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General Comment

See attached file(s)
The docx file is a letter to NRC. Attachment A is a pdf file, a prepublication page proofs copy of a paper coming out soon in a peer-reviewed journal. Attachment B, in the docx file, lists three corrections to be made in the page proofs of Attachment A.

Attachments

North Risk Analysis Jan 2013 Rev 3 Page Proof

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Perspective

Can Sisyphus Succeed? Getting U.S. High-Level Nuclear Waste into a Geological Repository

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The U.S. government has the obligation of managing the high-level radioactive waste from its defense activities and also, under existing law, from civilian nuclear power generation. This obligation is not being met. The January 2012 Final Report from the Blue Ribbon Commission on America's Nuclear Future provides commendable guidance but little that is new. The author, who served on the federal Nuclear Waste Technical Review Board from 1989 to 1994 and subsequently on the Board on Radioactive Waste Management of the National Research Council from 1994 to 1999, provides a perspective both on the Commission's recommendations and a potential path toward progress in meeting the federal obligation. By analogy to Sisyphus of Greek mythology, our nation needs to find a way to roll the rock to the top of the hill and have it stay there, rather than continuing to roll back down again.

KEY WORDS: Nuclear waste management

1. INTRODUCTION: SISYPHUS AND HIS TASK

In *The Myth of Sisyphus*[1] Albert Camus uses a minor character from Greek mythology to explore the search for meaning in life. Sisyphus is condemned by the gods to roll a heavy rock up a hill. When he gets close to his goal, he loses to gravity: the rock rolls down the hill and he must try again. Camus asks his readers to consider how Sisyphus must feel, as once again, his rock rolls back down the hill.

Is Sisyphus, with his ongoing task, an appropriate metaphor for the human condition? Or, on a smaller scale, might it be appropriate for the program that our democracy has established for dealing with its legacy of high-level nuclear waste (HLW)? Will this program ever succeed, or will it continue, as it has for the past three decades, to have the milestones recede, on average, more than one year for every year of the program's history? The 1982 Nuclear Waste Policy Act (NWPA) set up a requirement that the federal government begin to take possession of high-level wastes from electric utilities with nuclear power plants, beginning in 1998. Thirty years have passed since this Act, and it is now 14 years beyond the mandated date for federal acceptance of the waste. There is no facility in place, under construction, or even agreed to between federal and state authorities, that will allow the federal government to take possession of these wastes, as required by law. The federal government has incurred liabilities of the order of $50 billion in funds that it has received from utilities but not spent, and in actual and anticipated damage awards for not having met its legal obligations under the NWPA.

While some nations have made more progress, no nation has yet constructed a geological repository for HLW from defense activities or spent nuclear fuel (SNF) from commercial power reactors. The efforts in the United States to develop such facilities appear to have stalled, if not ended in expensive failure.

The one successful U.S. effort is the Waste Isolation Pilot Plant (WIPP). Large quantities of defense

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waste containing transuranic (TRU) elements, considered a special category of radioactive waste,[1] have been emplaced, beginning in 1999, more than 2,000 feet underground in a bedded salt deposit near Carlsbad, New Mexico.[2] This is the only operating repository for long-lived nuclear waste in the world.

A new effort at assessment and planning, the Final Report[(5)] of the Blue Ribbon Commission on America's Nuclear Future (BRC), does not give any new, readily available solution. It does provide valuable guidance. On February 1, 2012, less than a week after this report was released, I gave invited testimony[(6)] before the Subcommittee on Environment and the Economy of the House Energy and Commerce Committee. In this "Perspective," written in response to an invitation from Michael Greenberg, I explain why I believe our national leadership should follow the recommendations in the BRC report, and I sketch what I believe is a path to roll the rock back up the hill.

Perhaps if we can emulate and expand on our nation's one modest success on WIPP in negotiation with potential host communities and states, the needed solutions and facilities can be developed.[3] Unlike Sisyphus, we might ultimately succeed—with a lot more effort, over a long period of time. At this point, however, the rock must go a long way back up the hill, and we need a better path than the one used previously.

2. BACKGROUND AND CURRENT STATUS

2.1. History: The 1957 National Academy of Sciences Report Recommending Disposal in an Appropriate Geological Setting

In 1957, when I was reading Camus in high school and the first commercial nuclear power plant began operation in Shippingport, Pennsylvania, a committee of the National Academy of Sciences (NAS) recommended that the high-level waste resulting from reprocessing nuclear fuel should be placed in a geological repository. The committee, in a succinct eight-page report,[(13)] noted that the radioactive materials created through nuclear fission could not be disposed safely at, or near, many of the then-existing nuclear facilities. Although the wastes could be stored in containers, this was a temporary solution. Ongoing management would be required on a long time scale, perhaps a thousand years or more, to assure that the waste did not get out of the containment and into the environment and cause damage, particularly to human health. Some geological settings could provide adequate safety for emplacing these dangerous materials for the long time needed for the radioactivity to decay. The NAS committee suggested a particular kind of geological setting, salt deposits, and several alternatives, including putting the radioactive materials in a highly insoluble form, then placing them deep in abandoned mines. By a combination of choosing the right geological setting and engineered barriers to prevent migration of the material from its containment, it should be possible to assure that wastes could be emplaced so that, in the absence of human intervention, they would remain isolated until the radioactivity had decayed to insignificant levels.[4] Ongoing oversight and management to assure containment integrity would not be needed.

2.2. Activities Leading Up to the 1982 Nuclear Waste Policy Act, Its 1987 Amendments, and Characterization of the Yucca Mountain Site

Over five decades since, many distinguished groups of experts have endorsed geological repositories as the only solution that avoids the need for

[1] The Nuclear Regulatory Commission considers TRU waste as distinct from its low-level waste classes. TRU waste is material contaminated with radioactive elements with atomic number higher than uranium: neptunium, plutonium, americium, and others. Most such waste is from reprocessing spent fuel or using plutonium in the fabrication of nuclear weapons.

