Chapter 2.3.6 is found at ML090710071; Chapter 2.3.9 is found at ML081560543; and Chapter 5, Cover - Page 5.11-18 of the SAR is found at both ML081560572 and ML090710110. To avoid confusion, this article diverges from standard citation format and instead includes the appropriate ADAMS Accession Number in each footnote where an SAR section is cited. The ADAMS Accession Number that is cited in a footnote will apply to all subsequent SAR citations in the same footnote, unless otherwise indicated.

[41] *See infra* notes 212-14, 217-18, 249-51, 306-07 and accompanying text (regarding the approval of DOE's expert elicitations despite their variations from the specific steps enunciated in NUREG-1563).

[42] NUREG-1563, *supra* note 1, at 22. For instance, an expert elicitation process used to address seismic source characterization would presumably differ from an elicitation process regarding ground motion. *See* NUREG/CR-6372, *supra* note 40, at 69. And, indeed, DOE's expert elicitations regarding these two issues did differ somewhat. *See infra* notes 236-37, 244-45 and accompanying text. Moreover, the NRC staff has observed that expert elicitation is not appropriate in all risk assessment contexts. *See* 2 NUREG-1829, *supra* note 27, at v ("[B]ecause the alternative aggregation methods can

fact expected that even the sequence of steps would be altered to fit those needs and that several of the steps would "proceed or . . . be initiated concurrently, subject to repeated iterations and opportunities for feedback from the subject-matter experts."[43]

The NRC staff concluded that formal elicitation procedures could help to "ensure that expert judgments are *well-documented* and that the technical reasoning used to reach those judgments is *openly displayed for review*."[44] According to the staff, such documentation and openness offer numerous advantages. For instance, the staff observed that "[a] structured, *thoroughly documented procedure* allows reviewers to reconstruct the logic and events involved in the elicitation and use of expert judgment."[45] Presumably, in using the word "reviewers," the staff was referring to any or all of the following: peer reviewers, the NRC administrative judges who conduct the prehearing and hearing stages of the *Yucca Mountain* adjudication, the NRC Commissioners, and any Federal judges or justices who consider any appeals of final NRC actions in *Yucca Mountain*.

The NRC staff also listed the following additional advantages to expert elicitation: "(a) to improve decision-making associated with public policy; (b) to enhance communication; (c) to facilitate peer review, appraisal, and acceptance; (d) to recognize and minimize biases in expert judgment; (e) to indicate the current state of knowledge about important technical and scientific matters; and (f) to provide a basis for updating that knowledge."[46] Further, the staff explained that, when properly conducted, "formal [expert] elicitation [47] can reveal a wide range of

lead to significantly different results, a particular set of LOCA frequency estimates is not recommended for all risk-informed applications. *The purposes and context of the application must be considered when determining the appropriateness of any set of elicitation results*.") (emphasis added). *See also supra* note 9 and accompanying text.

43 NUREG-1563, *supra* note 1, at 22.

44 *Id.* at 8 (emphases added). The initial absence of sufficient documentation to support DOE's expert elicitations was of considerable concern to the NRC staff. *Id.* at D-2.

45 *Id.* at 22.

46 *Id.* at 29–30.

47 Occasionally, writers have used the terms "formal elicitation" and "informal elicitation." *See*, *e.g.*, *id.* at 7 ("[T]he staff has relied on informal elicitations . . . ."); *id.* at 8 ("[The] staff believes that formal elicitation procedures . . . can help ensure that expert judgments are well-documented."); VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at 2-4 (referring to "formal expert elicitation"); U.S. NUCLEAR REGULATORY COMM'N, OFFICE OF NUCLEAR SAFETY & SAFEGUARDS, ISSUE RESOLUTION STATUS REPORT;

scientific and technical interpretations, thereby exposing (and possibly quantifying) the uncertainties in estimates concerning repository siting, design, and performance attributable to limitations in the state of technical knowledge."[48]

According to the NRC staff, expert elicitation can "also help groups of [subject-matter] experts resolve differences in their estimates by providing a common scale of measurement and a common vocabulary for expressing their judgments."[49]

But despite all these advantages, expert elicitation is hardly a panacea.[50] If not carefully structured and managed, the panel

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KEY TECHNICAL ISSUE: EVOLUTION OF THE NEAR-FIELD ENVIRONMENT 141, 169-70, 220, 223, 231, 234 (2000) (ML003746694) (referring to "informal expert elicitation"). The addition of "formal" to the term "expert elicitation" is unnecessary because expert elicitation is, by its very nature, a formal process. For the same reason, the addition of "informal" to the term is inaccurate. Presumably, the latter refers to expert judgment exclusive of elicitation. Some other writers have used the term "formal expert judgment," the meaning of which is unclear. VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at § 2.1.1, at p. 2-4. *See generally infra* notes 83-90 and accompanying text (discussing the distinction between expert judgment and expert elicitation). The NRC staff, in a recent guidance document, has sought to distinguish the agency's expert judgment practice from traditional expert elicitation—referring to the former as "multiple-expert assessment". NUREG-2117, Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies xv-xvi (Rev. 1, Apr. 2012) (ML12118A445).

Likewise, as will be seen throughout this article, the nuclear community does not use uniform terminology when referring to the different players in an expert elicitation. For example, DOE uses the terms "evaluators," "panel members," "experts," and "subject-matter experts" when referring to the individuals who serve on an expert elicitation panel. *See*, *e.g.*, SAR, *supra* note 40, at 5.4-1 (ML081560572, ML090710110), (using the term "experts"); *id.* at 5.4-3 (using the term "panel members"); VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 1-4 (ML090700898) (using the term "subject matter experts"); *id.* at p. 2-11 (referring to "evaluator"). This article uses only the terms "subject-matter expert" and "panel member" because those two terms are both unambiguous and more comprehensible to people unfamiliar with expert elicitation. For different names that can be used to describe the support team that facilitates an expert elicitation, *see infra* notes 66–82 and accompanying text; *infra* note 73 and accompanying text (stating two different terms for a resource expert). The general term "expert" can refer not only to resource experts (or implementers) but also to normative experts, generalists, facilitators, and technical specialists. *See infra* notes 62-82 and accompanying text.

[48] NUREG-1563, *supra* note 1, at 8.

[49] *Id.*

[50] *See generally* U. S. NUCLEAR REGULATORY COMM'N, SENIOR SEISMIC HAZARD ANALYSIS COMMITTEE, SEISMIC SOURCE CHARACTERIZATION WORKSHOP App. H (1997) (ML080090004) [hereinafter SEISMIC SOURCE CHARACTERIZATION WORKSHOP] (providing critique of Seismology Expert Elicitation) (This source is Vol. 2 of NUREG/CR-6372).

may be subject to "dominance by a single (outspoken) individual".[51] In addition, the process can be more expensive and time-consuming[52] because it involves more people than the solicitation of a single expert's judgment.[53] Moreover, it can be difficult to represent a panel's wide diversity of expert opinions about technical issues.[54]

Furthermore, the results of expert elicitation may be less defensible in adjudications because no single expert "owns" the result.[55] As the NRC's Advisory Committee on Nuclear Waste (ACNW) pointed out, there may be difficulties in a licensing board admitting an expert elicitation report into evidence if not all subject matter experts are available to participate at an evidentiary hearing.[56] Exhibits such as expert reports have typically required an expert witness to "sponsor" them for admission into the administrative record.[57] Yet one subject-matter expert (or, for that matter, less than all subject-matter experts) may be deemed by a board to be insufficient "to represent, as his or her [or their] own, the full range of the

[51] *Id.* at H-3.

[52] 1 NUREG-1829, *supra* note 27, at p. 1-10 (discussing higher cost and time requirements); Certified Minutes of the ACRS [Advisory Committee on Reactor Safeguards] Reliability and PRA [Probabilistic Risk Assessment] Subcommittee Meeting on Level 3 PRA on March 6, 2012, at 97, attached to Memorandum to ACRS Members from John Lai, Senior Staff Engineer, Technical Support Branch, Advisory Committee on Reactor Safeguards (Sept. 18, 2012) (NRC Staff member Alan Kuritzky opines that the use of expert elicitation in the Full-Scope Site Level 3 PRA Initial Project Plan "could have deleterious effects on our schedule.") (Mar. 6, 2012) (ML120820526); Full-Scope Site Level 3 PRA Initial Project Plan 3-4 n.10 (May 11, 2012) (same) (ML121320310). For instance, the expert elicitation associated with the Loss of Coolant Accident Rulemaking (described and discussed *infra* Part II.D) lasted from February 2003 until April 2008. *See* 1 NUREG-1829, *supra* note 27, at p. 3-8 and second title page).

[53] SEISMIC SOURCE CHARACTERIZATION WORKSHOP, *supra* note 50, at H-3 (indicating that several people must be involved in an expert elicitation). 1 NUREG-1829, *supra* note 27, at p. 1-10 (citing, as drawbacks of formal elicitation, the time and resources required); Interview with Commissioner George Apostolakis (Mar. 8, 2012) [hereinafter Apostolakis Interview] (using NUREG-1150 as an example, the Commissioner observed that expert elicitation can be quite an expensive process) (referring to U.S. NUCLEAR REGULATORY COMM'N, OFFICE OF NUCLEAR REGULATORY RESEARCH, 1 NUREG-1150, SEVERE ACCIDENT RISKS: AN ASSESSMENT FOR FIVE U.S. NUCLEAR POWER PLANTS, FINAL SUMMARY REPORT (1990) (ML040140729) [hereinafter NUREG-1150]).

[54] VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-1.

[55] SEISMIC SOURCE CHARACTERIZATION WORKSHOP, *supra* note 50, at H-3.

[56] NUREG-1563, *supra* note 1, at F-4.

[57] *Id.*

technical arguments contained in the . . . elicitation."[58]

Pursuant to the guidance set forth in NUREG-1563, subject-matter experts in an expert elicitation panel should be individuals who:

> (a) possess the necessary knowledge and expertise;
>
> (b) have demonstrated their ability to apply their knowledge and expertise;
>
> (c) represent a broad diversity of independent opinion and approaches for addressing the topic(s) in question;
>
> (d) are willing to be identified publicly with their judgments; and
>
> (e) are willing to publicly disclose all potential conflicts of interest.[59]

The NRC staff's guidance document goes on to state a preference, though not a requirement, that the expert also have "at least some rudimentary knowledge of both decision-making theory and statistics."[60] The staff also recommends that the subject-matter experts be selected, at least in part, from a group of individuals nominated (i) by sources outside the NRC (e.g., professional and academic societies, national laboratories, private industry, representative public interest groups, knowledgeable federal agencies and international organizations), (ii) by "recognized peers" in the nominees' specialized field, and (iii) based on reviews of the scientific literature.[61]

The NRC staff in NUREG-1563 proposed that expert elicitation participants include not only subject-matter experts but also four other kinds of "support team" participants. The first is the generalist, who "understands the context in which the results of the expert elicitation will be used, guides the structure of the elicitation to produce the needed results, provides relevant

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[58] *Id.*

[59] *Id.* at 15 (citation omitted). *See also id.* at 23. This is the second step of NUREG-1563's nine-step protocol. *See id.* at 22–25 (discussing panel member selection); NUREG-1804, *supra* note 2, at pp. 2.5–62, 2.5–64 (discussing panel member selection). In some instances, few experts will be available to serve on an expert elicitation panel. The sponsor of the elicitation may therefore need to turn to experts who are affiliated with the sponsor, either as employees or contractors. *See* Fleming, *supra* note 3, at 113–14 (noting that "internal experts" may be turned to when insufficient external experts are available, and pointing out the conflicts of interest that inherently exist in such situations). In those circumstances, it is particularly important that the affiliated experts disclose their conflicts of interest. *Id.*

[60] NUREG-1563, *supra* note 1, at 15 n.13.

[61] *Id.* at 23, 24. For a variation on this approach to selecting panel members, *see* Kuzma, *supra* note 27, at 555.

information and documentation to the subject-matter experts, and helps to train them."[62] The generalist also plays the role of translator amongst panel members from different disciplines or areas of expertise.[63] In this regard, the generalist must "not only know enough of the language of [the different experts'] cultures to act as an interpreter, but [must] also understand enough of their world-views or paradigms to encourage them" to exchange ideas.[64]

The second is the normative expert, who has "training and experience in statistics, decision analysis, and probability encoding" and whose main function is to "structure the . . . elicitation and train the subject-matter experts in probability encoding."[65] Statistics is particularly important in scientific and technical expert elicitations because the issues that those panels address often involve the likelihood of a particular event occurring within a particular time period.[66] Other issues may

[62] *Id.* at 3. *See also id.* at 15, 23 (discussing the role of the "generalist"). The pre-elicitation training of the subject matter experts (Step 5) includes:

(a) Familiarization with the subject matter;

(b) Familiarization with the elicitation process;

(c) Education in uncertainty and probability encoding and the expression of expert judgment, using subjective probability;

(d) Practice in formally stating judgments and clearly identifying their associated assumptions and rationales; and

(e) Identification of biases that could unduly influence judgments.

NUREG-1804, *supra* note 2, at pp. 2.5-62, 2.5-64. Commissioner Apostolakis observes that (c) is often the most difficult element in which to train scientists because they simply are not used to dealing in probabilities. Apostolakis Interview, *supra* note 53. Regarding (e), the Commissioner likewise points out that any expert will be biased in obvious ways, such as towards their employer, and/or more subtle ways. *Id.*

[63] *See* Emma Fauss et al., *Using Expert Elicitation to Prioritize Resource Allocation for Risk Identification for Nanosilver*, 37 J.L. MED. & ETHICS 770, 771 (2009) (suggesting that the differences between experts that must work together in expert elicitation may be bridged by using an "agent" to facilitate communication).

[64] *Id.*

[65] NUREG-1563, *supra* note 1, at 3. *See also id.* at 23 (adding psychology to the list of the normative expert's areas of training and experience). For a detailed description of the normative expert's role, *see* NUREG/CR-6372, *supra* note 40, at 29–31 (using the term "TFI" ("Technical Facilitator-Integrator") to include "normative expert"); SEISMIC SOURCE CHARACTERIZATION WORKSHOP, *supra* note 50, at H-5 to H-6. Because few individuals would have all the different kinds of expertise needed to be the sole normative expert, an elicitation panel will likely include more than one normative expert. *Id.* at H-5; NUREG/CR-6372, *supra* note 40, at 106.

[66] NUREG-1563, *supra* note 1, at 4.

include "the value of a parameter to be used in a model" and "the relative merits of alternative conceptual models."[67] The staff explains that generalists and normative experts are essential to a successful elicitation because the process "is not a 'do it yourself' activity" but instead "requires experienced practitioners to conduct the exercise."[68]

Third, an elicitation support team requires at least one "resource expert" or "implementer" who handles logistics and mailings, takes technical notes at the meetings, etc.[69] The resource expert can be a technical expert in his or her own right, but would not be a subject-matter expert for purposes of the elicitation.[70] Because of the technical nature of the elicitation's subject matter, the resource expert should be well-versed in the subject at issue.[71]

Regarding these first three support team participants, neither the terms nor the specific roles of "generalist," "normative expert," and "resource expert" are carved in stone. Some elicitations have combined the roles, others have not used one or more of the terms, and still others have used alternative terminology such as "Methodology Development Team,"[72] "facilitation team,"[73] "Technical Integrator,"[74] or "Technical Facilitator/Integrator."[75] The important point here is that, for an

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[67] *Id.* at 4.

[68] 2 NUREG-1829, *supra* note 27, at B-5.

[69] NUREG/CR-6372, *supra* note 40, at 106. *See also id.* at 25.

[70] *See id.* at 25, 73 (explaining that resource experts is not "elicited" for his expertise because his role in the elicitation process is different).

[71] *Id.* at 106.

[72] VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at pp. 1-3 to 1-4. The members of the Volcanology Expert Elicitation's Methodology Development Team were responsible for "developing a strategic plan, facilitating workshops, eliciting members of the expert panel, performing calculations, . . . documenting methodology and results[,] . . . . reviewing the progress of the study[,] and recommending mid-course adjustments to ensure that the study met its objectives." *Id.* at p. 1-4. *See also* GEOMATRIX CONSULTANTS, INC. & TRW, SATURATED ZONE FLOW AND TRANSPORT EXPERT ELICITATION PROJECT p. 1-4 (1998) (ML031640590) [hereinafter 1998 Saturated Zone Flow Expert Elicitation].

[73] Seismology Expert Elicitation, *supra* note 36, at p. 2-1.

[74] VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at pp. 2-4 to 2-5. *See id.* at pp. 2-11 to 2-12 (describing the role of a technical facilitator/integrator).

[75] *Id.* at pp. 2-11 to 2-12:

> The role of technical facilitator/integrator . . . is key to facilitating the interactions among the experts, eliciting the expert judgments, and ultimately integrating the assessments into a single quantitative result . . . .

expert elicitation to succeed, the members of its support team must collectively play all three roles.[76]

The fourth and final member of a support team is the "technical specialist"—an expert who presents data, interpretations, or training to the subject-matter experts during workshops or field trips, but who is not a member of the elicitation panel.[77]

Before moving to an examination of the expert elicitation process, it is important to distinguish between expert elicitation and three related concepts – "expert judgment," "peer review," and conventional consensus-building. It is particularly important to distinguish between "expert elicitation" and "expert judgment"—given the loose use of the terms. [78] The former is a subset of the latter, although the latter term is sometimes inaccurately used in lieu of the former. The NRC staff has defined "expert judgment" as "information, provided by a technical expert, in his or her subject matter area of expertise, based on opinion, or on a belief based on reasoning."[79] The staff has also explained that "expert judgment does not create knowledge [but] rather . . . 'synthesizes disparate and often conflicting sources of information to produce an integrated

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> The facilitator is a technical individual who is responsible for facilitating this interaction by: providing for proper preparation by the experts, ensuring that two-way communication occurs during discussions, promoting technical challenge of ideas, providing a hazard focus to the technical discussions, defusing tensions and personal confrontations, leading the elicitations, and ensuring complete documentation by the experts. The 'integrator' role . . . refers to the process of aggregating the assessments of the panel into an overall probability distribution.

