

# **How Safe is Yucca Mountain?**

**Remarks of**

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**At the**

**Symposium**

**Uncertainty in Long Term Planning-  
Nuclear Waste Management, a Case Study**

**In honor of  
Distinguished Professor Frank L. Parker**

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## **ABSTRACT**

Dr. Cochran will review the history of failed efforts to develop a geologic repository for nuclear high-level waste and spent fuel in the United States; the federal policies and the site selection process leading to the selection of Yucca Mountain as the sole proposed geologic repository, the failure of the Environmental Protection Agency to develop adequate criteria to be used in licensing of the proposed repository; and the inability of the Nuclear Regulatory Commission and outside experts to judge the adequacy of the Department of Energy's safety assessments of the proposed Yucca Mountain repository.

It is a pleasure to speak at a symposium at Vanderbilt University honoring Professor Frank Parker. I was a student at Vanderbilt from 1958 to 1967. During two of those years, 1962-1964, I was an Atomic Energy Commission Health Physics Fellow. Dr. Karl Morgan and others from Oak Ridge National Laboratory (ORNL) used to drive from Oak Ridge to Nashville to teach us health physics. We got our on the job training during the summer of 1963 at ORNL where we were cycled through various laboratories including Frank Parker's lab.

Here at Vanderbilt and at ORNL I learned the basic tenet of the health physics profession—any exposure of radiation is assumed to entail a risk of deleterious effects and radiation exposures should be kept As Low As Practicable (ALAP). We were also schooled in the methodologies for assessing risk and minimizing exposure.

Almost a decade earlier, in 1955 the Atomic Energy Commission (AEC) contracted with the National Academy of Sciences (NAS)<sup>1</sup> to evaluate options for geologic disposal of nuclear waste and recommend programs of research that should be carried out. Two years later the NAS released *The Disposal of Radioactive Waste on Land*,<sup>2</sup> the first of numerous nuclear waste assessments undertaken by the Academy over the next fifty years. This could be said to mark the beginning of several failed attempts by the Federal government to dispose of high-level nuclear waste and spent nuclear fuel.

It is useful to recall two of the Academy's conclusions of fifty years ago. The first, which is most often cited, is that

Disposal in cavities mined in salt beds and salt domes is suggested as the possibility promising the most practical immediate solution of the problem. (Abstract)

Of perhaps more interest here is the Academy's admonition:

Unlike the disposal of any other type of waste, the hazard related to radioactive waste is so great that no element of doubt should be allowed to exist regarding safety. Stringent rules must be set up and a system of inspection and monitoring instituted. Safe disposal means that wastes shall not come in contact with any living thing. Considering the half-lives of the isotopes in waste this means for 600 years if Cs<sup>137</sup> and Sr<sup>60</sup> are present or for about one-tenth as many years if these two isotopes are removed. (p. 3)

In 1957-1958, the AEC conducted the first site specific study of the disposal of high-level waste (HLW) in salt at Hutchinson, Kansas. Between 1961 and 1963, the AEC conducted experiments at the Cary salt mine at Lyons, Kansas. In 1970 the AEC, along with the

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<sup>1</sup> The *National Academy of Sciences* is now part of the *National Academies*.

<sup>2</sup> National Academy of Sciences, *The Disposal of Radioactive Waste on Land, Report of the Committee on Waste Disposal of the Division of Earth Sciences* (Washington. D.C., 1957).

Kansas governor, announced tentative selection of the Cary salt mine for a demonstration HLW repository. Opposition, primarily by the Kansas Geological Survey, and concerns over conditions in the mine, the presence of numerous oil and gas well in the vicinity, and the fact that there was solution mining at an operating adjacent salt mine operated by American Salt Company forced the AEC to abandoned the site by 1972.

Following the demise of the Lyons repository effort, the AEC announced in 1972 that it intended to develop a 100-year Retrievable Surface Storage Facility (RSSF). This proposal was opposed by the Environmental Protection Agency (EPA) and others because in their view it would divert attention and resources from efforts to find a permanent means of geologic disposal. As a consequence of this opposition the Energy Research and Development Agency (ERDA)<sup>3</sup> gave up its plans for a RSSF in 1975. Between 1975 and 1982, ERDA and the Department of Energy (DOE) continued to search for potential repository sites in various rock types in the states of Michigan, Ohio, New York, Utah, Texas, Louisiana, Mississippi, Washington, and Nevada. Various degrees of resistance from state and local representatives combined with geological and technical problems stalled efforts to find a repository site.

