

Guidance on Implementing Sierra Club Policy on the Management of High-Level Nuclear Waste

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Introduction

Sierra Club opposes the continued reliance on nuclear power because its entire life cycle, including the production of high-level radioactive waste, poses grave threats to public health and the environment. Additionally, reliance on nuclear power impedes the transition to safe, clean, renewable energy sources. Sierra Club policy advocates the establishment of a permanent repository for high-level nuclear waste as soon as possible. However, a permanent repository should not be established before its scientifically-based safety and security can be certain for a million years. Moreover, Sierra Club opposes Consolidated Interim Storage (CIS) of high-level nuclear waste and the transportation of radioactive waste to any centralized site for the purpose of interim consolidation. Sierra Club maintains that the establishment of one or more CIS facilities is a counterproductive, unnecessarily risky, and costly extra step to the process of permanently housing high-level nuclear waste.

The federal government has failed to make progress on establishing a viable, permanent repository for high level nuclear waste, but in the absence of a permanent repository the nuclear industry is pressuring states and the Department of Energy (DOE) to approve the establishment of temporary consolidated interim storage sites to receive spent nuclear fuel (SNF) transported from nuclear-power generation plants. It should be noted upfront that the Nuclear Regulatory Commission (NRC) and DOE use the “spent nuclear fuel” term while many activists do not prefer this term; however, we sought to avoid confusion by continuing to use the same term being used by federal regulators. When reactor fuel is discharged from a nuclear reactor it is far more radioactive than fresh fuel, so the term “spent” only refers to used fuel from the reactor itself.

Specifically, Sierra Club policy on [High-Level Radioactive Waste](#) states:

"The Sierra Club believes that, pending the establishment of a permanent repository, interim storage can best be accomplished through the dry storage of spent fuel at the site of generation, except that when there is a clear and present danger, spent fuel should be transferred to a more stable reactor site for storage. For the long term, a geologic repository, selected according to rigorous criteria, presently appears to represent the safest method of isolation of high-level radioactive waste."

It is [estimated that nearly 80,000 metric tons](#) of radioactive spent fuel are being stored at reactor sites around the US in 2020. Serious concerns about the safe handling and secure containment of that extremely hazardous waste are mounting for many Sierra Club chapters, especially where nuclear reactors are being decommissioned and where siting of storage is increasingly hazardous. There are long-standing and growing concerns that the US Nuclear Regulatory Commission (NRC) is a captured agency compromising public safety. This is documented by its former Chairman, Gregory Jaczko, in *Confessions of a Rogue Nuclear Regulator*. (See Appendix I for a review of the book.)

The purpose of this guidance is (1) to provide local Sierra Club leaders with important perspectives and key background considerations and information for evaluating local management of SNF from commercial US reactors and identifying potential measures to reduce risks; and (2) to guide them as to

the decision-making process for taking positions regarding the relocation of waste storage in alignment with Sierra Club policy, where that is determined to be necessary to address immediate risk.

The guidance addresses the following topics:

- Cooling Pools
- On-site Dry Storage and Hardened On-Site Storage
- High Burnup Fuel
- Spent Nuclear Fuel Transportation
- Consolidated Interim Storage
- Community Engagement and Informed Consent
- Environmental Justice and Equity

This guidance document was prepared by a Sierra Club nationally appointed working group of volunteer leaders Peter Andersen, John Buchser, Lon Burnam, Susan Corbett, Robin Mann, Don Safer, David von Seggern, and Barbara Warren and national staff member John Coequyt.

Section 1. Executive Summary

Cooling Pools

Every nuclear reactor has a spent fuel pool (SFP) which is arguably the most vulnerable part of the nuclear plant. Any damage or loss of water from the pool can result in catastrophic releases of radiation. Cooling pools are necessary as the storage area when fuel rod “assemblies” no longer fission enough to provide the heat energy necessary to generate electricity. When they are “spent”, the rods are removed from the reactor vessel and placed in the cooling pool, to allow for thermal cooling, as the assemblies are extremely hot. The pools also provide shielding to the workers, as the assemblies are also highly radioactive. Rods typically remain in the pools for at least 5 years, to allow thermal heat to dissipate. Cooling pool buildings are typically not designed to protect from terrorist threats like small missiles and are also vulnerable to natural disasters, like the accident at Fukushima, Japan. Loss of water from the pool will result in fire, fission, damage to the rods themselves and releases of deadly amounts of radiation to the environment. The risk is increased if the pools are overcrowded and filled beyond their original design specifications, as is true at most, if not all, US reactors.

Dry Storage and Hardened On-Site Storage (HOSS)

When heat has decreased in specific fuel assemblies in the cooling pool (usually a minimum of 5 years), the radioactive fuel rods are removed, carefully dried, and placed into canisters. Canisters, which typically are in the 400 degree Centigrade range, are placed into concrete casks, providing air-cooling of the canister. The radioactivity of a canister remains dangerous to life for over 1,000,000 years. Ensuring safety for something this dangerous is a task never before undertaken by human beings.

Dry storage is intended to contain the SNF radiation, allow cooling, and provide shielding to the workers. Current radiation leakage monitoring is inadequate. Inspection of the contents and the integrity of the canisters is impossible, so there is no advance warning of potential problems or possible emergencies. If leakage is detected, systems are not in place to address and mitigate it. Most reactor safety planning focuses on the reactor itself, with less attention to the cooling pool and on-site dry storage.

A number of years ago, the nuclear activist community developed the Hardened Onsite Storage [Principles for Safeguarding Nuclear Waste at Reactors](#) (HOSS), endorsed by Sierra Club in 2006, to advance the safety of dry storage. The HOSS principles were developed to address the shortcomings in current on-site storage practices, like those mentioned above. HOSS is intended to minimize cask movement, protect casks from external damage, and maximize leakage monitoring. If leakage is detected, systems need to be in place to address and mitigate it. A large number of organizations have supported the HOSS principles; however, they are yet to be adopted by the industry.

A common misconception regarding retired reactors is that moving SNF to an alternative location is safe and easy. Any movement should be based on real, future risks of damage to the SNF canisters and the probability of radiation release. Movement of these wastes should be minimized and the risks at a destination community as well as the long-term suitability of the new location should be carefully considered.

High Burnup Fuel (HBF)

Burnup is the measure of duration of nuclear reactor fuel usage, referred to in gigawatt-days per metric ton of uranium (GWd/MTU). Fuel over 45 GWd/MTU is high burnup. As burnup increases so does the radioactivity and temperature of the fuel assemblies, which intensifies challenges in storage and transportation. HBF has three to four times more radioactivity than Low Burnup Fuel (LBF). HBF saves nuclear reactor operators costs by increasing the time between refueling. Allowable burnup levels have increased from industry pressure and NRC complicity. The current limit in the US is 62 GWd/MTU. There are troubling and potentially dangerous uncertainties in the stability and safety of aging HBF that seriously complicate storage, transport, and disposal of SNF. All SNF is deadly and must be kept out of our biosphere for at least a million years; running the fuel to high burnup levels makes that much more difficult.

Natural and Human-induced Disasters

While frequent attention has been given to the operational safety of nuclear reactors, their cooling pools, and their dry-storage sites, less attention has been paid to possible natural and human-caused disasters which could jeopardize the safety of nuclear sites and lead to radiation releases.

Such threats include earthquakes, tsunamis, seiches, flooding, sea-level rise, high winds, rockslides, mudslides, wildfires, tornados, and hurricanes. Tools exist for estimating the potential occurrence of natural disasters at any particular location in the US. Some, but not all, of these tools have been applied to nuclear power plant sites. Additionally, new threats can arise — for instance, the recent problem of higher earthquake risk in the eastern and central US due to oil and gas fracking activities.

Non-natural disasters can occur from infrastructure development in the US and government failure to maintain public infrastructure. When these occur near nuclear reactors, cooling pools, or dry-storage facilities, they can present new and potentially catastrophic events involving radiation releases because such events were not considered at the time of plant development.

In short, constant vigilance is required for the impact of natural disasters and creation of human-caused disasters that might affect a nuclear power site, and operational safety in response to thorough assessment of risks must be evaluated constantly.

Consolidated Interim Storage

Consolidated Interim Storage (CIS) has been discussed and proposed by our principal nuclear agencies, the Nuclear Regulatory Commission (NRC) and Department of Energy (DOE). However, adequate consideration of technical and political issues as well as safeguards for handling and storing massive quantities of high-level radioactive waste, until a permanent repository is identified, constructed, and implemented, has been absent.

Given the inherent hazards of concentrating thousands of metric tons of highly radioactive SNF in just a few interim locations, promulgation of new regulatory standards would be essential to provide the public with ample assurance of the government's commitment to safety and public health. Without a

comprehensive regulatory structure for CIS facilities, NRC is relying on obsolete regulations adopted years ago for shorter term dry storage facilities at existing nuclear power reactors.

The federal General Accounting Office testified in 2015 that, without new authority, DOE cannot site a CIS or a permanent disposal facility and make related transportation decisions for commercial SNF. The Nuclear Waste Policy Act prohibits DOE from taking title to nuclear waste from commercial generators at an interim site, as a precaution against the site becoming a de facto permanent repository.

The Sierra Club does not support CIS of SNF for multiple reasons. Moreover, the concentration of large amounts of SNF in one or a few locations also should not be used to advance reprocessing, which has demonstrated multiple very costly failures as well as dire environmental consequences.

Transportation

Presently, the federal government has no transportation plan and no intent to involve the public in decisions to ensure safe movement of SNF. This document identifies issues associated with the hazardous undertaking of massive movement of SNF across the nation. For decades the US has lagged in infrastructure investments, and the extraordinary weight of these shipments will stress that infrastructure. Also, there are numerous scientific unknowns associated with transportation such as those related to HBF, where research has lagged despite the 2010 recommendations of the Nuclear Waste Technical Review Board and their follow-up in 2016.

Potential terrorism and national security measures have not been shared with the public. Many emergency responders are volunteers with little training for hazardous materials and even less for radiological incidents. The National Transportation Safety Board (NTSB) should be put in charge of radioactive shipments and require redundant safety measures that protect the public from potential disasters. It is not acceptable that only radioactive shipments escape the purview and expertise of the NTSB, which can call for improved inspections and reporting, conduct thorough investigations, make recommendations and produce reports. Given these and many other deficiencies, the absence of extensive information about the transportation of SNF poses a major risk with serious consequences. Transportation could be the weakest link in the chain leading to disaster.

Community Engagement and Informed Consent

Informed consent should be required for the complex issues surrounding transportation and storage of nuclear waste. The significant risks for public health and catastrophic damage demand that people who face the highest risks from SNF transportation and storage should be engaged in a process that is based on reliable, objective information to evaluate and ameliorate those risks and to decide if proposed actions are acceptable.

Informed consent to SNF transportation and storage has, unfortunately, only recently been seriously discussed for US SNF by public and private entities. This challenge exists world-wide as few countries have addressed consent-based processes. Likewise, the US history of SNF consent-based processes is scant. Only after the Fukushima, Japan accident and the subsequent Report of the Blue Ribbon Commission on America's Nuclear Future in 2012 was planning for an informed consent-based process for nuclear waste started by the DOE. As of this writing, that planning has stalled.

Some quasi-consent processes exist in the US, but they have generated intense controversy. Among them are: the Skull Valley Band of Goshute related to a CIS proposal, the citizens of New Mexico related to the now-operational Waste Isolation Pilot Plant, and the citizens of Nye County, Nevada, where the designated high-level nuclear waste storage site was to be built. Currently, CIS facilities are proposed in New Mexico and Texas, but a consent process is non-existent.

Lack of trust exists between target states, communities and government agencies concerning what, where, and when SNF transportation and storage will occur. Agencies must become transparent on nuclear waste issues and accept the public as an equal in thorough consent-based processes. No community should be forced to accept nuclear waste without expressing informed consent.

Environmental Justice and Equity

The history of the US nuclear fuel cycle is characterized by environmental injustice, disproportionately burdening poor and people-of-color communities, especially indigenous communities, with exposure to highly toxic pollution and destructive extraction practices. While exercising its discretion to follow the Clinton administration's Executive Order on environmental justice and adopt agency policy to implement it, the NRC has failed to pursue a meaningful and effective approach to environmental justice in its deliberations regarding facility siting and transportation. The agency has failed to embrace its statutory authority under the Atomic Energy Act to protect the public health of all people. Confronting present and future issues around SNF should not perpetuate or exacerbate historical environmental injustice and racism.

Section 2 - Spent Nuclear Fuel at Nuclear Reactors

2.1 Cooling Pools

2.1a Cooling Pool Purpose and Design

Within a nuclear power reactor, a controlled fission process generates heat which is used to run turbines that produce electricity. As the amount of uranium-235 in the fuel pellets decreases, the amount of radiation increases, and fission can no longer be safely sustained. This results in the entire assembly holding the pellets needing to be removed and replaced with a new assembly in the reactor. This is done during refueling of the reactor. (These assemblies are also called fuel cores; we avoid that terminology here to avoid confusion with the core of the reactor). They are actually more radioactive when they are moved out of the reactor than when they were put in. They are so thermally hot and radioactive that the safest shielding is a large pool of water.

These cooling pools are arranged with spacing frames to hold the used fuel assemblies, called spent nuclear fuel (SNF). Since most reactors were designed for the lower levels of radioactivity in the fuel (LBF, for low burnup fuel), the entire facility was designed with this constraint. A lot of attention was placed on the reactor itself to ensure safety of the facility. The cooling pool was not as likely as the reactor to present operational challenges -- just remove the SNF from the reactor and put it in the cooling pool for about 5 years. After five years, the SNF would still be radioactive and thermally hot, but cooler. Accordingly, the next step was to remove the SNF from the cooling pool and place it in containers (dry storage) which could be sent to a permanent repository.

As cooling pools became crowded with SNF, industry resisted moving assemblies to dry storage because of the high costs. As a result, the NRC approved the use of dense racking of fuel assemblies, instead of the open racking used in original designs for the pools. As research by the industry and the NRC proceeded, it was determined that incrementally increasing the 'burnup level' was acceptable. This high burnup fuel (HBF) [See Section 2.2 on HBF] takes longer to cool in the cooling pool, but the cooling pools were not redesigned to address the longer cooling needed. Whereas the original designs for the cooling pools allowed for temporary air cooling if the amount of water in the pool dropped below the SNF, the increased number of fuel assemblies has created a situation where a 'loss of water' event would be very dangerous and potentially catastrophic, since air cooling is not adequate with dense racking.

Analysis of the 2011 Fukushima Daiichi disaster led to many recommendations. Among these recommendations was to improve the security and safety of cooling pools. The NRC has not made significant progress (if any) since then to address improvements. The increased density of SNF in these pools has increased radioactivity and heat, leading to degradation problems with the concrete as well as concerns for the associated safety systems.

Cooling pools at nuclear reactors provide four essential functions:

- i. containing massive amounts of deadly radiation;
- ii. cooling the hot fuel assemblies when they are removed from a reactor;
- iii. serving as a protective barrier for workers to the high levels of radiation emitted from the SNF;
- iv. preventing criticalities - uncontrolled nuclear fission.

2.1b Cooling Pool Technical Problems Resulting From Increased Packing Density

Since the 2011 Fukushima disaster, nuclear regulators have failed to effectively implement additional safety measures for monitoring SNF pools. Dense packing of fuel pools has been exacerbated by the use of HBF, which discharges more heat and must stay in the pools longer than LBF ([Alvarez Memo dated Dec.17, 2013](#)). Overcrowding is stressing pool-cooling systems; and, as a result, they are likely to need upgrading as the percentage of HBF in the pool increases. Moreover, many experts contend that SNF cooling pools are much more vulnerable to terrorism, military strikes, and natural disasters than storage in dry casks ([Science Magazine, May 24, 2016](#)). A 2011 NRC-sponsored study found that, as nuclear plants age, increasing degradation of spent fuel pools occurs – several nuclear power plants have experienced pool leakage. Accurate assessment is difficult due to limited access to observe pool conditions associated with other structures and equipment (see [Alvarez Memo dated Dec.17, 2013](#)).