See also id. at p. 2-5 (describing the role of a technical facilitator/integrator as "facilitat[ing] the interactions of multiple experts and elicit[ing] their interpretations to represent the community distribution").

[76] To avoid confusion, this article uses only the term "support team," except in quotations that use other terminology.

[77] VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at pp. 1-4, 2-11. Resource experts may also serve as technical experts and make presentations to the subject-matter experts. *See* NUREG/CR-6372, *supra* note 40, at 25, 73 (noting that resource experts, who may have "expertise in particular methodologies or procedures of use to the evaluators" can make presentations to share this material with the subject-matter experts).

[78] For instance, the NRC staff has criticized DOE for confusing these two terms. *See* NUREG-1563, *supra* note 1, at E-1. Commissioner Apostolakis prefers the phrase "expert judgment elicitation" rather than "expert elicitation" – because the agency elicits the experts' judgment rather than the experts themselves. Apostolakis Interview, *supra* note 53.

[79] *Id.*

picture.'"[80] Expert elicitation can be distinguished from "expert judgment" in two ways. First, the former is a formal approach while the latter is informal,[81] "often implicit and undocumented."[82] Second, the former involves a panel of experts who specialize in a variety of fields while the latter generally involves only one subject-matter expert.[83]

Further, expert elicitation has the following advantages over the judgment of a single subject-matter expert:

> Expert elicitation is a structured process which enhances . . . accuracy, consistency, credibility, and thus acceptability compared to informal, less-structured processes. The emphasis on a structured decomposition of the issues improves accuracy and credibility, thus making the results more acceptable to the stakeholders. Expert elicitation reduces the likelihood of bias and enhances the consistency and comparability of the results. The emphasis on documentation leads to improved scrutiny and acceptance of the results.[84]

Moreover, expert elicitation is distinguishable from "peer review." The latter has many of the same attributes as expert elicitation, such as disclosure of panelists' potential conflicts, documentation of the decision-making, and the use of expert judgment.[85] But it differs in one crucial respect. Elicitation leads or contributes to the creation of a scientific opinion or the solution to a problem, while peer review seeks expert judgment "regarding the soundness and quality" of an existing or proposed scientific opinion or solution.[86] In at least two instances, the NRC has obtained external peer review of a specific elicitation

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[80] *Id.* (quoting S.C. Hora, *Acquisition of Expert Judgment: Examples from Risk Assessment*, 118 J. OF ENERGY ENGINEERING 136, 136–48 (1993)).

[81] *Id.* at 3, A-1 (describing expert elicitation as "formal" and "highly structured" and describing expert judgment as "informal").

[82] VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-2.

[83] NUREG-1563, *supra* note 1, at 3 (describing expert judgment as "information . . . provided by a technical expert" and describing expert elicitation as a "process whereby judgments, usually of multiple experts, are obtained").

[84] 1 NUREG-1829, *supra* note 27, at p. 1-10.

[85] *Id.* Some have characterized peer review as a kind of "formal application[] of expert judgment." VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-3. *See also* Fleming, *supra* note 3, at 110 (describing peer review as a "formal, well-documented, explicit, form of expert judgment"). The author finds this odd given that expert elicitation is already defined as a "formal" process. *See supra* notes 2, 27.

[86] *See* NUREG-1563, *supra* note 1, at 5.

process.[87]

Finally, expert elicitation differs from conventional consensus-building in several significant respects. Although both involve groups of experts who collectively address issues, the "classic consensus-building processes" are designed to achieve agreement amongst the experts,[88] while expert elicitation is designed to aggregate the opinions of multiple subject-matter experts who represent diverse viewpoints of the scientific community as a whole.[89] For instance, DOE emphasized to its subject-matter experts throughout the entire elicitation process that disagreements among the members were both "expected and accepted"[90]—a position completely incompatible with the goal of

[87] *See* 2 NUREG-1829, *supra* note 27, at xxv-xxvi (regarding risk-informed changes to loss-of-coolant accident technical requirements); VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 1-6 (tbl. 1-1), p. 2-10, p. 2-19 (regarding "participatory peer review" in the volcanology expert elicitation). In the latter document, DOE drew a distinction between "participatory peer review," where the peer reviewer conducted an ongoing review throughout the elicitation, and "late-stage peer review," which occurs at or near the end of the elicitation, usually after submittal of the draft final report. *Id.* at p. 2-19.

[88] NUREG/CR-6372, *supra* note 40, at 33.

[89] *See id.* at 35 ("[T]he primary objective . . . is not capturing the judgment of any individual expert . . . nor even capturing the composite judgment of any specific subset of experts (including the panel). . . but rather . . . capturing as best possible the composite judgment of the overall scientific community of informed experts."). The aggregator can, but is not required to, assign equal "weight" to each participant in an expert elicitation. *See* VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at pp. 2-5, 2-34. For the most part, DOE took this approach in the elicitation upon which it relied in its Yucca Mountain application. *See infra* notes 204, 252-53, 272, 325, 351, 382 and associated text. By contrast, the aggregator may "weigh" the panel members' conclusions and choose to give disproportionately greater or lesser weight to some conclusions. The aggregator may choose to engage in this "weighing" (as opposed to "equal weighting") in order to develop an assessment she or "he believes best captures the range of views and uncertainties." VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2–5. At times, problems have occurred during studies involving multiple experts where applying equal weight was inappropriate:

> [E]xperts playing the role of a proponent and being unwilling to evaluate alternative interpretations; outlier experts whose interpretation is extreme relative to the larger technical community and may be overrepresented on a small expert panel; insufficient expert interaction such that experts misunderstand the hypotheses presented by others; uneven access to pertinent data sets such that the experts are relying on different data to arrive at their interpretations without knowledge of other data; and insufficient feedback such that the experts are not aware of the significant issues or the relative impact of each part of their assessments.

Id. at p. 2-18.

[90] SAR, *supra* note 40, at p. 2.2-94 (ML090700908).

consensus-building. Elicitation avoids the risk that a consensus is more the result of negotiation and strong personalities than it is the result of "diversity of education, experience and reasoning within a group."[91] Expert elicitation also avoids "the risk of understating the appropriate range of uncertainty by suppressing discussion of differences and focusing on points of agreement."[92]

II. INSTANCES WHERE THE NRC USED, OR REVIEWED AN APPLICANT'S USE OF, THE EXPERT ELICITATION PROCESS

A. Probabilistic Risk Assessment

The NRC's first use of expert elicitation began in the mid-1980's, when the agency was updating a 1975 assessment of the severe accident risk at five nuclear power plants.[93] Several years into the assessment, during the late 1980's, the staff applied "a formal protocol to elicit expert judgment in areas of the risk studies [of the five plants] where little or no operational data existed."[94] The elicitation involved seven panels of experts performing complete probabilistic risk assessments for each of the five plants.[95]

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[91] NUREG/CR-6372, *supra* note 40, at 33.

[92] *Id.*

[93] *See* NUREG-1563, *supra* note 1, at 5 (explaining the early history of expert elicitation at the NRC).

[94] *Id.* at 6 (referring to the elicitation that culminated in the issuance of NUREG-1150).

[95] VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-6. Oddly, NUREG-1150 lists the membership of only six panels, whose panelists numbered from six to eleven. *See* NUREG-1150, *supra* note 53, at xviii-xix. Neither the NRC nor DOE appears to be concerned about panels with this small a number of subject-matter experts. *See id. See also* sources cited *infra* note 107 (using sixteen experts for a measurable atmospheric dispersion and deposition); *infra* note 154 (using ten experts for an assessment on volcanology); *infra* note 224 (using eighteen seismic experts and seven ground motion experts for an assessment on seismology); *infra* note 300 (using five experts to address saturated zone flow transport); *infra* note 333 (using a panel of six experts for a waste form study); *infra* note 358 (using seven experts for an unsaturated zone flow study); *infra* note 398 (using twelve experts for the LOCA study). It is worth noting that seventeen is a more typical number of panelists. *See* Kuzma, *supra* note 27, at 556 (also giving a range of 5-20 experts). Some authors who are experienced in expert elicitation consider fifteen subject-matter experts to be so small a number as to call the elicitation's conclusions into question. *See* Susan Bartlett Foote, *Commentary: Evaluating Oversight of Human Drugs and Medical Devices*, 37 J.L. MED.& ETHICS 629, 631 (2009) (describing the use of

In the early 1990s, the staff reviewed and modified the expert elicitation process used in the late 1980s, to make it both "more formal and rigorous, by the identification nine discrete process steps" in the expert elicitation process (steps that were eventually memorialized in NUREG-1563).[96] Shortly thereafter, the Commission's Office of Nuclear Regulatory Research and the Commission of European Communities jointly used an expert elicitation panel of sixteen international experts "to develop a library of uncertainty distributions for selected consequence parameters . . . [regarding] measurable atmospheric dispersion and deposition."[97]

B. Probabilistic Seismic Hazards Assessment

In the mid-1980s, the NRC sponsored a study of seismic risk at 69 reactor sites.[98] The study was conducted by Lawrence Livermore National Laboratory (LLNL).[99] At roughly the same

only fifteen experts as a "limitation" and questioning the validity of its results); *see also* Jordan Paradise et al., *Developing U.S. Oversight Strategies for Nanobiotechnology: Learning from Past Oversight Experiences*, 37 J.L. MED. & ETHICS 688, 696–97 (2009) ("Even in the case studies with [20] respondents, the sample size is still fairly small, although other studies in the literature using expert elicitation report similar samples sizes."). DOE's Probabilistic Volcanic Hazard Analysis for Yucca Mountain also offers brief descriptions of other nuclear-related expert elicitations: (i) an expert elicitation that "assess[ed] the long-term radionuclide releases from the Waste Isolation Pilot Plant (WIPP), an underground radioactive waste repository in southeastern New Mexico"; (ii) an expert elicitation examining "uncertainties associated with the earthquake potential of the Cascadia subduction zone and associated ground motions at a nuclear power plant site in western Washington"; (iii) expert elicitations examining the seismic risks associated with the New Production Reactor Program for both the Idaho National Engineering Laboratory and the Savannah River Site; (iv) an expert elicitation estimating the future climate in the Yucca Mountain area; and (v) a study demonstrating a methodology for "evaluating fault displacement at the Yucca Mountain repository using expert elicitation." VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at pp. 2-6 to 2-7.

[96] NUREG-1563, *supra* note 1, at 6.

[97] *Id.* at 6 (citing U.S. NUCLEAR REGULATORY COMM'N & COMM'N OF EUR. CMTYS., NUREG/CR-6244, PROBABILISTIC ACCIDENT CONSEQUENCE UNCERTAINTY ANALYSIS: DISPERSION AND DEPOSITION UNCERTAINTY ASSESSMENT (1994)). A Westlaw search in March 2013 indicates that NUREG/CR-6244 is the only expert elicitation to which the Federal courts have explicitly referred in their published decisions, at least in the context of nuclear-related technical issues. *See* Cook v. Rockwell Int'l Corp., 580 F. Supp. 2d 1071, 1093 (D. Colo. 2006) (citing NUREG/CR-6244).

[98] NUREG-1563, *supra* note 1, at 6 (discussing seismic hazard study).

[99] *Id.*; NUREG/CR-6372, *supra* note 40, at 2–3, 162 (referring to Bernreuter, D. L., J. B. Savy, R. W. Mensing, & J. C. Chen, 1989, Seismic Hazard

time, EPRI conducted a similar study of 56 reactor sites in the same regions.[100] Although both studies used expert elicitation and largely the same sets of data, they arrived at significantly different results.[101]

A subsequent examination of these two studies suggested that the difference in results was attributable, at least in significant part, to the way in which "elicited information was aggregated in the respective elicitation processes."[102] The support team for the EPRI elicitation arranged the expert panel into six teams, each with a range of expertise.[103] It then conducted workshops on technical issues, and each team independently arrived at its own "consensus estimates of the uncertainties associated with seismic source characterizations and documented the technical basis for [each team's] assessments."[104] By contrast, the NRC-sponsored study elicited expert judgments from individual panel members rather than from teams, did not conduct workshops or other events at which the experts could interact, and did not document the technical basis for the conclusions of the individual panel members.[105]

Because these two studies yielded such different answers to the same seismological questions, the NRC, DOE, and EPRI developed a detailed methodology for conducting such

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Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains, Report NUREG/CR-5250, vols. 1-8, prepared by Lawrence Livermore National Laboratory for the U.S. Nuclear Regulatory Commission); VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-6.

100 *See* NUREG 1563, *supra* note 1, at 6, 34 (referring to RISK ENGINEERING, INC., WOODWARD-CLYDE CONSULTANTS, INC., GEOMATRIX CONSULTANTS, INC., & THE CYGNA CORPORATION, SEISMICITY OWNERS GROUP/ELECTRIC POWER RESEARCH INSTITUTE, SEISMIC HAZARD METHODOLOGY FOR THE CENTRAL AND EASTERN UNITED STATES [FINAL REPORT], (July 1986)); NUREG/CR- 6372, *supra* note 40, at 2–3; VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-6; Seismology Expert Elicitation, *supra* note 36, at p. 2-2.

101 NUREG-1563, *supra* note 1, at 6; NUREG/CR-6372, *supra* note 40, at 3.

102 NUREG-1563, *supra* note 1, at 6. *See* NUREG/CR-6372, *supra* note 40, at 3 ("[T]here was a strong feeling in the PSHA [probabilistic seismic hazard analysis] community that procedural issues rather than technical earth-sciences issues *per se* were an important reason for the differences."); SAR, *supra* note 40, at p. 5.4-2 (noting after examination of the studies that "the process used to conduct an expert elicitation can have a significant effect on the results of the elicitation") (ML081560572, ML090710110). *See also* NUREG/CR-6372, *supra* note 40, at 104 (outlining the procedural differences).

103 VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-6.

104 *Id.*

105 *Id.*

elicitations.[106] The resulting final guidance document was NUREG/CR-6372.[107]

C. Yucca Mountain Adjudication

1. General Observations

The only adjudicatory proceeding where expert elicitation played a significant role was the *Yucca Mountain* adjudication.[108] As the NRC staff has explained, "[n]early every aspect of [the Yucca Mountain] site characterization and performance assessment . . . involve[d] significant uncertainties."[109] To address those uncertainties, DOE conducted eight expert elicitations in the *Yucca Mountain* proceeding. DOE relied upon three of these expert elicitations to support its application's conclusions regarding: (i) volcanology,[110] (ii) seismology,[111] and (iii) saturated zone flow and transport.[112] DOE also conducted expert

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[106] SAR, *supra* note 40, at p. 5.4-2 (ML081560572, ML090710110).

[107] *Id.*

[108] In one other adjudication, a Licensing Board referred in passing to the process of expert elicitation, but the process did not appear to play a significant role in at least the adjudicatory portion of that proceeding. *See* Duke Cogema Stone & Webster, LBP-05-4, 61 N.R.C. 71, 94–95 (2005).

[109] NUREG-1563, *supra* note 1, at 1.

[110] *See* VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25. *See also* SAR, *supra* note 40, at p. 5.4-2 (ML081560572, ML090710110) ("The DOE relies on expert elicitations to directly support the license application in the areas of igneous activity . . . ."); *id.* at pp. 2.2-90 to 2.2-101 (ML090700908) (detailing the DOE's use of and reliance upon the expert elicitation on volcanology). The volcanology elicitation is discussed *infra* Part II.C.3.a.

[111] *See* Seismology Expert Elicitation, *supra* note 36. *See also* SAR, *supra* note 40, at pp. 2.2-64 to 2.2-67 (ML090700908) (conducting a probabilistic seismic hazard analysis for the Yucca Mountain site). *See also* U.S. NUCLEAR REGULATORY COMM'N, OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS, NUREG–2108, TECHNICAL EVALUATION REPORT ON THE CONTENT OF THE U.S. DEPARTMENT OF ENERGY'S YUCCA MOUNTAIN REPOSITORY LICENSE APPLICATION; PRECLOSURE VOLUME: REPOSITORY SAFETY BEFORE PERMANENT CLOSURE, pp. 1-23 to 1-26, 1-50 to 1-53 (2011) (ML11250A093) [hereinafter NUREG-2108] ("DOE investigated the geological, geophysical, and seismic characteristics of the Yucca Mountain region to obtain sufficient information to estimate how the site would respond to vibratory ground motions from earthquakes."). The seismology elicitation is discussed in *infra* Part II.C.3.b.

[112] 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36; 1998 Saturated Zone Flow Expert Elicitation, *supra* note 72. *See also* SAR, *supra* note 40, at p. 5.4-10 (ML081560572, ML090710110) (describing the 1998 saturated zone flow expert elicitation).

