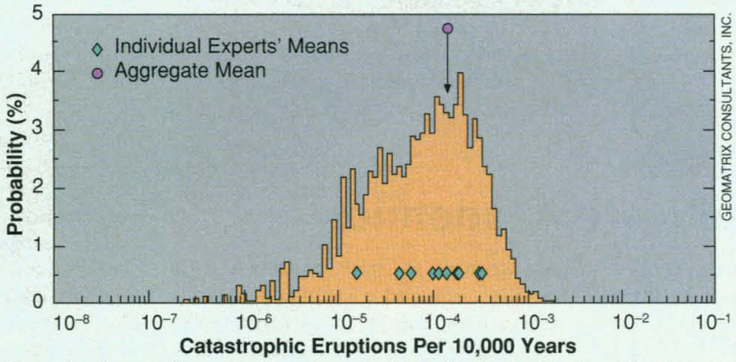
RISK ASSESSMENT

A New Way to Ask the Experts: Rating Radioactive Waste Risks

To opponents of the proposed nuclear waste repository at Yucca Mountain, Nevada, the view from the air is unsettling. Within 40 kilometers of the site, a dozen or more young volcanoes pock the desert, each one raising a troublesome question: How likely is a volcanic eruption through the repository, which is meant to keep 70,000 tons of highly radioactive spent fuel rods from nuclear power plants undisturbed for the next 10,000 years? In a debate that exemplifies the difficulties of making decisions in the face of scientific uncertainty, researchers haven't been able to agree on the exact age of the nearby volcanoes, much less on the larger question of how safe the site is. With so many conflicting opinions, everyone—scientists, the public, and regulators—has been understandably confused about just what the experts know, and how certain they really are.



Risky business. Given nearby volcanoes *(top)*, the final estimate of the risk of eruption at Yucca Mountain in the next 10,000 years was about 1 in 10,000.

Now, some earth scientists are turning to a new approach to evaluating hazards, one that rationally and explicitly accounts for uncertainty at every step. Called "expert elicitation," the method pulls together a panel of experts, carefully assesses the uncertainties in each of their views, then mathematically combines their risk estimates along with the accompanying uncertainties. "Science hasn't been able to handle public policy very well; the expert judgment process is a key process in trying to link science and societal choices," says volcanologist Bruce Crowe of Los Alamos National Laboratory, who was on a panel that has just made such an assessment of the Yucca Mountain volcanic hazard for the Department of Energy (DOE).

In this case—the latest and most sophisticated example of the process—the panel of 10 earth scientists concluded that the probability of a volcano erupting through the repository during the next 10,000 years is about 1 in 10,000. Ironically, these numbers match the only other numerical analyses of the problem, made as early as 15 years ago before recent arguments flared up. The scientific controversy was valid, but the flash points in the debate turned out to be irrelevant to the total risk, says Crowe.

The method has already been applied to seismic hazards in the eastern United States and climate change at Yucca Mountain, and so far, it wins high marks. "When I first got into it, I expressed concern about the way it was being done," says volcanologist and panel member Alexander McBirney, emeritus professor at the University of Oregon. "Later, I realized that I was wrong, that this was a great improvement. It is a very welcome change."

Despite such praise, some scientists wonder whether the method artificially reduces the uncertainty. And attaching a number to the risk of volcanic eruption—which took 18 months and $2 million—is only one of many assessments needed before there can be a consensus on where to store nuclear waste.

Still, the new analysis does appear to have cut through the miasma of scientific discord about the volcanoes around Yucca Mountain, where DOE is investigating the suitability of burying radioactive waste 300 meters below the surface. Scientific controversy over the site has erupted before, with independent suggestions that the now-dry repository could be flooded, and that the nuclear waste in the repository could go critical and blow up (*Science*, 30 June 1995, p. 1836). Both claims were dramatic but clearly flawed, and were readily squashed by traditional committees of experts.

