October 23, 2019

Now comes Robert Alvarez, who makes the following declaration under penalty of perjury:

Summary

Based on a review of the recent report "Preparing for Nuclear Waste Transportation"[1] by the Nuclear Waste Technical Review Board I have concluded that:

- *With about a third of the world's spent power reactor fuel (SNF), the magnitude of long-distance transport of spent nuclear power fuel and high-level radioactive waste in the United States is unprecedented.* According to the Board, "The U.S. nuclear industry has some experience with transporting commercial SNF over long distances (e.g. cross-country) but has not done so with large quantities of SNF (e.g. thousands of metric tons)."[2] The quantity of spent nuclear fuel at closed or soon-to-be closed sites far exceeds that which the nuclear industry has transported in the past. Currently, about 20% of the spent nuclear fuel in the U.S. is stored at 24 closed and soon-to be closed reactor SNF storage facilities. In terms of safety, cost and timing, the Board's report underscores the highly speculative nature of environmental reports submitted by Waste Control Specialists and Holtec.

- *Concerns surrounding the integrity of high-burnup spent nuclear fuel in dry storage are not resolved and may result in prolonged onsite storage for several decades.* Evidence is mounting that nuclear fuel cladding under high burnup conditions may not be relied upon as a primary barrier to prevent the escape of radioactivity, especially during prolonged dry storage. The Board concluded in 2016 that the Nuclear Regulatory Commission and the Energy Department lack a technical basis in support of the safe transport of high burnup SNF. By virtue of its high radioactivity and decay heat, high burnup SNF could be "trapped" at reactor sites, significantly increasing on-site storage costs, for which licensees can seek recovery from the U.S. Government. For instance, based on data provided by DOE [3]and the U.S. Government Accountability Office, I estimate the total 80-year onsite management and operating (M&O) expense for 24 closed or soon-to-close reactor sites is approximately $3.23 billion.[4] The 20-year M&O expense is approximately $834 million.[5]

- *There is a substantial lack of data regarding potential damage of SNF during transport.* Without this basic and elemental information, the safety and transport of SNF to the

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[1] Nuclear Waste Technical Review Board, "Preparing for Nuclear Waste Transportation," report of the U.S. Nuclear Waste Technical Review Board, September 19, 2019 (Hereafter known as NWTRB 2019);
PDF: https://www.nwtrb.gov/docs/default-source/reports/nwtrb_nuclearwastetransport_508.pdf?sfvrsn=6
[2] NWTRB 2019 p.37 (PDF p. 69)

[3] U.S. Department of Energy, Form GC-859 (Nuclear Fuel Data Survey, 2013).
[4] United States Government Accountability Office, Outreach Needed to Help Gain Public Acceptance for Federal Activities That Address Liability, GAO-15-141, October 2014. http://www.gao.gov/assets/670/666454.pdf)
[5] Ibid

proposed Centralized Storage Site is ill advised. The Board is very clear about this shortcoming by stating. "No comprehensive examinations of U.S. commercial SNF have been conducted following transportation to determine if the SNF was damaged in transit. However, SNF handling, loading and shipping operations can subject the SNF assemblies to vibration loads, small impulse loads (e.g. bumps in the road), and severe conditions such as an accident, strong shock loads. How these vibrations and impulse loads may affect the SNF and its ability to meet transportation requirements are not fully understood…"[6]

- *Repackaging SNF for transport and disposal is an important missing element that has a major impact on the timing and implementation of a national SNF transportation program.* None of the dry casks storing SNF are licensed for geological disposal and will likely require repackaging. According to the Board, "if DOE accepts only unpackaged, bare SNF assemblies, then SNF sealed in dry-storage casks or canisters will have to be repackaged into new casks or canisters provided by DOE."[7] "As many as 483,000 SNF assemblies may require repackaging." [8] "Developing and starting up a new nuclear facility such as an SNF repackaging facility," the Board concludes "is a major undertaking that can cost hundreds of millions of dollars (or more) and take decades to complete."[9] DOE estimates the total cost to design, build and startup cost for such a facility ranges from $1 to $2 billion.[10] "Given the time and cost to develop a new nuclear facility, such as an SNF repackaging facility, significant advance planning will be necessary, and the planning will have to begin in time to support the anticipated start of SNF transportation."[11] The Board concludes, "if no repackaging occurs, some of the largest SNF canisters storing the hottest SNF would not be cool enough to meet the transportation requirements until approximately 2100."[12]