Unfortunately, all available electronic and hard copies of the 1998 version of the Saturated Zone Flow Elicitation report omit Chapter 2 - Process for Eliciting Expert Judgments. This chapter, as its title indicates, is directly relevant to

elicitations regarding (iv) waste package degradation,[113] (v) unsaturated zone flow,[114] (vi) near-field environment and altered zone coupled effects,[115] and (vii) waste form degradation and radionuclide mobilization.[116] Ultimately, however, DOE chose not to use these four elicitations in support of its application.[117] Finally, DOE conducted an eighth elicitation, regarding human reliability[118]—though this too appears not to have been used in support of DOE's *Yucca Mountain* application.[119]

Although the elicitations were prepared by DOE rather than the NRC staff, the latter took numerous opportunities during the pre-hearing phase of the proceeding to comment on the expert elicitation process generally and DOE's elicitations in particular.[120] The staff issued its first set of observations in 1996,

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this article. It is missing from not only the ADAMS electronic version, but also the earlier microfiche version in the NRC Headquarters Public Reading Room, and the even-earlier, hard-copy documents in the NRC's "Official Records" Archives. The author has also been unable to find a complete copy of the 1998 version at the DOE or the Nuclear Waste Technical Review Board (which reviewed many of the DOE's Yucca-related documents). For these reasons, this article's citations to Chapter 2 of the Saturated Zone Flow Expert Elicitation report are perforce limited to the 1997 version. Both the 1997 and 1998 versions are discussed in *infra* Part II.C.3.c.

[113] SAR, *supra* note 40, at p. 2.3.6-2 (ML090710071) (referring to CRWMS, Waste Package Degradation Expert Elicitation Project (Rev. 1. 1998)). At least under this document name, Revision 1 is not available in ADAMS, but the original report dated August 1997 can be found at ML003742155.

[114] *See id.* at p. 5.4-3 (ML081560572, ML090710110) (referring to GEOMATRIX CONSULTANTS INC. & TRW, CIVILIAN RADIOACTIVE WASTE MANAGEMENT SYSTEM MANAGEMENT AND OPERATING CONTRACTOR (CRWMS), UNSATURATED ZONE FLOW MODEL EXPERT ELICITATION PROJECT (1997) (ML032200146) [hereinafter UNSATURATED ZONE FLOW EXPERT ELICITATION]).

[115] *See id.* (referring to Near-Field/Altered Zone Coupled Effects Expert Elicitation (May 29, 1998)).

[116] *See id.* (referring to Waste Form Expert Elicitation).

[117] It did, however, use indirectly the fifth (unsaturated zone flow) to confirm the reasonableness of the unsaturated zone percolation flux distribution. *Id.*

[118] *See* GEORGE ADAMS, CNWRA, QUANTIFYING LOW PROBABILITY HUMAN FAILURE EVENTS, at p. 1-2 (2011) (ML112720213) [hereinafter CNWRA] (referring to an NRC "expert elicitation approach from A Technique for Human Events Analysis").

[119] This eighth elicitation was also the only one not mentioned in the SAR's section specifically addressing expert elicitations. *See* SAR, *supra* note 40, at § 5.4 (ML081560572, ML090710110). *Cf.* CNWRA, *supra* note 118, at p. 3-6 (explaining why DOE did not include a sensitivity analysis on a particular example of human failure).

[120] *See*, *e.g.*, NUREG-1563, *supra* note 1, at 1; NRC, Notice of Availability and Public Comments and Responses, Yucca Mountain Review Plan, NUREG-1804, Revision 2, Final Report, 68 Fed. Reg. 45,086 (July 31, 2003).
In addition to the NRC staff, the ACNW has repeatedly considered the use of

when it published its "Branch Technical Position" addressing expert elicitation (NUREG-1563), along with several other documents in the *Yucca Mountain* proceeding. In the NUREG, the staff set forth "technical positions that: (1) provide[d] general guidelines on those circumstances that may warrant the use of a formal process for obtaining the judgments of more than one expert (i.e., expert elicitation); and (2) describe[d] acceptable procedures for conducting expert elicitation when formally elicited judgments are used to support a demonstration of compliance with NRC's geologic disposal regulation."[121] The staff made clear, however, that an applicant's "adherence to a sound elicitation process" such as the one set forth in NUREG-1563 would not guarantee that the judgments arising from the elicitation would satisfy "the applicant's burden of proof

this process in the Yucca Mountain adjudication. *See* NRC, ACNW; Notice of Meeting, 71 Fed. Reg. 38,906, 38,906 (July 10, 2006) ("A DOE representative will present an evaluation of the results of this drilling which has been done in support of the ongoing update of the 1996 expert elicitation on Probabilistic Volcanic Hazard Analysis."); NRC, ACNW; Notice of Meeting, 61 Fed. Reg. 46,832, 46,832 (Sept. 5, 1996) ("A continuation of discussions with the Department of Energy on Total System Performance Assessment will be held with emphasis on the use of expert elicitation panels."); NUREG-1563, *supra* note 1, at app. F (setting forth the NRC staff's response to the ACNW's comments on the staff's Feb. 1996 Draft Branch Technical Position (predecessor draft to NUREG-1563)); NRC, ACNW; Notice of Meeting, 61 Fed. Reg. 36,399, 36,399 (July 10, 1996) ("The Committee will review the NRC staff's draft technical position on the use of expert elicitation in the licensing of a nuclear waste disposal facility."); NRC, Notice of Meeting, ACNW Joint Working Group on Expert Judgment and Human Intrusion in the Performance Assessment for Nuclear Waste Disposal; Meeting, 56 Fed. Reg. 24,848, 24,848 (May 31, 1991) ("The Working Group will focus on the mechanics of the expert elicitation process and the utilization of the results of that process. Participants will address the appropriate procedures for selection of experts and issues. . . . This is the second meeting addressing the role and the extent of expert judgment in the site characterization and licensing process with respect to the disposal of nuclear waste."); NRC, Advisory Committee on Reactor Safeguards (ACRS) and ACNW; Proposed Meetings, 56 Fed. Reg. 11,765, 11,767 (Mar. 20, 1991) ("[The] ACNW Working Group . . . will continue the examination of methodologies of expert judgment, specifically on the methodology of an expert elicitation. The focus on the expert judgment reliance is the human intrusion scenario for the HLW repository.").

[121] NUREG-1563, *supra* note 1, at iii; NRC, Notice, Availability of Final Branch Technical Position on the Use of Expert Elicitation in the High-Level Waste Program, 61 Fed. Reg. 67,354, 67,355 (Dec. 20, 1996); *Accord* NRC, Notice, Availability of Draft Branch Technical Position on the Use of Expert Elicitation in the High-Level Waste Program, 61 Fed. Reg. 7568, 7569 (Feb. 28, 1996) (reiterating the NRC's same two specific technical positions).

regarding the substantive issues addressed by the elicitation."[122] Conversely, however, a flawed or poorly documented elicitation could well "undermine the credibility of any demonstrations of compliance. . ." that the elicitation was intended to support.[123]

In other 1996 *Yucca*-related documents, the NRC staff similarly made clear that the final report of an expert elicitation panel would *not* be the final word on the subject of the panel's analysis.[124] The staff explained that, although the agency had long considered different forms of expert judgment when "evaluat[ing] and interpret[ing] the factual bases of license applications," the agency had used the expert judgment merely "*to complement and supplement* other sources of scientific and technical information, such as data collection, analyses, and experimentation."[125]

Seven years later, the staff issued a Notice of Availability of its 2003 Yucca Mountain Review Plan. There, the staff explained that it had incorporated into that Plan the expert elicitation standards set forth in NUREG-1563.[126]

Presumably because the *Yucca Mountain* adjudication never reached the evidentiary hearing stage, the Licensing Boards in that proceeding seldom mentioned DOE's various expert

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[122] *See* NUREG-1563, *supra* note 1, at 8. *See also id.* at 22, D-3, F-1 to F-4 (setting forth the comments of the ACNW); *See also* CRWMS, SATURATED ZONE FLOW AND TRANSPORT PROCESS MODEL REPORT p. 4-8 (Apr. 2000) (ML003724584) ("Even though the NRC indicate[s] that the expert elicitation was conducted and documented in an acceptable way, they also caution . . . that the 'NRC staff is not bound by the conclusions of an elicitation *a priori* solely based on adherence to guidance provided by the staff.'"). *Accord* CRWMS, SATURATED ZONE FLOW AND TRANSPORT PROCESS MODEL REPORT pp. 4-8, 4-9 (Oct. 2000) (ML003774387).

[123] NUREG-1563, *supra* note 1, at 22.

[124] *See* NRC, Notice, Availability of Final Branch Technical Position on the Use of Expert Elicitation in the High-Level Waste Program, 61 Fed. Reg. 67,354, 67,355 (Dec. 20, 1996) (discussing the documentation of changes and clarifications made to the original reports).

[125] *Id.* (emphasis added). *See also* NRC, Availability of Draft Branch Technical Position on the Use of Expert Elicitation in the High-Level Waste Program, 61 Fed. Reg. 7568, 7569 (Feb. 28, 1996) (reiterating that expert elicitation is used to supplement the collected data); NUREG-1563, *supra* note 1, at 8 ("[T]he use of expert elicitation should not be considered as an acceptable substitute for traditional analyses based on adequate field or experimental data, when such data are reasonably available or obtainable, or the analyses are practicable to perform."); Apostolakis interview, *supra* note 53.

[126] *See* NRC, Notice of Availability and Public Comments and Responses, Yucca Mountain Review Plan, NUREG-1804, Revision 2, Final Report, 68 Fed. Reg. 45,086, 45,100 (July 31, 2003) (quoting NUREG-1563).

elicitations. A March 2013 Westlaw search of the NRC library of adjudicatory decisions produced only two decisions explicitly referring to expert elicitation.[127] The first, merely referred to a contention that DOE's description of the update to the volcanology elicitation "fail[ed] to comply with 10 C.F.R. § 63.21(c)(19)[128] or the guidance of NUREG-1563, which DOE formally committed to follow."[129] Similarly, the second merely alluded, in an appendix and without discussion, to three of DOE's expert elicitations.[130]

2. Use of Expert Elicitation in Pre-Adjudicatory *Yucca Mountain* Activities in the early 1990s

In 1990, the NRC published a general study regarding expert elicitation and its potential application to performance assessments in the then-anticipated *Yucca Mountain* proceeding.[131] Three years later, the NRC published a study by the CNWRA applying expert elicitation specifically to the prediction of future climate at Yucca Mountain.[132] The following year, the NRC published a second study by the CNWRA, examining expert elicitation more broadly and identifying situations where the process might be useful in the NRC's high level waste program.[133] Also, during the early 1990's, the staff used the expert elicitation process "to evaluate potential quantitative criteria to clarify the '. . . substantially complete containment requirement.'"[134]

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[127] *See* U.S. Dep't of Energy, LBP-09-29, 70 N.R.C. 1028 (2009); U.S. Dep't of Energy, LBP-09-6, 69 N.R.C. 367 (2009).

[128] This regulation provides that an applicant must include in its Safety Analysis Report an explanation of how it used any expert elicitation. *See* NUREG-2107, *supra* note 40, at p. 20-1.

[129] U.S. Dep't of Energy, 70 N.R.C. at 1032.

[130] U.S. Dep't of Energy, 69 N.R.C. at 496.

[131] *See* NUREG-1563, *supra* note 1, at 7 (citing NUREG/CR-5411, ELICITATION AND USE OF EXPERT JUDGMENT IN PERFORMANCE ASSESSMENT OF HIGH-LEVEL RADIOACTIVE WASTE REPOSITORIES (MAY 1990) (PREPARED BY THE SANDIA NATIONAL LABORATORIES) (ML040150792)).

[132] *Id.* at 32, B-1 to B-2 (describing the rationale of, and lessons learned from, the expert elicitation addressing the future climate at Yucca Mountain). DOE did not file its application until June 3, 2008. *See* Letter from Edward F. Sproat, III, Dir., Office of Civilian Radioactive Waste Mgmt., to Michael F. Weber, Dir., Office of Nuclear Material Safety and Safeguards (June 3, 2008) (ML081560407).

[133] NUREG-1563, *supra* note 1, at 7.

[134] *Id.* (citing CNWRA, U.S. NUCLEAR REGULATORY COMM'N, CNWRA 92-016, SUBSTANTIALLY COMPLETE CONTAINMENT" ELICITATION REPORT (1992)

3. Specific Elicitations Conducted for the *Yucca Mountain* Application

As noted above, the *Yucca Mountain* proceeding provides multiple examples of expert elicitation panels. Specifically, DOE relied upon expert elicitation to support its conclusions regarding volcanology, seismology, and saturated zone flow and transport (i.e., hydrology).[135] DOE's and the NRC staff's descriptions of the process used to address these three topics provide good insights into how the expert elicitation process works. In addition, DOE's elicitations regarding "waste form degradation and radionuclide mobilization" and "unsaturated zone flow model" provide still further insights. All five elicitations are discussed below.

a. Volcanology

In 1995, DOE conducted its probabilistic volcanology hazards assessment using the expert elicitation process to address the uncertainties associated with the probability of a volcanic event affecting the Yucca Mountain high-level radioactive waste repository.[136] DOE published the expert elicitation panel's final report the following year.[137]

DOE acknowledged that one of the important objectives of a formal expert elicitation is "to ensure that the probability distribution developed during the study adequately represents the diversity of views in the larger informed technical community."[138] Accordingly, DOE selected for its expert elicitation panel ten subject-matter experts[139] who it considered to have, collectively, "a wide range of expertise and experience and who [were] associated with a variety of institutions (e.g., universities[,] national laboratories),"[140] the federal and state

(ML033640128).

135 SAR, *supra* note 40, at p. 5.4-2 (ML081560572, ML090710110).

136 *See* SAR, *supra* note 40, at pp. 2.2-100 to 2.2-101 (ML90700908) (providing a brief technical description of the uncertainties that the expert elicitation panel addressed); *id.* at pp. 5.4-3 to 5.4-6 (ML081560572, ML090710110) (describing how DOE implemented each of the nine expert elicitation steps set forth in NUREG-1563).

137 NUREG-2107, *supra* note 40, at p. 20-2.

138 SAR, *supra* note 40, at p. 2.2-101 (ML90700908).

139 *Id.* at p. 5.4-4 (ML081560572, ML090710110); NUREG-2107, *supra* note 40, at p. 20-2; VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 17, at p. 2-20.

140 SAR, *supra* note 40, at p. 2.2-101 (ML090700908). *See* VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at pp. 2-22 to 2-23 (listing in

governments, and private practice.[141] The panel's members were selected from among a group nominated by thirteen volcanologist (plus a few nominated by the elicitation support team),[142] and were all specialists "in physical volcanology, volcanic hazards,

detail the selection criteria). *But see infra* note 209 and accompanying text (stating that a wider range of viewpoints would have been achieved had there been a greater balance of panel experts).

[141] *See* VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-23. Allocation of spots on the panel to members of different professional communities (e.g., industry, government, academia, national laboratories) may raise both practical and credibility issues. *See* Paradise, *supra* note 95, at 697 (commenting that one weakness of his and his fellow authors' non-nuclear expert elicitation was, generally, the "uneven distribution of affiliation of respondents," and, more particularly, the overrepresentation of academics on the elicitation panels that made "comparisons by expert affiliation difficult."). The elicitation at issue in that article (and others like it that are examined in the same volume of J.L. Med. & Ethics) is, however, largely distinguishable from the nuclear-related elicitations discussed in this article. The elicitations examined in 37 J.L. Med. & Ethics sought to evaluate the strengths and weaknesses of *existing* governmental oversight programs while the elicitations examined in this article relate, for the most part, to *proposed* entities (a rule, a repository). The exceptions to the latter are the nuclear-related elicitations from the mid-1980s to mid-1990s concerning probabilistic risk assessment and probabilistic seismic hazards assessment. *See infra* Part II.A; *infra* Part II.B.
A determination of an existing program's strengths and weaknesses is, by its very nature, both subjective and (to a large extent) policy-oriented. Kuzma, *supra* note 27, at 551 ("[W]e hope our work contributes to a better understanding of how to both evaluate oversight from multiple perspectives and formulate good policies and systems for overseeing emerging technologies."). Its expert elicitation would therefore be more amenable to the inclusion of representative samples of various public interest groups, lobbyists, or other agenda-driven constituencies. *See*, *e.g.*, *id.* (referring to "stakeholder interviews" as a source of information to supplement the results of an expert elicitation; referring to "quantitative expert and stakeholder elicitation;" and commenting that "[w]e blend literature analysis, experts and stakeholder interview data, and expert elicitation to strive for a holistic picture of how the oversight system for GEOs has performed in society."); Choi & Ramachandran, *supra* note 36, at 635 ("[Q]uantitative expert and stakeholder elicitation"). By contrast, a determination of the scientific or engineering acceptability of a proposal is technically oriented and, consequently, lends itself more to a representative sample of members of the *professional* community. Although no community (professional or otherwise) from which an elicitation panel draws its members can be said to be totally value-neutral, it would seem likely that professional scientists and engineers would have more of a proclivity in that direction than, say, members of an issue-driven public interest group or industrial lobby, or employees of a governmental agency whose principal project could be affected (either favorably or adversely) by the results of an expert elicitation.