[2] References on the history of WIPP include: Mora;[(2)] McCutcheon;[(3)] and chapter 5 of Stewart and Stewart.[(4)]

[3] Society of Risk Analysis members who are expert in SRA on risk perception and communication (many of whom were funded by the Nevada Nuclear Waste Project Office (NWPO)) have written extensively on reorienting the U.S. program: Flynn *et al.*[(7)] and Easterling and Kunreuther.[(8)] See also Rosa *et al.*;[(9)] Jenkins-Smith;[(10)] Whipple;[(11)] and North.[(12)]

[4] Radioactive decay is highly predictable. It follows an exponential curve characterized by a single number, the half-life, or time for half of the material to decay. After 10 half lives, only 0.1% ($0.5^{10} = 0.001$) of the material will remain. Cesium 137 and strontium 90 are two of the most significant fission products, with half-lives of 30 and 29 years, respectively. The time scale for 99.9% decay for waste composed of fission products is thus on the order of a thousand years. Plutonium 239 has a half-life of about 24,360 years. The time to assure containment for 10 half-lives for spent nuclear fuel (which contains on the order of 1% plutonium) is therefore much greater, approaching a million years. Geologic disposal of spent nuclear fuel therefore requires consideration of a much longer period than geologic disposal of fission products. Although there are fission products such as iodine 129 with long half-lives, these are minor contributors to the radioactivity until after most of the cesium and strontium have decayed.

ongoing management.[5] The quantity of HLW has grown much larger over this period, and this inventory continues to grow. Initially, much of the waste came from the manufacture of nuclear weapons and used fuel from reactors used for ship propulsion, but more than 90% of the inventory for the first designated repository comes from civilian nuclear power plants.

Valiant efforts by the technical community and by the leadership in Congress and in successive presidential administrations have been made to implement a geological repository. After a failed effort to emplace waste in a salt deposit in Lyons, Kansas,[6] and then extensive study during the Carter Administration,[19] Congress passed the NWPA in 1982 designating a process for selecting sites and then developing two geologic repositories. Amendments to this Act passed by Congress in 1987 overrode the selection process and designated a single site, at Yucca Mountain, Nevada. Yucca Mountain is located in an unpopulated desert area on the edge of the Nevada Test Site, about 90 miles north of Las Vegas.[7] The Yucca Mountain site was recommended to proceed to licensing as a federal repository by the Secretary of Energy to President Bush in 2002. This recommendation was endorsed by the president, and subsequently both houses of Congress overruled (by margins of 306–117 and 60–39)[8] a formal notice of disapproval by the Governor of Nevada on behalf of his state. DOE prepared and submitted in 2008 the application for a construction authorization. The application was to be evaluated in no more than four years by the Nuclear Regulatory Commission (NRC), using Yucca-Mountain-specific criteria for acceptable safety established by the Environmental Protection Agency, which after court remand extended the duration of the safety evaluation out to a million years.

2.3. The Present Impasse on Yucca Mountain

Sisyphus' rock, as it was thought to be approaching the top of the hill, then seemed to roll back down again.

Barack Obama declared his opposition to a geological repository at Yucca Mountain while campaigning in Nevada during the contested primaries leading to the 2008 election by which he became president. His administration, in concert with a Congress in which Harry Reid from Nevada is Majority Leader for the Senate, has done its best to withdraw the application for a construction license, cut funding, and disband the portion of DOE responsible for carrying out the development of a geologic repository at Yucca Mountain.

The staff of the NRC nearly completed the evaluation of safety for the repository design set forth in DOE's application, but the evaluation is yet to be finalized. NRC Chair Gregory M. Jaczko, designated by President Obama in 2009 and formerly a member of Senator Reid's staff, stopped the evaluation process in 2010, claiming lack of budget as justification.[9] A redacted version of the NRC long-term safety evaluation is publicly available.[22] The completion of the NRC evaluation is now being litigated before the U.S. Court of Appeals.[10]

The legal challenge to DOE and NRC on whether to proceed with evaluation of the license application for a Yucca Mountain repository is not resolved. The November 2012 election has resulted in a new Congress not much altered in its political balance from the previous one, and continuation of President Obama for a second term. The impasse will continue, and actions to resolve it will take considerable time and effort by our nation's political leadership.

Withdrawal of the proposed repository at Yucca Mountain implies a new strategy for what to do with nuclear fuel that has been used in a nuclear reactor. This "used fuel" contains fission products and transuranic elements. There are two basic ways for managing this "back end" of the nuclear fuel cycle. In 1957, it was assumed that nuclear fuel would be reprocessed to remove the fission products and retrieve the uranium and plutonium, which could be used for further energy generation. Because of a worldwide abundance of high-grade uranium ore and concerns about diversion of plutonium for weapons use, the

[5] In addition to the BRC report,[5] see National Research Council, 2001;[14] Bredehoeft *et al.*;[15] Hebel *et al.*;[16] and National Research Council.[17]

[6] See, for example, Carter,[18] pps. 65–71.

[7] The Nevada Test Site, now renamed the National Nuclear Security Site, was used for testing nuclear weapons from 1951 to 1992.

[8] Vandenbosch and Vandenbosch[20] in Chapter 9, page 139 and following, give a detailed discussion of the congressional voting in the 2002 override of Nevada's notice of disapproval.

[9] This decision was immediately criticized by other NRC commissioners and members of Congress,[21] then litigated. Allison Macfarlane replaced Gregory Jaczkow as NRC Chair on July 9, 2012.

[10] As of November 2012, it appears that the U.S. Court of Appeals will issue a writ of mandamus within a few months that will order the NRC to continue its evaluation. See U.S. Court of Appeals, DC Circuit.[23]

United States decided about 1977 to forego reprocessing of reactor fuel.[11]

Should this past decision be reconsidered, and the national commitment to geologic disposal after a once-through use of the nuclear fuel be changed to reprocessing? Reprocessing was considered by the BRC, but not recommended except in the broad context of continuing research on advanced nuclear technology. Even with reprocessing, there is a clear need for one or more repositories for geologic disposal.

There may be value to retrieving and reprocessing used nuclear fuel in the future, perhaps many centuries hence. Such retrieval can be straightforward and inexpensive, or extremely difficult, depending on the geologic medium and design of the repository.