In 1976 President Gerald Ford halted the reprocessing of commercial nuclear fuel. In the following year President Jimmy Carter reinforced the ban on commercial reprocessing and tried to halt the development of commercial breeder reactor development. These actions reinforced the need for prompt development of a geologic repository. In 1977 ERDA also announced that it would accept custody of commercial spent fuel and store it at Away From Reactor (AFR) storage facilities.

The Carter Administration established an Interagency Review Group (IRG) to develop broad federal policy with respect to geological disposal of high-level waste and spent nuclear fuel. As a consequence of the work of the IRG, EPA was given overall responsibility for establishing regulations related to the geologic disposal of radioactive waste, and that DOE would systematically examine alternative geologic media and sites. Potential host states and Indian tribes would participate in the decision-making process.

In its 1979 report, the IRG recommended a repository design approach in which the natural and engineered barriers worked as a system, so that some barriers would continue to function even if others failed, and so that none of the barriers were likely to fail for the same reason or at the same time. This design strategy is called defense-in-depth. The barriers included the natural characteristics of geologic repository, the chemical and physical forms of the waste, and the waste packages and other engineered barriers. The IRG recommendations formed the basis for Nuclear Waste Policy Act (NWPA) of 1982, the first comprehensive piece of legislation addressing nuclear waste disposal, including geologic disposal of HLW and spent fuel.

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<sup>3</sup> The AEC operated from 1946 until 1975, when it was abolished and its functions transferred to the ERDA (1975-1977) and the NRC (1975 to present). ERDA was abolished in 1977 and its functions transferred to the DOE (1977-present).

The NWPA established the Office of Civilian Radioactive Waste Management (OCRWM) within the DOE; required that DOE take title to commercial spent fuel beginning in 1998 when the repository was scheduled to open, and established a Nuclear Waste Fund (one mill per kilowatt hour) to pay for repository development. It also set forth a siting process which required detailed study and characterization of three repository sites from which to make a final choice; imposed a schedule for opening a repository by 1998; and provided for participation by states and Indian tribes. Two repositories were to be developed, one in the west and a second in the eastern part of the United States to achieve geographical equity and provide a fair sharing of the disposal burden. The Nuclear Regulatory Commission (NRC) was assigned the duty of licensing the repository, while the EPA was required to establish standards for its safety performance.

In the ensuing twenty-five years the Federal government has managed to corrupt the site selection and licensing of the geologic repository and established a safety assessment methodology that makes it impossible for the NRC staff and outside experts to follow or reproduce the radiation dose calculations. We will address each of these in turn.

### **Corruption of the Siting Process**

With respect to siting, rather than search for the best geologic media and then choose the best alternative sites within each media category, DOE decided that it would expedite matters if one or more of site alternatives were located on Federal land, preferably at a DOE facility. In the site selection process, DOE went so far as to develop a conceptual engineered facility directly below the B-Plant at the DOE-owned Hanford Reservation. The B Plant was an early chemical separation plant that had been converted in 1968 to a waste fractionation plant for removal of strontium and cesium from HLW. The Hanford Reservation itself was selected in 1943, during the Manhattan Project for reasons that had nothing to do with geologic disposal of nuclear waste.

The Hanford site was among the nine sites DOE identified as potentially acceptable in 1984, and among the three sites identified in 1986 as worthy of site characterization. The other two sites proposed for characterization were Yucca Mountain and Deaf Smith, a bedded salt site in Texas. In 1986, DOE discontinues study of second-round sites in the Midwest and East. DOE's handling of the study and selection process provoked widespread concern and opposition in both the first- and second-round states.

In 1985 DOE began to investigate crystalline rock formations to identify sites for a second repository. In 1986 DOE recommended 12 potential areas in seven states for a second repository. When it became apparent that the cost of characterizing three sites for the first repository would be huge, and a second repository would most likely be located in granite in Michigan or Vermont, the senate, led by senators from the eastern states, restructured the site selection process by passing the Nuclear Waste Policy Act Amendments of 1987, or what became known as the "Screw Nevada Act." The Congress decided that Yucca Mountain would be the sole repository site to be studied, despite the fact that technical studies were just beginning. Further work at Deaf Smith, Texas, and Hanford, Washington, was canceled. The amendments passed in the waning days of

December and were attached to the 1987 Budget Reconciliation Act, discontinuing all work on second-round sites and halting DOE's efforts to locate a Monitored Retrievable Storage site in Tennessee.