But the issue of volcanism, a long-time concern among scientists inside and outside the project, has eluded settlement. The controversy focuses on a scattering of small volcanoes, driven by deep heating across a broad area of the West, that have flared up near Yucca Mountain during the past 9 million years. A million years ago, one volcano came as close as 10 kilometers; another called Lathrop Wells popped up 15 kilometers away sometime within the past 100,000 years, perhaps as recently as 20,000 years ago.

Since past volcanism is considered the best predictor of future activity, much of the scientific debate about the site has focused on the age of these volcanoes. Geochronologist Brent Turrin of the U.S. Geological Survey in Menlo Park and his colleagues argued in a series of recent papers that radiometric dating of Lathrop Wells showed that it was about 140,000 years old. But geomorphologist Stephen Wells of the Desert Research Institute in Reno and his colleagues, including Crowe, countered that Lathrop Wells showed little sign of weathering and instead had the fresh appearance of a feature only 20,000 years old. And critics such as Nevada Governor Robert Miller claimed that such youthful volcanism should immediately disqualify the site.

To make headway in this contentious atmosphere, scientists turned to expert elicitation, which is a means of quantifying estimates of both probability and uncertainty that are largely detached from subjective influences like politics, explains geologist Kevin Coppersmith of Geomatrix Consultants, Inc., of San Francisco, which ran the study for DOE. Adds Crowe: "You use expert judgment to enhance your understanding of the uncertainty of the data, especially of how much uncertainty is introduced by different interpretations of the data."

First, Coppersmith and crew chose the 10 panel members on the basis of expertise and institutional affiliation—plus "strong communication and interpersonal skills, flexibility, and impartiality." Workshops and field trips with outside experts followed. Then interviewers spent two days with each panel member, extracting the expert's best estimate for values such as the location and frequency of expected eruptions, and the accompanying uncertainties for each parameter. Those parameters were then plugged into a chain of calculations leading to the probability that a magma conduit would cut through the repository. The 10 experts' resulting probabilities—and associated uncertainties—were eventually combined into the aggregate probability of 1 chance in 10,000 during the next 10,000 years, which falls near estimates made for DOE in 1982 and 1995. The 90% confidence interval runs from 5 chances in 1 million to 5 chances in 10,000.

Throughout, the experts were asked to put aside their favorite hypotheses and instead act as impartial evaluators of various theories. For example, they were asked to consider multiple models of how a particular volcanic process works, rather than solely their preferred model, although their final estimates weighted each model. This stepping back from previously held positions is "not scientists' accustomed role," says Allin Cornell of Stanford University, a statistician who advised the study, "but they warm up to it."

In the end, only one-third of the uncertainty in the final estimate was due to the conflicting opinions among experts, while two-thirds stemmed from the uncertainties perceived by each expert. In fact, the conflict over recent volcanism didn't have much effect. For example, whether Lathrop Wells was 20,000 or 140,000 years old didn't matter as much as the fact that a dozen volcanoes had peppered the area at unpredictable intervals of 100,000 years to 3 million years. "You're swamped by the uncertainties of your limited database," says Crowe.

The power of expert judgment elicitation to cut through such misperceptions has a strong appeal to many scientists. "It's hard for me to think of a better way to go about this," says volcanologist William Melson of the National Museum of Natural History, who tracked the process closely but was not on the panel. "The final result has a lot more value than one or two opinions."

A crucial part of the process, of course, is the choice of panel members. Geologist Eugene Smith of the University of Nevada, Las Vegas (UNLV), who is funded by the State of Nevada to check up on DOE's work, notes that one panel member, Crowe, was a team leader in DOE's earlier evaluations of Yucca Mountain. Apart from that, even Smith says "they did a very nice job of choosing panel members."