In the discussion below, I follow the BRC's use of the term "spent nuclear fuel" (SNF) instead of "used" nuclear fuel. The BRC uses the term "geologic disposal." Better terminology, not prejudging the potential for retrieval in the distant future, is "used nuclear fuel" and "geologic repository." I used "geologic disposal" in my testimony, and I return to this usage a few times below, as I did in my testimony.[(6)]

2.4. The Blue Ribbon Commission on America's Nuclear Future

President Obama requested the Secretary of Energy to establish a Blue Ribbon Commission on America's Nuclear Future to reexamine national policy and recommend a "new strategy" with respect to the back end of the fuel cycle and, also, the disposition of high-level defense waste. The BRC worked from March 2010 through January 2012, at which time it issued its Final Report.[(5)] The BRC states in its cover letter to DOE Secretary Chu that it was asked not to serve as a siting commission, and therefore, it did not evaluate Yucca Mountain or any other location as a potential site for storage or disposal. The cover letter states that the Final Report "neither includes nor excludes Yucca Mountain as an option for a repository." The scope of the BRC Report therefore does not include discussion of any facilities at Yucca Mountain in America's nuclear future.[12]

Characterizing the Yucca Mountain site as the sole candidate for our nation's first geological repository has been the principal focus of the federal program over the past several decades. I can accept language, such as in the first paragraph of the BRC Executive Summary, that national policy has "been troubled for decades and has now all but broken down." I would have preferred more clarity at the outset in this report as to where responsibility for this shortfall lies. In my estimation, the staff of the federal agencies—DOE, NRC, and the Nuclear Waste Technical Review Board (NWTRB), their contractors, and consultants—have worked diligently to implement the NWPA passed by Congress in 1982 and amended in 1987, and their technical accomplishments have been commendable. These accomplishments are reflected in the many endnotes in the BRC Report citing the work of these organizations. In the main text of the Final Report[(5)] the BRC recognizes that the shortfall in the nation's program lies with the law established by Congress, the deficiency and inconsistency in national leadership in implementing this law (e.g., the cancellation of a program to site and develop a second repository in the eastern United States), and the strong and ongoing opposition by state political leaders, especially those from Nevada.

A major finding in the 2001 NAS report[(14)] from a distinguished committee of international experts that I had had the honor to chair was that "the biggest challenges ... are societal" (meaning policy or political) and not technical. Our first principal recommendation was that national governments should provide the leadership and support for solving the problems. In the United States, there has not been consistent congressional and senior administration leadership adequate to meet the challenges. As a result, there is now a situation badly in need of corrective action. The BRC has, within its scope, provided commendable guidance on this corrective action.

Much of this guidance is consistent with findings and recommendations of earlier reports. The BRC found no major breakthrough in understanding or

[11] Carter,[(18)] p. 91. While this decision was reversed by President Reagan in 1981, no commercial entity then or since has elected to apply for a license. See Carter,[(18)] pp. 92–93. It should be noted that reprocessing does not eliminate the need for a geologic repository, but reduces the amount of radioactive material to be disposed, especially plutonium and other actinides, many of which have long half-lives.

[12] The BRC comments on page xii of its Final Report:[(5)] "We recognize that current law establishes Yucca Mountain in Nevada as the site for the first U.S. repository for spent fuel and high-level waste, provided that the license application submitted by DOE meets relevant requirements."

from the emergence of new technology that functions as a "silver bullet," eliminating the need for geologic disposal. The nation needs a program to move SNF and defense HLW from where these materials are now located into one or more geologic repositories, where these dangerous materials will be safe over a "long-term" determined by the time for radioactivity to diminish, ten thousand to one million years. As the BRC report[5] describes, there is general international consensus on how to accomplish this goal, and many nations are making good progress. In this country, in 25 years since the law was last revised, our nation has spent over 10 billion dollars and has a policy that BRC judges "has all but broken down." Our country has a liability of nearly $50 billion: $30 billion in the Nuclear Waste Fund,[24] money (including interest) the federal government has received from electricity ratepayers but not yet spent in providing geologic disposal services, plus at least $20 billion[5] in legal penalties for failure to take possession of spent fuel beginning in 1998, as mandated under law and existing contracts. The BRC report[5] states, in large type at the outset of Chapter 4: "The central flaw of the U.S. nuclear waste program to date has been its failure to develop permanent disposal capability."

The strategy set forth in the BRC Final Report[5] consists of eight recommendations:

(1) A new, consent-based approach to siting future nuclear waste facilities.
(2) A new organization dedicated solely to implementing the waste management program and empowered with the authority and resources to succeed.
(3) Access to the funds nuclear utility ratepayers are providing for the purpose of nuclear waste management.
(4) Prompt efforts to develop one or more geologic disposal facilities.
(5) Prompt efforts to develop one or more consolidated storage facilities.
(6) Prompt efforts to prepare for the eventual large-scale transport of SNF and HLW to consolidated storage and disposal facilities when such facilities become available.
(7) Support for continued U.S. innovation in nuclear technology and for workforce development.
(8) Active U.S. leadership in international efforts to address safety, waste management, nonproliferation, and security concerns.

From the perspective of persons such as myself who have been involved with nuclear waste management over the past several decades, there are only minor variations from what has been the national strategy. What the BRC report essentially does is reaffirm policy elements on which national leadership has been weak or lacking. In my testimony on February 1, I strongly endorsed these eight recommendations. I view them as a needed course correction to get policy for the back end of the fuel cycle onto the proper path after it has strayed from that path.

The BRC reaffirmed geologic disposal as #4. It did not advocate reprocessing of SNF instead of a once-through fuel cycle, but the option of retrieving SNF and reprocessing in the future is left open. #7 is continued research on advanced fuel cycle and reactor technology, which is a continuation of current DOE R&D. Reprocessing and, more generally, separation and transmutation of radioactive isotopes, will require massive effort and expense.[13] At a future time when uranium has become much more expensive to obtain and when the improved nuclear technologies become available, such technologies may be deployed, in the United States and in other nations. #8, international cooperation and leadership, is also a continuation and reaffirmation of the U.S. policy of past decades.

Since an alternative repository site in the United-States to Yucca Mountain may take at least 20 years to develop, #5 calls for a consolidated interim storage site. Such interim storage was included in the NWPA and its 1987 amendments. Despite the efforts of a federal Nuclear Waste Negotiator and communities, including Native American tribes, willing to host such a facility, opposition at the state level has so far prevented the proposals for an interim storage facility for SNF from going forward.[20]

The BRC's first recommended element is a "new consent-based approach" to siting nuclear waste management facilities. This is not a new idea, but one that has been around for decades. It would supplement federal law that at first required a technical evaluation of candidate sites to pick the three best, but then, after 1987, designated only a single site to be characterized.