During the site selection process the Department of Energy had adopted geologic criteria for acceptable sites (10 CFR 960). After Yucca was selected, and after DOE later realized that Yucca Mountain leaked worse than originally thought, DOE in 2001 adopted a new site selection rule (10 CFR 963) that dropped all of the troubling geologic criteria that were in the original rule. Under the new rule the Secretary of Energy could recommend the Yucca site to the president and Congress if he thought it could be licensed by the NRC, the only condition in the rule. The Secretary promptly did so.

In sum, despite having first proposed a defensible site selection process based on meeting reasonable geologic criteria, the Yucca Mountain site was selected as a candidate because the government already owned the land adjacent to the Nevada Test Site. Secondly, it was selected as the sole site to be developed for political reasons, and finally, when it became clear that Yucca did not meet the original siting criteria, the criteria were abandoned instead of the site.

### **Corruption of the Yucca Mountain Licensing Process**

Section 121 of the NWPA of 1982 directed EPA to establish generally applicable standards to protect the general environment from offsite releases from radioactive materials in repositories and directs the NRC to issue technical requirements and criteria. It has been twenty-five years since EPA was given this statutory authority and even longer since EPA knew it would have this responsibility, yet today we still have no final regulations.

Twice, in 1985 and again in 2001, EPA published final Yucca Mountain criteria or rules that were subsequently found by the Courts to be unlawful. EPA first issued standards in 1985, but these were vacated in 1987 in part because the EPA had failed to fulfill its separate duty under the Safe Drinking Water Act (42 U.S.C. §300h) to assure that underground sources of water will not be "endangered" by any underground injection.<sup>4</sup> EPA's second attempt to at setting standards for Yucca<sup>5</sup> was vacated by the United States Court of Appeals for the D.C. Circuit in 2004.<sup>6</sup> The D.C. Circuit found that EPA's Yucca Mountain rule (and the corresponding NRC standard), which ended its period required compliance with the terms of those rules at 10,000 years was not "based upon or consistent with" the recommendations of the NAS as required by the 1992 Energy Policy

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<sup>4</sup> *Natural Resources Defense Council v. Environmental Protection Agency (NRDC v. EPA)*, 824 F.2d 1258 (1st Cir. 1987).

<sup>5</sup> 66 Fed. Reg. 32,074 (June 13, 2001) (codified at 40 C.F.R. pt. 197 (2004)).

<sup>6</sup> *Nuclear Energy Institute, Inc. v. EPA*, 373 F.3d 1251 (2004).

Act and therefore must be vacated.<sup>7</sup>

The failure to develop and issue adequate nuclear waste disposal criteria of course does not lie solely with EPA. President Carter decided that all federal regulations should be reviewed and approved by the White House before being issued by agencies under its purview. This precedent has been followed by subsequent Administrations, some of which appear to place a higher priority on protecting the nuclear industry than future generations. As a consequence the White House Office of Management and Budget (OMB) holds secret meeting and oversees secret interagency reviews of EPA's proposed criteria, permitting OMB, DOE and the NRC to water-down any EPA proposed criteria that might be difficult for Yucca Mountain to meet. Although EPA and NRC are supposed to be independent regulators, they have held secret meetings with DOE on the formulation of the EPA and NRC rules. This continues even today as we await EPA's third "final" rule, which is being held up by interagency differences over the final language. As before, the positions of the various agencies—EPA, DOE, NRC, the Justice Department and OMB—in this dispute are withheld from the public. They are State secrets.

The estimated impact on future generations is derived by computer modeling. The current model used by DOE for this purpose is called the Total System Performance Assessment ("TSPA") simulation program. The program conducts sets of Monte Carlo runs—in this case a set of calculations of the radiation dose to a hypothetical person at a specified site as a function of time, where the uncertainties of the numerous parameters in the model are varied from run to run. The calculated radiation doses from each of these runs, which change over time, can be compared to the level of radiation exposure is deemed acceptable.