As the delays are being allowed to continue on transferring cooled SNF to dry storage, the risks of over-crowded pool storage are compounding. In order to prevent nuclear criticalities from occurring in pools, neutron absorber panels are being inserted or boron is being added to pool water. However, additional neutron absorbing panels can also restrict water and air circulation making it more difficult to remove decay heat, leading to dangerous overcrowding and potential overheating ([Alvarez Memo dated Dec.17, 2013](#)). And adding boron to the pool water has the potential to degrade the pool concrete.

The potential for fuel pools to fail catastrophically has increased due to the higher concentration of HBF in fuel pools. HBF has 3-4 times more radioactivity than low burnup fuel. For HBF a typical Pressurized Water Reactor (PWR) assembly has about 270,000 curies as compared to 88,000 for an LBF assembly. For HBF a typical Boiling Water Reactor assembly has about 127,000 curies as compared to 30,000 curies for a LBF assembly. Cesium-137 constitutes about 40% of these curies and is highly radioactive, and its volatility leads to easy distribution as a gas over long distances (see [Alvarez Memo dated Dec.17, 2013](#)).

After irradiation in a nuclear reactor, SNF is a million times more radioactive than new uranium fuel (personal communication from Kevin Kamps of Beyond Nuclear). As reactors were originally designed, SNF irradiated fuel assemblies would be placed in open racks that promote the circulation of water and the dissipation of heat in the pools. As the pools filled with SNF and no ready disposal plan for SNF was available, the [Nuclear Regulatory Commission \(NRC\) began accommodating industry](#) concerns about the costs of transferring the waste to dry storage by allowing the use of more densely-packed racks for the fuel assemblies -- allowing roughly five times more capacity for fuel assemblies than open racking. Serious overcrowding of the pools has resulted.

Open racks also enable air cooling in the event water is lost in the pool. With today's densely-packed racks, air cooling would not be adequate if pool water is lost ([Alvarez et.al., 2003](#)).

Nuclear reactor plants are filling up their storage pools, with more than 70% of the nation's 80,000 metric tons of SNF now in cooling pools. Roughly one-fourth of this amount is HBF; and it is increasing, as [all reactors are now using HBF](#). The pools themselves are steel-lined thick concrete, but the structures above and around the pools are not robust, unlike the containment for the reactor itself.

The key threat from a cooling pool relates to the sudden loss of coolant (water). Coolant loss could occur via a deliberate terrorist event, a power failure, dropping heavy equipment that damages the pool,

a natural event (such as an earthquake), or simple equipment deterioration. The loss of coolant can occur via a leak in the pool or via the failure of cooling equipment, in which case the water would boil away, uncovering the fuel. With dense packing of the fuel assemblies, air circulation alone is unable to remove the heat. Following loss of coolant a self-propagating fire would ensue, resulting in a catastrophic release of cesium-137, affecting a [region larger than that affected by Chernobyl](#). (Chernobyl was a new reactor that involved only the reactor core in the accident, not a cooling pool loaded with SNF.) Other radioactive gases would be released (xenon, krypton, iodine, and chlorine); however cesium-137 represents about 40% of the gases released and has significant immediate health impacts. Other radionuclides would also be released, but cesium-137 is of most concern related to immediate health impacts. A [study done for NRC in 1997](#) found the consequences of a single SNF pool fire to be 54,000-143,000 extra cancer deaths, 2000-7000 km² (770 to 2700 sq. mi.) of condemned farmland, and \$117-566 billion of economic costs due to evacuation. These findings were consistent with a follow-up study ([Alvarez et al., 2003](#)). Large areas of land and water resources would be contaminated in urban and suburban areas as well. These modeling studies were done prior to the widespread use of HBF, and thus they only reflect the impacts associated with a SNF pool containing LBF. The consequences today would be much greater with the widespread use of HBF. While [experts](#) have urged rapid transfer of SNF out of reactor pools and into dry storage due to these risks, the NRC has apparently been more concerned about not imposing additional economic costs on plant owners.

SNF pools were not originally considered as part of a reactor's safety system, so there was no "defense in depth" applied to this part of a nuclear reactor facility. In [2016 the National Academy of Sciences](#) (NAS) made recommendations to increase the safety of SNF pools in a lengthy report. One of the report's recommendations indicated:

"The U.S. nuclear industry and its regulator should give additional attention to improving the ability of plant operators to measure real-time conditions in spent fuel pools and maintain adequate cooling of stored spent fuel during severe accidents and terrorist attacks. These improvements should go beyond the current post-Fukushima response to include hardened and redundant:

- (1) physical surveillance systems (e.g., cameras),
- (2) radiation monitors,
- (3) pool temperature monitors,
- (4) pool water-level monitors, and
- (5) means to deliver pool makeup water or sprays even when physical access to the pools is limited by facility damage or high radiation levels."

Unfortunately, the NRC failed to require all five of these recommendations -- only water-level monitoring is required.

There are frequent complaints that the NRC is much too lax when it comes to ensuring safety of nuclear facilities. In the case of cooling pool safety, it is clear that the straightforward guidance from the NAS has not been followed by the NRC in regulating industry. For more insights on safety risks of nuclear plants, including cooling pools, see the [Center for Public Integrity story](#) about the NAS review and findings. The nuclear industry has supported flexible options only for replacing water in the event of loss of pool water. This includes hooking up portable pumps by workers, but this option can only be used if there is no fuel damage and radiation is not elevated. If operators are unable to provide make-up water due to high radiation levels, a catastrophe could ensue (as almost occurred at Fukushima).

2.1c Inadequate Procedures for Damaged Canisters

One potential safety feature of cooling pools is that they provide a possible emergency purpose. If a dry-storage cask of used fuel is damaged, there are several possible means to address the problem: (1) remove the canister from the cask and place it in a larger canister, (the Russian doll solution); (2) remove the contents of the canister and place in a new canister (requires a radiation-shielded hot cell or Dry Transfer System, DTS), or (3) place the entire canister back in the cooling pool. At present, there are problems with all of these strategies. First, larger canisters do not exist at any reactor. Second, unloading the canister requires an expensive DTS, not available at any commercial reactors. And finally, to avoid a severely damaged cask leaking radiation to the entire area, making containment near impossible, a fall-back option is to place the canister back in the cooling pool. This option is possible only during decommissioning with an empty cooling pool, after removal of all of the SNF. In this instance the further spread of radioactivity into the immediate region around the reactor could be controlled.

In 2014 NRC's Final Continued Storage Rule, the agency required DTSs for all Independent Spent Fuel Storage Installations (ISFSIs). Unfortunately, NRC is no longer implementing these [requirements](#).

2.1d Guidance

Local Sierra Club chapters and individuals should reference the following recommendations when advocating for safer nuclear waste storage. The early transfer of Spent Nuclear Fuel (SNF) to dry-storage facilities remains an important priority to reduce the catastrophic risks associated with fuel pools. However, SNF must not be removed before enough heat has dissipated through radioactive decay in order to avoid over-stressing the cladding and other components. The higher the burn-up level, the longer it should be kept in the pools -- 5, 10 or more years.

1. Cooling Pools pose catastrophic risks that can exceed by many times the risks from the reactor itself. The implementation of post-Fukushima National Academy of Sciences (NAS) recommendations to improve safety of fuel pools should be raised at every reasonable opportunity. These recommendations are "hardened and redundant":

- (i) physical surveillance systems (e.g., cameras),
- (ii) radiation monitors,
- (iii) pool temperature monitors,
- (iv) pool water-level monitors, and
- (v) means to deliver pool makeup water or sprays even when physical access to the pools is limited by facility damage or high radiation levels."

2. Regular inspections of the condition and integrity of pool structures as well as the adequacy of water-cooling equipment are needed. Newer pool designs are generally less robust, and older designs have aged more; in either case, inspections are very important. This equipment was not designed for the current higher heat loads of high burn-up fuel (HBF).

3. Repairs and/or upgrades to fuel pools and cooling equipment must be made when determined to be needed. This situation is particularly true where an extended reactor life is planned and the fuel in the pool is primarily HBF. Currently license extensions are granted too easily by NRC without a serious look at actual reactor conditions. License extensions should be vigorously opposed by Sierra Club.

4. **Reports on the condition of the fuel pools should be requested in all proceedings, including details about whether a full inspection was possible, given access limitations on inspection of the pool.**
5. **Operators should move spent nuclear fuel (SNF) from pools to lower risk, hardened on-site dry storage as soon as possible. HBF, however, requires longer residence time in a pool.**
6. **All fuel pools and their equipment should be connected to backup diesel generators and batteries in order to be protected in the event of an electric grid outage or damage to the primary electrical supply.**
7. **All fuel pools around the country should be assessed for and protected from natural disasters and terrorist attacks. This should include concrete and steel structures to protect from a shoulder-launched missile or aircraft impact.**
8. **Require documentation to show that cooling-pool equipment at a given nuclear power plant was designed to safely handle the current higher heat loads of high-burnup fuel (HBF).**

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2.2 High Burnup Fuel

2.2a High Burnup Fuel Issues and Challenges

Intensified challenges for storage and transportation of nuclear waste are posed by the generation of “high burnup fuel” in nuclear power plants. Burnup is stated in gigawatt-days per metric ton of uranium (GWd/MTU). Fuel over 45 GWd/MTU is termed “high burnup fuel” (HBF). Burnup levels of US nuclear fuel have been increasing since the early days of the industry. In 1972 average burnup for all discharged assemblies was 12.4 GWd/MTU for boiling water reactors and 23.3 GWd/MTU for pressurized water reactors. It stayed below 30 GWd/MTU until 1985 but by 2012 the average for boiling water reactors was 45.1 and 46.6 GWd/MTU for pressurized water reactors. A higher level of enrichment of U-235 is used in the fuel assemblies to reach the higher burnup. The current allowable burnup upper limit is 62 GWd/MTU. This was reviewed by the Nuclear Regulatory Commission ([NRC in 2019](#)). All SNF is highly irradiated and deadly, at any burnup level. It delivers a lethal dose within minutes at close range. It remains a threat for millions of years.

HBF has 3-4 times more curies (a measure of radioactivity) than low burnup fuel (LBF). A curie is 37 billion radioactive disintegrations per second. For HBF a typical PWR (Pressurized Water Reactor) assembly has about 270,000 curies as compared to 88,000 for LBF assembly. For HBF a typical BWR (Boiling Water Reactor) assembly has about 127,000 curies as compared to 30,000 curies for a LBF assembly (see [Alvarez memorandum of Dec. 2013](#)).

The core of an operating reactor is an intensely hot, toxic environment with nuclear fission throwing off heat, neutrons, and many highly radioactive particles. Temperatures reach over 2000 degrees Fahrenheit ([Argonne National Laboratory in 2011](#)). This takes its toll on the ceramic fuel pellets, the structure of the fuel cladding, and the assembly parts holding the fuel rods together. HBF is subjected to these stresses for longer times. HBF is more radioactive and operates at higher temperatures and pressures than LBF. These facts provide clues as to the differences between high and low burnup fuels when removed from a reactor.

The [most extensive research](#) that identified substantial differences between HBF and LBF involved 4,400 measurements of commercial fuel rods irradiated in reactors around the world. Problematic changes in physical character of the cladding (the primary physical radiation barrier) starts at about 35

GWd/MTU, the previous NRC conventional value used to separate LBF and HBF. The oxide layer on the HBF cladding was found to be 2.5 to 3 times thicker than for LBF. Besides oxidation, hydrogen is absorbed by the Zircaloy metal in the cladding and forms hydrides, leading to embrittlement of the fuel rods. The hydrogen content of the cladding was found to be about 2 times greater for HBF than for LBF. Residual water from an incomplete drying process can provide both oxygen and hydrogen for these two types of degradation. Oxidation and hydrides also result in [thinning of the metal cladding](#). The longer the fuel is used in a nuclear reactor, the greater the damage. The zirconium cladding is approximately the thickness of an aluminum beverage can. It is the critical first radiation barrier or containment for radiation in the fuel during operation, wet storage, dry storage, transport and long-term storage. During extended irradiation the cladding surface thins through oxidation, becomes more brittle from absorbing explosive hydrogen gas, and is subject to increased internal pressure from fission gas buildup. The cladding of the fuel rods rubs against the metal grid holding them in place, causing wear and possible failure.

Everyday realities of nuclear power often pit economic interests against safety concerns. HBF is a case in point. As the fuel burns and burnup levels increase, physical deterioration stresses the fuel cladding, the uranium dioxide pellets, and the assemblies holding the fuel rods together. These changes and the effects of higher heat and radiation levels on safe storage, transport, and eventual disposition are only now being studied on actual HBF rods and assemblies. Prior physical studies had been conducted on much lower burnup fuel. The [Nuclear Waste Technical Review Board Report 2010](#) (p. 54-56) expressed serious concern that the entire scientific basis for understanding the behavior of HBF was based on a single study of LBF. The NWTRB believes much more research must be done on HBF rather than relying on data from a study of LBF. It is important to note there are many significant challenges and remaining uncertainties in the storage, transport, and long-term disposition of LBF.

What we do know is that HBF involves more risk and different characteristics than LBF. Inside the fuel rods, uranium dioxide ceramic pellets, about 1 cm in diameter and 1 cm long, are stacked single file. There is a small gap between the pellet and the cladding. As the fuel is used, fission gases build up, putting pressure on the cladding, increasing the cladding-pellet gap, and microscopic fractures in the pellets multiply. In a [peer-reviewed article in *Materials Today*](#), it is reported that the physical and chemical state of the fuel is changed as it is subjected to the stresses of nuclear fission. The new structure has been named "high burn-up structure". The most deterioration is experienced on the outer rim of the uranium-dioxide pellets.

Fuel rods are submerged in water while in use. Once they have reached the end of their productive capacity and their targeted burnup level, they are kept submerged and moved to a cooling pool at the reactor. HBF must be kept in the cooling pool significantly longer than less radioactive fuel before it is safe to place in dry storage. The higher heat and radiation must be accounted for in the pool, both to dissipate the heat and prevent the fuel from again reaching criticality. (Criticality is defined as occurring when there is sustained nuclear fission, either controlled or runaway.) Drying the fuel rods to move them to dry storage adds more stress to the cladding, pellets and assemblies.

These various stresses add up and create troubling levels of uncertainty about the physical behavior and structural stability of all irradiated (used) fuel rods in dry storage, transport, and long-term storage. These uncertainties are greatly magnified at high burnup levels. Cladding failure is a serious safety concern and is more likely to occur in HBF. Our knowledge of the life expectancy of cladding is limited; US nuclear reactors have only been generating high burnup fuel for less than 20 years. [Actual studies](#) of the fuel in dry storage began in 2016 with results expected in 2026.

Inert helium gas serves a vital role in dry storage of SNF. Pressurized helium is pumped into and sealed in the canisters to displace oxygen rich air. Helium aids conduction of heat away from the fuel assemblies, and its presence is essential to preventing oxidation of fuel and cladding and hydrogen absorption. Unfortunately, the continued presence of helium cannot be assured in canisters that are welded and there is no internal monitoring for helium. We have only computer simulations to give us an idea how the HBF will behave over longer time frames; [NRC considered](#) the behavior of the fuel cladding over 300 years of dry storage and estimated that flaws would develop near the end of that period.

The lack of basic knowledge about HBF raises concerns related to transport for storage and/or disposal. The fuel and the cladding have experienced higher radioactivity, higher temperatures, and higher pressures, and potentially are more vulnerable to fracturing and ruptures of the thin metal cladding as a result of vibrations and shocks related to transport. Transport of HBF should not be conducted until more research results are evaluated. A prudent approach would also be to delay any “permanent” disposal of HBF until we know more. Some experts have recommended keeping it at or near the Earth’s surface for 100 years or more.