The "new" approach of searching for sites that both meet technical criteria for safety and were acceptable for the host state and local community, has been advocated by many groups. President Carter,

[13] See, for example, National Research Council.[25]

even more than his advisors, advocated such an approach in the period immediately prior to the NWPA in 1982.[14]

In passing the NWPA Congress considered the issue that a host state might object to a disposal site, and included a NWPA provision for state objection, which would require an affirmative vote from both houses of Congress to override. As noted previously in this essay, a veto from Nevada of Yucca Mountain was overridden by both Houses, by large majorities.

Many U.S. state governments have opposed a nuclear waste disposal or storage facility in their state. Although Nevada's state legislature initially encouraged use of the Nevada Test Site for storage and processing of nuclear material,(26) Nevada established in 1985 under state law the Nevada Nuclear Waste Project Office (NWPO), when the Yucca Mountain repository site was under active consideration. This date preceded by two years the 1987 Amendments Act designating Yucca Mountain as the sole site to be characterized. The Nevada NWPO and the state's elected leaders have for 27 years carried out a strong campaign opposing development of the Yucca Mountain site. I met with the NWPO Board, including former Nevada Governor Grant Sawyer, early in my service from 1989 to 1994 on the NWTRB. The Board expressed to me quite clearly that its mission was to oppose. I was equally clear that the NWTRB mission established in the 1987 Amendments Act was oversight to improve the technical aspects of the federal nuclear waste management program. Accessing the NWPO website as I wrote my testimony on January 29, I found the NWPO mission has remained the same. It has not been improved scientific understanding and support for wise decision making, but rather a mission of sustained opposition. I noted that the allegations of dangers posed by a Yucca Mountain disposal facility are on a webpage first posted in 1998 and unchanged since.(27)

While most of the current political leadership of Nevada remains adamantly opposed to Yucca Mountain, the local government jurisdiction in which Yucca Mountain is located, Nye County, has for many years cooperated with federal authorities, and since the issuance of the BRC Final Report,(5) has offered to engage in negotiations in a manner consistent with the BRC's recommended approach.(28) The Governor of Nevada has written a letter rejecting such negotiations.(29)

The local communities around WIPP seem receptive to allowing more nuclear waste besides TRU waste to be emplaced at WIPP. Discussions between DOE and the State of New Mexico are underway, which could lead to *in situ* testing at WIPP for heat-generating wastes. While the State of New Mexico is discussing cooperating on such research, its representative has stated emphatically that such co-operation does not imply willingness to host a repository for HLW.[15]

A pattern of local community support, and skepticism or outright opposition at the state level, may be expected to continue. Consent from both local community and host state may be difficult to achieve, but it should not be regarded as impossible. Reorientation from a federal mandate for a single repository site to seeking consent on multiple sites is an appropriate change in federal policy. The BRC suggests that consent be defined as "willingness of the host state (and other units of government, as appropriate) to enter into a legally binding agreement with the facility operator, where these agreements enable states, tribes, or communities to have confidence they can protect the interests of their citizens."[16] A "flexible and substantial incentive program" might be a part of this agreement.[17]

Recommendations #4 and 5 have an important interaction with #1. The time scale to achieve a legally binding agreement is essentially the time to reach what was described in the Republican presidential candidates' debate in Las Vegas October 18, 2011 as "a pretty good deal."(31) Other states—such as New Mexico, which over 25 years negotiated a "pretty good deal" with the federal government on WIPP—might agree to a new facility or expansion of existing facilities (i.e., WIPP) to take additional nuclear waste. The new approach for the U.S. nuclear waste management program is negotiation to achieve

[14] Interagency Review Group,(19) Memo to President Carter with annotation in his handwriting: "Reluctantly agree. You all seem to want to run an experiment rather than find waste disposal site(s) and use it (them). J" (dated October 24, 1979).

[15] F. David Martin, Secretary, New Mexico Environment Department, in a public presentation on April 3, 2012,(30) discussed a possible Memorandum of Cooperation (MOC) with DOE for research on heat-generating waste in salt, but included the caveat: "Nothing in this MOC obligates the State to host a HLW repository, nor shall anything in this agreement be construed as a signal of the state's intent to serve as a future host of such a repository." Current federal law, including the WIPP Land Withdrawal Act, will need to be changed to allow HLW to be placed in WIPP.

[16] BRC Final Report(5) box, p. 57.

[17] BRC Final Report,(5) p. ix.

an agreement, not overcoming the opposition based on a federal mandate in existing law.

Recommendation #2 is that a new organization should replace DOE in the leadership of the national program. Again, this is not a new idea. It was proposed and considered two decades ago.[32]

Recommendation #3 is an important and needed correction to a short-sighted policy that has been established by Congress and the executive branch in previous administrations. The Nuclear Waste Fund (NWF), a one mil per kilowatt-hour charge to ratepayers for nuclear-generated electricity established under the 1982 NWPA, has been used for decades to offset the national budget deficit. This practice should stop. The remainder of the money received by the federal government each year from the NWF and money actually spent on nuclear waste management should be placed in a trust account and taken out of the federal budgeting process, as the NWPA intended.

Recommendation #6, preparation for transport and storage, is in some ways the biggest change in existing policy. It is a correction to a problem created by the past failures to appropriate adequate funding for more than continued investigation of a potential repository at Yucca Mountain. Actions are needed well in advance to prepare for the time when waste management facilities become available, possibly at Yucca Mountain, or at other locations.