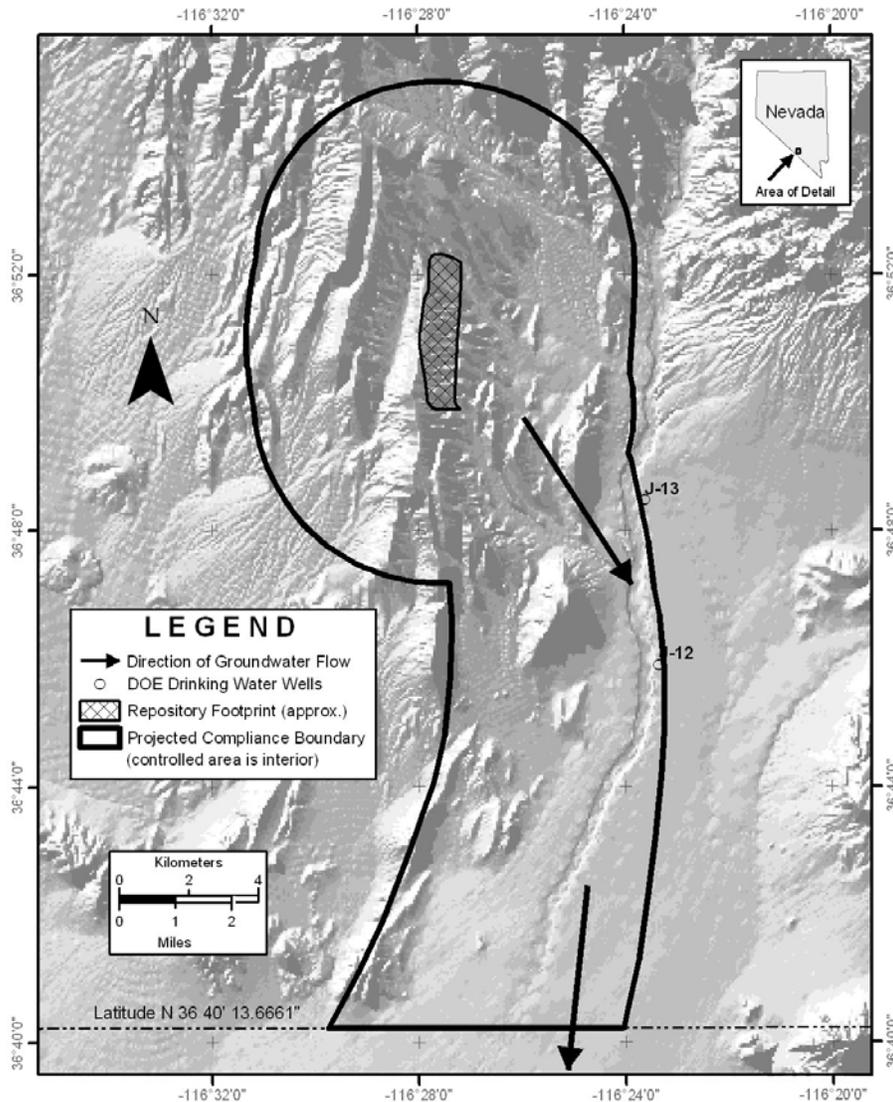
The key parameters or assumptions related to the Government's effort to establish radiation protection standards tailored to Yucca Mountain are thus: 1) where is the potential exposure measured and the dose limit assessed, that is how close to the repository do we assume people will be exposed; 2) over what period of time, or for how long will the dose limits be imposed; and 3) what is assumed to be an acceptable level of radiation exposure to future generations. Also important is how the uncertainties in the Monte Carlo calculations are taken into account.

One can see the results to date of the Government's effort to establish a Yucca Mountain specific radiation protection standard by tracking these three parameters or assumptions that are central to the protection of future generations from potential leakage of radionuclides from the repository.

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<sup>7</sup> In August 1995, the National Research Council of the NAS published the study referenced under section 801 of the Energy Policy Act of 1992, entitled *Technical Bases for Yucca Mountain Standards* ("NAS Report"). Among other findings, the NAS Report found that it would be scientifically unsupportable for the EPA to limit the period of performance for its Yucca Mountain site standards to the 10,000-year period used in its generic standards under 40 C.F.R. Part 191. Concluding that peak radiation risks at the Yucca Mountain site were likely to exceed that time limitation, the NAS panel recommended that the standards for individual risk apply at the time of peak doses. *Id.* at 55. Drawing on its own prior research, the NAS Report instructed EPA that adopting the 10,000-year limitation "might be inconsistent with protection of public health." *Ibid.*

**Projected Groundwater Standards Compliance Boundary for Spread  
of Radioactive Contamination at the Yucca Mountain Project**  
Measurement of Radioactive Contamination Takes Place Outside of Controlled Area



NRDC produced this visual representation from the following information:

"The controlled area may extend no more than 5 km in any direction from the repository footprint, except in the direction of groundwater flow. In the direction of groundwater flow, the controlled area may extend no farther south than latitude 36° 40' 13.6661" North ... [T]he size of the controlled area may not exceed 300 square km." 66 Fed Reg. at 32117 (June 13, 2001). The direction of groundwater flow is from FEIS (February 2002) at 5-21, Figure 5-3. The repository footprint is from the Yucca Mountain Science and Engineering Report, DOE/RW-0539, at 1-17, Figure 1-3, and the area is approximately 4.27 square km. The area within the projected compliance boundary, as shown in this map, is about 230 square km. The relief image was created from a 1 arc-second Digital Elevation Model from the USGS National Elevation Dataset, April 2002. This map is based on a Nevada State Plane Central projection, North American Datum 1927.