HBF is relatively new to the nuclear fuel cycle and presents new challenges to containment and safety after its removal from reactors. It is significantly different from the LBF that was originally examined for durability over time. Assumptions made on HBF’s stability and behavior based on that of LBF should not be trusted.

In addition to problems when HBF is put into cooling pools or dry storage, HBF has in-reactor effects that are currently awaiting understanding and action by the NRC itself. On March 15, 2007, Mark Leyse (the petitioner) submitted a [Petition for Rulemaking](#) (PRM) to the NRC requesting that all holders of operating licenses for nuclear power plants be required to operate such plants at operating conditions (e.g., levels of power production and light-water coolant chemistries) necessary to effectively limit the thickness of crud or oxide layers on fuel-rod-cladding surfaces.

These factors increase cladding temperatures during loss of coolant accidents for reactors. After public comments were received on the proposed rulemaking, NRC staff delivered the rulemaking package to the Commission in March 2016. Unfortunately, the Commission has not taken final action on this rulemaking for over 4 years. The draft final rule package can be obtained at the [NRC website](#).

It is now abundantly clear that NRC permission to allow reactor operators to run their fuel to high burnup levels in reactors should have been more thoroughly considered prior to its approval. HBF will have significant effects across all the fuel stages -- in reactors, in cooling pools, in dry storage, during transport, in interim storage, and at a permanent repository. The Department of Energy (DOE) should also not allow mixing of HBF with LBF fuel in dry storage canisters. There is no factual basis for ensuring that the placement of HBF with LBF will not increase temperatures in hot spots to greater than 400 degrees Centigrade (the recommended temperature limit under normal conditions -- see [NWTRB 2010 report](#), p. 38).

Monitoring only applies to the entire canister, not to hotspots. Even if the overall temperature limit is not exceeded, it could be exceeded in hot spots, affecting cladding and fuel and possibly leading to ruptured fuel rods.

2.2b Guidance

1. The nation's nuclear agencies, NRC and DOE, and research labs should address the substantial unknowns associated with HBF, identified by the NWTRB in their 2010 report. Until the unknowns are adequately addressed, the agencies should maintain and enforce rigorous monitoring and surveillance that is essential to health and safety. Independent experts are required to verify that all SNF storage and disposal plans and practices are the least risky possible and based on the best, most-up-to-date science.
2. The factual basis for 400°C as the limit for normal conditions of HBF (High Burnup Fuel) should be reconsidered.
3. NRC should continue to implement and enforce requirements related to temperature monitoring and adequate cooling periods in pools and dry storage prior to transport. There should be no relaxation of previous requirements.
4. Radiation monitoring of individual storage casks remains important to early identification of a leak and the need for early action, so this requirement should not be weakened and additional types of internal and external monitoring should be developed. Continuous radiation monitoring of the exit air vents of the external casks is essential.
5. The NRC should approve, without further delay, the proposed in-reactor rulemaking to ensure that the accumulation of corrosion products on HBF does not result in damage to fuel assemblies during a loss-of-coolant accident. Such damage can carry over and worsen during dry storage and transportation.

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2.3 Onsite Dry Storage of Nuclear Waste and Hardened Onsite Storage (HOSS)

2.3a Introduction to Onsite Dry Storage

The management goal for used nuclear fuel is to allow radioactivity to decrease and the physical temperature to drop to about 400 degrees centigrade while in the cooling pool, and then transfer to dry storage. This cooling process within the pool takes about 5 years for low-burnup fuel (LBF), and about 10 years for high-burnup fuel (HBF). The industry has successfully lobbied the NRC to leave fuel in the cooling pool longer than this, and in a higher density than original reactor designs.

The transfer to dry storage is a dangerous process, requiring shielding of workers from the radioactivity while the fuel cores are lifted from the pool, dried, and then placed in a canister. The canisters have helium gas added and are sealed shut, either by welding them or bolting. The canisters are then placed

in an exterior cask, which is air-cooled, with a minimum of two vents allowing for flow of air. Then these casks are stored on-site. If stored at ground level, these casks are vulnerable to natural disasters and terrorism, so one approach is to place them just below ground level in concrete structures.

A permanent geologic repository for nuclear waste has not been approved. As a result, the nuclear power industry uses onsite storage of spent nuclear fuel (SNF) in dry canisters and casks. Although this is not meant as a permanent solution, these facilities (Independent Spent Fuel Storage Installation -- ISFSI) are licensed by NRC in the US. They present many problems in design, implementation, monitoring, security, and long-term robustness.

The NRC has created a “backgrounder” document on dry cask storage [on the NRC website](#). Dry cask storage facilities exist at 75 sites in the US, thus including nearly every nuclear power plant. In the majority of cases, the dry storage consists of inner stainless steel canisters and outer concrete casks. In a few cases, the dry storage is in thick metal casks with bolted lids.

More than 200 groups nationwide, including the Sierra Club, signed onto the Hardened Onsite Storage (HOSS) [Principles for Safeguarding Nuclear Waste at Reactors](#), in 2006, to advance the safety of dry storage. This document succinctly addresses the most important issues with SNF, including safety concerns related to both cooling pools and dry storage. Unfortunately, these principles have not been adopted by the industry or government regulators, and in the case of the proposed CIS facility in New Mexico, the NRC explicitly rejected HOSS. (See [NRC EIS](#), pp. 2-21.) Some sites have improved berms around the facilities; however, this is a small step in the right direction.

The major recommendations of the HOSS Principles include:

- i. **Reduce terrorism risks.** Place spent nuclear fuel in Hardened Onsite Storage (HOSS) facilities. HOSS facilities would have hardened concrete and steel structures around a waste cask in addition to a surrounding berm of gravel and rock. These barriers would significantly reduce consequences of a terror attack. In the case of above ground storage, there would also be increased separation between each SNF cask to provide more protection than current dry storage.
- ii. **Dedicated funding,**
- iii. **Periodic review of safety measures, and**
- iv. **Independent monitoring.**

2.3b Issues and Challenges with Dry Storage/ISFSIs

Onsite dry storage presents the following key challenges:

- i. No means to deal with leaking casks. Significant worker shielding is required.
Options are:
 - a) Remove canister from cask and place in new cask;
 - b) Place canister/cask unit in larger cask;
 - c) Move canister or canister/cask back to cooling pool (this is least desirable).

- ii. Inadequate environmental monitoring of canisters/casks and their contents;
- iii. No experience with long term storage and resulting effects on storage canisters, casks, and contents (only simulations and medium-term storage);
- iv. At shut-down reactors some decommissioning plans include removal of SNF from the fuel pools before it has had adequate time to cool;
- v. If inadequate dry storage space is available, the SNF is left too long in the cooling pool, leading to crowding in the cooling pool;
- vi. Decommissioning frequently includes removal of the cooling pool, resulting in no short-term emergency strategy for a leaking cask.

Spent fuel rods encased in protective canisters and casks in dry storage areas present possible environmental risks. The contents, which include 10-37 fuel-rod assemblies, each having dozens of fuel rods, remain very hot thermally and highly radioactive for centuries. At 10 years, if the cask and inner canister were removed, a person at one meter could receive a lethal radiation dose in 1 minute (personal communication from Marvin Resnikoff, Ph.D.) For a discussion of radiation doses and weighting factors, see Appendices II and III. Such extreme exposure to individuals is unlikely, but a range of various failures could release some of the contents of the canisters to the environment, leading to radiation threats, the necessity to evacuate large areas, and extremely costly cleanup efforts. The long-term ability of the canisters and casks to contain the radioactive contents may be compromised in several ways, including various physical and chemical processes that cause deterioration of the fuel-rod cladding, the assemblies holding the fuel rods, and the canisters themselves. Any of these degradation processes would present substantial challenges to maintaining the dry casks onsite and to later movement should they be taken to an interim storage site or to a permanent storage site.

There are numerous types of canister/cask designs and systems being used world-wide for the storage of SNF. The most common type involves an inner stainless steel canister that is only 5/8-inch thick and sealed by welding. This inner canister is then inserted into a concrete cask that provides shielding and ventilation for heat removal. The other type is a metal cask, approximately 8-12 inches thick with a lid that is bolted on. Various types of steel or cast iron are used for these metal casks. This type of cask with a removable lid enables internal sensors as well as inspection of SNF. Heat is removed through the metal cask wall with no vents. Cask placement position can be vertical or horizontal; on a concrete pad, sub-surface, or in a mausoleum-type building. Systems can be approved by NRC for storage only or for transport and storage. The first casks loaded in the US were at the Surry nuclear reactors in Virginia in 1986. There [could be over 10,000 canisters](#) in the US by 2050. (For further description, see [NWTRB 2010 report](#), p.66.)

There is much unknown about the aging of SNF and the storage canisters, particularly at today's high burnup levels. Dry casks were originally licensed for 20 years; some have been relicensed for an additional 40 years. As these systems age, time will tell which ones are the most robust. In the absence of a long-term disposition plan, it is likely that the duration of their usage will be much longer than originally anticipated when they were designed.

It is crucial to prevent catastrophic failure of a storage canister. Canisters being loaded today contain very high amounts of radiation and a breach of containment, even a small breach with the resulting loss of helium gas, is likely to result in a major disaster.

To be as certain as possible that our systems are as safe as possible, canisters or casks must be inspectable both inside and out for any developing flaws, cracks or leaks. They must be adequately maintained, and not subject to critical degradation (such as stress corrosion cracking). They must be transportable. They must have a continuous early-warning monitoring system to enable corrective action before radiation releases. There must be an on-site plan to replace containers as needed for safe storage and eventual transport. Spent fuel pools should not be destroyed, or another means of transfer such as a hot cell should be on-site until the spent fuel is removed from the site. Continuous, on-line, publicly accessible radiation monitoring should be in place. Continuous monitoring of the temperature of the outside of the casks should be required, as a jump in temperature is an indication of helium loss.

Environmental monitoring of dry-storage casks is inadequate at most ISFSI sites. This is apparent in the NRC documents on licensing of ISFSIs and their license renewals (see guidance documents [NUREG 1567](#) and [NUREG 1927 R1](#), respectively). NRC is attempting to correct this and recently had a NUREG out for comment which addresses the aging of casks ([NUREG 2214](#)).

NUREG-2214 is a 527-page document describing at least 30 different aging mechanisms that may affect dry storage casks and their contents. These NUREGs should be high on the list of documents to review when a chapter or group is faced with ISFSI licensing or renewal of licensing.

10 CFR 72 (Code of Federal Regulations) addresses the licensing of dry cask storage sites and systems for spent nuclear fuel. The requirements for monitoring the state of dry casks and their contents are put forth in 10 CFR 72.122(h)(4), which summarizes the necessity of this process:

“Storage confinement systems must have the capability for continuous monitoring in a manner such that the licensee will be able to determine when corrective action needs to be taken to maintain safe storage conditions. For dry spent fuel storage, periodic monitoring is sufficient, provided that periodic monitoring is consistent with the dry spent fuel storage cask design requirements. The monitoring period must be based upon the spent fuel storage cask design requirements.”

This part of the CFR defines monitoring in only very general terms. The use of ‘periodic’ monitoring without further clarification leaves much to be desired, and ‘continuous’ monitoring would be preferred.

A good introduction to physical monitoring related to dry cask storage of SNF is contained in the report: [Available Methods for Functional Monitoring of Dry Cask Storage Systems](#), prepared for NRC in 2014. In the Executive Summary of this report, the authors state:

“A number of technical issues and data needs associated with extended storage of SNF have been identified in the U.S. Nuclear Regulatory Commission (NRC) gap assessment.”

The report elucidates these issues by providing a thorough review of available sensing methods and of their applicability to dry cask storage. Given that most dry casks are sealed, not meant to be opened, and do not now contain any sensors, the retrofitting of sensors to current casks presents substantial challenges, especially if opening or penetration of the cask is required to place sensors inside. Sensing

incipient corrosion and other degradation failures is challenging to both internal sensing and more significantly to external sensing.

Whereas modern motor vehicles have dozens of sensors that monitor conditions in real-time, similar requirements for dry casks are currently lacking, with older ISFSIs, in particular, having little environmental sensing of casks. Given the fact that the cost of single dry casks in the US can be one million dollars or more, it is unacceptable that they not include, at a small fraction of that cost, the sensing systems needed to monitor them and ensure their integrity over long time periods. Such sensing systems become part of the “aging management” strategy. The general challenges of monitoring and inspecting dry casks are [highlighted by EPRI](#) (Electric Power Research Institute).

2.3c Common Physical Problems with On-Site Dry Storage

i. Helium Leakage

Casks are filled and pressurized with helium and then sealed by bolting lids or by welding. The purpose of the helium, an inert gas, is twofold:

- 1) to prevent damaging chemical reactions (including fire) that would occur if normal air were allowed to fill the canister, and
- 2) to provide convective heat transfer to the cask surface so that the fuel rods do not overheat.

The integrity of the welds or seals of the cask is crucial in maintaining the helium environment. The loss of helium can allow air into the canister -- allowing rapid oxidation of the nuclear fuel, increasing its volume, and rupturing the fuel rods. Helium has an advantage as an inert gas in that it is a very small molecule; so it would start to leak through small cracks, allowing early intervention if a canister is being properly monitored. Other inert gases may be put to use in the future, as helium availability is limited (helium is a byproduct of natural gas production).

The need for periodic or continuous monitoring of helium pressure within the casks is underscored by [NRC Information Notice 2013-07](#). This Information Notice reported a case of corrosion where helium was escaping at a slow rate. The leak was detected by a pressure monitoring system. Such a monitoring system should be an essential, required part of every ISFSI design. Argonne National Laboratory proposed [another means of detecting helium loss](#), based on the change in temperature on the outer canister surface.

ii. Corrosion and Cracking

Chemical corrosion of the interior of casks and their contents presents major challenges for monitoring. Because the current ISFSIs were not built for long-term storage, there is no means of monitoring or inspecting the interiors of steel canisters. Inspection of the exteriors is somewhat easier, but even this is not presently required by the NRC. The susceptibility of spent fuel rod cladding, steel assemblies, and canisters to corrosion and other forms of chemical deterioration has been a subject of recent research, especially in regard to high-burnup fuel (see Section 2.2 on High-Burnup Fuel). The state of knowledge of multi-year or multi-decade performance of casks is poor, and EPRI has only recently commissioned a [10-year study](#), the final results of which won't be available until 2027, on the performance of an actual loaded dry cask. NRC issued an Information Notice ([IN 2012-20](#)) discussing the possibility of such cracking in near-marine environments.

Unfortunately, no means are currently employed to detect microscopic cracks in SNF steel canisters; such cracks could release radiation, if they pierce the entire canister wall. No exterior inspections of steel canisters for corrosion or cracking are required, and interior inspections are never done. The task is complicated by the fact that the concrete shielding of the casks would have to be removed to allow inspection of the exterior of the steel canister. Workers would be exposed to high levels of radiation unless a fully shielded facility is available for the inspection. Agencies have not proposed opening canisters for routine inspections of aging or degradation as part of research. This situation makes the discovery of stress corrosion cracking unlikely in the current regulatory environment.

iii. Temperature

Temperature monitoring of the interior of a cask may be unnecessary if exterior monitoring is performed continuously or regularly, as described by the [Argonne Laboratory study](#) cited above. Such exterior monitoring, coupled with robust computer models of heat transfer in the particular cask design, should provide a sufficiently accurate estimate of interior temperatures. Since NRC has recently authorized increased heat loads for SNF going to dry storage, increased frequency of temperature monitoring is in order.

iv. Natural and Non-Natural Disaster Resistance of Casks/Canisters and Site Itself

Prediction of natural disasters is an inherently science-based activity. A good introduction to the broad scope of natural disasters and prediction is found in a [Tulane U. report](#). Natural disasters pose a threat to dry-storage nuclear waste sites, just as to any infrastructure. The difference, however, is in the innate hyper-toxicity of the contents of SNF dry-storage canisters. Among the natural disaster threats are earthquakes, tsunamis, floods, high winds, mass slides, and hurricanes. While none of these disasters is likely to breach the canisters and expose the spent fuel rods, they may internally damage the systems such that dangerous repackaging is required in order to ensure the continued safety of the radioactive contents. [Refer to Section 2.4. on natural disasters for a more extensive discussion.]