Introduction

Recently, the U.S. Nuclear Waste Technical Review Board (NWTRB) of the U.S. Department issued a report addressing "Technical Issues That Need to Be Addressed in Preparing for a Nationwide Effort to Transport Spent Nuclear Fuel and High-Level Radioactive Waste."[13]

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[6] NWTRB 2019, p. 38 (PDF p. 70)
[7] NWTRB 2019, p. 23 (PDF p. 55)
[8] Jeffrey Williams, U.S. Department of Energy, NWTRB Workshop-Inventory, Washington D.C. November 2013.
[9] NWTRB 2019, p. 67 (PDF p. 99)
[10] NWTRB 2019, p. 68 (PDF p.100)

[11] Ibid

[12]NWTRB 2019, p. 77 (PDF p. 109)

[13] Op. cit. 1

This memo focuses on issues raised by the Board regarding the transport of spent power reactor fuel for consolidated surface storage and disposal in a geological repository.

After 60 years (1957-2017), nuclear power reactors in the United States have generated roughly 30 percent of the total global inventory of spent nuclear fuel (SNF) – by far the largest. There are approximately 80,150 metric tons stored at 60 sites in 29 states, of which 97 remain operational.[14]

The NWTRB Report findings

The magnitude of spent nuclear fuel transport in the U.S. is unprecedented.

The Board concludes:

- "However, transporting large quantities of SNF and HLW has not been done and will require significant planning and coordination by DOE."[15]

- "The U.S. nuclear industry has some experience with transporting commercial SNF over long distances (e.g. cross-country) but has not done so with large quantities of SNF (e.g. thousands of metric tons)."[16]

- The quantity of spent nuclear fuel at closed or soon-to-be-closed sites far exceeds that which the nuclear industry has transported in the past. Currently, about 20% of the spent nuclear fuel in the U.S. is stored at 24 closed reactors and a spent nuclear fuel storage facility (Figure 1).

- All told the Board noted that with the exception of "a small portion of existing packaged waste (e.g. certain commercial SNF in NRC-approved, dual purpose [storage and transportation] canisters…work on resolving the associated technical issues must begin long before he waste can be moved – in some cases, more than 10 years in advance."[17]

The Board identifies the resolution of 30 technical issues as a prerequisite for having a national SNF and HLW transportation program

- For instance, one issue, the development of a new transportation cask for licensing by the Nuclear Regulatory Commission, "the board finds that a period of at least 10 years should be allotted…The period may be longer if special design features are included. Furthermore, coordinating the resolution of all 30 technical issues in parallel will require

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[14] U.S. Department of Energy, Energy Information Administration, June 18, 2019. https://www.eia.gov/tools/faqs/faq.php?id=207&t=3

[15] NWTRB 2019, p. xxii (PDF page 24)

[16] NWTRB 2019, p. 69. (PDF p.37)

[17] NWTRB 2019, p. xxvii (PDF p. 29)

significant planning, integration, and interaction with other federal agencies, the nuclear industry, state and local agencies and others.

- Another key issue involves the uncertainties surround the integrity of high-burnup spent nuclear fuel in dry storage. Evidence is mounting that nuclear fuel cladding under high burnup conditions may not be relied upon as a primary barrier to prevent the escape of radioactivity, especially during prolonged dry storage. The Board noted in 2016 that the Nuclear Regulatory Commission lacks data to establish a technical basis for the long-term storage of high-burnup SNF. It was take at least 10 years before the Energy Department's study of actual high burnup SNF can yield any results.