In our view EPA (actually the Executive Branch for reasons noted above) has systematically corrupted all three parameters and the methodology for accounting for uncertainties in order to insure the licensability of the proposed Yucca Mountain repository. The most glaring case is the first assumption. EPA used a 5 kilometer (km) (approximately 3 miles) exclusion zone around the Waste Isolation Pilot Plant (WIPP).

For Yucca Mountain, EPA gerrymandered the control boundary, extending it in the direction of water flow, so that the dose limit to protect future generations is applied at a point 18 km (approximately 11 miles) from the site, thus permitting the aquifer to substantially dilute the flow of radionuclides leaking from the repository before assessing their impact on humans that may reside in the area thousands of years into the future. In effect the EPA proposed rule permits the creation of a large cesspool of radioactive waste within 18 km of the repository.

At the control boundary EPA applies its dose limit to a “Reasonably Maximally Exposed Individual” (RMEI), but the RMEI is not assumed to be a farmer drinking well water, rather EPA established a much weaker standard which assumes the RMEI drinks two liters of water a day after it has been further diluted in 3,000 acre-feet of clean water.

Giving significant deference to the agency, the D.C. Circuit did not vacate EPA’s gerrymandered compliance boundary for the Yucca Mountain site, so the boundary and the methodology, however flawed, is legal.

There are alternative approaches to licensing a geologic repository. At the WIPP facility, designed solely for disposal of transuranic waste, no reliance is placed on the waste container whose lifetime in any case would be limited relative to the half-life of the waste. The geology is the primary barrier, in fact, the sole barrier.

An alternative would be to build into the licensing criteria requirements for the waste canisters and other engineered barriers that are separate and independent from the requirements that must be met by the surrounding geology. Here, for example, one could require that the geology be the primary barrier to the release of radionuclides, and the canisters serve as a backup for a period of thousands of years. This defense-in-depth approach was initially adopted for licensing nuclear reactors, where the primary requirement is to insure that the reactor fuel does not melt, but with separate requirements imposed on the secondary containment assuming that a full core meltdown has occurred (10 CFR 100). This approach has been adopted by Finland, whose regulations state that “the long-term safety of disposal shall be based on redundant barriers so that deficiency in one of the barriers or a predictable geological change does not jeopardize the long-term safety. The barriers shall effectively hinder the release of disposed radioactive substances into the host rock for several thousands of years.”<sup>8</sup>

A third approach—the one adopted by the U.S. government for Yucca Mountain—is to establish a single make-or-break radiation dose limit and require that the entire system of man-made barriers and surrounding geology to be sufficient, such that the dose limit is not exceeded. This third approach is similar to the probabilistic Risk Assessment (PRA) approach currently favored by the NRC.

Initially, the EPA selected a 10,000 year cut-off in radiation exposure limits to future generations. By adopting this cutoff and a single make-or-break dose limit, the proposed Yucca Mountain repository would be licensable if DOE could develop a canister with a

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<sup>8</sup> <http://www.stuk.fi/saannosto/YVL8-4e.html>

10,000 year lifetime, no matter how bad the Yucca Mountain geology turned out to be. The Government no doubt hoped to get by with the package alone and ignore the problems of the site.

EPA further weakened the standard by requiring only that the *mean* dose of many Monte Carlo computer runs be less than the allowed dose limit, rather than having high confidence that the standard would be met. The use of the *mean* effectively eliminates having to protect against the very real chance that the dose could be appreciably greater than the best estimate. Thus, the Government has abandoned completely the NAS' 1957 admonition that "... the hazard related to radioactive waste is so great that no element of doubt should be allowed to exist regarding safety."

Unfortunately, at least for EPA, in 1992 Senator Bennett Johnson, a strong supporter of nuclear power and who is said to have feared that EPA would adopt too strict a standard related to the release of carbon-14 from the repository, pushed through legislation that required EPA's final rule be consistent with the recommendations of the NAS.