2.3d Dry Cask Storage: Security, Emergency Response, and Mitigation

i. Role of the Department of Homeland Security in Nuclear Security

Since the 2001 terrorist attack on the New York twin towers of the World Trade Center and the Pentagon, the federal government has taken many steps to improve security within the US borders. A broad [National Infrastructure Protection Plan](#) (NIPP) has been developed, divided into many “sectors”. The Department of Homeland Security (DHS) has been assigned the *Nuclear Reactors, Materials, and Waste Sector*. In response, DHS has developed a specific plan for the nuclear sector of the US; a [2015 version of this plan](#) is the latest available.

In the *Executive Summary* of that plan, DHS writes:

“The Nuclear Reactors, Materials, and Waste Sector (or Nuclear Sector) includes the Nation’s 99 commercial nuclear power plants; 31 research, training, and test reactors (RTTRs); 8 active fuel cycle facilities; waste management; 18 power reactors and 6 fuel cycle facilities that are being decommissioned or inactive. It also includes the transport, storage, use, and safe disposal of more than 3 million packages of radioactive or nuclear materials and waste annually.” (p. v)

Unfortunately, in describing the nuclear sector of the US, the document does not specifically single out dry-storage sites for SNF but lumps them in with the nuclear plants at which they are located.

The document sets out five goals and priorities to harden the nuclear sector to natural and human threats, yet it leaves actual regulation up to the NRC and implementation to the nuclear industry and to various federal, state, and local entities.

Clearly, DHS takes seriously the extremely high human and infrastructure costs associated with any natural or human-caused disaster at nuclear power plants, at SNF storage sites, and at transportation facilities. They state: “A significant incident or failure at a major nuclear facility would likely result in extremely high economic costs, major onsite and/or offsite property damage, and evacuations.” (p. 9) The 2011 Fukushima disaster in Japan is, of course, the prime example of this.

The document lists several "Significant Nuclear Sector Risks":

- Natural disasters and extreme weather
- Structural issues
- Aging infrastructure and workforce
- Deliberate attacks and terrorism
- Cyberattacks
- Supply chain disruptions
- Source diversion or mishandled and orphaned radioactive sources

The document shows the complex and extended web of agencies, departments, military units, and other federal or quasi-federal entities that have some responsibility for security and resilience of the nuclear sector. It lists the industry and non-profit organizations that are involved with this as well. **This raises some concern as to which agency or individual bears the responsibility of a response.**

A substantial “Risk Management” section of the document describes some of the activities that should be pursued for reduction of risks in the nuclear sector. One is to bring together federal, state, and local entities into an “integrated response” configuration.

NRC has an emergency response resource at its Operations Center 24/7 and staff on call to respond to emergency situations in the nuclear sector. They will coordinate with the nuclear plant or storage site operator to determine courses of action. An industry-funded response center exists for replacement equipment and for emergency equipment that may be needed on short notice due to an extreme event at a nuclear power facility.

Finally, the document sets out the means for measuring needed improvements in all aspects of nuclear sector disaster preparedness. Periodic assessments are done by panels of experts. The DHS plan for the nuclear sector is expected to be updated at regular intervals.

ii. Security and Prevention

Naturally occurring safety issues related to the design and robustness of dry casks are not the only ones to be aware of and concerned about. Both natural and unnatural disasters in relation to possible safety of dry casks are discussed below. We need to be aware of potential problems arising from deliberate attempts (i.e., sabotage, terrorism, or war) to breach or damage casks and to disrupt or damage the site

where they are stored. Even a small release of highly radioactive material from a cask could adversely affect a widespread area. Increasingly powerful small weapons are becoming available to individuals or groups who may seek to sabotage an ISFSI site.

Prevention is the first line of defense. Consideration of factors that may make it easier for deliberate disruption or destruction should be a part of every ISFSI licensing, or relicensing procedure. In 2013 the NRC did address the prevention goal with Regulatory Guide DG-5033, "[Security Performance \(Adversary\) Characteristics for Physical Security Programs for 10 CFR Part 72 Licensees](#)." But on its public website, NRC states "DG-5033 is not publicly available because it contains safeguards information." Thus, it is not possible to know all the factors being considered by NRC in relation to security of ISFSIs. This type of redaction is understandable in that description of weaknesses may actually enable saboteurs to devise successful strategies, however it does not enable independent assessments of the quality of such safeguards. The Federal Community Right to Know Act overcomes some of these barriers through Local Emergency Planning Committees (LEPCs) and their ability to review sensitive information. Key personnel may also be able to provide summary information to the public regarding safeguards in place.

10 CFR 72 requires that the dry-storage area be within the "protected" part of the power plant facility, but it does not specify the degree of protection necessary. Questions regarding security against armored-vehicle forced entry are important to raise in specific cases. Clearly, it will be more difficult to provide security against projectile explosives fired from outside the "protected" part of the power plant facility because distances of up to miles would need to fall under surveillance. Regulations in 10 CFR 73.51 specify requirements for physical protection of stored SNF and high-level radioactive waste, including numerous detailed requirements. An important one is that the ISFSI site has an "...effective physical protection plan..."

Since 9/11/2001, awareness of possible terrorist attacks in the US has risen significantly, and security of ISFSI sites needed to be revisited. In a 2006 [public report](#) to Congress, the National Research Council of the National Academy of Sciences (NAS) studied the security of dry-cask storage along with cooling-pool storage. It is important to note the NAS finding that: **"Dry casks were designed to ensure safe storage of spent fuel, not to resist terrorist attacks."** [p. 64; emphasis added] Although the robust nature of the casks, plus their overpacks, does inherently provide substantial resistance to sabotage, it is not clear that licensing takes the risks of sabotage into account.

The NAS report looked at large aircraft impacts as a means of assault given the history of such attacks. Although the studies are classified, NAS could report that results obtained by Sandia National Laboratory through numerical modeling show that "...predicted releases of radioactive material from the casks, mainly noble gases, were relatively small for all of the scenarios considered by Sandia." It is unlikely that the full results will ever be made publicly available. And, even if they were, it is important to note that the study was made on only one specific cask system.

The NAS study offered these recommendations for preventing releases of radioactive materials due to attacks:

- Additional surveillance could be added to dry cask storage facilities to detect and thwart ground attacks.

- Certain types of cask systems could be protected against aircraft strikes by partial earthen berms. Such berms also would deflect the blasts from vehicle bombs.
- Visual barriers could be placed around storage pads to prevent targeting of individual casks by aircraft or standoff weapons. These would have to be designed so that they would not trap jet fuel in the event of an aircraft attack.
- The spacing of vertical casks on the storage pads can be changed, or spacers (shims) can be placed between the casks, to reduce the likelihood of cask-to-cask interactions in the event of an aircraft attack.
- Relatively minor changes in the design of newly manufactured casks could be made to improve their resistance to certain types of attack scenarios.

In comparison to storage in cooling pools, the NAS committee found that dry storage has several advantages in regard to possible attacks. In particular, they state **“The recovery from an attack on a dry cask would be much easier than the recovery from an attack on a spent fuel pool.”** (2006 NAS Report, [p. 69](#).) This is due to the fact that the dry storage damage will be more confined, thus hopefully limiting the extent of the radioactive release relative to that in a cooling pool.

The NRC should take proactive measures in response to the results of the vulnerability analyses including upgrading the requirements in 10 CFR 72 for dry casks, specifically to improve their resistance to terrorist attacks.

iii. Emergency Response Plans

Emergency response to radioactive material releases is primarily an ISFSI operator responsibility, but various levels of local or regional emergency response must be involved also. 10 CFR 50.54 and 10 CFR 72.32 govern emergency response plans of operators of ISFSI sites, either before or after decommissioning. The various levels of city, county, and state emergency planning are often found in conjunction with the operator plans governed by NRC. These local, county, or state plans will be very specific to the ISFSI under consideration, but citizens should analyze these plans in context for depth and breadth. Clearly, the threats posed by radioactive waste releases present a large, unique hurdle to emergency response planning.

iv. Mitigation Plans

In the case of radioactive material releases, mitigation plans to control the release of radioactive material and to minimize exposure to human populations may share many facets in common with the impacts of natural or unnatural disaster and the impacts of sabotage. Mitigation plans may also overlap with emergency response plans.

The Nuclear Energy Institute in 2016 issued a white paper, [NEI 14-01, Rev. 1](#), discussing the role of the nuclear power industry in response and mitigation. That paper discusses Severe Accident Management Guidelines (SAMGs) as an industry initiative; and it states that “There is currently no regulatory requirement for licensees to develop, maintain, train, drill or exercise SAMGs.” This paper only addressed accidents within the nuclear reactor and cooling pools and not at ISFSI sites; however, some of the guidance can be projected to ISFSI radiation releases. Another set of guidelines, called Extensive

Damage Mitigation Guidelines (EDMGs) is under NRC order, prompted by lessons learned from the Fukushima, Japan, nuclear plant disaster. The establishment of requirements by NRC relating to EDMGs is ongoing; but, again, the application to ISFSI sites seems to be mostly ignored.

2.3e Transfer of Waste to Less Risky Dry Storage Location

A chapter concerned about the safety of SNF at a reactor site should engage with the Sierra Club's Nuclear Free Team, in an effort to determine if the dry-storage system being used at the reactor site is sufficiently protective from natural and manmade threats. If the chapter determines that the site represents a "clear and present danger," the chapter *may* advocate to the Sierra Club Board of Directors about moving the casks to a less risky location *within* the state (consistent with the principles of informed consent detailed in this guidance), until a permanent disposition facility is available.

If the chapter and the Board of Directors determine, based on a comprehensive risk analysis of current siting, transportation to an alternative location, and other factors discussed in this guidance, that the storage of SNF at a current, closed reactor site represents a "clear and present danger" and a suitable in-state location is not identified, the chapter will need to seek approval from the Board of Directors (in consultation with impacted chapters and the Nuclear Free Team) before supporting any plan to move the waste to a nearest, less risky, out-of-state storage site.

Under no circumstances should a chapter advocate for moving the waste to another state absent the explicit permission from the Board of Directors. Furthermore, Sierra Club support for the transfer of waste out of state is conditioned on there being a host community, state and chapter agreeing to the storage through an informed consent process that satisfies Sierra Club informed-consent guidelines and is predicated on transfer to a permanent repository as soon as available. Chapters should not advocate for moving waste from operating reactors. **Under no circumstances may a chapter advocate for moving waste to a centralized CIS facility.** [See Section 3, Guidance on centralized or consolidated storage.]

2.3f Minimum Safety Requirements for Dry Storage of Highly Radioactive Waste

Multiple groups and experts have collaborated with Nuclear Information and Resource Service (NIRS) to put together a follow-up to the HOSS Principles titled "Minimum Safety Requirements for Dry Storage of Highly Radioactive Waste". The most recently circulated draft of this two-page document is Appendix IV of this guidance document.

2.3g Guidance

- 1. External or remote sensing, preferably continuous and real-time rather than periodic, should be required for all casks at current ISFSI sites to track containment integrity over multi-year or multi-decade use.**
- 2. The integration of sensors into current and future cask designs is imperative.**
- 3. A helium monitoring system should be an essential part of every ISFSI design. It must be robust, it must be applied to all casks, it must provide periodic readouts, and the data must be publicly available.**

4. A temperature-monitoring program is essential to implement for every ISFSI. Additionally, further studies should be performed to address potential hot-spots which could exist by mixing HBF (high burnup fuel) with LBF (low burnup fuel) in casks.
5. There should be continuous radiation monitoring of all ventilation exit holes in casks.

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2.4 Natural and Human-caused Disaster Resistance of Cooling Pools, Casks/Canisters, and Site Itself

Prediction of natural disasters is an inherently science-based activity. A good introduction to the broad scope of natural disasters and prediction is found in a [Tulane U. report](#). Natural disasters pose a threat to dry-storage nuclear waste sites, just as to any other infrastructure. The difference, however, is in the inherent hyper-toxicity of the contents of SNF dry-storage canisters. Among the natural disaster threats are earthquakes, tsunamis, floods, high winds, mud slides, and hurricanes. Although none of these disasters is likely to breach the canisters and expose the spent fuel rods, they may internally damage the systems such that dangerous repackaging is required in order to ensure the continued containment of the radioactive contents. Each of these possible disaster types is examined below.

2.4a Earthquakes

Seismic activity is a major risk in many parts of the country. Moreover, the recent (since 2009) increase in seismicity in the central and eastern US can largely be attributed to oil and gas fracking and the disposal of brines pumped from oil and gas wells into deep disposal wells ([US Geological Survey webpage](#)). This increase over the natural background seismicity is called “induced seismicity”. The US Geological Survey (USGS) has recognized the importance of this earthquake threat and has begun to publish [induced seismicity maps](#) that are updated annually. There is also [evidence](#) that large surface bodies of water, particularly reservoirs, induce earthquakes. Due to the rapidly increasing nature of induced seismicity, the annual update cycle for maps of induced earthquake risk is important to nuclear waste storage and disposal. Many Independent Spent Fuel Storage Installations (ISFSI) sites exist in the central and eastern US where induced seismicity has become a recognized hazard. These ISFSI sites were installed under prior circumstances wherein only natural seismicity was a hazard. Review of current ISFSI sites in light of the latest available induced seismicity maps should be mandatory and the siting of any further ISFSI must be done in the light of the latest available USGS maps.

Earthquake hazard is specifically incorporated in 10 CFR 72.103 (“Geological and seismological characteristics for applications for dry cask modes of storage on or after October 16, 2003”). This section of the code states ground motion maxima for the basis of design of on-site storage. Note that 10 CFR 72.103 (a) and (b) separates the US into western and eastern regions and that criteria for seismic safety are treated somewhat differently. Section 72.103, however, does not explicitly take into account the large increase in seismic hazard due to induced seismicity across the central and eastern US since about the year 2009.

Researchers have recently obtained important laboratory data on the [effects of earthquake shaking on dry casks](#). But the laboratory models were only 40% of the size of actual casks, due to weight limitations in the testing facilities. The reported studies recommend several means to mitigate the effects of earthquake shaking on dry casks: decreasing the height-radius ratio of dry casks, strongly anchoring the dry casks, and connecting dry casks in groups at the top. Such means are not being undertaken routinely at ISFSI sites.

Other earthquake shaking threats to the fuel-rod assemblies, the rods’ attachment to the canisters, and to the fuel rods themselves are of concern. Severe earthquake shaking in one or more earthquake events would likely cause weakening of attachments and could cause degraded fuel-rod cladding to disintegrate.

2.4b Tsunamis

Although significant damage was caused at the Fukushima nuclear power plant in Japan by the magnitude 9.0 earthquake, the subsequent tsunami increased the damage and added to the radiation release at the plant. That release was associated with the reactor vessels and cooling pools, not with dry-storage canisters. It is important to note that Fukushima employed thick-walled, ductile steel storage casks with bolted, removable lids, used in European countries, not the thin-walled canisters in common use at US dry-storage sites. A complete analysis of the Fukushima accident is given in two publications of the National Academy of Sciences regarding Lessons Learned (NAS, [Phase 1](#) and [Phase 2](#)).