[142] *See* VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-23 (discussing the thirteen written responses and one oral response received by the volcanologists).

geophysics, and[/or] geochemistry."[143] The subject-matter experts were selected from more than seventy nominees.[144] The panel was led by a Technical Facilitator-Integrator (which DOE also called a Methodology Development Team)[145] who, though not a panel member, shepherded the panel members through "carefully structured, intensive interactions among the panel members, including workshops and field trips."[146] Throughout the entire elicitation process, it was emphasized to the subject-matter experts that one of the key purposes of the expert elicitation was "to identify and understand uncertainty, not to eliminate it," and that disagreements among the members were both "expected and accepted."[147]

Before the first workshop, DOE assembled site-specific information and data and submitted them to each subject-matter expert.[148] Based on this information, each of the panel's subject-matter experts independently arrived at his or her own initial conclusion as to the probability distribution of a volcanic disruption,[149] e.g., 2×10^{-8} to 4×10^{-9}. Distribution of relevant data and information also continued throughout the remainder of the elicitation.[150]

At the first workshop, the subject-matter experts received training in the expert elicitation process.[151] They also identified the significant issues, characterized the available data, and identified the data still needed to conduct the elicitation.[152] Immediately following the workshop, the support team culled the technical presentations given at the workshop and, from that information, compiled the available data sets that were specific

143 SAR, *supra* note 40, at p. 5.4-4 (ML081560572, ML090710110).

144 VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-23.

145 *See id.* at pp. 2-11 to 2-12 (discussing the facilitating role of the technical/facilitator integrator as a "technical individual").

146 SAR, *supra* note 40, at p. 2.2-94 (ML090700908). *See also* NUREG-2107, *supra* note 40, at p. 20-2.

147 SAR, *supra* note 40, at p. 2.2-94 (ML090700908).

148 *Id.* at p. 5.4-5 (ML081560572, ML090710110); VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-20.

149 SAR, *supra* note 40, at p. 5.4-5 (ML081560572, ML090710110); *see also* NUREG-2107, *supra* note 40, at p. 20-2.

150 VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at pp. 2-13, 2-20.

151 *See* NUREG-2107, *supra* note 40, at p. 20-6 (describing the pre-elicitation training that the subject-matter experts received).

152 VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at pp. 2-20, 2-25.

to the Yucca Mountain repository.[153] The support team also compiled other relevant data sets from the technical presentations and other sources.[154] The support team then distributed lists of these data sets to the experts, to enable them to "choose the data they wanted to receive."[155] In addition, many of the proponents who had made technical presentations to the panel offered to provide relevant unpublished data, upon request.[156]

The first workshop was followed by a field trip that provided the experts with field data and was led by "earth scientists with considerable experience in the area and from a variety of institutions and disciplines."[157]

At the second workshop, the subject-matter experts explored the different volcanic hazard models proposed for Yucca Mountain and other similar regions.[158] Technical experts (proponents) made presentations in support of the different models and were asked questions about them.[159] By the end of the second workshop, the subject-matter experts had begun to discuss how to modify or refine the models.[160]

The following two elicitation-related events occurred between the second and third workshops.[161] At the experts' request, the support team arranged for a second field trip—this time to observe other similar geological areas.[162] Then, the support team sponsored a one-day informal meeting to enable panel members to discuss "various probabilistic methods available to model the spatial and temporal aspects of hazard analysis."[163]

The third workshop was divided (unlike Gaul[164]) into two

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153 *Id.* at p. 2-25.

154 *Id.*

155 *Id.*

156 *Id.* at pp. 2-25 to 2-26.

157 VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at pp. 2-20, 2-26.

158 *Id.* at p. 2-20.

159 *Id.* at pp. 2-20 to 2-21.

160 *Id.* at pp. 2-26 to 2-27.

161 *Id.* at pp. 2-21, 2-27.

162 *Id.* (this second field trip, according to DOE, exemplified the importance of flexibility to make "mid-course corrections" in an elicitation).

163 VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-27.

164 *See* Julius Caesar, *The Gallic Wars* (Translated by W. A. McDevitte and W. S. Bohn), *available at* http://classics.mit.edu/Caesar/gallic.1.1.html ("All Gaul is divided into three parts").

parts.[165] In the first part, the subject-matter experts were trained in the process of the elicitation interview (the step that would follow the third workshop).[166] The second part was a series of presentations by proponents on various technical issues.[167]

The following six significant, enumerated events occurred, in the following sequence, between the third and fourth workshops. First, each panel member was given the same set of questions to facilitate the revision of their evaluations.[168] Second, using an innovation not reported in any of DOE's other elicitations, the support team conducted a trial (or mock) elicitation interview with a member of the support team who was himself an expert in many of the issues under consideration.[169] The mock elicitation's stated purpose was to enable the elicitation interview team "to gain insight into the structuring of the assessment, sequencing of questions, methods to capture uncertainties, data and maps to have available, and documentation procedures[,]" and thereby to assist the team in refining its "framework for the actual elicitations of the experts."[170] It would logically follow that the panel members themselves would have likewise benefited from the mock elicitation interview, in that they would have come away with a better understanding of the interview process and could therefore prepare for and participate in it more effectively.

Third, each panel member engaged in a formal individual elicitation interview[171] in which s/he "provided . . . interpretations, expressed . . . uncertainties, and specified the technical basis for his [or her] assessments."[172] Fourth, the elicitation team documented the elicitation during the interview and provided the panel member with a draft summary.[173] Fifth, the panel member "reviewed, revised, and supplemented" his or her draft summary,[174] which the support team then reviewed for technical consistency and clarity.[175] And sixth, the support team

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[165] VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-28.

[166] *Id.* at p. 2-30.

[167] *Id.* at. p. 2-28.

[168] *Id.* at p. 2-30.

[169] *Id.* at p. 2-21, 2-30.

[170] *Id.* at p. 2-21.

[171] VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-31.

[172] *Id.* at p. 2-21; *see also id.* at p. 2-31 (describing the interview process).

[173] *Id.* at pp. 2-21, 2-31.

[174] *Id.* at p. 2-21.

[175] *Id.* at pp. 2-32 to 2-33.

compiled and distributed to all panel members the written draft elicitation summaries for each panel member;[176] prepared preliminary calculations which aggregated the then-current elicitation summaries;[177] and conducted sensitivity analyses and reviewed each elicitation summary for logical consistency.[178]

Following these six events came the fourth and final workshop, where the members reviewed each other's assessments and conclusions, and questioned each other's views.[179] At this workshop, the panel members confirmed that their collective interpretations provided a reasonable representation of the larger, informed technical community.[180] Following this workshop, the members further revised their initial elicitation summaries to reflect the feedback they had received,[181] independently arrived at their own revised conclusions as to the probability distribution,[182] and submitted a revised summary to the support team.[183] This concluded the subject-matter experts' involvement in the expert elicitation process.[184]

In the final stage of the elicitation process, the support team prepared a collective final report, which provided the documentation of the elicitation process, the subject-matter experts' individual summaries, and the calculation methodologies and results.[185] To perform the calculations, the support team combined the subject-matter experts' distributions, assigning equal weight to each expert's conclusion, to arrive at the aggregate probability distribution.[186]

Although the NRC staff ultimately concluded that this

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[176] *Id.* at p. 2-29.

[177] VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-21.

[178] *Id.* at p. 2-22.

[179] SAR, *supra* note 40, at p. 2.2-94 (ML090700908); *see also* VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at pp. 2-28 to 2-29 (describing the fourth workshop).

[180] SAR, *supra* note 40, at p. 2.2-101 (ML090700908).

[181] *Id.* at p. 2.2-94 (ML090700908).

[182] *Id.* at p. 2.2-100 (ML090700908). *See also* NUREG-2107, *supra* note 40, at p. 20-2.

[183] VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at pp. 2-31 to 2-32.

[184] *Id.* at pp. 2-22, 2-33.

[185] *Id.*

[186] SAR, *supra* note 40, at pp. 2.2-93 (ML090700908), 5.4-9 (ML081560572, ML090710110). Although DOE later updated its expert elicitation, DOE chose not to rely on the update in support of its application. NUREG-2107, *supra* note 32, at p. 20-7.

elicitation was conducted in a manner consistent with Commission guidance,[187] the staff did express four reservations.[188] The first involved DOE's use of insufficiently specific definitions of the terms "igneous event" and "event class."[189] The second (related) reservation concerned DOE's decision not to reconvene and seek the opinions of its expert elicitation panel once DOE had adjusted its data to reflect the more specific definitions of those two terms.[190] The third reservation was "that a greater balance of panel experts would have encompassed a wider range of viewpoints."[191] The staff's fourth reservation was that DOE's documentation of the expert selection process and the potential sources of bias or conflicts of interest could have been more thorough.[192]

Without specifically expressing reservations, the staff did observe that DOE had not followed two of the recommendations in NUREG-1563. The first of these had urged applicants to require subject-matter "experts to document revisions to their initial assessments."[193] DOE had instead followed the slightly different approach recommended in another NRC guidance document, NUREG/CR-6372.[194] DOE was specifically concerned that requiring documentation of such revisions could "anchor the experts to their initial evaluations, making them reluctant to revise an evaluation after the feedback process."[195] The staff did

187 NUREG-2107, *supra* note 40, at p. 20-7.

188 *Id.* at p. 20-4.

189 *Id.*; s*ee also* VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-34 ("[E]ach expert had a slightly different definition of a volcanic 'event.'").

190 *See* NUREG-2107, *supra* note 40, at p. 20-4 ("Because separate probability estimates needed to be developed for the DOE Total System Performance Assessment, DOE developed . . . probability estimates subsequent to the 1996 [volcanology elicitation report] without re-engaging the experts to seek their opinions."). *But see id.* at p. 20-7 ("DOE did, however, reconvene the [volcanology] elicitation in 2004 to consider new information and to rely on a consistent set of event definitions and extrusive scenarios.").

191 *Id.* at p. 20-5. To the extent this observation was intended as a criticism, the author believes it was an unfair one, given that DOE offered panel positions to seventeen subject-matter experts, but only ten accepted the offers. VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at p. 2-23.

192 NUREG-2107, *supra* note 40, at p. 20-5.

193 SAR, *supra* note 40, at p. 5.4-5 (ML081560572, ML090710110).

194 *Id.* at pp. 5.4.2, 5.4-5 to 5.4-6 (ML081560572, ML090710110); NUREG-2107, *supra* note 40, at pp. 20-6 to 20-7.

195 SAR, *supra* note 40, at p. 5.4-6 (ML081560572, ML090710110); *see also* NUREG-2107, *supra* note 40, at p. 20-6 (stating again that this could anchor the experts).

not object to DOE's approach[196] and elsewhere stated in general terms that "DOE adequately explained how expert elicitation was used consistent with the applicable guidance in NUREG-1563."[197] In the second recommendation from NUREG-1563, the staff had urged applicants to insist that their subject-matter experts disclose potential conflicts of interest—a mandate that DOE had not explicitly imposed upon its experts.[198] The staff observed, however, that the experts nonetheless provided enough information to satisfy the intent of this recommendation.[199]

The staff was not alone, however, in offering what was essentially a list of "lessons learned" from the volcanology expert elicitation. DOE compiled its own list:

> [1] All of the experts should be provided with, or have access to, a uniform data base.
>
> [2] Workshops or other meetings where interactions can take place are important to allow the experts to discuss data bases, clarify their interpretations, and challenge the interpretations of others.
>
> [3] The optimal number of experts for geologic hazard assessments is variable, but should be in the range of 4 to 12 individuals.
>
> [4] Workshops provide an opportunity to share and challenge interpretations; however, the best vehicle for the actual elicitation is individual interviews.
>
> [5] Interviews should include the technical expert, a normative expert (trained in probability), and a generalist to help translate between the two.
>
> [6] Each expert should have the opportunity to review the documentation of his or her assessments prior to actual calculations and aggregation of results across multiple experts.
>
> [7] The technical basis for the expert judgments should be documented in sufficient detail that a third party can understand the data, models, and thought processes used by the expert[s] to arrive at the judgments.[200]

Regarding the seventh of these, DOE offered an additional, related "lessons learned:" "Documentation of the expert elicitations began with notes taken by the elicitation team during the course of the interviews. Experience on several other expert

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196 NUREG-2107, *supra* note 40, at p. 20-6.

197 *Id.* at p. 20-7.

198 SAR, *supra* note 40, at p. 5.4-4 (ML081560572, ML090710110); *see also* NUREG-2107, *supra* note 40, at p. 20-5.

199 NUREG-2107, *supra* note 40, at p. 20-5.

200 VOLCANIC HAZARD ANALYSIS FOR YUCCA MOUNTAIN, *supra* note 25, at pp. 2-7 to 2-8.

assessment projects has shown that other documentation methods are less effective (e.g., written questionnaires, experts writing their interpretations following the interview, etc.)."[201] DOE also observed that proper documentation not only "allows third parties to review and understand the thought processes followed by the experts" but also "can help the experts to organize their thoughts, consider the strengths and weaknesses of their arguments, and properly express their uncertainties."[202]

b. Seismology

i. Overview, General Comments, and Comparison of the Two Seismology Groups

In the late 1990s, DOE conducted an expert elicitation to determine how the Yucca Mountain site would respond to vibratory ground motions from an earthquake.[203] Unlike the other four *Yucca Mountain* expert elicitations addressed in this article, the seismology elicitation was performed by *two* groups of subject-matter experts.[204] The first group was comprised of six three-member teams of geologists and geophysicists (seismic source teams), and the second was comprised of seven seismology experts (ground motion experts).[205] Both of these groups "were supported by technical teams [also called "facilitation teams"[206]] from DOE, the U.S. Geological Survey, and Risk Engineering Inc. . . . which provided the [subject-matter] experts with relevant data and information; facilitated the formal elicitation,

[201] *Id.* at p. 2-31.

[202] *Id.* at p. 2-16.

[203] NUREG-2107, *supra* note 40, at p. 20-2 (referring to Seismology Expert Elicitation, *supra* note 36); NUREG-2108, *supra* note 111, at pp. 1-23 to 2-26 (providing a technical description of the issues addressed in this expert elicitation). *See* SAR, *supra* note 40, at pp. 5.4-6 to 5.4-10 (ML081560572, ML090710110) (describing how DOE, in its Seismology Expert Elicitation, implemented each of the nine expert elicitation steps set forth in NUREG-1563).

[204] This article uses the term "group" to refer to either the ground motion experts collectively or the seismic source experts collectively. The article refers to all subject-matter experts in both groups, collectively, as the "panel."

[205] Seismology Expert Elicitation, *supra* note 36, at p. 2-1, ES-2. *See id.* at pp. 2-7 to 2-9 (detailing the history of this elicitation's selection process). NUREG-2108, *supra* note 111, at pp. 1-24; NUREG-2107, *supra* note 40, at pp. 20-3, 20-5. *See also* SAR, *supra* note 40, at p. 5.4-7 (ML081560572, ML090710110) (indicating that a similar two-group distinction was used in the DOE analysis initiated in 1995).

[206] *See* Seismology Expert Elicitation, *supra* note 36, at ES-2.

including a series of workshops designed to accomplish the elicitation process; and integrated the hazard results."[207] The seismic source teams also went on a field trip to Yucca Mountain.[208]

These panel members were experts in "regional and local earthquake and fault tectonics, earthquake physics, ground motion modeling, and seismic hazard analyses."[209] They were selected not only because of their subject-matter expertise, but also because of their (i) "willingness to participate in open workshops," (ii) willingness "to diligently prepare the required evaluations," (iii) willingness to "openly explain and defend technical positions," (iv) "strong communications skills," (v) "flexibility and impartiality" (including the willingness to "forsake the role of proponent") (vi) "the ability to simplify and explain the basis for interpretations and technical positions," and (vii) "availability and willingness to commit the time required to complete the project."[210]

DOE considered all but one of NUREG-1563's selection criteria—the willingness to disclose publicly any conflicts of interest.[211] As with the volcanology panel,[212] DOE asserted that the experts themselves had expressed no objection to this obligation and in fact provided information that, in effect, satisfied this criteria.[213]

As in the volcanic elicitation, the seismic source teams and ground motion experts participated in a series of structured, facilitated workshops,[214] with each group having its own facilitator and generalists.[215] The two groups were, however, on different procedural tracks. The seismic teams' track was more

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[207] NUREG-2108, *supra* note 111, at p. 1-24. For a complete description of all the support teams, *see* Seismology Expert Elicitation, *supra* note 36, at pp. 1-7 to 1-10. For a list of the support team members, together with their affiliations, *see id.* at pp. 1-18 to 1-20 (tbls. 1-1 to 1-3).

[208] Seismology Expert Elicitation, *supra* note 36, at p. 1-7; NUREG-2107, *supra* note 40, at p. 20-6.

[209] SAR, *supra* note 40, at p. 5.4-6 (ML081560572, ML090710110).

[210] *Id.* at p. 5.4-7 (ML081560572, ML090710110); *see also* Seismology Expert Elicitation, *supra* note 36, at pp. 2-6 to 2-8.

[211] SAR, *supra* note 40, at p. 5.4-7 (ML081560572, ML090710110); NUREG-2107, *supra* note 40, at p. 20-6.

[212] SAR, *supra* note 40, at pp. 5.4-4, 5.4-7 (ML081560572, ML090710110).

[213] *Id.* at p. 5.4-4 (ML081560572, ML090710110); *see also* NUREG-2107, *supra* note 40, at p. 20-5; Seismology Expert Elicitation, *supra* note 36, at p. 2-9.

[214] SAR, *supra* note 40, at p. 5.4-8 (ML081560572, ML090710110).