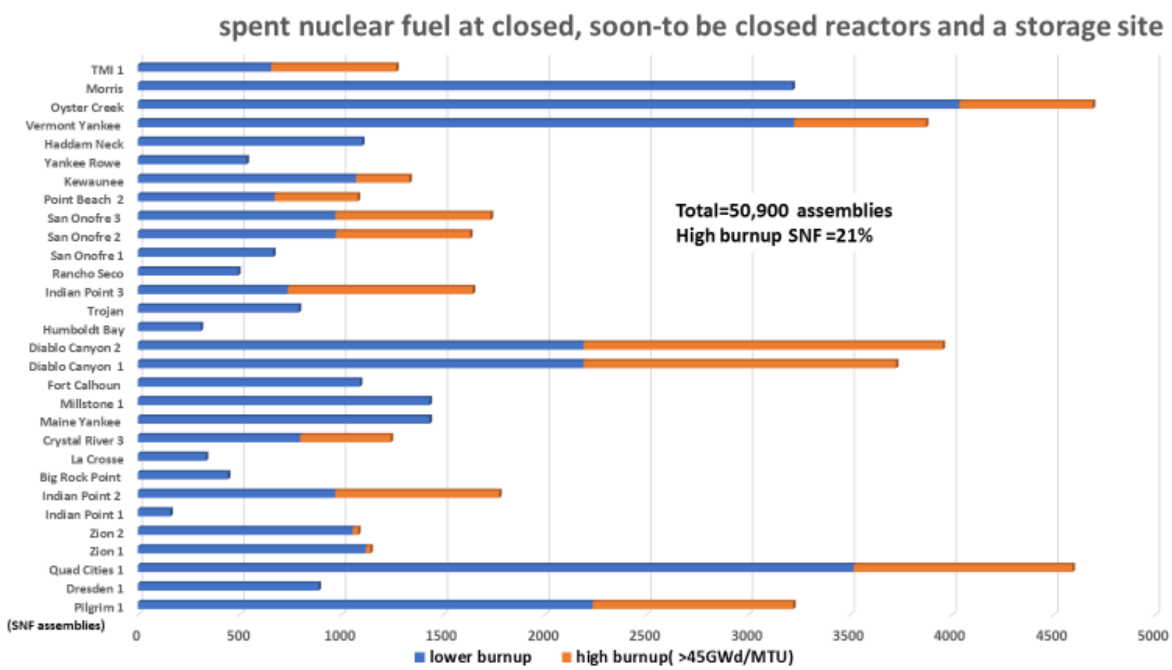
- There is a substantial lack of data regarding the potential damage of SNF from transport. According to the Board's most recent report on transportation, "No comprehensive examinations of U.S. commercial SNF have been conducted following transportation to determine if the SNF was damaged in transit. However, SNF handling, loading and shipping operations can subject the SNF assemblies to vibration loads, small impulse loads (e.g. bumps in the road), and severe conditions such as an accident, strong shock loads."[18]

- SNF storage containers have not been inspected for transport. *"No casks or canisters of commercial SNF now in dry storage have received full-surface inspections since they were placed in dry storage. Furthermore, there is no equipment fully developed to conduct inspections of 100 percent of the surface of SNF canisters in storage. [Emphasis added.]"*[19]

- The infrastructure required for the safe transport of SNF, in key instances, leaves much to be desired. The Board notes that "at some sites, significant work will have to be done to bring the transportation infrastructure back into good working order."[20] This includes the failure to maintain rail lines and access to ports.