During my initial time on the NWTRB more than 20 years ago, DOE had a program in place to develop the system planning for packaging and transporting spent fuel from its location at many reactor sites to either interim storage or a final disposal site. NWTRB reviewed and encouraged this planning.[18] But as Congress cut the annual appropriations, DOE reduced its activities in this area. The limited funds made available to DOE were reprioritized and spent almost entirely on site characterization activities supporting the license application for Yucca Mountain. The other aspects were forced to be deferred. The BRC added its recommendation #6, on preparing for transport, to the seven recommendations in its draft report, because the Commission heard from many parties on the need to do this planning and preparation.[19] A lead time on the order of a decade is needed before waste transport begins. Shorting the needed appropriation of funds for this purpose, funds already being paid by ratepayers, was the result of decisions by Congress, and not a failure by DOE, by the technical community, or by state and local government. In contrast, for WIPP, timely and effective advance planning and preparation for the transport of waste was done by DOE and its contractors in cooperation with state and local agencies, as described in the BRC report.

Nuclear utilities are currently loading large (over 15 metric tons (MT) uranium equivalent of SNF) canisters with higher fuel burn-up levels. These loaded canisters will have to be received "as is" in whatever disposition (either consolidated interim storage or direct disposal) facility that may be developed. A number of reactors have been decommissioned, and the utilities have demolished the spent fuel handling buildings at these sites. As more reactors reach the end of their useful lives, this number of large loaded canisters will substantially increase. The analysis of the system for accepting waste, storing and transporting it, and finally placing it into a repository, must consider the costs, radiation exposures to workers, and risks in repackaging to enable emplacement in possible geologic settings that may not be compatible with the large canisters in which SNF is now loaded.

2.5. Detailed Regulation Versus Improved Public Understanding of Safety Criteria

Steve Frishman's statement to the BRC is cited in the BRC Final Report endnote 260. He has for more than two decades worked for the Nevada NWPO, and he and I came to know each other well when I served on the NWTRB. I agree with his point that "the interested public has often been confused about the roles of the respective agencies, and the motivation, scope, and meaning of the regulation proposed ..." and, I will add, the existing regulation. Performance assessment as the basis for compliance with detailed regulations can become

[18] Many of the NWTRB reports to the U.S. Congress and the Secretary of Energy discuss systems analysis for transportation, storage, and emplacement of SNF. *First*, March 1990, *Second*, November 1990, *Third*, May 1991, *Fifth*, June 1992, *Sixth*, December 1992, *Report for January to December 1993, Report for January to December 1994*, Letter Report of February 1994. The last stressed the importance of having Congress increase monies from the NWF for "critical research and testing." NWTRB reports are available at www.nwtrb.gov.

[19] Large amounts of TRU waste and other highly radioactive materials have been shipped in containers on trucks and railroad cars over the past six decades without an accident involving a significant release of radioactivity into the environment. But the potential for such release remains a major public concern. See National Research Council.[33]

mind-numbingly complex, even for those of us who are specialists. The goals and the compliance process need to be explained in simple language to the interested and affected members of the public.

Let me illustrate such risk communication by putting the summary of U.S. disposal facility regulations (a box on page 91 of the BRC Final Report[5]) into terms more readily understood. Like many members of Congress who represent states far from Washington, DC, I travel often by plane from my home in California to the East Coast. Modern commercial jet aircraft fly above much of the atmosphere, so radiation we receive from cosmic rays is not attenuated as it is when we are at ground level. Figure 7 on page 15 of the BRC report lists 40 microsieverts of radiation exposure for a one-way flight from New York to Los Angeles, roughly the same distance as my flight from San Francisco to Washington-Dulles. Two round trips is $4 \times 40 = 160$ microsieverts, slightly above 150 microsieverts (equal to 15 millirems, the old dose measure), as listed on page 91 in the box as the limit for the first 10,000 years. The goal set forth in the existing regulation for a repository at Yucca Mountain is that there should be a reasonable expectation that no member of the public will receive more than this dose of radiation annually: two cross-country round trip flights worth per year. The standard for ten thousand to one million years is less stringent. It corresponds to the higher level of exposure from about one round trip flight across our country per month, or 12 round trips each year.

Most members of the public do not understand what microsieverts and millirems signify. But if they come to understand that the requirement for nuclear waste disposal facilities is for limiting radiation exposure to all members of the public to such low levels, comparable to exposures most of us accept without concern, they might come to understand that compliance with the regulations should assure acceptable safety, now and far into the distant future.

Unlike the United States, Sweden set up its nuclear waste management program more than 30 years ago with a strong emphasis on research and dialogue about the risks posed by a repository and a requirement for local acceptance.[5,18,20] As noted in the BRC report,[5] the U.S. program should engage the public as Sweden did, in dialogue on understanding the risks, costs, and benefits to stakeholders, including the local community. A geologic repository should be designed to meet extremely stringent criteria for human exposure over very long time scales. A strong and widely understood safety case has been developed by the Swedish program, and a site acceptable to the local community has been selected. A similar crystalline rock program in Finland has also achieved local acceptance for the site and the repository design. Both these nations plan to proceed soon with repository construction upon successful completion of licensing processes.[20]

Many of us in the technical community believe that a strong safety case has been made in the DOE license application for a repository above the water table in volcanic tuff rock at Yucca Mountain. Similar sites are available in the western United States in addition to the Yucca Mountain site. It is therefore very valuable to learn about the safety for such sites from the detailed investigation of Yucca Mountain, which cost many billions of dollars. Many of us in the technical community therefore strongly favor completion and release by NRC of the evaluation of the DOE license application and completion of the licensing proceeding.[36] Many lessons have been learned from the Yucca Mountain experience that should apply to other geologic media as well as volcanic tuff.[37]

3. A PERSPECTIVE ON THE PATH FORWARD

Our nation needs a program for managing SNF from the large number of U.S. nuclear power reactors and the defense HLW resulting from manufacture of nuclear weapons and from naval propulsion. We need to change course from a focus on a single repository site and instead develop a waste management system, to get these wastes from their present locations into safer storage, and, ultimately, into geologic repositories. It seems clear that our nation will need more than one repository, as noted in the BRC Final Report.[5]

Although it requires a change in existing law, interim storage could be at a repository site. However, until the suitability of the site for a repository has been established, such interim storage might call into question the credibility of the site suitability investigation.[38] Emplacement of the large inventory, particularly of SNF, will take time measured in many decades. A major factor in dealing with repository design is the heat resulting from radioactive decay.

[20] As of the end of October 2012, the Finnish program is moving into construction.[34] The Swedish Radiation Safety Authority has requested further data before the Swedish program proceeds.[35]

As this decay progresses over time, the heat released decreases.