In this case, the [tsunami height of up to 15](#) meters significantly exceeded the height predicted for tsunamis at the Fukushima Daiichi nuclear plant; however, there was controversy on the predicted

values and some evidence of similarly high tsunamis in the past. Dry storage casks were not damaged at all. These casks were the more robust thick-walled casks of 9-10 inches of steel. The casks are steel, equipped with inner and outer bolted closures that can be removed for inspection, and bolted to the foundation of the cask storage building. (see [Figure 2.1](#)). Nine casks containing a total of 408 fuel assemblies were in storage on March 11, 2011. [See Appendix 2A.3 of the NAS Phase 2 report.]

[Japan's electric company \(TEPCO\) provides](#) a detailed drawing of the casks used for dry storage (slide 14), but it should be noted that casks were also stored in an on- site building (slide 12). In the US casks are not stored in a building.

The most immediate danger at Fukushima was ensuring that the spent fuel pools had sufficient water to prevent a fire and a large release of radioactivity. The difficulty was that workers had no way to know the status of the pools as there was inadequate monitoring equipment and the radiation was too high to enable worker access.

This is only one particular case from around the globe where the actual disaster exceeded the predicted event (e. g. floods, hurricanes, wildfires, etc.). “Hazard” is the probability of a certain natural event of a given size happening. “Risk” is the estimation of human or infrastructure loss associated with a given hazard size times the likelihood of that hazard in a given location. Risk and hazard are intertwined: by setting a risk level, one defines the hazard size; conversely, setting the hazard size defines the risk in a given location.

Related to tsunamis are seiches, which are tidal waves on inland bodies of water. Any nuclear power plant on a sizable lake shore (e.g., Great Lakes) could be vulnerable to a seiche generated by high winds, sudden changes in atmospheric pressure, earthquakes, or large earth movement such as a rockslide. [Seiche heights of 3-10 meters are feasible in Lake Tahoe](#) in response to an earthquake of magnitude 7. Seiches have been observed on the great lakes in excess of 5 meters. Modeling of specific locations would reveal whether a seiche should be considered as a hazard for that location.

2.4c Floods, Including Dam Failures

Floods have already inundated several nuclear power plants (e. g., Fort Calhoun in Nebraska). Flood levels due to abnormal precipitation amounts can be fairly well predicted due to modern basin drainage modeling. However, in an era of climate change and extreme weather, flooding may exceed historic levels. Water from floods builds up over hours or days and risk modeling can be updated on an as-needed schedule. Much infrastructure development is keyed to the flood predictions of FEMA which maintains a [portal to flood hazard maps](#). Cooling of fuel assemblies is entirely via natural ventilation of dry storage casks. Standing water around dry storage casks can halt the flow of natural ventilation and result in elevated temperatures of the SNF assemblies with the resulting risks for release of radiation.

However, there are numerous reasons to be suspicious of flood maps, just as there are for earthquake maps. Mainly, we do not have centuries of data in the US to properly establish accurately the rate of recurrence of any flood levels. Accurate stream gauges have been around for only a century in the US, and many major rivers have been only accurately monitored for even less time. Another reason to distrust predicted flood maps is the increasing likelihood of major storm events due to global warming and climate change. This is a subject of recent research, such as in the [US National Climate Assessment](#); climate scientists predict longer and more intense storm patterns over the continental US. But merging these recent predictions into current flood models is difficult, with the only sure prediction

being that there should be an anticipated increase in predicted flood levels for most parts of the US over coming years.

Whereas floods due to abnormal precipitation are somewhat predictable and mitigation procedures can be implemented with a fair amount of warning, floods due to sudden and unexpected dam breaches may not provide enough warning time to implement mitigation at the ISFSI site. For example, Duke Energy had issued a warning about an unstable dam above the nuclear power plant at Oconee, South Carolina. It is important to consult the [FEMA inventory of dams](#) in the US when considering nuclear plant and storage sites. The aforementioned website has interactive map features that allow one to see what dams are near to a given ISFSI site and to ascertain the characteristics of those dams.

2.4d Flooding Due to Sea-Level Rise

For those nuclear power plants near the ocean, the looming threat of sea-level rise over the time frame of likely dry storage of SNF needs to be examined on a case-by-case basis. [Recent global modeling of sea-level rise](#) shows an extreme prediction of one to two meters by the year 2100. At any particular site, one needs to determine how far above the current sea level the ISFSI is located and how far above it would be in the extreme prediction case in perhaps 20-, 50-, and 100-year time spans from current. Jenkins, Alvarez, and Jordaan [in a 2020 article](#) identify five sites that will be particularly vulnerable to sea rise including three sites, Crystal River, Florida, Turkey Point Florida, and Humboldt Bay, California that are listed as extremely vulnerable to sea level rise. Note, however, that their inferences are based on the most extreme sea-level rise in the National Oceanic and Atmospheric Administration (NOAA) study underlying their research. Because models of sea-level rise do not predict uniform rises around the land-sea interface of the globe, these numbers need to be adjusted for the actual site. NOAA offers a detailed [sea-level-rise prediction viewer](#). It is likely that sea level will continue to gradually rise so that necessary relocation of the ISFSI site to higher ground, or onsite mitigations, could be taken with time to spare, provided that such actions could be done safely. Additionally, sea-level rise exacerbates the risks of other dangerous events such as earthquakes and tsunamis.

2.4e High Winds

High winds due to abnormal shear wind patterns or due to tornados are a threat throughout the US but particularly likely and dangerous in central and southern US states. High winds may occur with very little warning and in unexpected areas. The possible effect on ISFSI sites are considered to be negligible because dry casks are extremely heavy and resistant to wind damage. However, the presence of high winds in conjunction with a rare occurrence of leakage from a dry cask presents a dangerous situation. On one hand the high winds would disperse radioactive gases and reduce risk at any particular point, but on the other hand that lesser risk is spread over a larger area potentially affecting considerably more people.

2.4f Rockslides and Mudslides, and Other Erosional Events

Extreme erosion via rockslides, avalanches, and mudslides has been shown to be a significant [natural hazard around the world](#). Mudslides often occur in conjunction with abnormal precipitation and rockslides often occur with earthquakes; both are seldom predicted. This may be particularly problematic at Palisades and other locations on the Great Lakes where unstable sand dunes present a problem. Moreover, the record high water in the Great Lakes may make shoreline erosion even more

likely. Such events could potentially damage casks from interaction with rock and strong forces associated with a slide-- resulting in some loss of containment. Such events can sometimes stretch out over many miles in a watershed, so even sites far removed from the source area may be vulnerable. Geological evidence of past rockslides and/or mudslides can be assembled with modest effort though they may not fully predict future events.

2.4g Hurricanes

Although hurricane force winds are unlikely to damage properly installed dry casks, those sites near the ocean are subject to storm surges of water caused by the hurricane winds. Hurricanes can also hurl substantial debris and cause damage to casks. These events share many of the threatening attributes of inland floods and/or tsunamis in that casks may be inundated for significant periods of time. General predictions of storm surge heights at oceanside ISFSIs are difficult, but the National Hurricane Center [has attempted to do those predictions](#). While prior storm surge data are useful, we have witnessed several record hurricane storm surges in the past two decades and other large events induced by climate change are likely in the future. Such storm surges are also possible on large water bodies; for instance, the Great Lakes.

2.4h Non-natural disasters

Finally, non-natural, or human-caused, disasters can present significant threats to ISFSIs. Examples of such disasters are wildfires caused by humans or air-traffic crashes. Hazardous facilities and operations can often be found adjacent or nearby nuclear reactors or dry-storage facilities for SNF. A recent example is New York State's intervention with the Federal Energy Regulatory Commission (FERC) to ensure that a new large-diameter gas pipeline across the Indian Point nuclear power plant is regularly tested to confirm that valves can be quickly closed remotely in an emergency. New York State also asked FERC not to allow nearby gas pipelines to increase operating pipeline pressures in the future.

2.4i Guidance

- 1. Current ISFSI sites should have mandatory reviews that consider the latest available earthquake and induced seismicity maps. Also, the siting of any future ISFSI site must be done in the light of the latest available USGS seismicity maps.**
- 2. For earthquake resistance, it is important to decrease the height-radius ratio of dry casks, strongly anchor the dry casks, and possibly connect dry casks in groups at the top.**
- 3. In dealing with risk to nuclear power facilities and ISFSI sites, citizens should carefully question the predictions of the severity of natural hazards that could affect them and the projected levels of risk.**
- 4. Every new license or license renewal for an ISFSI should take into account the latest flood predictions for the particular site, carefully describing the protection methods to be used. Introduction of safety factors to address the predictions for ongoing global-warming effects is obligatory.**

5. Dams upstream of ISFSI sites should be examined with respect to their age, type, and vulnerability to earthquakes or other credible natural disasters.
6. For current ISFSI sites near the ocean or high tides, sea-level rise should be monitored, and movement of dry casks or hardening of the site should be considered well before actual need.
7. The predictions of sea-level rise bear sufficient credibility that, for those nuclear plants without a current onsite ISFSI location but with a future need for one, a location at higher elevation at a short distance should be sought where safety conditions are better than the former location.
8. Because hurricane strength, numbers, and tracks are some of the variables to be affected by global warming, any licensed ISFSI near the ocean should be reexamined in regard to its storm-surge resiliency. License renewals for such ISFSIs need to take into account the latest available storm-surge maps.

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Section 3 - Consolidated Interim Storage

3.1 What is consolidated interim storage (CIS) of nuclear waste?

Consolidated interim storage (CIS) is another problematic attempt by the nation's nuclear agencies to develop a solution for the massive amount of spent nuclear fuel (SNF), approximately 80,000 metric tons, currently stored at nuclear reactors across the nation in temporary storage, following use in a nuclear reactor. While no longer useful for generating power, SNF contains very high immediate radiation hazards and also radionuclides that are hazardous for very long time periods – hundreds of thousands to millions of years.

The current [Sierra Club policy on High Level Radioactive Waste](#) (1984, and as amended in 1987) reflects the Club's position regarding consolidated interim storage (CIS), also referred to as monitored retrievable storage (MRS). Sierra Club also expressed concern that such storage could promote reprocessing, which the SC opposes.

“The Sierra Club believes that, pending the establishment of a permanent repository, interim storage can best be accomplished through the dry storage of spent fuel at the site of generation, except that

when there is a clear and present danger, spent fuel should be transferred to a more stable reactor site for storage. For the long term, a geologic repository, selected according to rigorous criteria, presently appears to represent the safest method of isolation of high-level radioactive waste.”

In the same policy statement, it is indicated that:

“The Sierra Club finds the monitored retrievable storage facility (MRS) for high-level radioactive waste (HLRW), as proposed by the Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM), is unnecessary, adds increased transportation and handling risks to the overall HLRW management system, diverts energies of OCRWM's personnel from their main mission of developing a permanent HLRW repository, wastes money of the Nuclear Waste Fund, may become the de facto final, above-ground repository and possibly, the preferred site for reprocessing the nation's HLRW.”

Federal nuclear agencies and Congress are currently engaged in discussion and planning for SNF storage at Consolidated Interim Storage (CIS) facilities in [New Mexico](#) and [Texas](#). Yet, major obstacles remain as none of these states have agreed to host a centralization of SNF in their states. The federal nuclear agencies are also developing transportation plans to move SNF from the sites of closed nuclear reactors over thousands of miles to these storage or disposal facilities. However, major technical, legal and legislative obstacles remain. In 2015 [testimony to Congress](#), the General Accounting Office (GAO) indicated that the Nuclear Waste Policy Act (NWP) amendments of 1987 directed DOE to terminate work on sites other than Yucca Mountain. Without clear authority, DOE cannot site a CIS or another permanent disposal facility and make related transportation decisions for commercial SNF. Furthermore, the NWP only allows DOE to take ownership of irradiated nuclear fuel at an operating permanent geologic repository and no such site presently exists. DOE discontinued both funding and work at Yucca Mountain in 2010.

According to [GAO](#), reports spanning several decades cite societal and political opposition as key obstacles to siting and building a permanent repository for disposal of SNF. “The National Research Council of the National Academies reiterated this conclusion in a 2001 report, stating that the most significant challenge to siting and commencing operations at a repository is societal. Our analysis of stakeholder and expert comments indicates the societal and political factors opposing a repository are the same for a consolidated interim storage facility. ... This lesson has been borne out in efforts to site, license, build, and commence operations at a consolidated interim storage facility. ” ([GAO 2014](#), p. 31)

3.2 Lack of a more permanent solution for nuclear waste

3.2a More permanent solutions for nuclear waste prove illusory

A key part of the problem is that the federal government was supposed to develop plans for a permanent geological repository for high level nuclear waste, where nuclear waste would be placed in a rock formation selected to be stable for the very long-term future. Salt formations were excluded. Unfortunately, rather than developing detailed scientific and technical criteria for a permanent geological repository first and then searching for a site that would meet those criteria, the federal government made a few site selections first and then Congress narrowed them to Yucca Mountain in Nevada. This decision appears to have been a political one, not one based on scientific criteria. Subsequently the federal government faced the reality of insurmountable scientific and technical

obstacles, one of which meant the repository and the waste would be impacted by water infiltration over the lifetime of operation. The costs of isolating this dangerous waste for a minimum of a million years also escalated dramatically. Facing what appeared to be insurmountable technical hurdles, and skyrocketing costs, the DOE abandoned the Yucca Mountain Project and no longer sought funding for it. While some officials continue to pursue this project even today, there has been no official agency work on it for more than a decade.

Even more problematic, after cancelling the Yucca project, our federal government has not launched a scientific and technical effort to identify the necessary elements for a permanent repository and all the key safeguards. Instead the federal government is now jointly participating in research being conducted by other countries, using Underground Research Laboratories for the studies.

3.2b Extensive research at underground research laboratories in other countries identify new problems

Multiple European countries are engaged in extensive, ongoing research related to permanent geological storage of nuclear waste. To date they are identifying new problems that are challenging and finding no easy solutions. However, these mostly European countries are engaging in serious research and pursuing responsible solutions for long term storage. The US Nuclear Waste Technical Review Board regularly reviews these new developments inviting presentations from these countries at regularly scheduled meetings. See recent [NWTRB Report](#).

3.2c Responsibility and costs are dramatically increasing for the management of nuclear waste and are largely borne by the federal government

Since the federal government has the responsibility for long-term management of SNF from nuclear reactors, and given the unexpected delays in developing a repository, private companies sought relief from the ongoing costs of storage of nuclear waste at reactor sites. As a consequence, the lack of a repository means DOE is now obligated to reimburse private nuclear reactor companies for these interim storage costs for commercial nuclear waste. Thus, these formerly private costs have been shifted to the federal government.

At the same time the nation's nuclear activities including defense have contributed to a large number of nuclear waste sites that will need years of complex cleanup efforts. Estimated future costs are, as of January 2019, eight times the actual annual budgets dedicated to such cleanup efforts according to the [GAO in 2019](#).

This translates to continuing and increasing population health risks associated with nuclear power, weapons, and waste. Inadequate funding means many sites are not initially adequately evaluated in order to identify severe or immediate risks and install safeguards. Systematic evaluations and funding that prioritizes risks and allocates funding accordingly is urgently needed.

SNF is one of the most hazardous substances known to man, and many of the radionuclides are extremely long-lived representing potential harm to many generations in the future, an intergenerational injustice. Short-term reliance on nuclear power generates waste that must be isolated from humans and the environment essentially forever. SNF must be 100% contained, guaranteed, and supervised by the federal government in perpetuity to ensure it remains isolated from the environment and the public.

In the absence of an acceptable permanent repository, our nuclear agencies are feeling pressure to approve temporary, poorly analyzed, and potentially dangerous solutions for the most hazardous nuclear waste—transporting SNF to CIS facilities.

CIS facilities would pose unique hazards under inadequate safety standards and should not be seen as any solution to the problems of SNF disposal. They also invite the specter of reprocessing of SNF, a dangerous and false solution for the waste.