[18] Op. cit. 6
[19] NWTRB 2019 p. 80 (PDF p.112)
[20] NWTRB p. 44(PDF p. 76)

Figure 1



<u>The Board identifies the resolution of 30 Significant technical issues as a prerequisite for having a national SNF and HLW transportation program</u>

<u>(See Appendix)</u>

All told the Board noted that with the exception of "a small portion of existing packaged waste (e.g. certain commercial SNF in NRC-approved, dual purpose [storage and transportation] canisters…work on resolving the associated technical issues must begin long before he waste can be moved – in some cases, more than 10 years." [21]

New Transport Casks

For instance, on one issue, the development of a new transportation cask for licensing by the Nuclear Regulatory Commission, the Board found that "a period of at least 10 years should be allotted;"[22] and furthermore, "the period may be longer if special design features are included…"[23]

The Board also concluded that "coordinating the resolution of all 30 technical issues in parallel will require significant planning, integration, and interaction with other federal agencies, the

[21] Op. cit. 17
[22] Ibid.
[23] Ibid.

nuclear industry, state and local agencies and others."[24] While the Board did not believe all issues must be resolved before the first waste can be transported, it insisted that "all technical issues must be resolved before the nation's entire inventory of waste can be transported."[25]

High Burnup Spent Nuclear Fuel

Another key issue involves the uncertainties surround the integrity of high-burnup spent nuclear fuel in dry storage. By increasing the percentage of uranium-235, the key fissionable material that generates energy, high burnup fuel allows reactor operators to effectively double the amount of time fuel is irradiated while reducing the frequency of costly refueling outages. This has been a major contributor to higher capacity factors in the US over the past couple of decades. Twenty years ago, the average burnup for the US reactor fleet as measured by the amount of energy expressed in gigawatts days per metric ton of uranium was 35 GWd/MTU. Currently, power reactor fuel burnups now routinely exceed the Nuclear Regulatory Commission (NRC) limit set for reactor operation for high burnup at 45 GWd/MTU. A growing amount of spent nuclear fuel has burnups higher than 55 GWd/MTU and reactor operators want it as high as 75 GWd/M.

Concerns raised about high burnup SNF include:

• fuel cladding thickness is reduced to form a hydrogen-based rust of the zirconium metal which can cause the cladding to become brittle and fail;

• increased pressure between the pellets and the inner wall of the cladding causes the cladding to thin and elongate;

• high burnup fuel temperatures make it more vulnerable to damage from handling and transport; removal from the pool, vacuum drying and emplacement in canisters can result in cladding failure High-burnup waste reduces the fuel cladding thickness and a hydrogen-based rust forms on the zirconium metal used for the cladding, which can cause the cladding to become brittle and fail. High burnup fuel temperatures make the used fuel more vulnerable to damage from handling.[26] The Board has already noted that the NRC and DOE lack a technical basis for the transport of high burnup spent nuclear fuel.[27]

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[24] NWTRB 2019 p. xxvii (PDF p. 30)
[25] Ibid.
[26] Robert Alvarez, Memorandum, High Burnup Spent Power Reactor Fuel, December 13, 2013. http://www.environmental-defense-institute.org/publications/Alvarez%20Memo%20re-%20High%20Burnup%20Nuclear%20Fuel.%2012-17-2013%20rev.%202docx.pdf
[27] Nuclear Waste Technical Review Board, Letter to Mr. John Kotek, Acting Assistant Secretary for Nuclear Energy, May 23, 2016. https://www.nwtrb.gov/docs/default-source/correspondence/rce0516.pdf?sfvrsn=15

Potential damage from transport

According to the Board's most recent report on transportation, "No comprehensive examinations of U.S. commercial SNF have been conducted following transportation to determine if the SNF was damaged in transit. However, SNF handling, loading and shipping operations can subject the SNF assemblies to vibration loads, small impulse loads (e.g. bumps in the road), and severe conditions such as an accident, strong shock loads. How these vibrations and impulse loads may affect the SNF and its ability to meet transportation requirements are not fully understood, but they are subject to ongoing DOE research."[28]