[215] NUREG-2107, *supra* note 40, at p. 20-6.

elaborate and is described in the "Seismic Group" subpart below.[216] The ground motion experts' track involved half as many workshops (three, as compared to six), two working meetings, and no field trip.[217] This second track is described in the "Ground Motion Group" subpart, which immediately follows the description of the seismic group.[218]

The seismic group initially identified the technical issues most significant to seismic hazards at Yucca Mountain, linked those issues to the most relevant data, specified the available relevant data, and identified the additional needed data.[219] To assist this group's teams, DOE provided them with both data and lists of sources of data relevant to their issues.[220] The ground motion experts likewise identified the principle issues relevant to their area of responsibility.[221] However, the ground motion experts may not have been provided their data until the first workshop.[222]

Once the workshops began, the two groups of experts went through essentially the same training and elicitation interviews as their counterparts on the volcanology panel.[223] The one exception was the interviews of the three-person seismic source teams.[224] The support team interviewed each of the seismic teams as a unit rather than separately interviewing each individual on the team.[225]

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[216] *See infra* Part II.C.3.b.ii.

[217] Seismology Expert Elicitation, *supra* note 36, at p. 3-14 (fig. 3-1).

[218] *See infra* Part II.C.3 b. iii.

[219] SAR, *supra* note 40, at p. 5.4-8 (ML081560572, ML090710110).

[220] *Id.*

[221] *Id.*

[222] *Compare* Seismology Expert Elicitation, *supra* note 36, at p. 2-5 ("Before the first workshop, the [seismic] experts were sent a number of data sets and publications.") *with* SAR, *supra* note 40, at p. 5.4-8 (ML081560572, ML090710110) ("The ground motion [group] identified data and analyses required to resolve their technical issues in the first workshop."); *See also* Seismology Expert Elicitation, *supra* note 36, at p. 5-2 (stating that "copies of all presentation materials were made available during each meeting.").

[223] *See* SAR, *supra* note 40, at p. 5.4-8 (ML081560572, ML090710110) (describing the pre-elicitation training completed by the volcanology and seismic and ground motion experts); NUREG-2107, *supra* note 40, at p. 20-6 (describing the pre-elicitation training completed by the seismic and ground motion experts).

[224] Seismology Expert Elicitation, *supra* note 36, at p. 2-6.

[225] *See* NUREG-2107, *supra* note 40, at p. 20-6 (noting the use of team interviews "where applicable"). *See also* Seismology Expert Elicitation, *supra* note 36, at p. 2-2 (stating that "each expert team in the seismic source and fault displacement characterization was expected to function as a single 'virtual'

Like the volcanology panel, the two seismic groups were encouraged to debate issues,[226] listened to proponents of various viewpoints relevant to the issues before the panels,[227] and had opportunities to revise their conclusions based on the discussions and feedback in the workshops.[228] And, like the volcanology panel, the members of the seismology groups were not required by DOE to document the rationale underlying any change in their initial positions.[229] DOE's justification for this omission was the same as the one DOE offered for the volcanology panel, as was the staff's response to those justifications[230]—to provide the subject-matter experts with the flexibility needed to make midcourse corrections, that is, to avoid anchoring them to their initial positions.[231]

Also like the volcanology panel, the ground motion experts' views were given equal weight and then aggregated to arrive at a final probability distribution.[232] But again, the seismic source teams were the exception. Unlike the ground motion experts and the volcanology panel, the conclusions of the six seismic source teams—not their individual experts—were given equal weight.[233]

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expert and to express their [sic] assessments and uncertainties as an individual expert").

[226] Seismology Expert Elicitation, *supra* note 36, at p. 2-5.

[227] *Id.*

[228] *See* SAR, *supra* note 40, at p. 5.4-9 (ML081560572, ML090710110) (describing the experts' use of post-elicitation feedback). *See also* Seismology Expert Elicitation, *supra* note 36, at p. 1-16 (allowing the experts to make changes to their evaluations after receiving feedback); NUREG-2107, *supra* note 40, at p. 20-6 (reporting that experts did not "document the rationale for any changes made" after receiving feedback).

[229] *See* SAR, *supra* note 40, at pp. 5.4-5, 5.4-9 (ML081560572, ML090710110) (noting that no volcanology or seismic expert was required to document the revisions he or she made after receiving feedback). *See also* Seismology Expert Elicitation, *supra* note 36, at p. 1-16; NUREG-2107, *supra* note 40, at p. 20-6.

[230] *See* SAR, *supra* note 40, at pp. 5.4-6, 5.4-9 (ML081560572, ML090710110) (providing the same justification for failure to document the experts' revisions after receiving feedback). *See also* Seismology Expert Elicitation, *supra* note 36, at pp. 1-15 to 1-16; NUREG-2107, *supra* note 40, at p. 20-6.

[231] *See supra* notes 174 and 211, respectively.

[232] SAR, *supra* note 40, at pp. 5.4-6, 5.4-9 (ML081560572, ML090710110).

[233] *Compare id.* at p. 5.4-6 (ML081560572, ML090710110) (aggregating the results of each individual volcanology expert) *with id.* at p. 5.4-9 (aggregating the teams' results). *See also* NUREG-2107, *supra* note 40, at p. 20-3 ("[R]esults were aggregated giving equal weights to the inputs from the source teams . . . [i]n other cases, equal weight was assigned to the results from each expert.").

ii. Seismic Group

Seismic group members attended a total of six workshops.[234] At the first, they identified key technical issues, as well as the available and missing data;[235] they also heard presentation from a series of technical experts.[236] The second workshop focused on "methods and approaches for characterizing seismic sources in the Yucca Mountain region."[237] As in the first workshop, a variety of technical experts presented the panel with their views on issues important to the elicitation.[238] In the third workshop, the group considered "alternative models, hypotheses and interpretations," and were provided opportunities for structured debate on those subjects.[239] The third workshop also included a four-day field trip to the Yucca Mountain area.[240]

At the fourth workshop, the group members presented their preliminary interpretations and conclusions regarding key issues and received feedback from each other.[241] They were also trained in both the characterization of uncertainty and the elicitation process (in anticipation of the six teams' upcoming elicitation interviews).[242] In addition, the group was presented with, and discussed, further information and interpretations relevant to the elicitation.[243]

The elicitations were documented during the interviews, and afterwards, the subject-matter experts independently prepared their own documentation to support their conclusions.[244] At the same time as the subject matter experts were preparing their documentation, the support team was providing each of the seismic expert teams with written documentation of its interview.[245]

Next, the subject-matter experts attended their fifth workshop, where each expert's conclusions and underlying support were

234 Seismology Expert Elicitation, *supra* note 36, at p. 3-2.
235 *Id.*
236 *Id.* at p. 3-3.
237 *Id.*
238 *Id.*
239 *Id.* at p. 3-4.
240 *Seismology* Expert Elicitation, *supra* note 36, at p. 3-4.
241 *Id.* at p. 3-5.
242 *Id.* at pp. 3-5 to 3-6.
243 *Id.* at p. 3-5.
244 *Id.* at pp. 2-6, 3-10 to 3-11.
245 *Id.* at p. 3-10.

examined by colleagues in his or her group.[246] At the end of this workshop, the six seismic teams and the ground motion team (which had been on a separate procedural track[247]) held a joint session to discuss common issues.[248] Before the sixth and final workshop, the support team prepared and distributed "a 'white paper' summarizing the fault displacement evaluation approaches developed by the expert teams."[249]

The sixth workshop had three purposes: "(1) review and discuss alternative methods and models for assessing fault displacement, (2) discuss uncertainties in parameter values and models, and (3) facilitate the expert teams' discussion of the pros and cons of alternative approaches, models, and submodels."[250]

Following this final workshop, and also at many stages following the earlier fourth workshop, the subject-matter experts from both groups and their support teams went through a series of revisions and technical reviews. At the end of the last set of revisions, each subject-matter expert or team prepared a final conclusion, together with supporting technical bases.[251] The support team then aggregated the results, allotting equal weight to each ground motion expert and, separately, to each seismic team.[252] This equal weighing was not a foregone conclusion from the beginning of the elicitation, but merely a goal.[253] Had one of the subject-matter experts been unwilling to play the role of neutral evaluator, the support team could have given that expert's conclusions less weight, or even removed the expert from the panel.[254]

iii. Ground Motion Group

The pattern of the ground motion group's elicitation process was much the same as, though more abbreviated than, the pattern of the seismic group's process. The first ground motion workshop was devoted to identifying key issues and the

246 Seismology Expert Elicitation, *supra* note 36, at p. 3-6.
247 *Id.* at p. 3-14 (fig. 3-1).
248 *Id.* at pp. 3-7 to 3-8.
249 *Id.* at p. 3-8.
250 *Id.*
251 *Id.* at pp. 2-6, 3-10 to 3-11.
252 Seismology Expert Elicitation, *supra* note 36, at p. 3-12; SAR, *supra* note 40, at p. 5.4-9 (ML081560572, ML090710110).
253 Seismology Expert Elicitation, *supra* note 36, at p. 3-12.
254 *Id.* at p. 3-13. *See also* Fleming, *supra* note 3, at 118–20 (describing the "downweighting of [the] outlier's views" to equalize the results).

unavailable data that was still needed to evaluate them.[255] The second workshop addressed methods, models, and preliminary interpretations, with technical presentations on several modeling issues.[256] In addition to these formal workshops, the subject-matter experts in this group also discussed the issues informally, often with one playing the role of proponent.[257] The two workshops were also supplemented with a working meeting in which the group members discussed various unresolved issues.[258]

The elicitation interviews of the individual group were conducted in the same way as in other elicitations (with the sole exception of the seismic group's team interviews).[259] Each was asked the same set of questions and the support team documented the answers.[260] In addition, each interviewee provided documentation to support his or her preferred model, and explained the reasons for preferring that model over other proposed models.[261] During or following the interviews, the support team identified inconsistencies to some of the subject-matter experts, who could then correct them.[262] In other instances, the support team pointed out that various subject-matter "experts had considered only a limited number of proposed models," and as a result of the support team's feedback, those experts tended to expand the scope of models that they considered.[263]

Following the interviews, the support team conducted a third workshop, in which the group members examined each other's preliminary interpretations and conclusions and also looked in depth into a small number of technical issues.[264] This workshop also included a joint meeting with the seismic teams.[265] Shortly after the third workshop, the group held a working meeting.[266]

Next, the group members revised their conclusions based on the feedback received in the third workshop and the subsequent

255 Seismology Expert Elicitation, *supra* note 36, at pp. 5-2 to 5-3.
256 *Id.* at p. 5-3.
257 *Id.*
258 *Id.*
259 *Compare id.* at pp. 5-3 to 5-4 (interviewing each expert individually) *with supra* note 245 and accompanying text (interviewing the experts in groups).
260 *Id.* at pp. 5-3 to 5-4.
261 Seismology Expert Elicitation, *supra* note 36, at p. 5-4.
262 *Id.*
263 *Id.*
264 *Id.* at p. 5-5.
265 *Id.*
266 *Id.*

working meeting.[267] These revisions began multiple cycles of the support team preparing revised models and the subject-matter experts revising their data or equations.[268] At the end of these cycles, each subject-matter expert documented the reasoning behind his or her conclusions, the support team reviewed the documentation for internal consistency and completeness, and the resulting documentation was reviewed by two other support team groups.[269]

iv. NRC Staff Review.

The staff reviewed and evaluated DOE's methodology, observed all of the groups' meetings, and reviewed all summary reports of those meetings.[270] Based on these reviews and observations, the staff concluded that the expert elicitation was consistent with the framework described in NUREG-1563[271] and that DOE had "reasonably developed the geological, geophysical, and seismological information necessary to support the expert elicitation."[272] The staff also observed that the two seismic groups represented an "appropriately broad spectrum of the larger seismology . . . communit[y]."[273] (In this respect, the staff's conclusion differed from that regarding the volcanology elicitation.[274])

Subsequently, although DOE chose not to update its seismology elicitation,[275] the NRC staff reviewed additional geological, geophysical, and seismological information that had been unavailable to the panel, and concluded that the information would not have substantially altered the results of the expert elicitation.[276]

c. Saturated Zone Flow and Transport

In 1997, DOE conducted an expert elicitation to evaluate

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[267] Seismology Expert Elicitation, *supra* note 36, at p. 5-6.

[268] *Id.*

[269] *Id.* For a technical description of the issues addressed in each of the procedural steps above, *see id.* at pp. 5-6 to 5-23.

[270] NUREG-2108, *supra* note 111, at p. 1-25.

[271] *Id.*; NUREG-2107, *supra* note 40, at p. 20-7.

[272] NUREG-2108, *supra* note 111, at p. 1-25.

[273] NUREG-2107, *supra* note 40, at p. 20-5.

[274] *Id.*

[275] *Id.* at p. 20-7.

[276] NUREG-2107, *supra* note 40, at p. 20-7; NUREG-2108, *supra* note 111, at p. 1-26.

saturated zone groundwater flow and radionuclide transport.[277] The goals of this elicitation "were (1) to quantify uncertainties associated with certain key issues . . . and (2) to provide a perspective on modeling and data collection activities that may help to characterize and reduce uncertainties."[278] The elicitation panel issued two "final" reports—the first in October 1997 and the second in January 1998.[279]

DOE selected a five-member elicitation panel to address saturated zone flow and transport.[280] DOE sought nominations from fifteen earth scientists and engineers, and received from them the names of fifty nine candidates.[281] In selecting the five panel members, DOE sought to ensure that they held diverse opinions, had the necessary technical expertise, and came from a variety of institutional and organizational backgrounds.[282] The

[277] SAR, *supra* note 40, at pp. 5.4-10 (ML081560572, ML090710110), 2.3.9-26 (ML081560543); NUREG-2107, *supra* note 40, at p. 20-4; CRWMS, Total System Performance Assessment- Viability Assessment (TSPA-VA) Analysis Technical Basis Document p. 8-50 (Aug. 1998) (ML003758622) [hereinafter Total System Performance Assessment]. For brief technical descriptions of the scientific issues that the panel considered, *see id.* at pp. 8-25 to 8-26, 8-29 to 8-31; SAR, *supra* note 40, at pp. 5.4-10 to 5.4-11 (ML081560572, ML090710110), 2.3.9-26 (ML081560543); NUREG-2107, *supra* note 40, at p. 20-5; For a description of how, in this elicitation, DOE implemented each of the nine expert elicitation steps set forth in NUREG-1563, *see* SAR, *supra* note 40, at pp. 5.4-10 to 5.4-12 (ML081560572, ML090710110).

[278] 1998 Saturated Zone Flow Expert Elicitation, *supra* note 72, at p. 1-2; 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36, at p. 1-2. *See also* SAR, *supra* note 40, at pp. 2.3.9-26 (ML081560543), 5.4-10 (ML081560572, ML090710110):

> The objective of [this elicitation] was to quantify uncertainties associated with models and parameters key to modeling flow and transport in the saturated zone. A second objective was to reveal needed data collection and modeling that could reduce some of the more significant uncertainties. In this way, the expert elicitation was used to complement and guide data collection already underway, as well as to provide input to iterative performance assessment modeling by DOE.

NUREG-2107, *supra* note 40, at p. 20-4.

[279] 1998 Saturated Zone Flow Expert Elicitation, *supra* note 72; 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36.

[280] NUREG-2107, *supra* note 40, at p. 20-4; SAR, *supra* note 40, at p. 5.4-10 (ML081560572, ML090710110); Total System Performance Assessment, *supra* note 277, at pp. 8-4, 8-25; GEOMATRIX CONSULTANTS, SATURATED ZONE FLOW AND TRANSPORT EXPERT ELICITATION: PROCESS AND SUMMARY OF RESULTS, slide 4 (Jan. 20-21, 1998) (listing the panel members) [hereinafter PROCESS AND SUMMARY], *available at* http://www.nwtrb.gov/meetings/1998/jan/coppersmith.pdf.

[281] 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36, at p. 2-6.

[282] *Id.* at. 2-7. The NRC staff agreed with DOE that this panel "collectively

panel's members came from academia, the private sector, and one of the national laboratories,[283] and had expertise in "methods for characterizing and/or methods for analyzing and modeling groundwater flow and radionuclide transport in saturated fractured rock."[284] DOE selected the members based on (*inter alia*) the following criteria: "knowledge and expertise in saturated zone flow and transport, technical competence, availability, willingness to participate, and a willingness to explain and defend their technical positions."[285] As with the volcanology and seismology elicitations, DOE considered all but one of NUREG-1563's criteria for selection of experts—the willingness to disclose publicly any conflicts of interest—and it offered the same justification (described above).[286] The staff later observed that the experts provided enough information to satisfy the intent of this recommendation.[287]

Again, similar to the panels in the volcanology and seismology expert elicitations, this elicitation panel participated in a series of workshops and one field trip to Yucca Mountain.[288] In the workshops, the experts broke the major issues down into more manageable subissues.[289] To enable the experts to examine the issues and subissues more effectively, DOE provided them with relevant literature and data sets.[290]

During the workshops, the experts received a variety of training to assist them in their responsibilities.[291] In the first workshop, the experts received training in the subject matter at issue, and included "discussion of available data and alternative models."[292] Prior to the second workshop, the subject-matter

represent[ed] an appropriately broad spectrum of the larger . . . hydrology communit[y]." NUREG-2107, *supra* note 40, at p. 20-5.

283 1998 Saturated Zone Flow Expert Elicitation, *supra* note 72, at p. 1-6 (tbl.1-2); 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36, at p. 1-6 (tbl.1-2).

284 SAR, *supra* note 40, at p. 5.4-10 (ML081560572, ML090710110).

285 *Id.*

286 *Id.*

287 NUREG-2107, *supra* note 40, at p. 20-5.

288 PROCESS AND SUMMARY, *supra* note 280, at slide 3. *See also* 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36, at p. 2-9 (describing the relevant field trip and workshops); SAR, *supra* note 40, at p. 5.4-10 (ML081560572, ML090710110); NUREG-2107, *supra* note 40, at p. 20-6.