The process to gain community acceptance is both a technical process of assuring safety and a sociopolitical process of creating trust. The United States has accomplished success in such a process on WIPP, and other nations are accomplishing it for storage and geologic repository facilities. It may take many decades to overcome the fears by members of the public of such nuclear facilities, and the entrenched belief of political leaders that they must oppose nuclear facilities in their states or lose votes to opponents unwilling to compromise in accepting such facilities.

With assurance of safety, both by thorough and transparent peer review within the technical community and dialogue to inform the public, and by adding in a "flexible and substantial incentive program," it may be possible to achieve consent by host states and communities. For example, there may be progress to expand WIPP from a repository for TRU to a repository for other types of radioactive waste.[21]

Given the legacy of the past 25 years, achieving consent from Nevada for proceeding with facilities at Yucca Mountain will require a reversal of strongly held political positions. But Yucca Mountain may be the only site that can be "shovel ready" to begin to accept SNF within the next 20 years. It is well-suited for assuring retrievability for SNF for centuries, since the emplacement zone is above the water table and the rock is sufficiently rigid to support very heavy canisters and ensure long-term stability of the openings.

WIPP appears to be better suited for defense HLW (excepting the spent fuel from naval reactors) than for SNF. Greater-than-class-C waste[22] and vitrified defense HLW will require additional testing and analysis, but emplacement of these wastes appears to be only a modest extension from what has already been accomplished at WIPP for TRU waste. The rooms excavated to receive waste at WIPP slowly close, encasing the waste containers and crushing them. This is not considered a problem for the TRU waste in small metal drums[23] currently being emplaced at WIPP. Defense HLW, fission products packaged into a glass matrix, can be emplaced in salt using containers of moderate size, which are easily transported via vertical shafts in the same way that TRU waste has been transported to the level 2,000 feet beneath the surface where waste has been emplaced. Most of the radioactivity in defense HLW will be gone within 1,000 years, so assuring safety is not so dependent on analysis considering what might happen over a time period out to a million years, as is needed for plutonium and TRU waste.

3.1. Separation of Defense HLW and SNF: Different Repositories?

Under the provisions of NWPA commercial SNF and defense HLW are to go into a repository sited and developed under the NWPA, unless the president decides that a separate repository for defense HLW is needed. President Reagan decided in 1985 that a separate defense waste repository was not needed, and since then DOE has planned to combine defense waste and commercial waste in the same repository. That "combined" strategy might have been appropriate if Yucca Mountain had proceeded into repository construction, as planned prior to the Obama Administration. Ratepayers fund SNF disposal via the NWF set up by NWPA. If a geologic repository has been established for SNF, then defense HLW encapsulated in glass and the used naval reactor fuel are a relatively modest add-on for a large repository for the nation's commercial SNF. But if there is no repository at Yucca Mountain or elsewhere, keeping the defense HLW in place, which is now at Hanford, WA, Savannah River, SC, and the Idaho National Laboratory, ID, will violate agreements to move the wastes out of state, and therefore pose serious problems for the federal government.[24] Taxpayers may need to pay for new facilities for interim storage or geological emplacement, so as to fulfill the federal agreements with states and EPA to remove defense wastes from their current interim locations, if a repository for SNF is not available soon to take defense HLW.

[21] Senators Bingham and Udall of New Mexico have written a letter[(39)] to Secretary Chu asking for FY2014 funding for heater tests at WIPP to study the effects of heat generating wastes on salt. See also footnote 18.

[22] The majority of greater-than-class-C waste is neutron-activated metal reactor components. Discussion of waste categories is in the BRC Final Report,[(5)] pp. 96–97.

[23] Waste now emplaced in WIPP includes 55-gallon drums, 10-drum packages, and waste boxes that are about a 7-drum equivalent.

[24] The U.S. Navy's ability to continue to move and store spent naval fuel in Idaho may depend on establishing disposal capacity elsewhere for defense HLW. See BRC Final Report,[(5)] pp. 28, 58.

It seems like an appropriate national policy for the federal government to negotiate with New Mexico to study heat-generating waste in addition to TRU waste. With favorable outcomes from research and agreement from state and local authorities in New Mexico, much of the defense HLW now at Hanford, Savannah River, and INL might go into WIPP, or similar salt formations in eastern New Mexico.

At least one and probably a second repository will be needed for SNF. Under NWPA these will be funded by ratepayers through the Nuclear Waste Fund. But a repository at a site other than Yucca Mountain may take at least another 20 years before it will be ready to begin construction, and perhaps another decade to begin emplacing SNF—and remaining defense HLW.

3.2. SNF in a Salt Repository

Disposal of SNF in salt may be more difficult than many have assumed. While disposal of SNF may be possible in a bedded salt formation such as at or near WIPP, or the proposed German salt dome site at Gorleben, there are substantial technical difficulties and potentially high costs compared to other geological settings.

Unless emplacement can be accomplished without human workers in the vicinity, SNF must be packaged in long, heavy containers that provide shielding for high radiation from the fission products in the fuel rods. One proposed container design for Gorleben has three fuel rods assemblies and weighs 55 tons.[25] Current thinking by DOE and its contractors is that a container for SNF in salt might have four fuel rod assemblies.[26]

In the United States, some spent fuel is already in containers weighing over 100 tons with many more fuel rod assemblies. Moving such heavy containers into a deep underground location poses an extreme challenge, either for vertical transport of these extremely heavy loads, or for construction and maintenance of a sloped pathway (i.e., a long "ramp") to bring containers in via transport vehicles that move horizontally.

The heavy SNF containers emit heat, and surface temperatures of the container must be kept below levels that might degrade the rock or the container material. SNF, primarily uranium, has a density much greater than that of salt. The SNF container may move over time, because salt is a plastic material that moves in response to pressure and heat.[41,18] In addition, salt is not, as was thought 50 years ago, a dry material, but rather investigations at WIPP showed that the salt contains a small amount of water that moves slowly and fills void spaces.[42] While all these factors might be overcome by clever engineering design and extensive analysis to assure long-term safety, the work needed to do this at a SNF repository salt site is likely to cost billions of dollars and take at least several decades. A recent report from Germany estimates that it will be at least 2035 before a repository at the Gorleben site might begin operation.[43] In its 2010 review of international programs, the NWTRB stated that "no country has yet advanced a comprehensive safety case for disposing of HLW and SNF in salt."[44] In contrast, extensive safety cases for SNF in tuff, crystalline rock (such as granite), and clay have been developed.[44] And because of the movement of the salt, assuring retrievability of SNF over a time period of even 50 to 100 years in a salt repository will be extremely difficult to accomplish.