The Board further notes that, "...the impact of longer periods of storage or of storing high burnup SNF are not fully understood and are subject to greater uncertainty (see Technical Issue #16). DOE is funding a research effort, led by EPRI and supported by Orano TN (formerly Areva), to study the effects of long-term storage on high burnup SNF (EPRI 2014). While this effort is expected to provide some useful information about the condition of high burnup SNF after 10 years of dry storage, this information may not be available before DOE (or another shipper) begins to ship commercial SNF, so DOE (or another shipper) may have to use other means to verify the condition of the SNF."[29]

No Inspections for Flaws

The Board finds that inspection of waste containers for flaws leaves much to be desired. According to the Board:

"No casks or canisters of commercial SNF now in dry storage have received full-surface inspections since they were placed in dry storage. Furthermore, there is no equipment fully developed to conduct inspections of 100 percent of the surface of SNF canisters in storage. [Emphasis added.] Prior to receiving approval to transport SNF, DOE will have to identify and develop the necessary inspection equipment and procedures and then conduct inspections of the SNF casks and canisters to be transported. If DOE finds a non-conforming condition that indicates the cask or canister does not meet the CoC [Certificate of Compliance] requirements, that condition will have to be addressed through means such as repair, replacement, or a request for NRC approval of an amendment to the CoC for transportation that allows the non-conforming condition.

As of April 2019, approximately 40 types of SNF casks and canisters (and variants) were in use that were approved for both storage and transportation (Carter 2016a, 2016b). In addition, approximately 20 types of storage-only casks and canisters (and variants) were in use that may be approved for transportation in the future. Although some of these 60 types of casks and canisters are similar in size and shape, most of them have different lengths, diameters, and weights. For example, lengths range from 2.9 to 5.0 m (115 to 197 in); diameters range from 0.9 to 2.8 m (37 to 110 in); and loaded weights range from 10.0 to 109.8 MT (22,000 to 242,000 lb. This large range of physical parameters will have to be accounted for as DOE develops the

[28] Op.cit 6

[29] NWTRB 2019, pp. 40-41 (PDF pp. 72-73.

procedures and equipment necessary to inspect all SNF casks and canisters before transportation." [30]

Transportation Infrastructure

According to the Board:

"To support the removal of SNF or HLW from waste storage sites, DOE will have to work with the site operator to ensure that the necessary transportation routes are available and capable of supporting the preferred mode of transportation. For shutdown commercial nuclear power plant sites, DOE has completed general assessments of the condition of transportation infrastructure at the sites. DOE also completed more detailed assessments at six shutdown sites. The results of these assessments show that, at some sites, significant work will have to be done to bring the transportation infrastructure back into good working order.

To illustrate the work to be done, DOE's review of the Big Rock Point Site noted the following conditions:

> Big Rock Point is not currently rail-served. Originally, the plant had rail access when it was being built in the early 1960s, which was used to move some SNF from the site in the 1960's, but the switch and track were removed in 1988.
>
> The [Big Rock Point] site currently only has road access, although reports indicate that it had rail and barge access at one time. … The previously used heavy haul roadway no longer exists on the site, and the current access road from the ISFSI to the highway was not built to support heavy haul transfers, and may need to be rebuilt or enhanced." [31]

Repackaging

The Energy Department has yet to decide on the repacking of spent nuclear fuel for disposal. Dry cask storage systems are either single purpose (storage only) or dual purpose (storage and transportation). None are currently licensed for disposal. "Direct disposal of thelarge canisters currently used by the commercial nuclear power industry is beyond the current experience base globally," a 2013 DOE study observes, "and represents significant engineering and scientific challenges." [32] A 2013 report by the staff of the Nuclear Waste Technical Review Board concludes, "repackaging the SNF may be a lengthy process and could impact operational

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[30] NWTRB p. 80 (PDF p. 112)

[31] NWTRB p. pp. 44-45

[32] U.S. Department of Energy, Office of Nuclear Energy, Task Order 12: Standardized Transportation, Aging, and Disposal Canister Feasibility Study, June 14, 2013. https://curie.ornl.gov/system/files/documents/not%20yet%20assigned/STAD_Canister_Feasibility_Study_AREVA_Final_1.pdf

schedules at the utility sites, at a consolidated storage facility, or at the repository, depending on where repackaging is performed."[33]