289 SAR, *supra* note 40, at p. 5.4-10 (ML081560572, ML090710110).

290 *Id.* at p. 5.4–11 (ML081560572, ML090710110).

291 *Id.* at pp. 5.4-10 to 5.4-11 (ML081560572, ML090710110).

292 *Id.*; *See also* 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36, at p. 2-8; PROCESS AND SUMMARY, *supra* note 280, at slide 3.

experts received a list of the specific topics to be covered in the elicitations interviews, and these topics were addressed in presentations during both the second and third workshops.[293] In the second workshop, the subject-matter experts were trained in "quantifying uncertainty for probability encoding, expressing alternative evaluations using subjective probability (weights), and understanding biases that might unduly influence expert evaluations."[294] The experts also "practiced articulating their judgments and the assumptions and rationales supporting their judgments."[295] The support team conducted the third and final workshop prior to the elicitation interviews.[296] In this workshop, the subject-matter experts presented and discussed their preliminary interpretations and uncertainties regarding the key issues before the panel.[297]

The panel members' elicitation interviews were structured in essentially the same way as those for the volcanology and ground motion group's (seismology) elicitation interviews.[298] During the remainder of the elicitation process, the subject-matter experts received feedback from their fellow panel members.[299] In addition, each expert was "provided elicitation summaries from all [other] members of the . . . panel" in order to provide him or her "with the broader perspective on the range of interpretations being developed."[300] The support team reviewed the first draft of each panel member's elicitation summary, in order to ensure "accuracy and completeness."[301] As with the volcanology and seismology elicitations, DOE did not require the elicitation panel members, during the feedback process, to document any revisions

293 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36, at p. 2-10.

294 SAR, *supra* note 40, at p. 5.4-11 (ML081560572, ML090710110). *See also* 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36, at pp. 2-9 to 2-10.

295 SAR, *supra* note 40, at p. 5.4-11 (ML081560572, ML090710110).

296 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36, at p. 2-9.

297 *Id.*; PROCESS AND SUMMARY, *supra* note 280, at slide 3.

298 *Compare* SAR, *supra* note 40, at p. 5.4-11 *with id.* at pp. 5.4-5 (volcanic), 5.4-9 (seismic) (ML081560572, ML090710110). *See also* 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36, at p. 2-10 (describing the interview process).

299 SAR, *supra* note 40, at p. 5.4-11 (ML081560572, ML090710110); 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36, at p. 2-11.

300 SAR, *supra* note 40, at p. 5.4-11 (ML081560572, ML090710110). *See also* 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36, at p. 2-12 (noting that written summaries were provided to each member of the panel).

301 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36, at p. 2-12.

to their initial assessments.[302] DOE offered the same justification as it had in the other two elicitations, and the staff's response was likewise the same. [303]

Once the subject-matter experts had reviewed the feedback information, they prepared their final expert elicitation summaries.[304] These were then aggregated, giving equal weight to the conclusions of each panel member.[305] As in the seismology elicitation, the equal weighing was not a foregone conclusion from the beginning of the elicitation, but merely a goal.[306] If one of the panel members had been unwilling to play the role of neutral evaluator, the support team could have given that expert's conclusions less weight, or even removed the expert from the panel.[307] DOE chose not to update this elicitation.[308]

d. Waste Form Degradation and Radionuclide Mobilization

In its *Yucca Mountain* application, DOE did not rely upon its expert elicitation regarding Waste Form Degradation and Radionuclide Mobilization.[309] The elicitation is, however, on the public record and, because it sheds at least some light on the elicitation process, a description is appropriate.[310]

This elicitation's objective was "to characterize the processes of degradation of spent fuel and high level waste . . . glass following breach of the waste packages and mobilization of radionuclides within breached waste packages."[311] DOE selected a panel of six subject-matter experts and also provided technical experts to inform the subject-matter experts with data, interpretations and three workshop trainings.[312] The panel was comprised of experts from the national laboratories, the industry, and the Atomic

[302] SAR, *supra* note 40, at p. 5.4-11 (ML081560572, ML090710110); NUREG-2107, *supra* note 40, at p. 20-6.

[303] *See supra* note 248 and accompanying text.

[304] SAR, *supra* note 40, at p. 5.4-11 (ML081560572, ML090710110).

[305] *Id.* at p. 5.4-12 (ML081560572, ML090710110); NUREG-2107, *supra* note 40, at p. 20-7; 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36, at p. 2-12.

[306] 1997 Saturated Zone Flow Expert Elicitation, *supra* note 36, at p. 2-12.

[307] *Id.* at p. 2-13.

[308] NUREG-2107, *supra* note 40, at p. 20-7.

[309] *See* SAR, *supra* note 40, at p. 5.4-1 (ML081560572, ML090710110) (listing the three elicitations relied upon).

[310] Waste Form Expert Elicitation, *supra* note 36.

[311] *Id.* at p. 1-1.

[312] *Id.* at p. 1-4.

Energy Agency of Canada.[313] Ten experts were selected from a group of 35 nominees, recommended by seventeen "[h]ighly regarded scientists and engineers."[314] Six of the ten invited experts agreed to serve on the panel.[315] Each panel member submitted information on potential conflicts of interest.[316]

The support team provided the panelists with relevant data and publications throughout the elicitation process.[317] During the workshops, technical experts made presentations to the panel regarding "pertinent data sets and alternative models and methods,"[318] and the panel members debated their different interpretations of the data and uncertainties.[319]

The first workshop was devoted to the identification of key technical issues and to presentations by thirteen technical specialists.[320] At the second workshop, the panel members reviewed "the key issues and uncertainties associated with waste form degradation and radionuclide mobilization," discussed "[a]lternative models, modeling results, and interpretations," and heard presentation from thirteen more technical specialists.[321] At the third workshop, experts had the opportunity "to present and discuss their preliminary interpretations and uncertainties," and also received training in the elicitation interview process.[322]

Following the third workshop, the support team conducted elicitation interviews of each panel member, documenting the elicitation during the interview.[323] "All data sets provided or made available to the experts during the project were present during the elicitation interviews."[324] The support team then prepared summaries of each interview.[325] The subject-matter experts reviewed the summaries and then revised their earlier preliminary conclusions from the third workshop.[326] Upon receiving the revised conclusions, the support team prepared a

313 *Id.* at p. 1-6 (tbl.1-2).
314 *Id.* at p. 2-4, 2-7.
315 *Id.* at p. 2-7.
316 Waste Form Expert Elicitation, *supra* note 36, at p. 2-7.
317 *Id.* at p. 2-8.
318 *Id.* at p. 2-5.
319 *Id.* at p. 2-4.
320 *Id.* at pp. 2-8 to 2-9.
321 *Id.* at p. 2-9.
322 Waste Form Expert Elicitation, *supra* note 36, at pp. 2-9 to 2-10.
323 *Id.* at pp. 1-5, 2-5, 2-10.
324 *Id.* at p. 2-10.
325 *Id.* at pp. 1-5, 2-5.
326 *Id.* at pp. 1-5, 2-4 to 2-5, 2-11.

draft report aggregating the elicitations and conclusions, and circulated it to all panel members so that they could review and comment on each other's conclusions and technical analyses.[327] Each panel member then reviewed the comments of his colleagues and, to the extent he saw fit, revised his own conclusions still further.[328] After receiving those revisions, the support team posed to the panel members any last-minute requests for clarification, then finalized the elicitation summaries, and issued the final elicitation report.[329]

When aggregating the conclusions of the experts' judgments, the support team accorded equal weight to each expert's conclusions.[330] Just as with seismology and saturated zone flow expert elicitations discussed above, the equal weighing here was not a foregone conclusion from the beginning of the elicitation, but merely a goal.[331] If one of the panel members were unwilling to play the role of neutral evaluator, the support team could have given that expert's conclusions less weight, or even removed the expert from the panel.[332]

One final point regarding this elicitation is worth noting. It differed from the larger elicitations discussed in the previous three subparts in the following respect:

> In some cases, the [Waste Form Expert Elicitation] process followed approaches that were more appropriate for a relatively modest multi-expert study than a larger, resource-intensive study. For example, after the elicitation interviews, feedback to the experts was accomplished by providing each expert with a feedback package that summarized all of their assessments and the implications of those assessments to certain key issues. The experts then were given an opportunity to revise their assessments in light of the feedback, as suggested in the [NUREG/CR-6372] guidance. A more resource-intensive approach might have been to conduct a feedback workshop. Either process enables the experts to review the assessments of others on the panel and to examine the calculated implications of their assessments.[333]

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327 *Id.* at p. 2-11.
328 Waste Form Expert Elicitation, *supra* note 36, at pp. 2-5, 2-11.
329 *Id.*
330 *Id.* at pp. 2-3, 2-12.
331 *Id.* at p. 2-12.
332 *Id.* at p. 2-13.
333 *Id.* at p. 2-3.

e. Unsaturated Zone Flow Model

Just as with the Waste Form Expert Elicitation, DOE did not rely upon its expert elicitation regarding Unsaturated Zone Flow Model in support of its *Yucca Mountain* application.[334] Still, this elicitation is on the public record and sheds at least some light on the elicitation process.[335] So a description of it is appropriate.

The elicitation's purpose "was to identify and assess the uncertainties associated with certain key components of the unsaturated zone flow system at Yucca Mountain."[336] DOE selected seven subject-matter experts who had a broad range of experience and expertise[337] and who came from academia, private industry, national laboratories, and another government agency.[338] The standards for selection were the same as for the other elicitations discussed above.[339] Twenty-two nominators submitted the names of 75 candidates for the panel.[340] Nine candidates were offered positions on the panel, and seven accepted.[341] Each panel member submitted information regarding potential conflicts of interest.[342]

The elicitation consisted of three workshops, one field trip, and a series of interviews. The support team provided the subject-matter experts with relevant literature and technical data throughout the elicitation process.[343]

The goals of the first workshop were "to introduce the panel to the Yucca Mountain project, identify significant issues related to both the unsaturated zone site-scale modeling and the Total System Performance Assessment, and to present the various data sets related to the significant issues."[344] Regarding this last goal, "[t]welve technical specialists presented and discussed the data sets collected over the past several years to characterize unsaturated zone hydrology at Yucca Mountain."[345]

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334 *See* Unsaturated Zone Flow Expert Elicitation, *supra* note 114, at pp. 2-5 to 2-7 (discussing the process used to choose experts from different fields).

335 *See id.* at p. 2-1 (describing the elicitation process).

336 *Id.* at p. 1-1.

337 *Id.* at pp. 1-1, 1-4 to 1-5, 1-8 (tbl. 1-2).

338 *Id.* at p. 1-8 (tbl. 1.2).

339 *Id.* at pp. 2-5 to 2-6.

340 Unsaturated Zone Flow Expert Elicitation, *supra* note 114, at p. 2-6.

341 *Id.* at p. 2-7.

342 *Id.*

343 *Id.* at p. 2-8.

344 *Id.*

345 *Id.*

In the second workshop, the panel members considered and discussed "alternative methods and conceptual models for evaluating" the technical issues before them.[346] At this workshop "[e]ighteen technical specialists made presentations"[347] and the support team provided elicitation training.[348]

At the third and final workshop, the subject-matter experts presented and discussed their own "preliminary interpretations and uncertainties regarding key issues in unsaturated zone flow processes."[349]

Following the third workshop, the support team:

> [O]rganized a one-day field trip to Yucca Mountain at the request of the expert panel members, who wanted to observe first-hand the general setting of Yucca Mountain. The field trip was led by earth scientists from the USGS and the U. S. Bureau of Reclamation [and enabled the subject-matter experts] to observe bedrock exposed in the Exploratory Studies Facility (ESF) and at the ground surface and to visit several data collection localities for the USGS infiltration studies.[350]

Prior to the elicitation interviews, the support team provided to each panel member a "Roadmap to the Elicitation"[351] with a list of topics to be discussed.[352] The elicitation interviews followed the same pattern used in the other elicitations described above.[353] The support team took notes during each interview, thereby freeing the subject-matter expert "to focus on thinking through his answers and thoroughly expressing his interpretations."[354]

"Following the interviews, the [support] team provided each expert with written documentation of the interview."[355] The experts then reviewed and edited their preliminary assessments to reflect the expert's revised interpretations.[356] The revised assessment of each expert was then distributed to all panel members so that each could review the other experts' judgments and technical analysis, and then offer written feedback to his or

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346 Unsaturated Zone Flow Expert Elicitation, *supra* note 114, at p. 2-8.
347 *Id.*
348 *Id.* at pp. 2-8 to 2-9.
349 *Id.* at p. 2-9.
350 *Id.*
351 *Id.* at pp. 2-9, 2-14 (tbl. 2.1).
352 Unsaturated Zone Flow Expert Elicitation, *supra* note 114, at pp. 2-9 to 2-10.
353 *Id.* § 2.2.4, at pp. 2-9 to 2-10.
354 *Id.* § 2.2.4.3, at p. 2-10.
355 *Id.*
356 *Id.* § 2.2.4.3, at pp. 2-10 to 2-11.

her fellow panel members.[357]

After considering the feedback, each expert could make further revisions to his or her elicitation summary to reflect any resulting changes in analysis and/or conclusions.[358] The support team reviewed these revised summaries and made any necessary requests for clarification.[359] Once the support team received the clarifications, it finalized the summaries and compiled them into a single report.[360]

Although the support team assigned "equal weight" to each participant in an expert elicitation,[361] it was not required to do so. Rather, the "equal weight" approach was a goal, not a mandate.[362] The support team could instead have chosen to give disproportionately greater or lesser weight to some experts' conclusions.[363] The team was free to choose to use the latter approach in order to develop an assessment it "believes best captures the range of views and uncertainties."[364]

The elicitation pointed to two examples where such an approach might be appropriate. The first concerned the hypothetical situation where a subject-matter expert was "unwilling to forsake the role of a *proponent* who advocates a singular viewpoint, for that of an *evaluator* who is able to consider multiple viewpoints."[365] Under those circumstances, that expert's views may be given less weight or he may even be removed from the panel.[366] Under a second scenario, a member's views could be given less weight "if the rest of the panel declared him to have extreme, outlier views relative to both the views of

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[357] *Id.*

[358] Unsaturated Zone Flow Expert Elicitation, *supra* note 114, at pp. 2-10 to 2-11.

[359] *Id.* at p. 2-11.

[360] *Id.*

[361] DOE took this "equal weight" approach in the volcanology, seismology and hydrology elicitations upon which it relied in its Yucca Mountain application, as well as in the Waste Form Expert Elicitation. *See supra* notes 260-62 and accompanying text.

[362] Unsaturated Zone Flow Expert Elicitation, *supra* note 114, § 2.3.4.5, at p. 2-12. This subsection follows immediately after section 2.2.4.4, and therefore appears to have been misnumbered. The intended section number was likely 2.2.4.5.

[363] *See id.* at p. 2-13 (explaining circumstances where less weight would be given to an expert member's conclusions).

[364] *Id.* at p. 2-3.

[365] *Id.* at p. 2-13.

[366] *Id.*

the rest of the panel and the larger technical community."[367] In this second situation, a weight of 14% (reflecting the outlier's position as one of seven panel members) "would be excessive relative to the true weight of his views when compared to the larger community (if, for instance, 1 in 100 might share the view)."[368]

Finally, this elicitation used a more abbreviated approach to expert elicitation than did the larger elicitations addressed in Part II.C.3.a through II.C.3.c of this article.[369] In this respect, it was similar to the Waste Form Expert Elicitation.[370]

D. Rulemakings

Expert elicitation has played a significant role in only one NRC rulemaking proceeding.[371] In 2005, the NRC proposed:

> [T]o amend its regulations to permit current power reactor licensees to implement a voluntary, risk-informed alternative to the current requirements for analyzing the performance of emergency core cooling systems (ECCS) during loss-of-coolant accidents (LOCAs) [and] . . . [to] establish procedures and criteria for requesting changes in plant design and procedures based upon the results of the new analyses of ECCS performance during LOCAs.[372]

LOCAs can be caused by breaks in pipes, resulting in the loss

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[367] *Id.*

[368] Unsaturated Zone Flow Expert Elicitation, *supra* note 114, at p. 2-13.

[369] *See id.* at p. 2-3 (explaining the different approaches used in a "relatively modest" elicitation versus a more intensive study).

[370] *See supra* note 340 and accompanying text.

[371] Expert elicitation has, however, been mentioned in passing in one other rulemaking proceeding. *See* NRC, Alternate Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events, 72 Fed. Reg. 56,275, 56,276-77 (proposed Oct. 3, 2007) ("The technical basis [for this proposed rule] was developed using a flaw density, spatial distribution, and size distribution determined from a small amount of experimental data, as well as from physical models and expert elicitation").