3.3. Evaluating Repository Sites in Concert with the Costs of Transporting and Possibly Repackaging SNF

As noted in the BRC report,[5] particularly in connection with its recommendation #6, the federal program has responsibility to manage SNF from its current locations at reactors or in storage containers to emplacement in a repository. The United States has an inventory of the order of 65,000 metric tons (MT) of SNF and is adding to this inventory at a rate of 2,000 to 2,400 MT per year.[5] Three thousand MT are located at sites where commercial reactors have been shut down. A large-scale effort involving many thousands of container trips is needed to move this inventory to one or more repositories, and possibly into and out of a consolidated interim storage site prior to transport to a repository.

Transport and storage become less expensive if a larger number of fuel rod assemblies can be placed in the container. Containers are now designed for dual use: both transport and storage. But if a salt site, or other alternative geological media at a repository, requires emplacement in a container with a much smaller number of fuel rods per container to manage overall weight and heat emission, then movement

[25] Karlsruhe concept design, discussed in Carter,[18] p. 284.

[26] Ernest Hardin *et al.*[40] The four fuel rod assemblies per container number is for pressurized water reactor (PWR) fuel. Boiling water reactor (BWR) fuel rod assemblies are smaller, so more can be accommodated in the container. Higher burn-up fuel increases the heat, and therefore may decrease the number of rod or require longer aging before emplacement.

of the radioactive fuel rods from large containers into smaller containers will be needed prior to emplacement in a repository. This could be a very large expense, involving large, nuclear-safety-grade "hot cell" facilities, with potential for significant worker exposure to radiation in the process. A repository where such transfer was not needed for SNF may have a large cost advantage over a repository for which such transfer was needed.

Analysis of the system of containers for transport, storage, and repository emplacement is urgently needed in connection with a decision to pursue characterization of repository sites with different rock types. Such analysis could show that placing SNF in salt will be much more expensive than placing SNF in a repository in volcanic tuff above the water table. A site with emplacement in tuff above the water table allows cooling in air prior to repository final closure. Such an "open" system for dealing both with heat from radioactive decay and the heavy weight of containers with a large number of fuel rod assemblies could be accommodated in a repository at Yucca Mountain, or in a site with similarly suitable geology in another location. Analysis of other repository sites may show that the cost of disposal at these other sites is much higher because of the cost of transporting waste in containers with fewer fuel rod assemblies and the cost of moving SNF from higher capacity containers to lower capacity containers prior to placing the SNF in the repository.

Progress on developing solutions to management and disposal of SNF may affect the extent to which nuclear reactors are used for electric power generation in the future. The NRC has in the past asserted that there will be such solutions and, therefore, new nuclear power reactors can be constructed, and use of existing reactors continued, with confidence. But some states, such as California, have passed laws that prohibit new reactors for power generation until disposal of SNF has been demonstrated. This "Waste Confidence" issue is coming up again. The Natural Resource Defense Council and four states filed suit in 2011 challenging NRC's most recent waste confidence rule.[27] The NRC is beginning the process of preparing an environmental impact statement, asserting that continued at-reactor pool and dry cask storage will be adequate while the nation seeks to develop means for management and disposal other than at a repository at Yucca Mountain. Several of us have expressed concern that the NRC needs to intensify and accelerate its process.[47] In the wake of the accident at Fukushima many political leaders and members of the public have become increasingly concerned that continued reliance on current SNF pool and dry cask storage may not provide adequate safety. Further analysis is needed on possible deterioration of fuel rod cladding, of degradation over time of pools and dry cask containment, and compliance with transportation safety requirements for SNF after extended storage.

[27] BRC report, p. 26. In June 2012 the DC Circuit of the U.S. Court of Appeals ruled[45] that NRC's current Waste Confidence Rule is inadequate. A two-year process has recently been initiated by NRC to develop a new Waste Confidence Rule.[46]

4. CONCLUSION

It is a big job to get the nuclear waste management "rock" back up the hill. Our national leadership should not wait for a shift from DOE to a new organization to implement the needed changes, but proceed vigorously; starting at once, with discussion with potentially interested communities as a part of the siting process, with the system studies, and with reconsideration of the Reagan-era assumption that defense HLW and SNF should go into one repository. Our nation needs a flexible and adaptive nuclear waste management program, with multiple repositories and interim storage facilities. The program should avoid being schedule-driven, but rather take the time and spend the money to find effective and safe sites and facility designs, working in partnership with states and local communities.[17]

I hope Congress and the administration will forge a bipartisan consensus to implement the recommendations in the BRC Final Report.[5] Enhanced national leadership was recommendation #1 in the 2001 NAS report.[14] The leadership weaknesses recognized by the BRC need to be remedied. While it has been difficult for changes to be made during 2012, a year with a contentious presidential election, major advances can occur in postelection congressional sessions and in the second Obama Administration. The preparatory work to enable these advances should be already underway or started as soon as possible.

Yucca Mountain remains in my judgment a viable siting option. The BRC stressed not precluding options, but engaging in adaptive management. The 2001 NAS report[14] and its successor, the "One Step at a Time" NAS report of 2003,[48] are cited as references on adaptive management. As urged in a letter[36] to the BRC signed by me and five other distinguished scientists (two of whom played key leadership roles in the success achieved for proceeding with WIPP) the NRC evaluation of the license application for a disposal facility at Yucca Mountain should be

completed. The public should have full access to the expert evaluation by NRC professional staff, of allegations by the Nevada opposition, and the plans and analysis submitted by the DOE staff and its contractors.