Under the Nuclear Waste Policy Act (42 USC 10101), which sets forth the process for disposal of high-level radioactive wastes, the U.S. Government cannot accept title to spent nuclear fuel until it is received at an open repository site. According to the law, "the persons owning, and operating civilian nuclear power reactors have the primary responsibility for providing interim storage of spent nuclear fuel from such reactors." [34] The U.S. Government Accountability Office reported in 2014: "per DOE, under provisions of the standard contract, the agency does not consider spent nuclear fuel in canisters to be an acceptable form for waste it will receive. This may require utilities to remove the spent nuclear fuel already packaged in dry storage canisters". In 2012, Energy Department researchers concluded that "waste package sizes for the geologic media under consideration …are significantly smaller than the canisters being used for on-site dry storage by the nuclear utilities."[35]

A nuclear industry study concluded in 2014 that "casks and canisters being used by the power utilities will be at least partially, and maybe largely, incompatible with future transport and repository requirements, meaning that some if not all, of the [used nuclear fuel] that is moved to dry storage by the utilities will ultimately need to be repackaged." [36] Existing large canisters can place a major burden on a geological repository –such as: handling, emplacement and post closure of cumbersome packages with higher heat loads, radioactivity and fissile materials. Repackaging expenses rely of the transportability of the canisters, but more importantly on the compatibility of the canister with heat loading requirement for disposal. In terms of geologic disposal, decay heat, over thousands of years, can cause waste containers to corrode, negatively impacting the geological stability of the disposal site and enhancing the migration of the wastes.[i]

According to the Board: "DOE estimated that if SNF was repackaged from large casks and canisters into smaller standardized canisters (and using standard assumptions about the operating lifetime of the U.S. feet of nuclear reactors), DOE could remove SNF from all nuclear power plant sites by approximately 2070. However, if no repackaging occurs, some of the largest SNF canisters storing the hottest SNF would not be cool enough to meet the transportation requirements until approximately 2100 (Figure 2)."