He does have some other reservations, however. "The diversity of opinion among panel members was tremendous," he says. "There were probably four or five different opinions about how to define a volcanic event, for example. I was flabbergasted that so much diversity could result in much the same probability" from each of the 10 experts. He and mathematician Chih-Hsiang Ho of UNLV have suggested that averaging expert opinions, when each opinion is itself an average of several different models, will lead to an unrealistically narrow range of probability. Their concern will be considered in agency critiques of the report. Meanwhile, expert elicitation is already proceeding apace: A few weeks ago, Geomatrix and other consultants began this type of analysis for the seismic hazards at Yucca Mountain.

–Richard A. Kerr

DEPARTMENT OF ENERGY

Weaponeers Cultivate Academics

LIVERMORE, CALIFORNIA—The government's nuclear weapons program is getting ready to build new bridges to U.S. universities on a scale not seen since the start of the Cold War. A half-century ago, universities and the military hurriedly formed the alliance that developed the atomic bomb. Then the vast weapons machine turned inward, doing research in large, secret laboratories and maintaining only selective ties with university researchers. Now, in an initiative that could funnel as much as $100 million to basic researchers next year, the $3.9 billion weapons program is reaching out again.

Last month in Dallas, university research administrators met with top officials from the U.S. Department of Energy's Office of Defense Programs and the directors of the three nuclear weapons laboratories for the first workshop on expanding their relationship. DOE's goals include shoring up waning academic programs in areas of keen interest to nuclear weaponeers, such as radiochemistry and nuclear engineering. One aim, says Victor Reis, head of nuclear weapons programs for DOE, is to ensure a supply of "the right kind of people" to recruit for the national labs. "We have to think now about those people and engage the universities in the science aspects of [the nuclear weapons] program," he says.

The increased interest in university ties reflects a fundamental change in the character of that program. For 50-plus years, the labs focused largely on applied science and engineering, because they could always check their bomb designs by testing them. But in 1992, the United States halted nuclear testing, and this September President Clinton signed a global test ban. Maintaining the nuclear weapons stockpile without testing will require a strong base in fundamental disciplines such as plasma physics and materials science along with powerful computer models. And that means that the labs "want to be sure they have their ear to the ground for exciting new developments. Those typically show up first in universities," says William Happer of Princeton University, a long-time consultant to DOE's weapons programs.

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As a first step, DOE floated a proposal at the Dallas workshop to bring universities into the Advanced Strategic Computing Initiative. The computing initiative, part of the new "stockpile stewardship" program, aims to develop the hardware and software needed for massive computer simulations. As part of that effort, the weapons program now wants to fund a handful of university computation centers that would specialize in developing simulation techniques in areas such as hydrodynamics and turbulence, which are crucial for predicting the performance of nuclear weapons. University scientists would actually do their work on a new generation of supercomputers at the weapons labs themselves, says Philip Morris, associate director of Penn State University's Institute for High Performance Computing Applications.

DOE is expected to solicit competitive proposals for the centers this month. A preliminary schedule calls for a decision by February on a couple of centers that would be funded out of DOE's current budget at $1 million to $2 million apiece, according to Morris. Eventually, DOE officials have said, they would like to fund a total of five centers at an annual cost of between $3.5 million and $5 million apiece. And they say they are in it for the long haul: They are discussing 5-year contracts for the centers, renewable for 10 years.

Howard Birnbaum, who heads a materials research laboratory at the University of Illinois, Champaign-Urbana, says DOE officials also discussed awarding $50 million to $100 million from next year's appropriation for a range of other university research activities. "None of this is set yet," he says. The agency plans a larger meeting in the spring to discuss specific areas of potential collaboration.

DOE and lab officials are careful to describe the initiative as an outgrowth of a long history of lab-university collaboration. "We always had, individually at the labs, a very strong association with universities," says Los Alamos National Laboratory Director Siegfried Hecker. "This is not a second Manhattan Project," adds Robin Staffin, head of research and development for DOE defense programs.

For universities facing a squeeze on funding, having a new suitor—even one regarded as unsavory in some circles—is a happy prospect. Says Birnbaum: "When you're entering an increasingly dark era, a few bright spots are nice to see occasionally."

–Peter Weiss

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