Release of a positive evaluation by NRC of the license application for a Yucca Mountain waste repository does not commit the nation to go forward with construction of this facility at Yucca Mountain. Congress must first appropriate the money, and that will require a positive vote by the Senate. At least four more years might pass before that could happen. But it will take at least 20 years, perhaps much longer, before a disposal facility for commercial SNF at another site can be brought to the point of approval on a construction license application, even when state and local community consent has been achieved. The type of site characterization and technical analysis carried out at Yucca Mountain takes time and resources; no other nation has been able to do it more quickly than on the order of 20 years. Our nation needs at least two sites for disposal facilities, as were called for 30 years ago in the NWPA. If there may be a 20-year wait before the first disposal site is ready for facility construction, the nation will need an interim consolidated storage facility, a strong motivation for BRC recommendation #5. It will take the order of 10 years to do the negotiating, planning, design, licensing, training, and other preparation for transport and storage of the waste materials. This transportation planning and preparation should be funded and restarted, via BRC recommendations #3 and #6.

The steps listed in chapter 13 of the BRC Final Report,[5] *Near-Term Actions*, should be undertaken by DOE and the current administration. Congress should move quickly to enact new legislation to enable the BRC recommendations. And to support discussion and debate on these changes in legislation, the DOE should designate a senior official, as BRC has recommended at the beginning of its chapter 13. The BRC has ended its work and has no further budget. This senior official should be supported by staff and consultants at the same level of excellence as the staff and consultants who participated in the preparation of the BRC report.

I hope Sisyphus can succeed. I do not expect to see success in my lifetime—though I hope to emulate my mother by living into my second century.

The nuclear waste management "rock" needs to go back up the hill, slowly and carefully, and not roll back down again.

ACKNOWLEDGMENTS

The author greatly appreciates helpful suggestions and comments on earlier drafts of this "Perspective" from a number of people, many of whom have decades of experience with the U.S. program for managing HLW and SNF.

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January 2, 2013

Dr. Keith McConnell
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Dear Dr. McConnell,

I appreciate the opportunity to provide comments for the NRC staffs' scoping process for an Environmental Impact Statement (EIS) to support rulemaking to update the Commission's Waste Confidence decision.

NRC has an important role in assuring the safety of nuclear power facilities, including the back end of the nuclear fuel cycle. In preparing its new EIS on Waste Confidence NRC must provide the public with detailed information on the consequences of lengthy delay in achieving the emplacement of used nuclear fuel in a geological repository if development of the Yucca Mountain site is no longer to be national policy, as set forth in current law but as strongly opposed by an Administration just beginning its second four-term term in office.

I am also providing comments as part of a group, the Science Panel of the Sustainable Fuel Cycle Task Force. These comments provide more detail about potential problems resulting from a delay of many decades in developing a geological repository at a site other than Yucca Mountain.

Shortly after the release of the Final Report of the Blue Ribbon Committee on America's Nuclear Future (BRC), on February 1 2012 I gave invited testimony before the House Energy and Commerce Committee, Subcommittee on Environment and the Economy. The main trust of my testimony (available at: http://energycommerce.house.gov/hearing/recommendations-blue-ribbon-commission-america%E2%80%99s-nuclear-future) was strong endorsement of the eight recommendations from the BRC and urging timely action to implement them. However, during the past eleven months there has been little indication that either the Administration or DOE has yet taken steps to implement these eight recommendations.

I have written a paper, "Can Sisyphus Succeed? Getting U.S. High-Level Nuclear Waste into a Geological Repository." This paper, which expands upon my testimony, has been accepted for publication in the peer-reviewed journal, *Risk Analysis*. The paper will appear in the January 2013 issue. A copy of the page proofs is Attachment A. Minor corrections to be made in the page proofs prior to publication are listed in Attachment B.

As NRC staff scope out and plan for the EIS on Waste Confidence, they should carefully consider the findings and recommendations of the BRC Final Report. In my *Risk Analysis* paper I have provided my perspective that an alternative to the Yucca Mountain site for a geological repository will take at least several decades to achieve adequate site characterization and regulatory approval. I have also emphasized the BRC's recommendation (6), for prompt efforts to prepare for the eventual large-scale transport of used fuel, and the potential problem that canisters used for storage and transport of used nuclear fuel may be unsuited for emplacement in a repository with different geology from volcanic tuff above the water table. The NRC's EIS should provide a detailed analysis of how many decades of delay can aggravate the difficulty of getting used fuel from the location and type of storage where the federal government accepts it, into acceptably safe emplacement in a repository whose location, geological characteristics, and engineering design are not yet identified.

Delays of many decades seem inevitable before our nation can construct one or more geological repositories at sites other than Yucca Mountain. A centralized storage site with facilities for handling and repackaging used nuclear fuel may also require decades to achieve, given past national experience with host state opposition. Such delays imply a need for much more detailed understanding of the risk involved in continued storage of used fuel at reactor sites, either in dry cask storage or in fuel pools, and the risk and cost involved in creating and implementing the system needed to take used nuclear fuel from the locations where the federal government accepts it to accomplish acceptably safe emplacement in a geological repository. The NRC's EIS needs to provide the interested public with information on what these delays imply for Waste Confidence. To the extent that the consequences of lengthy delay are uncertain, further research by NRC or other parties to achieve better understanding becomes an important priority, and a listing of research needs to achieve such understanding should be included in the EIS.

I will be pleased to assist NRC further with my comments as the EIS proceeds and NRC solicits further public input.

Sincerely,

D. Warner North, Ph.D.
Former Member, Nuclear Waste Technical Review Board, writing as a private citizen

cc: Michael Weber, NRC Deputy Executive Director for Materials, Waste, Research, State, Tribal, and Compliance Programs

Attachment A: *Risk Analysis* paper: sent separately as .pdf file

Attachment B: Corrections: on next page

Attachment B

Corrections to Page Proofs for D. Warner North paper in *Risk Analysis*, Jan 2013

1. A reference in footnote 21 to a previous footnote. This reference should be to footnote 15, not 18. Footnote 21, page 9, col. 1, last line, incorrectly designates footnote 18: "See also footnote 18." It should say, "See also footnote 15."
2. There is also an error on footnote 26, page 10, col.1, next to last line: The word "rod" should be replaced by "fuel rod assemblies".
3. The long list of multiple authors in the references should be matched with first author, *et al.* where the reference is called out. In one place this was not done: the *et al.* is missing and should be inserted. Footnote 3, page 2, under col. 1, last line, should read: Jenkins-Smith, *et al.;*