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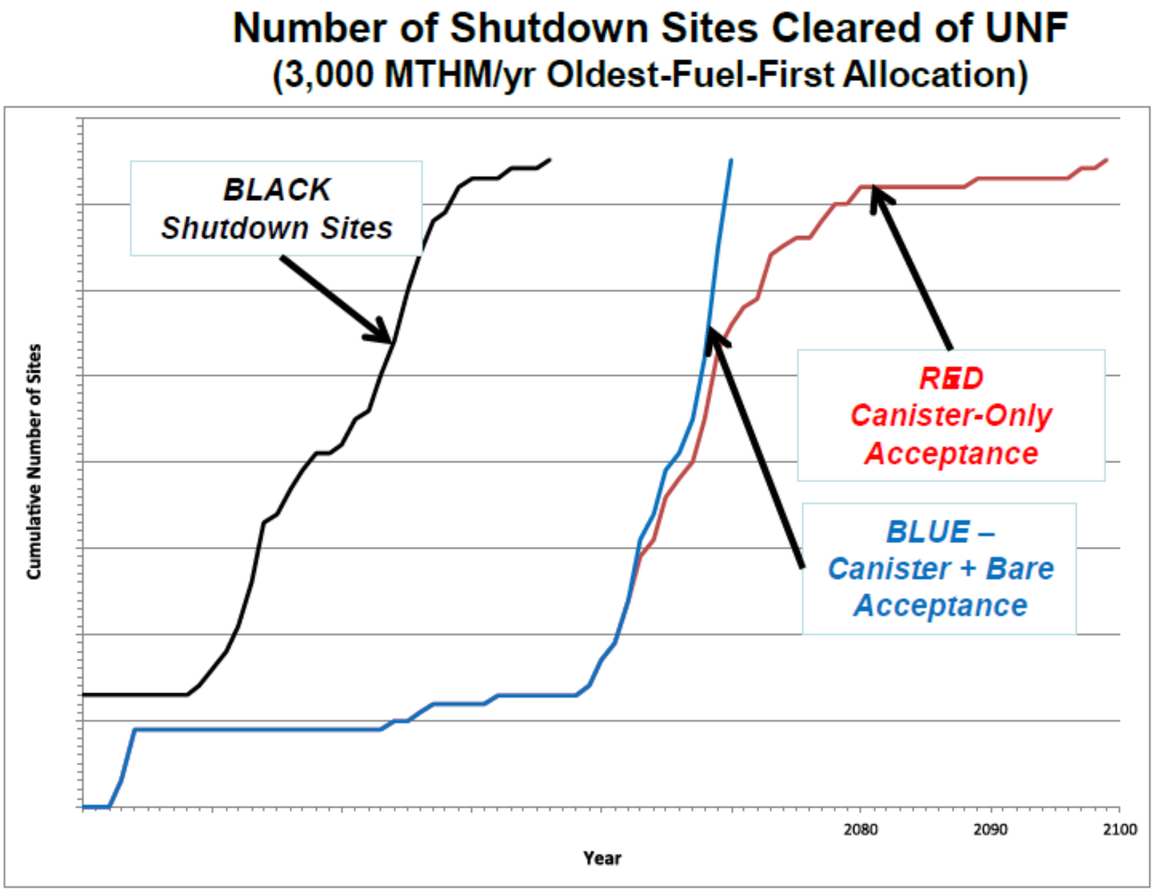
[33] U.S. Department of Energy, Nuclear Waste Technical Review Board, Staff Briefing Document Framework for the Technical Workshop on the Impacts of Dry-Storage Canister Designs on the Future Handling, Storage, Transportation, and Geologic Disposal of Spent Nuclear Fuel in the United States Washington, DC, November 18–19, 2013. http://www.nwtrb.gov/meetings/2013/nov/framework.pdf

[34] 42 U.S.C. 1010, Sections.123 & 131.

[35] U.S. Government Accountability Office, Spent Nuclear Fuel Management: Outreach Needed to Help Gain Public Acceptance for Federal Activities That Address Liability, GAO-15.141, October 2014, P. 30. http://www.gao.gov/assets/670/666454.pdf

[36]Ibid.

Figure 2



<u>Source: NWTRB-Williams 2013</u>

Table 2-1 from NWTRB 2019[37] Appendix

Table 2-1. Board-Identified Technical Issues to Be Addressed in Preparing a Nationwide Effort to Transport SNF and HLW