3.3 Key Problems with CIS

3.3a The lack of a permanent repository creates additional costly problems

If CIS were implemented, SNF would have to be transported twice, once to CIS and a second time to a repository, increasing total costs and doubling the transport risks.

As noted in a petition to NRC opposing the CIS facility proposed by Interim Storage Partners:

“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 on the transportability of the canisters, but more importantly on the compatibility of the canisters with heat loading requirements for disposal.” [See Alvarez, Bob, [Multiple Intervenors Petition to the NRC re: ISP, LLC CIS Facility.](#)]

Alvarez cites Energy Department researchers in 2012, who 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.” In addition, a 2014 industry study found that current dry storage would likely be incompatible with ultimate requirements for transport and disposal in a repository.

Alvarez cites the Government Accountability Office report [Spent Nuclear Fuel Management: Outreach Needed to Help Gain Public Acceptance for Federal Activities That Address Liability](#), [GAO-15.141, October 2014, P. 30.]

Alvarez also cites the 2014 paper by Chris Phillips, Ivan Thomas and Steven McNiven, [Nuclear Industry Study on the Feasibility of Standardized Transportation, Aging and Disposal Canisters for Used Nuclear Fuel](#).

3.3b Dry Storage of SNF poses unique technical problems for the long term that have not been solved

There are no available methods for detecting cracks or other defects in the sealed 5/8-inch-thick stainless-steel canister stored inside the thick concrete cask. Welds can degrade and cause radiation to leak from the canister and environmental conditions such as salty air can contribute to corrosion of the stainless steel. The stainless steel canister provides containment of the radioactivity so it is important to ensure that containment is maintained. Outer casks must be ventilated to prevent heat buildup and subsequent damage to the spent fuel assemblies, so they do not serve as containment, only shielding.

The thick concrete shielding is essential for workers to protect them from high levels of gamma emissions as well as dangerous neutron emissions. As a result, a visual inspection of the stainless steel canister is impossible. Efforts to develop a camera system to be inserted into the narrow space between the cask and the canister, which functions in that hostile environment have been unsuccessful.

Current CIS plans do not include a radiation- shielded facility where the canister could be safely removed from the outer cask to remotely inspect the canister for any defects. Such facilities with radiation shielding are called Hot Cells or Dry Transfer Systems (DTS). Plans also do not include the capability of transferring the fuel assemblies out of a damaged canister into a new one.

Microscopic cracks in the canisters can release radiation so radiation monitoring is essential. Unfortunately, even if cracks are found, there are no current methods available to repair these cracks in stainless steel canisters loaded with SNF. They cannot be re-welded. The only current approach is to transfer the canister into a larger container.

These problems exist at every dry storage site today, while some sites, such as those near saltwater, are more likely to experience more corrosion as the equipment ages.

3.3c Absence of reasonable standards and safeguards for long-term storage of large quantities of SNF at CIS facilities

Massive quantities of SNF at CIS facilities translates to enormous potential for severe radiological accidents and contamination of large areas of the US. CIS facilities are proposing to temporarily store more than the 70,000 metric tons of SNF originally proposed for the Yucca Mountain geological repository. The CIS facility in New Mexico plans to store 147,000 metric tons of SNF in open air facilities visible by air for hundreds of miles. The Texas facility proposes approximately 40,000 metric tons. Each CIS will receive SNF from many nuclear reactors.

NRC never developed specific regulations for CIS facilities. Instead NRC merely adopted the regulations used for dry storage at reactors around the country. Thousands of concrete casks would be placed on a concrete pad on the land surface in the absence of any protection from violent attacks. While hundreds of citizen groups throughout the country have supported HOSS ([hardened on-site dry storage](#)) at ISFSIs since 2006, nuclear regulators have not adopted these sensible recommendations to protect SNF storage from terrorist attacks. Other countries use reinforced concrete buildings as their hardened protection for dry storage casks.

Historically, “Waste Confidence” has been the NRC’s generic determination regarding the technical feasibility and environmental impacts of safely storing SNF beyond the licensed life for operations of a nuclear power plant. On October 25, 2012 the NRC announced that it was planning to develop an EIS and requested comments on the proposed scope of the GEIS in a Federal Register Notice. Following hearings and extensive public comments, the NRC finalized its Waste Confidence Decision in 2014 and issued a [Generic Environmental Impact Statement](#) (GEIS). At the time it changed its terminology from “Waste Confidence” to “Continued Storage of SNF.” Continued Storage applies to the storage of SNF after the end of the licensed life for operations of a nuclear reactor and before final disposal in a permanent repository. NRC’s long-term storage requirements issued at the time were used to claim there were no serious obstacles to long-term storage.

NRC established three timeframes in the proceeding:

- i. Short-term Storage – timeframe is 60 years beyond the licensed life for reactor operations. If a dry cask was loaded with SNF forty years prior to the end of reactor operations, at the end of 60 years of short-term storage the cask would have been in storage for a total of 100 years.
- ii. Long-term Storage- this timeframe is for 100 years beyond the short term storage timeframe. Assumes a repository becomes available by the end of this timeframe.
- iii. Indefinite Storage- No repository becomes available, so SNF must be stored and handled indefinitely.

Long-term storage of 100 years would apply to a new CIS facility and its Independent Spent Fuel Storage Installation (ISFSI.) Short-term storage would apply to reactors and their dry storage facilities or ISFSIs.

3.3d Shielded Dry Transfer Systems

These heavily shielded facilities, including air filters, would enable remote handling of casks and canisters to transfer SNF to new containers while preventing radiation exposure of workers. NRC discussed Dry Transfer Systems (DTSs) in its Waste Confidence proceeding as follows:

- i. Short-term Storage: Repackaging of SNF may be needed if storage continues beyond the short-term storage timeframe at reactors. In the GEIS, the NRC assumes that the dry casks would need to be replaced if storage continues beyond the short-term storage timeframe (100 years). [See [GEIS](#), App. B, p. 16-17.] NRC stated that repackaging requires a DTS.
- ii. Short-term and Long-term Storage: A DTS would be built at each ISFSI location, and be replaced once every 100 years.
- iii. Unfortunately, the DTS modelled and described in the 2014 GEIS is not capable of handling damaged fuel. [See [GEIS](#), p. 2-32.] Fuel can be damaged as a result of the shocks associated with transportation and the embrittlement associated with high burnup fuel. CIS facilities would therefore need a DTS capable of handling damaged fuel.
- iv. A CIS facility would be a long-term interim storage facility, and NRC institutional controls would remain in place. The planned institutional controls including DTSs should apply to the currently proposed CIS facilities.
- v. Operation of “away-from-reactor ISFSIs” would include receiving, transferring, storing, and repackaging of spent fuel. [See [GEIS](#), Section 2.2.1.4]

Neither of the proposed CIS facilities in New Mexico and Texas, which are away-from-reactor ISFSIs, include the building of a DTS as part of their proposal. Instead the plan is to merely return damaged casks to the original sender. NRC has not required that a DTS be incorporated in their CIS applications. A return-to-sender plan would, by necessity, be abandoned in the face of leaking radiation. However, such situations are not evaluated in specific environmental reports for each proposed CIS facility.

An oft-repeated solution to a leaking or damaged cask is to simply put it in a larger container. While this may be possible in some situations, the Holtec UMAX 37 PWR is unique in terms of its very large size, making the current availability of a larger container impossible.

When reviewing proposed CIS facilities, NRC is currently ignoring its own detailed plans for handling damaged shipments and leaking radiation by not requiring repackaging facilities or DTSSs, which the agency planned for in the GEIS for Continued Storage of SNF.

Today there are no commercial DTSSs in existence and none are planned for construction for commercial use, not even at the proposed CIS facilities. Research facilities may utilize small DTSSs, but relatively large units would be needed for handling SNF canisters.

3.3e Inadequate information on High Burnup Fuel resulting in safety limitations on this fuel in the Continued Storage Rule

Shorter licensing periods of 20 years were established for HBF. The GEIS notes: “Although NRC regulations for dry cask storage allow for a licensing period of up to 40 years for both initial and renewed licenses, licensing periods approved for storage casks for high-burnup fuel have been limited to 20 years due to the more limited data available for high-burnup fuel.” [See [GEIS](#), App. B, p.16]

In addition, reassurance of safe storage applies only to low-burnup fuel (LBF). NRC provides reassurance about the continued safe storage of SNF for a period up to 80 years (40 year license and 40 year renewal). However, that assurance is qualified as only applying to LBF. [See [GEIS](#), App. B, p.19] Currently federal agencies are allowing mixed loads of LBF and HBF.

This NRC decision regarding the Waste Confidence/ Continued Storage Rule was supposed to provide public assurance regarding the long-term safe storage of SNF. In the absence of actual implementation of the specific requirements discussed there, assurance for long-term storage of SNF has not been provided.

3.3f Planned research reflects large gaps in the state of our knowledge for long-term storage of SNF

Sandia National Laboratory recently [updated key knowledge gaps](#) and the research needed to address the gaps. We focus here on high priority gaps, which are given priorities 1 through 3 (1 being highest):

- i. A newly identified gap will evaluate the consequences of containment failure caused by stress corrosion cracking (SCC). This work will estimate radioactive releases caused by a through-the-wall crack in a stainless-steel canister. Gap Priority #3
- ii. This gap is related to atmospheric corrosion associated with welds on canisters. There are high stresses associated with welds and heat-treated zones, and these tensile stresses will be evaluated for potential for SCC. Gap Priority #1
- iii. External monitoring for cracks and corrosion of canisters without through-wall penetrations. EPRI, the Electric Power Research Institute, Inc., represents the nuclear industry with the NRC, and is primarily involved in exploring technologies for non-destructive monitoring for canister degradation. This work does not appear to be shared with federal research agencies. Gap Priority #3

- iv. Fuel Transfer Options. This need relates to surface facility storage design, such as CIS, to include the ability to inspect and repackage SNF into new canisters using a DTS. Gap Priority #3, previous priority #4.
- v. Drying Issues. Water was found to remain in canisters after removing assemblies from pools and conducting drying. The HBF Demo Project Cask was found to have 17,000 ppm or 100 ml of water within the helium gas. Remaining water provides a source of hydrogen for hydride embrittlement. Embrittled fuel rods are more likely to be damaged in transport. Gap Priority #2

This research tells us that significant knowledge gaps remain related to the potential for loss of containment at a CIS facility storing large quantities of SNF. Unfortunately, Sandia National Laboratory did not address the continuing need for research regarding high burn-up fuel.

3.3g Transportation of Spent Nuclear Fuel poses significant concerns related to proposed CIS facilities

The Transportation Section of this report reviews these issues in extensive detail.

It should be noted that NEPA, the National Environmental Policy Act, requires that transportation be evaluated at the same time as proposed facilities are reviewed.

Transportation planning would be extraordinarily complex for the movement of hazardous SNF thousands of miles to a CIS facility over many years without serious incident. Yet DOE and NRC are not developing transportation plans as part and parcel of the necessary approvals and environmental reviews for CIS facilities. The federal government currently plans to handle transportation separately from the CIS facilities, and it appears to be in the absence of significant public involvement. This is a violation of NEPA.

In addition, in its 2019 report [*Preparing for Nuclear Waste Transportation*](#) the US Nuclear Waste Technical Review Board identified 30 technical issues to be addressed over an estimated ten years before a national SNF transportation program is launched. The Board also identified a lack of information about potential damage to SNF during transport from vibrations and shocks. It noted “No comprehensive examinations of commercial SNF have been conducted following transportation to determine if the SNF was damaged in transit.”

3.3h Extensive restriction of essential information inappropriately excludes public participation in what should be consent-based decisions

Essential information is being denied to the public. It should include:

- i. Security and Terrorism – The evaluation of risks and precautions has not been provided to the public. It is worth noting that the National Academy of Sciences expressed concern about the absence of any information related to terrorism and national security when the Committee was asked to [*review the safety of transportation for SNF in 2006*](#). This significant knowledge gap remains unaddressed despite terrorist attacks on New York City and Washington, DC, 9-11-2001.

Public officials should receive more extensive information. However, the public should receive, at minimum, summaries of the risks evaluated and safety measures required to address the risks.

ii. Other essential information, including:

- Basic information pertaining to the principals involved in the CIS proposals and how various responsibilities will be allocated has been deemed proprietary by NRC, effectively denying information that should be readily available.
- Principals involved in the CIS proposals have indicated an interest in reprocessing for the future, a major dangerous addition to their proposals, but have provided no details at this time.
- Detailed transportation plans must include inspection and reporting on route conditions, as well as details about the preparation of the SNF package to reduce risk.

CIS facilities would be the first of their kind long-term temporary storage facilities for commercial SNF, planned to handle enormous quantities of this high-level radioactive waste in the absence of new comprehensive regulations or even the requirements NRC adopted in their Waste Confidence decision. Such a situation is ripe for major future problems.

3.3i Risks of delaying the long-term solution

The consolidation of massive and ever-expanding quantities of SNF on an interim or temporary basis allows the federal government and elected officials to assume that, in the long term, a repository will eventually be constructed. Unfortunately, such an assumption is potentially dangerous when there is no commitment to funding and a guarantee for permanent disposition. The safety and health risks will last for extremely long time periods, and certainty is needed about the long-term management of SNF.

Consolidation of SNF in one or two locations on the Earth's surface presents different terrorism risks than keeping it at multiple sites. These large facilities are ideal terrorist targets. If security risks and the potential for terrorism have been studied, the results have not been made available to the public. The individual storage containers are not protected by a building or other structure or by protective barriers such as concrete bunkers or berms. Such barriers would serve to isolate smaller amounts of hazardous inventory from the entire SNF inventory at each site. For years environmental groups including the Sierra Club have recommended the additional protection of Hardened On-site Storage (HOSS) for SNF. Neither of the recent CIS proposals have adopted HOSS principles to provide this additional security.

Also, consolidation in a few places removes the imperative for all states and the nation to take collective responsibility for developing a long-term repository and sharing the burdens of maintenance and monitoring for millions of years. Unfortunately, the reality is: "out of sight is out of mind."

3.3j Consolidation of SNF could encourage reprocessing

Reprocessing is a failed endeavor worldwide. Any rationale for engaging in reprocessing falls apart upon examination. Multiple experts have detailed the enormous problems associated with reprocessing. [See e.g., reports by von Hippel, Makhijani and Alvarez.] We list some of the major issues and problems here:

- A key driver for reprocessing, uranium fuel shortages, no longer exists.
- The development and use of MOX fuel is an essential step in reprocessing. The government invested in this process at the Savannah River plant; but it was finally cancelled in 2019, due to exorbitant and rising costs in the tens of billions of dollars.
- Since plutonium is no longer used as nuclear fuel, excess plutonium is currently being stockpiled as waste. The existing stockpile is enough to make tens of thousands of nuclear weapons.
- Global surveillance to police the associated threat of weapons development and use requires extraordinary levels of effort on the part of the US.
- Reprocessing is many times more costly than long-term storage and disposal.
- Significant public health, safety and environmental risks are involved.
- Reprocessing requires other costly facilities -- breeder or burner reactors -- that are sodium-cooled. Worldwide, breeder reactors have proved dangerous, experimental, expensive and not effective at reducing the volume of high-level waste. At present only Russia has operational breeder reactors.
- The private sector has indicated they will not pay for all that is required. The cost must be paid by the federal government.
- The government's failed effort to promote commercial reprocessing at West Valley, NY has left high-level radioactive waste, including the majority of *Greater than Class C* waste in the nation, to endanger the Great Lakes with contamination by long-lived radionuclides.

3.3k Essential information should be transparent

Unfortunately, there is little transparency regarding the relationships and responsibilities of the owners/operators of the CIS facilities and other controlling or involved entities. This is true of both proposed CIS facilities in New Mexico and Texas.