In its 1995 report the NAS recommended sole reliance on a PRA approach based on Monte Carlo calculations to account for ignorance, thus endorsing the government's earlier abandonment of the defense-in-depth and separate criteria for the man-made barriers and the geology. However, the Academy did recommend that standards be applied at the time of peak dose and specifically recommended against the 10,000 year cutoff EPA used in its existing rule, and recommended applying the annual dose limit to the *mean* annual dose of the Monte Carlo runs.

When the Court vacated the EPA rule for its failure to comply with the NAS recommendations, EPA published a new proposed rule—a two-tiered dose rate limit that left its previous 10,000 year standard intact (15 mrem limit on the *mean* annual dose of the Monte Carlo runs), but then set a much higher post-10,000 year standard—350 mrem on the *median* annual dose of the Monte Carlo runs. In true fashion EPA once again attempted to ensure the licensability of the Yucca site, this time relaxing the last of the three important parameters for protecting future generations. It should be noted that during the post 10,000 year period, the projected *median* annual dose of the Monte Carlo runs is typically on the order of three times lower than the *mean* annual dose. Thus, a limit of 350 mrem *median* annual dose is equivalent to about 1,000 mrem (or 1 rem) *mean* annual dose.

To appreciate how incredibly permissive this new proposed rule is, we can compare the allowable dose limit with current cancer risk estimates by the NAS. According to the latest estimates of the NAS' BEIR Committee, absent excess radiation exposure today a woman's lifetime risk of getting cancer is about 37.5 percent, with an 18 percent risk of dying of cancer. Were she exposed to a dose rate of one rem per year over her lifetime, the BEIR VII committee's best estimate is that these risks would increase by about 27 percent. For other chemical and (radiological) hazards, EPA considers an agent or activity to be safe if it does not impose a lifetime risk greater than one chance in a

million. If the risk is higher EPA imposes regulations to reduce the risk to within a range of one in 10,000 to one in a million.

### **Judging the Total System Performance Assessment (“TSPA”) Simulation Program**

The DOE has developed its TSPA simulation program to model the post-closure performance of the proposed Yucca Mountain repository and compare the mean and median annual doses from Monte Carlo runs with the limits in the proposed EPA criteria that the NRC must adopt for licensing the Yucca Mountain project.

In an April 10, 2007, letter to NRC Chairmen Klein, the State of Nevada noted:

We understand that DOE may now be running or is about to run its Total System Performance Assessment (“TSPA”) simulation program, the results of which will form the basis for DOE’s license application for its proposed Yucca Mountain nuclear waste repository, which DOE plans to file with NRC by June 2008. Accordingly, Nevada has been paying special attention to the new TSPA. We have purchased the GoldSim computer model (for \$10,000) and have run various scenarios that arose in DOE’s earlier Site Recommendation TSPA (“TSPA-SR”).

After our detailed review, we thought it imperative to call your attention to a glaring and critical problem with DOE’s TSPAs, including its newest one. In short, the TSPA *does not meet* the basic requirements of a calculation intended to form the basis for a government license. The model is so complicated and so large, and takes so many computers to run it, and it must be run so many times for the answer to converge, that it is fundamentally not capable of being checked by any third party, including the NRC Staff. We doubt there is even anyone in DOE who has a comprehensive command of the entire model.

We understand that NRC Staff has developed its own model (the “TPA”), less complicated than DOE’s, in order to help Staff to understand the issues. But the Staff is not the applicant, and its model cannot be the primary ground for license approval. The application has to stand or fall on the validity of DOE’s model and results. That model must be transparent and capable of being checked. NRC cannot license Yucca Mountain on results from a black box, and it should so inform DOE.”

In sum, as noted by the State of Nevada, no independent scientist can check the accuracy of the DOE model that will be used as the basis for calculations used to judge the licensability of the site. In fact, even the regulatory bodies responsible for judging the acceptability of the site cannot run the DOE model, but are forced to use a simplified model to aid in formulating questions to be addressed the DOE and its contractors.

**Conclusion**

So where does all this leave us. We have a proposed geologic repository for spent fuel and high-level waste that was selected through a corrupted site selection process, that cannot meet the original site selection criteria, that will be judged against thoroughly corrupted licensing criteria developed in collusion with DOE, the licensee, and judged with the aid of a computer simulation model that cannot be independently checked or run by the regulators or outside experts.

This is far removed from the tenets of health physics that I was taught here at Vanderbilt by Frank Parker and others 45 years ago.