[372] NRC Risk-Informed Changes to Loss-of-Coolant Accident Technical Requirements, 70 Fed. Reg. 67,598 (proposed Nov. 7, 2005) [hereinafter Risk-Informed Changes]. *See generally* 2 NUREG-1829, *supra* note 27, at xv-xxvi (providing an extensive description of the process used in the LOCA expert elicitation. A reader interested in a detailed description of each phase of this elicitation will find it in 1 NUREG 1829, *supra* note 27, at pp. 3-1 to 3-35 (detailing the particular approach the NRC used in this elicitation). The appendices to NUREG-1829 provide voluminous background information regarding the elicitation process and its participants. Particularly relevant is Appendix B, which sets forth the detailed minutes of the expert elicitation panel's meetings. 2 NUREG-1829, *supra* note 27, at B-1 to B-67.

of coolant to the reactor. One of the key elements in analyzing LOCAs is the "transition break size" (TBS)—that is, the size of the break, hole, or fracture in a pipe.[373]

Two approaches have traditionally been used to estimate LOCA frequencies and their relationship to pipe size. However, the NRC concluded that "[n]either approach [was] particularly suited to evaluate LOCA event frequencies due to the rareness of these events and the modeling complexity."[374] Therefore, the NRC turned to expert elicitation.[375]

Prior to the initiation of the expert elicitation process, the NRC staff performed its own "pilot" elicitation to identify at least some of issues that the subject-matter experts would need to evaluate.[376]

The NRC used a twelve-expert panel[377] to help establish the TBS. This expert elicitation panel included a diverse group of

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[373] *See* Risk-Informed Changes, *supra* note 372, 70 Fed. Reg. at 67,599 (noting that "one candidate area identified for possible revision was emergency core cooling system . . . requirements in response to postulated loss-of-coolant accidents"), 67,602 (explaining the relevancy of TBS).

[374] *See* 2 NUREG-1829, *supra* note 27, at xv (discussing the negative attributes of the approaches).

[375] *Id.* It is also notable that the NRC's ACRS and its relevant subcommittees took considerable interest in this rule, meeting many times to discuss it. *See* NRC Advisory Comm. on Reactor Safety, Meeting Notice, 72 Fed. Reg. 65,358 (Nov. 20, 2007) (discussing final draft of NUREG); NRC Advisory Comm. on Reactor Safety Subcomm. on Reliability Probabilistic Risk Assessment, Meeting Notice, 72 Fed. Reg. 61,189, 61,190 (Oct. 29, 2007) ("The Subcommittee will discuss the estimation of frequencies of occurrence of . . . LOCAs through the expert elicitation process."); NRC Advisory Comm. on Reactor Safety, Meeting Notice, 70 Fed. Reg. 8857 (Feb. 23, 2005) (considering what would later become a Draft NUREG on expert elicitation); NRC Advisory Comm. on Reactor Safety, Meeting Notice, 69 Fed. Reg. 68,411 (Nov. 24, 2004) (same); NRC, ACRS, Meeting of the ACRS Subcommittee on Regulatory Policies and Practices Notice of Meeting, 69 Fed. Reg. 63,564 (Nov. 2, 2004) (same); NRC Advisory Comm. on Reactor Safety, Meeting Notice, 68 Fed. Reg. 38,106, 38,106-07 (June 26, 2003) ("The Committee will hear presentations by and hold discussions with representatives of the NRC staff with regard to conducting an expert elicitation as directed by the Commission in the March 31, 2003 Staff Requirements Memorandum related to risk-informing 10 CFR 50.46.").

[376] 2 NUREG-1829, *supra* note 27, at xvi.

[377] Risk-Informed Changes, *supra* note 372, 70 Fed. Reg. at 67,603; *See also 2* NUREG-1829, *supra* note 27, at xvi (detailing the twelve person panel); Each subject-matter expert had "at least 25 years of relevant technical expertise." SECY-04-0060, Loss-of-Coolant Accident Break Frequencies for the Option III Risk-Informed Reevaluation of 10 CFR 50.46, Appendix K to 10 CFR Part 50, and General Design Criteria (GDC) 35, (April 13, 2004), at 3 (unnumbered) (ML040860129) [hereinafter SECY-04-0060].

subject matter experts,[378] plus nine members of the "facilitation team"[379] (comprised of generalists, a normative expert, and two recorders.[380]). The panel examined "degradation-related pipe breaks"[381] in typical reactors in order to "develop pipe break frequencies as a function of break size."[382] The panel's focus was limited to one narrow issue—"determining event frequencies that initiate by [certain kinds of] failures related to material degradation."[383] The panel estimated LOCA frequency "by consolidating service history data and insights from probabilistic fracture mechanics . . . studies with knowledge of plant design, operation, and material performance."[384]

The panel at its initial meeting discussed the project staff's list of technical issues and developed a way of quantifying the effects of those issues.[385] This involved the lugubrious-sounding process of "decomposing" the complex technical issues into more manageable sub-issues.[386] The panel, together with the facilitation team, "then developed [the necessary] background technical information and [with the help of the project staff,] prepared the elicitation questionnaire."[387]

At the second meeting, the panel reviewed and refined both the technical information and the questionnaire. The panel members then returned to their respective home institutions and prepared

[378] *See* 2 NUREG-1829, *supra* note 27, at xxv (identifying the organizations with which each individual was affiliated); *See also id.* at app. A (providing detailed descriptions of each subject-matter expert's background).

[379] *Id.* at xxv. The facilitation team in the LOCA elicitation played the same role as the "Technical Facilitator-Integrator" in the Yucca Mountain volcanology elicitation, and same role as the support teams in all the elicitations addressed in this article.

[380] *See id.* at xvii (describing the makeup of the facilitation team).

[381] Risk-Informed Changes, *supra* note 372, 70 Fed. Reg. at 67,603, 67,604.

[382] *Id.* at 67,603.

[383] *Id. See also* NRC Risk-Informed Changes to Loss-of-Coolant Accident Technical Requirements, 74 Fed. Reg. 40,006, 40,026 (supplemental proposed rule Aug. 10, 2009) (explaining the focus of the elicitation).

[384] NRC Notice of Availability of Draft Report for Comment: Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process, NUREG-1829, 70 Fed. Reg. 57,901, 57,901 (Oct. 4, 2005). For a detailed description of this expert elicitation, *see generally* 2 NUREG-1829, *supra* note 19, at xv-xxii; SECY-04-0060, *supra* note 377 (describing the approach taken to develop LOCA frequency estimates).

[385] 2 NUREG-1829, *supra* note 27, at xvii; SECY-04-0060, *supra* note 377.

[386] 2 NUREG-1829, *supra* note 27, at xvii.

[387] SECY-04-0060, *supra* note 377, at 3 (unnumbered); *See also* 2 NUREG-1829, *supra* note 27, at xvii (explaining the tasks set to the panel at the first and second meetings).

their own separate issues analyses in order to answer the questionnaire.[388]

Following these initial meetings, the facilitation team met separately with each panel member in a series of day-long elicitation interviews.[389] At these sessions, each subject-matter panel member "answered the elicitation questionnaire by providing quantitative estimates and a qualitative rationale to support" the expert's conclusions regarding the questions he or she self-selected for discussion at the meeting.[390] Each subject-matter expert also specified the uncertainty associated with his or her conclusions.[391]

Following this series of individual meetings, the subject-matter experts again returned to their home institutions, where each revised his or her conclusions based on the feedback received during the interview.[392] The project staff, upon receiving the subject-matter experts' revised conclusions and rationales, "compiled the panel's [revised] responses and developed preliminary estimates of the LOCA frequencies."[393]

The project staff presented these revised conclusions and rationales to the panel at a third meeting.[394] "Panel members were invited to fill in gaps in their questionnaire responses and, if desired, to modify any of their responses based on group discussion of important technical issues considered during individual elicitations."[395] Based on these further revisions, the project staff recalculated the earlier preliminary estimates of LOCA frequencies and provided the updated estimates to the

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388 2 NUREG-1829, *supra* note 27, at xvii; SECY-04-0060, *supra* note 377, at 3-4 (unnumbered).

389 2 NUREG-1829, *supra* note 27, at xvii; SECY-04-0060, *supra* note 377, at 4 (unnumbered).

390 SECY-04-0060, *supra* note 377, at 4 (unnumbered); 2 NUREG-1829, *supra* note 27, at xvii.

391 2 NUREG-1829, *supra* note 27, at xvii; SECY-04-0060, *supra* note 377, at 4 (unnumbered).

392 2 NUREG-1829, *supra* note 27, at xvii.

393 *Id.*; *See also* SECY-04-0060, *supra* note 377, at 4 (unnumbered) (addressing the "median responses and associated uncertainty bounds" received from the panel members).

394 *Id.*; *see also* 2 NUREG-1829, *supra* note 27, at xvii (noting that the preliminary estimates were presented at the "wrap-up meeting" that followed the first two meetings).

395 2 NUREG-1829, *supra* note 27, at xvii-xviii. *See also* 1 NUREG-1829, *supra* note 27, at p. 3-1 (footnote omitted); SECY-04-0060, *supra* note 377, at 4 (unnumbered).

subject-matter experts.[396]

Finally, at a fourth (video-conference) meeting, the subject-matter experts met yet again to discuss the most recent set of results.[397] The project staff then revised those results still further, to reflect the feedback during the fourth meeting.[398]

Following the computation of the LOCA frequencies after the fourth meeting, the project staff initiated an external peer review of the expert elicitation and solicited public comment on the then-current draft report.[399] Once these two processes were completed, the project staff revised the report one last time, to reflect the input from the peer review and public comments.[400] NUREG-1829 was the end-product of the LOCA elicitation process, which lasted from February 2003[401] until April 2008.[402]

After the completion of the expert elicitation process, the NRC staff used the panel's conclusions along with other information, to determine the TBS.[403] The staff began this process by considering the results of the expert elicitation, but it then took a final step of adjusting those results to take into account the "uncertainty in the elicitation process, other potential mechanisms that could cause pipe failure that were not explicitly considered in the expert elicitation process, and the higher susceptibility to rupture/failure of specific piping in the RCS [reactor coolant system]."[404] The Proposed Rule offered the

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396 2 NUREG-1829, *supra* note 27, at xviii.

397 1 NUREG-1829, *supra* note 27, at p. 3-1.

398 *See id.* at p. 3-2 (depicting a flow chart of the entire LOCA elicitation process).

399 *Id.* at pp. 3-1, 3-34 to 3-35. Earlier studies had recommended, or at least hinted at, peer review of the expert elicitation process and results. NUREG-1563, *supra* note 1, at 5; NUREG/CR-6372 Vol. 1, *supra* note 40, at 48-50.

400 *See* 1 NUREG-1829, *supra* note 27, at p. 3-35 (explaining the method of obtaining results from aggregating the individual estimates and interpretations for the final report).

401 *Id.* at p. 3-8.

402 *Id.* at second title page.

403 *See* NRC Risk-Informed Changes to Loss-of-Coolant Accident Technical Requirements, 70 Fed. Reg. 67,598 67,603 (proposed Nov. 7, 2005) (describing NRC's process of determining the TBS through the use of elicitation evaluations).

404 *Id. See also* NRC Risk-Informed Changes to Loss-of-Coolant Accident Technical Requirements, 74 Fed. Reg. 40,006, 40,028 (supplemental proposed rule Aug. 10, 2009) ("The baseline TBS was adjusted upward to account for uncertainties and failure mechanisms leading to pipe rupture that were not considered in the expert elicitation process"). In this regard, the NRC staff's action was analogous to DOE's approach, in its saturated zone flow expert elicitation, of "making sure that the [saturated zone] model has a specific

following description of how, after the conclusion of the expert elicitation, the NRC took into account the uncertainties associated with each panel members' conclusions:

> The uncertainty associated with each expert's generic frequency estimates was . . . estimated. This uncertainty was associated with each expert's confidence in [his or her] generic estimates and frequency differences stemming from broad plant-specific factors, but did not consider factors specific to any individual plants. Thus, the uncertainty bounds of the expert elicitation do not represent LOCA frequency estimates for individual plants that deviate from the generic values. Variability among the various experts' results was also examined. A number of sensitivity analyses were conducted to examine the robustness of the LOCA frequency estimates to assumptions made during the analysis of the experts' responses.[405]
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> To address the uncertainty in the expert opinion elicitation estimates, the staff selected a pipe break frequency having approximately a 95th percentile probability of 10^{-5} per reactor-year. . . . However, this does not account for all failure mechanisms. In addition, the results of an expert opinion elicitation do not have the same weight as actual failure data. Therefore, choosing the 95th percentile values gathered from the expert opinion elicitation leaves additional margin for uncertainty than would be necessary if the mean frequency had been calculated from actual failure data [*sic*].[406]

This final step was somewhat analogous to the staff's consideration of post-elicitation information in the Yucca Mountain elicitation because it reflects the staff's decision *not* to take the expert elicitation panel's conclusions as the final word.[407] But the final step in this rulemaking process goes further by demonstrating the staff's willingness to actually refine those conclusions to suit the Commission's particular needs regarding

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discharge that is higher than that predicted by the expert elicitation committee." Office of Civilian Radioactive Waste Mgmt., CALIBRATION OF THE SITE-SCALE SATURATED ZONE FLOW MODEL DRAFT (For Audit Purposes Only), at p. I-98 (Apr. 2000) (ML003724528).

405 Proposed Rule, 70 Fed. Reg. at 67,603.

406 *Id.* at 67,604.

407 *See*, *e.g.*, *id.* at 67,606 ("The initial TBS was adjusted upward to account for uncertainties and failure mechanisms leading to pipe rupture that were not considered in the expert elicitation process."). *See also supra* notes 132-33 and associated text.

the rulemaking.[408]

III. CONCLUSION & RECOMMMENDATIONS

The NRC's last full-scale examination of the expert elicitation process occurred in 1996. In that examination, the staff deconstructed the elicitation process into nine separate steps. The staff, however, wisely indicated that those nine steps were not carved irrevocably in stone but instead provided merely a general framework that could be customized or revised to suit the needs of the elicitation at issue. During the succeeding fifteen years, the NRC developed significant additional experience with the expert elicitation process in both the rulemaking and adjudicatory contexts. Yet during this period, the process flew largely—perhaps entirely—under the radar of the Commissioners themselves.

This changed in 2011, when Commissioner Apostolakis urged a reevaluation of the process, believing it could significantly help to resolve difficult regulatory challenges such as cyber security, digital instrumentation and control, small modular reactors, and material aging issues. Such a reevaluation, particularly as it is being initiated at the highest level of the NRC, should enable the agency to determine how to take best advantage of expert elicitation's many positive attributes while minimizing the effects of its negative attributes.

The purpose of expert elicitation is to garner expert judgment for decision makers to use when resolving issues that do not lend themselves to other, more traditional and less formal evidentiary methods (e.g., data or modeling approaches). But however garnered, expert judgment is useless to a decision maker unless it is credible. As it happens, credibility is one of the expert elicitation process' most significant positive attributes—and is obtainable because of the process's transparency. Transparency provides credibility to the elicitation process because it allows someone outside that process (i) to see all the relevant information that led to the elicitation's conclusions, (ii) to follow all communications amongst the panel members during their deliberations so that the outsider can understand the basis for the conclusions, (iii) to see how the panel used those same conclusions to reach the ultimate outcome of the elicitation, and

[408] *See id.* at 67,601 (describing the NRC staff's request for guidance to make changes in accordance to the Commission's decisions).

(iv) to understand why expert judgment was chosen over other less-formal, information-gathering methods. Such transparency should enhance the Commissioners', the NRC staff's and the public's confidence in any expert judgment arising from the elicitation.

Additional advantages include (a) improvement in NRC decision-making associated with public policy; (b) recognition and minimization of possible biases in expert judgment; (c) determination of the current state of knowledge about important technical and scientific matters and, perhaps, a basis for updating that knowledge; (d) revelation of the range of scientific and technical interpretations relevant to the issues at hand; (e) quantification of uncertainties associated with resolving those issues; and (f) resolution of differences in experts' estimates of uncertainty by providing a common vocabulary for expressing their judgments.

Expert elicitation is, however, no panacea. For instance, an elicitation panel may be subject to dominance by a single outspoken member. In addition, the elicitation process can be considerably more expensive and time-consuming than other forms of obtaining expert judgment, because it involves more people than the solicitation of a single expert's judgment or a handful of experts' collective judgment. Moreover, it can be difficult to empanel experts whose views actually represent the broad array of opinions within the professional community. Furthermore, the results of expert elicitation may be less defensible in adjudications because no single expert "owns" the result. One subject-matter expert—or, for that matter, less than all subject-matter experts—may be deemed by an NRC licensing board to be insufficient to represent the full range of technical viewpoints contained in an expert elicitation report.

To determine how best to weigh these advantages and disadvantages, the Commission has directed the NRC staff to conduct a thorough reexamination of its experience with expert elicitations. Such a reevaluation of the expert elicitation process should provide the Commission and its staff with an in-depth understanding of the different approaches the NRC has used in past elicitations, and should, in the future, enable the agency to choose the approach or blend of approaches best suited to address any issue requiring technical judgment from experts representing a broad spectrum of opinions.

The reevaluation should address the following dozen major

issues that have surfaced subsequent, and in some cases prior, to the issuance of the staff's 1996 initial examination of expert elicitation:

- Should the staff's nine-step process for elicitation be revised?
- How should the complexity and number of issues to be addressed in an elicitation affect the number of workshops, informal working meetings, or field trips held during the elicitation process? Compare the small Waste Form Expert Elicitation[409] with the much larger Seismology Expert Elicitation.[410]
- How should the complexity and number of issues to be addressed in an elicitation affect the number of subject-matter experts selected for the panel? Compare DOE's recommendation of a range between 4 and 12 subject-matter experts for geological hazard assessments with other elicitation experts' preference for much higher numbers outside the context of nuclear energy.
- What are the best means of preventing or at least minimizing the empaneling of subject-matter experts with conflicts of interest? What are the best means of documenting conflicts of interest, and neutralizing the adverse effects where such conflicts are unavoidable?
- What are the best procedures for the selection of subject-matter experts, to assure that they are highly expert, are not invested in the outcome, and are not cherry-picked to produce a particular result in advance? Commissioner Apostolakis considers this the single most important element of the expert elicitation process because the elicitation's results can so easily turn on the make-up of its expert panel.[411]
- What is the best way to ensure that the allocation of places on an elicitation panel is well balanced amongst different professional communities (e.g., industry, government, academia, national laboratories), so as to ensure a wide array of professional viewpoints?
- Should subject-matter experts be required to document revisions to their initial assessments during the

409 Waste Form Expert Elicitation, *supra* note 36.
410 Seismology Expert Elicitation, *supra* note 36.
411 Apostolakis Interview, *supra* note 53.

process? Or would such a requirement "anchor" the subject-matter experts to their initial evaluations and make them reluctant to revise those evaluations during and after the feedback process?