Holtec Intl. is a principal in New Mexico and is connected with the Eddy-Lea Alliance, a quasi-local government entity. In Texas, Waste Control Specialists (WCS) is the property owner, planning to lease property to an entity known as Interim Storage Partners, LLC (ISP). The relationships and all responsibilities should be detailed explicitly so that the public and all local and state government officials have a clear understanding of future operations. Local and state governments cannot be expected to pick up extraordinary and unexpected costs.

Fundamental details regarding these relationships and which entities are responsible for what are largely unknown, and the public is left in the dark. The legal agreements associated with the principals involved should be made known, so the public clearly understands how various responsibilities are being handled including financial responsibility for damages or health impacts. NRC has instead allowed much of this information to be deemed proprietary, and therefore the arrangements have not been disclosed to the public. In the case of the Texas CIS facility, WCS owns the property but plans on leasing it to ISP to build and operate a CIS facility. However, the application indicates that ISP may only opt for a 20-year lease, while the facility is needed for as long as 100 years, until a repository is

developed. What will happen when the 20-year lease ends? In the case of New Mexico, Holtec appears to rely on local government expertise to handle emergency responses (based on its responses to NRC) when local governments are ill-equipped financially and technically to do so, thus jeopardizing public safety. In the past almost all privately owned nuclear waste sites have been abandoned by their owners, defaulting to public ownership, with costs of long-term cleanup and management falling on local and state taxpayers as well as the federal government.

Complex management relationships, which have not been clearly delineated in legal and financial agreements and subject to the review of the public and their elected officials, are a recipe for extraordinary future problems with potential for disastrous consequences. How will serious emergencies be handled? Will adequate equipment and funds be available when needed? Who is responsible for what adverse outcomes and their resolution? Will funds be held in escrow for emergencies? Such decisions should be ironed out in advance of adverse consequences, so confusion does not reign in the middle of an emergency. Will the federal government guarantee adequate funding to address extraordinary and disastrous consequences involving extensive radiological contamination?

3.31 Sierra Club is not advocating CIS as an interim storage solution for SNF

CIS is not a sound approach given the nature of the hazard. There are significant issues for each of the proposed CIS facilities. Just three issues are raised here -- two related to Holtec, Intl, the company involved in the New Mexico proposal, and one related to Interim Storage Partners, LLC, the company involved with WCS in Texas.

Holtec, Intl. is a principal contractor associated with the San Onofre nuclear reactor in California. It signed a full-service contract for all of the nuclear waste management at San Onofre.

Problem #1. Holtec manufactured and delivered casks to San Onofre that contained loose parts. It made a last-minute design change of substituting different parts with shims. This was an unapproved change. Upon delivery loose shims were found in the bottom, but loading proceeded. These casks are supposed to be inspected at the factory after completion to assure no loose parts are present. The required inspections were never done. During shipping loose parts could cause damage to fuel assemblies from shocks and vibrations.

Problem #2 Holtec failed to provide correct training and materials to its workers and failed to develop an adequate procedure for the loading of the canisters into its UMAX system. Workers were trained on a different model that had a 1-inch total clearance for the entire circumference of the canister. Holtec neglected to inform workers about the installation of a new piece of equipment that resulted in a clearance of just ¼ inch. The most serious problem was a potential load-drop incident, which was never supposed to occur if proper procedures were followed. Workers could not visualize what they were doing. As a result, they were exposed to excessive radiation. Significant damage occurred to 29 canisters from scratching and gouging during insertion of the canister. As a result, it is likely that these canisters will suffer from more rapid corrosion as they age. In addition to the millions of dollars spent on these now damaged canisters, the same system, the Holtec UMAX system, will be used at the planned CIS facility in New Mexico if it is ever constructed. NRC issued multiple severe violations to the utility, Southern California Edison. However, NRC did not require a fix to this Holtec engineering design problem, and thus it is more likely that the same problem will occur at the New Mexico CIS

facility, if approved. Increased inspections and repackaging will likely be necessary, but a DTS is not planned to be constructed. [See [2018 NRC Special Inspection Report](#).]

Problem #3 Interim Storage Partners, LLC (ISP) is proposing to lease property from Waste Control Specialists (WCS) which operates a nuclear waste disposal facility in Texas. ISP is a majority-owned foreign company. Foreign ownership is restricted in the US for nuclear reactors. ISP is owned by Orano USA LLC, which is ultimately majority owned and controlled by FAE AEC, an entity of the French government. However, the Atomic Safety Licensing Board ruled that an independent SNF storage facility under 10 CFR Part 72 is neither a production nor a utilization facility, thus not subject to the provision restricting foreign ownership under the Atomic Energy Act, sections 103 and 104. It should be noted that should Orano apply to engage in reprocessing, it likely would be considered a production facility. [See [Atomic Safety Licensing Board. Contention 7](#): p. 78-79, Aug 23, 2019.]

Clearly ISP is not proposing ownership, but a short-term lease arrangement, as short as just 20 years with WCS. However, a short-term lease is inadequate: ownership and financial responsibility should be clearly defined for the full duration of consolidated storage, pending transfer to a permanent repository. The public should have legal and financial assurance that the hazards and risks will not be abandoned and ultimately left to be borne by the public.

3.4 Guidance

1. An independent scientific effort should be launched to identify all the hazards and risks, as well as the necessary safeguards, for CIS of spent nuclear fuel, including transportation.

Adequate funds must be allocated to assure that facts and science are at the core of the research effort. Total costs of operating consolidated interim storage and a permanent repository should be compared to total costs of operating only a permanent repository.

2. States should be provided with full disclosure of information pertaining to CIS proposals and receive funding sufficient to enable them to challenge the adequacy of safeguards at these facilities.

3. All Chapter Leaders and activists should speak against any attempts to transport SNF to any centralized or consolidated interim storage facilities, except as addressed in the next recommendation.

4. All Chapter Leaders and activists should advocate that SNF be stored at the site of origin in the safest manner possible, consistent with SC policy on dry storage of SNF and hardened on-site storage (HOSS). A Chapter concerned about the safety of SNF at a reactor site should engage with the Nuclear Free Team, in an effort to determine if the dry-storage system being used at the reactor site is sufficiently protective from natural and manmade threats. If the Chapter determines that the site represents a “clear and present danger,” the Chapter may advocate to the Sierra Club Board of Directors about moving the casks to a less risky location within the state (consistent with the principles of informed consent detailed in this guidance), until a permanent disposition facility is available.

If the Chapter and the Board of Directors determine, based on a comprehensive risk analysis of current siting, transportation to an alternative location, and other factors discussed in this guidance, that the storage of SNF at a current, closed reactor site represents a “clear and present danger” and a suitable

in-state location is not identified, the Chapter will need to seek approval from the Board of Directors (in consultation with impacted Chapters and the Nuclear Free Team) before supporting any plan to move the waste to a nearest, less risky, out-of-state storage site.

5. Reprocessing should be permanently barred by law for the nation. There is no reasonable rationale for pursuing it.

6. The potential for natural disasters should be a consideration for all storage of SNF and appropriate plans developed. See Section 2.4 of this report on natural disasters.

7. Given that CIS proposals are rather new and that such facilities may have long-term status, every effort should be made to ensure that they meet or exceed safety standards that were required of a permanent repository in regard to natural and human-caused disasters.

Other Recommendations:

See extensive recommendations regarding transportation at the end of Section 4.

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4.1 Introduction and Summary

One of the most significant issues regarding nuclear waste is the danger associated with transportation of high-level nuclear waste. This section focuses specifically on the transportation of spent nuclear fuel (SNF) from commercial nuclear reactors. This section includes an especially lengthy guidance section, in light of the federal agencies' failure to address SNF transportation comprehensively.

Major questions related to the federal government's legal authority for consolidated interim storage (CIS) remain unresolved in 2020. Yet, simultaneously, transportation planning has begun for nationwide movement of the one of the most hazardous materials known on Earth, SNF, which is far more radioactive after leaving a nuclear reactor and contains radionuclides dangerous for thousands to millions of years. Unfortunately, federal regulatory agencies have not involved the public in these important discussions about transportation planning.

Planning for the long-distance transportation of SNF will take a decade or more, even if adequate funds are made available for such a significant long-term project. Federal appropriations for nuclear waste are typically handled through annual budget appropriations, making long-term planning difficult. Unfortunately, nuclear waste appropriations are not currently meeting existing cleanup needs for most sites around the nation. The General Accounting office ([GAO report 19-28 \(2019\)](#)) reports the fact that growing environmental liabilities by the Department of Energy (DOE) for nuclear waste are currently 8 times spending on actual nuclear waste cleanups as of the end of FY 2018, \$377 billion needed compared to \$46.8 billion appropriated. In addition, DOE has failed to identify national priorities and to develop a program-wide strategy that could reduce costs of nuclear waste cleanup. Under the National Defense Authorization Act for FY 2011, DOE is supposed to report annually to Congress regarding costs and funding needs for future cleanup activities. There were only two reports to Congress -- in 2011 and 2017. The latest report was incomplete in that it did not include planned activities and funding needs or existing compliance agreements with states. As a result, Congress does not have adequate information to address the full costs of long-term nuclear waste cleanup.

Unfortunately, DOE has not yet focused on the development of detailed transportation plans for SNF. In 2018 funding for DOE transportation planning was cut, and a core planning meeting had to be cancelled. So, while the Nuclear Regulatory Commission (NRC) is currently reviewing applications for two CIS facilities, one in New Mexico and the other in Texas, there is enormous uncertainty regarding future transportation plans and their adequacy. DOE and NRC have separated transportation planning from CIS facility planning.

Despite the current nuclear waste funding deficit, a major national program to transport SNF would have to be launched with sufficient funding to address the substantial, long-neglected infrastructure needs. In subsections below existing problems and needs associated with transporting SNF are explored. It is clear that developing and implementing a national transportation plan that thoroughly handles the plethora of transportation issues and needs with adequate and redundant safeguards will potentially cost billions of dollars.

Natural and human-caused hazards present additional risks for nuclear waste shipments. A review of various primary sources on nuclear transport reveals that there has been little to no consideration of nuclear shipments interacting with natural or human-caused hazards and conventional transportation accidents.

In general, the nation has completely failed to develop a broadly acceptable plan for the long-term management of highly irradiated SNF. Because the US has not developed an approved permanent repository, it is now taking steps to develop CIS facilities where large quantities of SNF, 40,000 to over 100,000 metric tons, would be stored. In the absence of a permanent repository, it is not known how long CIS storage facilities might be required to be in operation, although they would initially be licensed for up to 100 years. The SNF would be kept above ground or just below the ground surface at a CIS facility. Meanwhile at reactor sites, Independent Spent Fuel Storage Installations (ISFSI) for SNF are [licensed for 40 years](#) by the NRC with renewals possible. The licensing requires that SNF be monitored and protected against accidents; but the efficacy of the monitoring and safety protections have serious deficiencies. In the absence of definitive plans for a permanent repository, there are concerns that CIS facilities would become permanent (see Sec. 3 on CIS above). Two types of storage, interim and permanent, will require two major transportation

programs as well as possible repackaging of SNF into new canisters. If a permanent repository is approved in the future, a second transportation process would be necessary.

4.2 Existing Transportation Infrastructure and Deficiencies

Infrastructure refers to built, fixed structures and moving components of the transportation system. For rail, this includes stations, rail yards, repair and maintenance facilities, bridges, tunnels, thousands of miles of track, switches, crossings where tracks intersect or where roads and tracks cross, and communication systems that enable rail transportation. The moving components include engines and various kinds of rail cars for handling a variety of solid, liquid and gaseous material, including hazardous materials. For the transport of SNF, the intent is to primarily rely on rail freight. This could require hauling SNF by truck or barge from a nuclear reactor site to a railhead or depot. Additional transfer equipment to handle and move heavy transport casks on and off trucks or barges would be needed.

Beyond physical infrastructure, there is an extraordinary amount of transportation planning and personnel training associated with the massive movement of SNF. This planning and training category is equally essential to prevent and respond to dangerous nuclear accidents.

Federal agencies have not ruled out long distance use of trucks or barges for significant portions of the SNF transport journey. At this time federal agencies have deliberately separated planning for transportation to CIS facilities from normal licensing and environmental review processes. This is a violation of the National Environmental Policy Act (NEPA), under which comprehensive analysis of projects is required.

This report primarily covers rail as the mode for the long-distance portion of the SNF transportation. Trucking of SNF poses additional risks on roadways due to very heavy weights, slower speeds and potential interaction with other vehicles. In addition, trucks must make regular stops for refueling and to address driver needs. Trucks have been found to veer onto local roadways rather than remaining on designated roadways, posing other risks for school buses, other local traffic and residents.

Barges pose additional risks, due to the potential loss of the SNF payload into the water body. Water facilitates fission to speed up and reach criticality. Use of barges would have to be restricted to very short distances, excellent docking and transfer locations, and avoidance of poor weather conditions.

4.2a Existing Fixed Infrastructure

Any transportation of SNF must rely primarily on the existing transportation infrastructure. The nation's infrastructure has received terrible grades from the American Society of Civil Engineers in their annual reports for more than a decade. (See [report card](#)) The grade was D+ for 2017. Yet Congress and the President have failed to pass a major infrastructure bill. Presentations by DOE and NRC for moving SNF have discussed potential transport routes, without raising any review or analysis of the adequacy of existing infrastructure. Because the preference is likely rail transport for SNF as the primary method, we recommend that for each proposed route a thorough infrastructure inspection should be conducted. It is likely major structural replacements or repairs are needed, so it could take years for the work to be completed. Structurally deficient bridges would be an example of a lengthy repair or replacement. Storage of a variety of materials is also a common fixed feature

of transportation hubs. As a result, inspections should identify all storage facilities that pose potential hazards to shipments and the general condition of storage near rail lines.

An assessment of infrastructure needs for the state of New York alone reveals that huge infrastructure investments are needed. We see these estimates in the [NYS 2008 Assessment of Rail Needs by DOT](#) – 20-year New York State needs from 2009-2028 for Class I -- Major Freight Railroads only. (This document is no longer available on the NY DOT website. See instead p. 165 of [NY 2009 Rail Plan](#).)

Maintain status quo –	\$590 million
Achieve Good Repair –	\$730 million
System Enhancement –	\$917 million
Expansion –	\$414 million
NYS Class I Total –	\$2.65 billion

In 2016 NY DOT released the Capital Plan for Transportation, which prioritized highways and bridges for funding through 2020, allocating approximately \$13.5 billion. Additional funds will flow to these priorities via the Federal Emergency Management Agency (FEMA) for critical flood-prone structures, although total expected FEMA funding was not identified. The NY Capital Plan for Passenger and Rail Freight combined through 2020 was just \$130 million, while \$590 million was needed for Class I freight railroads just to maintain the status quo. This limited funding could partially explain the removal of the important 20-year Rail Needs Assessment from easy public access.

The New York State analysis documented a dramatic drop in federal funding for rail from 1980 to 2003. Overall federal transportation expenditures increased threefold, primarily for highways, while aviation funds quadrupled. In contrast federal rail expenditures have declined in real dollar numbers by almost half and have decreased from 10% to only 2% of federal transportation expenditures in 2003. While the information in the 2008 Needs Assessment is no longer easily accessible, the 2009 NY DOT State Rail Plan Study repeats much of the same information regarding the financial needs for rail freight, including discussion of the Association of American Railroads (AAR) 2007 Study.

The AAR 2007 study, *National Freight Infrastructure Capacity and Investment Study*, which estimated a total of \$148 billion needed for infrastructure capacity improvements -- 91% of which was needed for Class I freight capacity alone, totaling \$135 billion. For NY alone, \$4.3 billion is needed over the next 20 years for rail freight with nearly half, \$2 billion, needed just to achieve good repair (p.174, NY 2009 Rail Plan).