Technical Issues Affecting All SNF and HLW and All Scenarios
1. Identify and mitigate (if needed) potential physical effects of transporting SNF, SNF casks and canisters, and HLW canisters to ensure they will meet transportation requirements and future storage requirements.
2. Identify requirements for verifying the condition of the waste forms (SNF and HLW) at the time of transport; develop and implement inspection procedures and equipment, if needed; and correct identified deficiencies.
3. Identify and implement waste handling and loading needs (e.g., facilities, equipment, procedures, training) at all waste storage sites.
4. Identify less-than-adequate transportation infrastructure (e.g., roads, rail lines, barge docks) at all waste storage sites; make needed upgrades.
5. Ensure the readiness of the technical aspects of emergency preparedness and response programs and organizations.
6. For waste forms and packaging not already approved for transportation: identify, develop, and validate computer models/programs (if not already done) to be used for structural, thermal, containment, shielding, and criticality evaluations in support of licensing for transportation; ensure the models/programs and input data meet the NRC requirements for quality assurance/quality control; and complete all necessary evaluations.
7. Complete the design, development, and implementation of integrated waste management system analysis and routing tools.
Scenario 1—Technical Issues Affecting Commercial SNF (if DOE accepts unpackaged, bare SNF assemblies)
8. Complete the design, licensing, fabrication, and testing of new SNF packages and transportation equipment on a timescale that supports the transportation schedule.
9. Identify and implement programs for designing, procuring, installing, and operating repackaging facilities and equipment at all sites, as necessary.
10. Identify and mitigate (if needed) potential adverse effects of repackaging operations on SNF assemblies to ensure the SNF will meet transportation requirements.
Scenario 2—Technical Issues Affecting Commercial SNF (if DOE accepts SNF assemblies already packaged in casks or canisters)
11. Identify and correct (if needed) damage, or mitigate degradation mechanisms leading to damage, to casks or canisters during dry storage that may affect the ability of the casks or canisters to meet transportation requirements.
12. Identify and remedy (if needed) types of dry-storage casks and canisters for SNF that are not approved for transportation as noted below: ▪ The cask or canister structural design or neutron absorber structural design does not meet transportation requirements. ▪ The cask or canister is not yet approved by the NRC (although similar casks or canisters are approved).
13. Identify and correct (if needed) individual dry-storage casks and canisters with contents or physical conditions that do not meet the requirements specified in the NRC-approved transportation Certificate of Compliance.
14. Identify inspection requirements, procedures, and equipment needed to verify the condition of all casks and canisters before transportation; perform inspections; and rectify identified problems, if needed.
15. Complete the design, licensing, fabrication, and testing of all needed transportation casks and associated components.
Technical Issues Affecting Commercial SNF (regardless of SNF packaging)
16. Identify and mitigate (if needed) degradation mechanisms in commercial SNF occurring over extended periods of dry storage that may affect the ability of SNF to meet transportation requirements.
17. Determine what burnup credit can be taken for all SNF types other than pressurized water reactor SNF (for which burnup credit is allowed by the NRC in its Interim Staff Guidance-8, Rev. 3).
18. Complete the design, licensing, fabrication, and testing of a commercial SNF railcar (e.g., the DOE Atlas railcar).

[37] **NWTRB 2019** pp 25-26 (PDF pp 57-58)

Table 2-1. Board-Identified Technical Issues to Be Addressed in Preparing a Nationwide Effort to Transport SNF and HLW (continued)

Technical Issues Affecting DOE-Managed SNF (naval SNF excluded)
19. Identify and correct (if needed) damage, or mitigate degradation mechanisms leading to damage, to dry-storage casks and canisters for DOE-managed SNF that may affect the ability of the casks or canisters to meet transportation requirements.
20. Complete existing designs, or develop new designs, for multi-purpose SNF canisters and complete the licensing, fabrication, and testing to accommodate all DOE-managed SNF that will not be processed at the Hanford Site, the Idaho National Laboratory, or the Savannah River Site.
21. Complete a new analysis to validate the structural integrity of the Hanford multi-canister overpack (MCO) design to support NRC approval of the MCO for transportation.
22. Define the transportation cask(s) to be used for DOE-managed SNF.
23. If not using an existing transportation cask, then design, license, fabricate, and test a new transportation cask for DOE-managed SNF.
Technical Issues Affecting DOE-Managed HLW
24. Identify and correct (if needed) damage, or mitigate degradation mechanisms leading to damage, to dry-storage canisters for DOE-managed HLW that may affect the canisters' ability to meet transportation requirements.
25. Finalize the decision on whether the sodium-bearing waste at the Idaho National Laboratory is remote-handled transuranic waste or HLW.
26. Complete the development and deployment of any required treatment process for calcined HLW at the Idaho National Laboratory.
27. Complete the design, licensing, fabrication, and testing of packaging for the Hanford cesium and strontium capsules.
28. Complete the design, licensing, fabrication, and testing of packaging for the ceramic and metallic HLW forms from the Idaho Fuel Conditioning Facility.
29. Define the transportation cask(s) to be used for DOE-managed HLW.
30. If not using an existing transportation cask, then design, license, fabricate, and test a new transportation cask for DOE-managed HLW.