- Should the NRC specify that the reports on individual elicitation interviews be based on notes taken during the interviews as compared with post-interview written questionnaires, or experts writing their own interpretations following the interview?
- Should the NRC use, or approve the use of, multi-member teams in lieu of individual subject matter experts (e.g., the seismic source teams in the seismology expert elicitation)? If so, should the members of each team be interviewed en mass or individually?
- Under what circumstances should the NRC or its licensees accord unequal weight to the conclusions of individual subject-matter experts or teams of experts? Under such circumstances, how should the support team determine the amount of weight to assign the expert or team? And how should those determinations be made transparent to the public?[412]
- Should elicitation panels be encouraged, or even required, to update their conclusions in light of new information that was unavailable during the panel's original deliberations? If not, should the Commission insist that the staff do so?
- Is the expert elicitation process amenable for use in setting policy? If so, how would the expert elicitation process generally, and the responses to the above eleven points in particular, differ if the subject of a nuclear-related elicitation were a policy determination rather than a scientific/technical evidentiary determination (as in the rulemaking and adjudicatory elicitations discussed in this article)?

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[412] 2012 COMMISSION VOTING RECORD, *supra* note 12, at Response Sheet from Comm'r Apostolakis ("[T]he staff should provide guidance on whether and under what circumstances future elicitation exercises should implement corrections to expert judgments, or, even better, whether results with both corrected and uncorrected judgments should be reported."). The Commissioner was referring to the LOCA expert elicitation, where "a unique feature of this project was that the expert judgments were 'corrected' for potential biases, something that is not done routinely in such exercises." *Id.*

The Commission should also evaluate or reevaluate the following six, less significant issues:

- If the NRC is an elicitation's sponsor, should the agency run a "pilot elicitation" prior to conducting the actual expert elicitation, in order to tune more finely the process to the issues before the expert panel?
- Who sets the agenda for the elicitation interview—the subject-matter expert or the facilitator?
- Should the elicitation sponsor conduct peer review of the expert elicitation process? If so, should the review occur during or after the elicitation?
- Should the elicitation sponsor use videoconferences in lieu of face-to-face meetings? What are the advantages and disadvantages of videoconferencing such meetings?
- Should the sponsor conduct a post-elicitation survey of all participants to develop a "lessons learned" list?
- How should the NRC capture the knowledge accumulated by the NRC's own specialists in the expert elicitation process before those specialists retire?

In addition, the NRC should review any "lessons learned" that have already been compiled by the staff, DOE, or other nuclear-related entities (e.g., EPRI, LLNL) following previous expert elicitations. And finally, the NRC should investigate the use of the expert elicitation process by other agencies—especially the Environmental Protection Agency (EPA). A particularly good starting point for EPA research would be that agency's Expert Elicitation Task Force's "White Paper"[413] and its underlying documents. EPA's "White Paper discusses the potential utility of using expert elicitation to support EPA regulatory and non-regulatory analyses and decision-making, provides recommendations for expert elicitation 'good practices,' and describes steps for a broader application across EPA."[414] Also, a recent[415] search of WestLaw's *Federal Register* library yielded 45 instances where the NRC used the term "expert elicitation,"[416] 42

[413] SCI. AND TECH. POLICY COUNCIL, EPA, EXPERT ELICITATION TASK FORCE WHITE PAPER (2011), *available at* http://www.epa.gov/stpc/pdfs/ee-white-paper-final.pdf. *See* JASANOFF, *supra* note 30, at 116-18 (providing a synopsis of EPA's experience with expert elicitation).

[414] EPA Science Advisory Board Office; Notification of Two Public Teleconferences of the Chartered Science Advisory Board, 74 Fed. Reg. 34,348 (July 15, 2009).

[415] This search was conducted on March 31, 2013.

[416] In case the Commission instructs the NRC staff to conduct further

instances for the EPA,[417] and 22 more instances for eight other agencies or departments.[418] Finally, other promising avenues of research include elicitations by the private sector,[419] academia,[420]

research into the NRC's and other Federal agencies' use of expert elicitation, this and the next two footnotes of this article provides short citations to all instances where a Federal agency has used the phrase "expert elicitation" in a *Federal Register* document. For the sake of brevity, and because the citations are not directly relevant to this article, the *Federal Register* citations associated with the textual paragraph above do not follow Blue Book citation format: 75 Fed. Reg. 13, 74 Fed. Reg. 40,006, 72 Fed. Reg. 65,358, 72 Fed. Reg. 61,189, 72 Fed. Reg. 56,275, 71 Fed. Reg. 38,906, 70 Fed. Reg. 67,598, 70 Fed. Reg. 62,352, 70 Fed. Reg. 60,859, 70 Fed. Reg. 57,901, 70 Fed. Reg. 55,637, 70 Fed. Reg. 53,639, 70 Fed. Reg. 25,622, 70 Fed. Reg. 10,901, 70 Fed. Reg. 8857, 69 Fed. Reg. 68,411, 69 Fed. Reg. 63,564, 68 Fed. Reg. 49,529, 68 Fed. Reg. 45,086 at 45,100, 68 Fed. Reg. 38,106, 68 Fed. Reg. 9098, 67 Fed. Reg. 79,168, 66 Fed. Reg. 55,732, 66 Fed. Reg. 32,074 at 32,101, 65 Fed. Reg. 10,121, 64 Fed. Reg. 8640, 62 Fed. Reg. 24,670, 61 Fed. Reg. 67,354, 61 Fed. Reg. 46,832, 61 Fed. Reg. 36,399, 61 Fed. Reg. 27,108, 61 Fed. Reg. 15,984, 61 Fed. Reg. 7568, 61 Fed. Reg. 6867, 60 Fed. Reg. 43,617, 60 Fed. Reg. 32,214, 60 Fed. Reg. 31,185, 60 Fed. Reg. 29,911, 60 Fed. Reg. 28,206, 59 Fed. Reg. 23,084, 59 Fed. Reg. 9253, 58 Fed. Reg. 49,531, 56 Fed. Reg. 24,848, 56 Fed. Reg. 11,765, & 54 Fed. Reg. 26,455.

[417] *See* 76 Fed. Reg. 74,854, 76 Fed. Reg. 57,106, 76 Fed. Reg. 55,673, 75 Fed. Reg. 25,324, 75 Fed. Reg. 22,896, 75 Fed. Reg. 14,670, 75 Fed. Reg. 9648, 74 Fed. Reg. 49,454, 74 Fed. Reg. 44,442,74 Fed. Reg. 39,075, 74 Fed. Reg. 34,348, 74 Fed. Reg. 24,904, 74 Fed. Reg. 21,136, 74 Fed. Reg. 14,799, 74 Fed. Reg. 9698, 74 Fed. Reg. 5157, 73 Fed. Reg. 59,034, 73 Fed. Reg. 37,096, 73 Fed. Reg. 35,838, 73 Fed. Reg. 25,098, 73 Fed. Reg. 21,128, 73 Fed. Reg. 3568, 72 Fed. Reg. 69,922, 72 Fed. Reg. 35,463, 72 Fed. Reg. 28,098, 72 Fed. Reg. 27,178, 72 Fed. Reg. 20,586, 72 Fed. Reg. 15,938, 72 Fed. Reg. 8428, 71 Fed. Reg. 39,154, 70 Fed. Reg. 61,283, 70 Fed. Reg. 17,766, 68 Fed. Reg. 7531, 67 Fed. Reg. 79,168, 66 Fed. Reg. 32,074, 64 Fed. Reg. 46,976, 63 Fed. Reg. 27,354, 62 Fed. Reg. 58,792, 61 Fed. Reg. 5224, 60 Fed. Reg. 5766, & 59 Fed. Reg. 31,238.

[418] Department of Health and Human Services (Food and Drug Administration) (78 Fed. Reg. 9701, 74 Fed. Reg. 15,293, 70 Fed. Reg. 23,813); Department of Transportation (National Highway Traffic Safety Administration) (77 Fed. Reg. 62,624, 76 Fed. Reg. 74,854, 76 Fed. Reg. 57,106, 75 Fed. Reg. 25,324, 74 Fed. Reg. 49,454) (all five overlapping with EPA); Department of Commerce (National Oceanic and Atmospheric Administration) (77 Fed. Reg. 66,799, 76 Fed. Reg. 41,217) (soliciting expert opinions derived from (inter alia) expert elicitation); Department of Agriculture (Food Safety and Inspection Service) (77 Fed. Reg. 73,441, 76 Fed. Reg. 80,873, 76 Fed. Reg. 19,952, 72 Fed. Reg. 16,327); Nuclear Waste Technical Review Board (62 Fed. Reg. 67,417, 62 Fed. Reg. 26,341); Department of Homeland Security (73 Fed. Reg. 18,384, 72 Fed. Reg. 69,819, 72 Fed. Reg. 35,088); Department of State (73 Fed. Reg. 18,384, 72 Fed. Reg. 35,088) (two overlapping with Department of Homeland Security); DOE (64 Fed. Reg. 67,054) (regarding *Yucca Mountain*).

[419] *See*, *e.g.*, EPRI REPORT, *supra* note 20 (setting forth the results of a trade association's expert elicitation).

[420] *See*, *e.g.*, Monte N. Stewart & H. Dennis Tolley, *Investigating Possible Bias: the American Legal Academy's View of Religiously Affiliated Law Schools*, 54 J. LEGAL EDUC. 136, 143-47 (2004); Fauss, *supra* note 56, at 771, 774-79

and the national laboratories.[421]

APPENDIX

NUREG-1563, at 15, 17-18 ("Branch Technical Positions")

In view of the aforementioned policy considerations and statements of regulatory consideration underpinning 10 CFR Part 60, the staff has adopted the following technical positions concerning the use of expert elicitation in demonstrating compliance with the geologic repository disposal regulations. As a supplement to the technical positions here, Appendix A provides definitions for certain key terms.

(1) In matters important to the demonstration of compliance, the use of formal expert elicitation should be considered whenever one or more of the following conditions exist:

(a) Empirical data are not reasonably obtainable, or the analyses are not practical to perform;

(b) Uncertainties are large and significant to a demonstration of compliance;

(c) More than one conceptual model can explain, and be consistent with, the available data; or

(d) Technical judgments are required to assess whether bounding assumptions or calculations are appropriately conservative.

(2) (a) When formally eliciting expert judgment, the applicant should use a consistent and systematic procedure that will ensure that the results obtained accurately reflect what is known and not known about the topic in question. The components in an acceptable elicitation process are described below and are illustrated in Figure 1. Although written largely for the elicitation of individual subject-matter experts, the same approach can be applied to a *panel* (or a team) of subject-matter experts.

(presenting an expert elicitation process quite different from the one used by the NRC and DOE). Additional articles included in 37 J.L. MED. & ETHICS likewise address the same expert elicitation process as Ms. Fauss, and are cited elsewhere in this article. *See* periodicals cited, *supra* notes 19, 28, 63, 94.

[421] *See*, *e.g.*, NUREG/CR-6372, *supra* note 40, at 2-3 (describing a study conducted at Lawrence Livermore National Laboratory using a formal elicitation process to produce the PSHA results).

Step No. 1 - Definition of Objectives

The objectives of the elicitation should be defined explicitly and in a manner that reflects a clear understanding of how the judgments obtained will be used. The explication of these objectives should then guide the choice of experts, the information provided to them, and the form of the judgments that will be 'required'.

Step No. 2 - Selection of Experts

Before selection of the subject-matter experts, whose judgments will be elicited, two other types of experts should be recruited - the normative expert and the generalist. Because these types of experts may influence the outcome of the elicitation by the manner in which judgments are elicited, analyzed, or used, care should be taken in their selection to ensure that they can perform in an objective and impartial manner. Working together, the normative experts and generalists generate and apply specific criteria for the selection of the subject-matter experts. The subject-matter experts selected for elicitation should be individuals who: (a) possess the necessary knowledge and expertise;[fn 13] (b) have demonstrated their ability to apply their knowledge and expertise; (c) represent a broad diversity of independent opinion and approaches for addressing the topic(s) in question; (d) are willing to be identified publicly with their judgments; and (e) are willing to publicly disclose all potential conflicts of interest.

> [fn 13]With regard to Item (a), it would be useful for members of the expert panel to possess at least some rudimentary knowledge of both decision-making theory and statistics. However, the possession or the lack of this knowledge should not be used as a selection criterion.

The criteria used to select the various experts of the elicitation team should be documented.

Step No. 3 - Refinement of Issues and Problem Decomposition

The generalists and normative experts should work with the subject-matter experts to decompose the broad objectives of the elicitation by clearly and precisely specifying more focused and simpler sub-issues.

Step No. 4 - Assembly and Dissemination of Basic Information

Assembly of background information should be initially conducted by the generalists and normative experts. As the elicitation process proceeds, the subject-matter experts may be able to recommend additional sources of information. Bias in the selection of this background material should be avoided such that a full range of views is represented and the necessary data and information are provided in a uniform, balanced, and timely fashion to all subject-matter experts.

Step No. 5 - Pre-Elicitation Training

Individual (or teams of) subject-matter experts should be provided training before the elicitations to: (a) familiarize them with the subject matter (including the necessary background information on why the elicitation is being performed and how the results will be used); (b) familiarize them with the elicitation process; (c) educate them in both' uncertainty and probability encoding and the expression of their judgments, using subjective probability; (d) provide them practice in formally articulating their judgments as well as explicitly identifying their associated assumptions and rationale; and (e) educate them with regard to possible biases that could be present and influence their judgments.

Step No. 6 - Elicitation of Judgments

The individual elicitation session with each subject-matter expert (or teams of subject-matter experts) should be held in a private setting conducive to uninterrupted discussion. The generalists and normative experts should be in attendance for the complete session with each subject-matter expert. At the start of the session for each subject-matter expert, the normative expert should summarize the issues to be covered and outline the logistics of the elicitation. All definitions and assumptions agreed to by the group during pre-elicitation meetings should be reviewed. All subject-matter experts should be queried in a uniform manner and asked to provide specific answers to questions about the issues considered and the reasoning behind their responses. Care should be taken to ensure that the required information is obtained and that it is internally consistent. Responses of all subject-matter experts should be documented thoroughly with one or more of the' following: written notes,

transcription, and audio or video tape.

Step No. 7 - Post-Elicitation Feedback

Each subject-matter expert (or teams of subject-matter experts) should be provided feedback from the elicitation team on the results of his or her elicitation as soon as practical after the elicitation sessions are completed. Each expert should be queried as to the need for revision or clarification of his or her respective judgments based on that feedback. As is the case for all the elicited judgments, the rationale for any revisions should be documented scrupulously.

Step No. 8 - Aggregation of Judgments (Including Treatment of Disparate Views)

Whatever aggregation method is employed, the individual expert's opinions must be preserved, documented, and provided to the NRC staff. Transparency in the aggregation process will render these judgments, including disparate views or outliers, [fn 14] useful for subsequent analyses. If disparate judgments are aggregated or combined, the applicant should: (a) provide some rationale for the specific aggregation techniques employed and provide documentation sufficient to trace the impact of the individual expert's judgment on the consolidated judgment; and (b) show what effect, if any, the disparate views would have on design and/or performance. When widely disparate opinions arise, extra effort should be taken to document thoroughly the bases for the differing views. Subject-matter experts with differing views should be asked to comment on opposing views during and/or after their individual elicitations. Should the disparity in views persist, then each of the significantly varying views should be provided as output of the elicitation so that it may be incorporated directly into technical analyses and performance assessments, or used to represent the extremes in a sensitivity analysis.

[fn 14]As used in this guidance, outliers" refers to those opinions which lie apart from the views or expected (average) views of other experts.

Step No. 9 - Documentation

Proper documentation of a formal expert elicitation should indicate what was done, why, and by whom. The resulting

judgments should be clearly described along with the reasoning supporting these judgments. The specific issues addressed by the elicitation should be precisely defined. Unambiguous definitions of all specific terms should be provided and any assumptions used in the elicitation should be explicitly stated. The judgments, as they are stated by each subject-matter expert, should be provided, accompanied by the logic and information on which they are based. Any calculations that the experts considered important in determining judgments or models used should be recorded and all literature used, whether public or restricted, should be properly referenced. Proper documentation should clearly distinguish between that information provided directly by each subject-matter expert and any subsequent processing of that information, such as smoothing, interpolation, extrapolation, or aggregation of the judgments of different experts.

[(2])(b) The approach described above envisions that all of these process steps would be part of a procedure for an expert elicitation. If preferred, some of these steps can be combined as long as all of the elements of the process are addressed. If one or more of the process steps are omitted from the recommended procedure, the staff may need additional information for its consideration before accepting the results of an elicitation for its review and evaluation.

(3) If information from an expert elicitation is to be submitted in support of a license application, and if additional data or information becomes available, subsequent to the completion of the elicitation, which could change opinions or judgments obtained in the formal elicitation, the results of the elicitation should be re-examined and updated, as appropriate. In addition to the information requested above, documentation should include a detailed description of the updating process.