Class I rail is needed for SNF transport because of its substantial weight. Many track and bridge structures associated with national, regional and short-line railroads (not Class I) are not adequate to meet the 286,000 lb. weight standard that would be required for SNF canisters, thus potentially requiring additional expensive reconstruction. Nuclear reactors not located near a Class I rail line may need to utilize trucks and then use special transfer equipment to move the heavy SNF casks to a specially-designed 12-axle railcar.

Unless a rail line is constructed leading to every nuclear reactor with dry-cask storage, some truck or barge transportation may be inevitable. Additional safeguards to address transportation risks would need to be applied to these transport methods.

Neither the DOE nor NRC have mentioned a review of infrastructure status as part of any reports regarding transport route plans. Given that rail infrastructure needs major improvements for many routes, a thorough inspection by qualified inspectors is essential prior to final approval of the chosen route along with upgrades of those routes, if they are in substandard condition. The National Transportation Safety Board (NTSB) has investigated numerous rail accidents that point to inadequate track maintenance and inspections, as well as insufficient oversight and enforcement by federal inspectors. As a result, the NTSB has identified a need for focused attention on maintenance, inspection, and repair for those routes handling hazardous materials. This must include SNF transport.

4.2b Rolling stock or non-fixed rail infrastructure

The National Academy of Sciences was convened to evaluate transportation of SNF to the proposed Yucca Mountain permanent repository and produced the report [*Going the Distance? The Safe Transport of Spent Nuclear Fuel and High-Level Radioactive Waste in the United States*](#) in 2006. At that time there was an understanding that a freight train would be designed and dedicated solely to SNF, not carrying other freight. There has not been a more recent commitment to the use of dedicated trains for SNF. Additional standards would be needed for mixed-freight trains.

The National Transportation Safety Board (NTSB) has identified critical improvements to trains themselves that require implementation. Two are particularly relevant for shipments of SNF.

The first is Positive Train Control (PTC) that uses collision avoidance technology. PTC precisely locates a train along the railroad grid and enforces signal and speed restrictions. PTC is a proven technology that prevents train-to-train collisions, overspeed derailments, and unauthorized train movement. This technology applies to passenger and freight trains handling hazardous materials, so it should be applied to trains transporting SNF. Unfortunately, [*PTC has not yet been fully deployed*](#) nationally in the United States. Most likely it will be deployed for Class I railroads by the time SNF is transported. We view PTC as absolutely necessary for SNF transport.

Secondly, the NTSB has recommended the replacement of older tanker cars with newer models that have more features to protect against a catastrophic release of hazardous materials. Unfortunately, there is no deadline for conversion to the newer tank cars. Clearly SNF transport necessitates a dedicated train that is not hauling other hazardous or flammable materials. We need a definite near-term deadline for completion of tank-car replacements by 2025.

Shipping containers used for SNF are only evaluated for a 30-minute engulfing fire, based on a small amount of fuel available from the transport vehicle only -- train or truck. Freight trains often have 20 or more tank cars carrying flammables. See Standard Review Plan for Transportation Packages for Spent Nuclear Fuel [NUREG-1617](#). Packages must have adequate structural integrity to satisfy 10 CFR 71 requirements for subcriticality, containment, shielding, and temperature.

Accidents with multiple tanker cars carrying flammables have burned for more than 24 hours. This type of fire would threaten SNF. The proximity of other trains with suboptimal tank cars carrying hazardous or flammable materials along the same train corridor would also present a risk to

dedicated trains carrying SNF only. Toxic gases and liquids could prevent workers from getting anywhere near the site of an accident to assess whether radioactive material is still securely contained. Therefore hazardous, flammable, and potentially explosive materials should not be permitted to travel on the same route as SNF.

In 2018 the DOE published the [Atlas Railcar Phase 2 Final Report](#) on the design of a railcar dedicated to SNF shipments. A summary of that report is provided in Appendix V; relevant safety issues are covered here.

The report notes (pp. 46-47) “The purpose of the American Association of Railroads (AAR) Standard S-2043 is to establish performance guidelines so trains carrying HLRW (high level radioactive waste) while using the best available technology to minimize the potential for derailments may enter general commerce with others trains in a standard railroad operating environment.” Note that high-level radioactive waste is a broad category that includes SNF. There are concerns regarding trains that carry SNF operating in a standard railroad environment given the number of catastrophic rail accidents that have occurred over the years, as documented by the NTSB. In addition, AAR revised the Standard S-2043 removing the requirement for electronically controlled brakes in 2017. However, the Federal Railroad Administration (FRA) continues to promote the adoption of electronically controlled pneumatic (ECP) brakes. Trains equipped with ECP brakes provide locomotive engineers with better train control, lowering the risk of derailment. They also complement other rail safety technologies like PTC systems. (See the [FRA report](#).)

Best available technology principles for the S-2043 model railcar would also require incorporation of the two priorities of the NTSB: PTC and upgrading of tanker cars carrying toxic and flammable materials on the same routes used for SNF transport. Recently the Trump administration has sought to allow liquefied natural gas (LNG) to be transported by railcars with a unit train (one that carries a single commodity) transporting as many as 100 LNG railcars at a time.

The US [Nuclear Waste Technical Review Board \(NWTRB\) 2010 Report](#) (p. 16) indicates that another piece of equipment needs more evaluation — the shipping containers or transportation casks that may have vulnerabilities making their shipment problematic. The NWTRB believes computer modeling and less-than-scale tests of potential accidents do not provide sufficient information to ensure cask integrity. Therefore, full-scale testing of transportation casks in likely accident scenarios should be conducted. The NWTRB recommends a new NRC test consisting of a full-scale rail package, including a full-size, larger-size transport cask containing surrogate fuel elements, mounted on a rail carrier car placed at 90 degrees to a simulated rail crossing. The package would be subjected to a collision with a locomotive and several freight cars traveling at 60 miles per hour, followed by a fully engulfing, optically dense fire for a duration of 30 minutes. The report states (p. 123): “Full-scale tests build more confidence in the public mind and are more transparent than numerical simulation research conducted by experts. Such tests would help put the public and politician minds to rest that the NRC licensed transport packages are sufficiently robust to ensure safe transport over a wide range of possible conditions.”

4.2c Transportation Planning & Training

A second category of transportation planning and funding is needed for the federal, state, and local personnel necessary for routine inspection and maintenance, route planning, and training for emergency response personnel. Federal and state personnel may provide particular expertise concerning radiological health impacts and emergency handling. However, local personnel are especially needed for understanding of major construction and transportation projects, local hazards, sensitive environmental concerns, such as surface water supplies and their proximity to a potential accident. Various kinds of technical expertise are needed as well as local knowledge of rail and road traffic interactions with the public when major events are scheduled. Engaging an entire network of relevant personnel is essential to conduct adequate planning. The Western Governors Association work on transportation to the Waste Isolation Pilot Plant (WIPP) should be a key example for this planning effort.

Funding is especially needed for the regular coordination meetings, training for inspectors and maintenance personnel, as well as for emergency responders. It should be understood that outside of major cities, the majority of emergency responders are volunteers who often have limited training in handling any type of hazardous materials, let alone SNF. Some consideration should be given to having radiation monitors, personal protective gear and other emergency equipment staged at regular locations along the transport route as well as training of local volunteers.

In a 2019 report, [Preparing for Nuclear Waste Transportation: Technical Issues That Need to Be Addressed in Preparing for a Nationwide Effort to Transport Spent Nuclear Fuel and High-Level Radioactive Waste](#), the US NWTRB highlighted the need for a repackaging facility saying it is an important critical missing element for transport and disposal that will be a major undertaking that could take longer than 10 years. “If no repackaging occurs, some of the largest SNF canisters storing the hottest fuel would not be cool enough to meet transportation requirements until approximately 2100.” (p. 77)

The NWTRB also identified 30 technical issues to be resolved prior to transportation of SNF, which will require significant planning, integration, and interaction with other federal agencies, the nuclear industry, state and local agencies, and others. (p. xxviii)

While the DOE lags in transportation planning for the movement of commercial SNF, there are at least two sets of experience with SNF to potentially draw upon: 1) the Naval program of transporting SNF from vessels with nuclear reactors to the Idaho National Laboratory, and 2) the shipments of transuranic waste to the WIPP facility in New Mexico. We briefly review these.

The first model is the Naval Nuclear Propulsion Program that transports nuclear waste to Idaho. The US Navy has dealt with nuclear materials ever since the first submarine was outfitted with a nuclear reactor in 1957. Due to the military nature of this activity, little is published on the handling of SNF by the US Navy, although many of the facts about the naval handling of SNF can be found in a 2016 [presentation](#) to the NWTRB. Currently as of 2019, there are 99 US naval vessels with nuclear reactors, mostly submarines and some aircraft carriers. SNF from these reactors has been transported over 850 times via rail to the facility at the Idaho National Laboratory, reportedly without incident of radiological release or other major problem. Fully loaded shipments may involve up to 260 tons of SNF. All shipments use the National Security Exemption (49 CFR 173.7b) which allows for no radioactive labeling of railcars or contents and no advance notification of communities along the rail corridor that is used. This exemption could mean that the public is not receiving full information related to dangerous or untoward transportation incidents.

Shipping routes are limited due to a small number of entry points for the SNF, possibly contributing to their successful transportation. Shipping “best practices” have been developed in conjunction with DOE. Realistic training scenarios have been conducted to prepare for accidents.

It is important to note that only two particular types of transport packages are employed in naval shipments. There are some significant differences between naval fuel and SNF and their shipping canisters; commercial SNF is far more dangerous. Naval fuel is solid metal, containing no flammable, explosive, or corrosive materials. It is built to withstand combat battle shock forces over 50 times the force of gravity. Naval spent fuel shipping containers are solid stainless steel from 10 to 14 inches thick. As a result, the radiation doses are a fraction of the doses associated with commercial SNF. Commercial SNF is clad with extremely flammable zirconium alloys; it contains significant quantities of explosive hydrogen; and the uranium dioxide ceramic pellets are nowhere near as robust as solid metal. Commercial canisters are only 5/8-inch thick stainless steel and are filled with an inert gas (usually helium) held under pressure because the irradiated fuel rods will oxidize if exposed to atmospheric oxygen.

A second potential model is the WIPP transportation program that was developed with the extensive involvement of state governments that are part of the Western Governors Association. This is probably the best example of multi-state cooperative efforts to oversee a successful SNF transportation program. WIPP has been in operation for over two decades, with a hiatus for about three years (2014-2017) due to a significant accident at the facility, which released plutonium and contaminated workers. The WIPP site in New Mexico is for [transuranic waste](#). Although not classified as “high-level waste”, transuranic waste, consisting of elements such as plutonium, americium, and curium, can be highly radioactive and should be transported with utmost care.

The Western Governors’ Association (WGA) has partnered with DOE to set out transportation guidelines to ensure the safety of shipments. The WGA 2017 [WIPP Transportation Safety Program Implementation Guide](#) is fairly comprehensive. States are involved in conducting their own inspections. The table of contents for the Guide lists the following:

- High-Quality Drivers and Carrier Compliance
- Independent Inspections
- Bad Weather and Road Conditions
- Safe Parking during Abnormal Conditions
- Advance Notice of WIPP Shipments; Shipment Status
- Medical Preparedness
- Training and Exercises
- Emergency Response Plans and Procedures
- Emergency Response Equipment
- Security Plan Public Information
- Highway Routing of WIPP Shipments
- Program Evaluation

Importantly, “Advance Notice” to states and communities is part of the protocol. All shipments to WIPP are by truck; rail shipments were evaluated by DOE but rejected. According to the [WGA Fact](#)

[Sheet](#) on WIPP transportation, updated 2017, “More than 11,800 shipments of transuranic waste have been transported safely to New Mexico from 12 DOE sites.” This kind of program with strong state involvement, inspection and enforcement could be a model for a future long-term SNF transportation plan.

4.2d Transportation Studies

In its 2006 study produced in anticipation of a major transportation program to move SNF to the planned Yucca Mountain repository, [Going the Distance?: The Safe Transport of Spent Nuclear Fuel and High-Level Radioactive Waste in the United States](#), the National Academy of Sciences reported this principle finding, including emphasis on the challenges:

“The committee could identify no fundamental technical barriers to the safe transport of spent nuclear fuel and high-level radioactive waste in the United States. Transport by highway (for small-quantity shipments) and by rail (for large-quantity shipments) is, from a technical viewpoint, a low-radiological-risk activity with manageable safety, health, and environmental consequences when conducted with strict adherence to existing regulations. However, there are a number of social and institutional challenges to the successful initial implementation of large-quantity shipping programs that will require expeditious resolution as described in this report. Moreover, the challenges of sustained implementation should not be underestimated.”

DOE repeatedly uses the first sentence of the above quoted paragraph to claim that the NAS has given unqualified support for the safe transport of SNF. However, the reality of that report is substantially different. Security and terrorism were not studied at all. Unfortunately, the participants in this NAS study expressed concern that they received almost no information related to security and terrorism due to restricted information and therefore were unable to deal with the topic of terrorism at all. The US NWTRB in their 2010 report urged incorporation of security concerns using a risk-informed approach (p. 16). Small missiles and other airborne explosive devices could impact casks, while forced collapse of high railway bridges could result in impacts that exceed cask integrity. The challenges discussed then are still relevant today, but additional ones have developed such as deteriorating conditions for existing infrastructure. The public receives none of the information related to the evaluation of security and terrorism concerns. At the same time, it is quite clear that currently proposed CIS facilities are not planned with the kind of protections needed to withstand a deliberate attack.

What is the historical record on shipments of SNF? In a [2016 DOE report](#), Oak Ridge and Argonne National Laboratories examined the historical record for SNF shipments around the world, including the US. They found that “At least 25,400 shipments of SNF have been made worldwide, but likely more than 44,400.” The wide range for the number of shipments is likely related to the absence of systematic data collection concerning these shipments. The transportation incidents described in this report may be classified as transportation accidents, instances of contaminated equipment transporting SNF, problems with or failure of conveyances, and disruptions to transporting radioactive material. “Review of the data sources shows that all of these shipments were undertaken without any injury or loss of life caused by the radioactive nature of the material transported.” However, exterior contamination of casks or vehicles was excessive in some instances. Table 2.7 of this report shows 4,161 shipments of SNF from reactors have occurred within the US up through the year 2007. (This does not include the Navy

shipments discussed above.) The report examined several accidents in the US, but no radiological release was reported in any of the accidents.

However, many concerns remain about previously reported accidents that were indeed serious and could have resulted in more disruptive outcomes. In a report from Nuclear Information and Resource Service (NIRS) entitled “[A Brief History of Irradiated Nuclear Fuel Shipments: Atomic Waste Transport ‘Incidents’ and Accidents the Nuclear Power Industry Doesn’t Want You to Know About](#)”, more detail is provided while calling into question the DOE’s conclusions in their 2016 report. This document maintains that radiological releases did occur in 8 cases and that many instances of shipping cask contamination were sufficiently radioactive that they amounted to radiological releases. One incident involved delivery of a “so-called empty cask” to the San Onofre nuclear facility. The shipper had installed lead shields because of the high radiation levels, but the cab of the truck exceeded safe levels by many times. The cask was not empty. It contained highly radioactive water—over 100 rems/hour. Multiple personnel were exposed to high levels of radiation. The shipment failed to meet required standards and should never have been shipped. Since this incident was not included in the 2016 DOE report, we question whether this incident was not counted as a transport incident because it arrived at a destination before high radiation levels were discovered. The DOE report notes that DOE shipments are not regulated by NRC and therefore DOE incidents would not be included in the RMIR (NRC Radioactive Materials Incidents Reports). These incident reports are no longer collected. Another serious incident that occurred at Battelle Labs was also transportation-related, but occurred after the shipment arrived (discussed also in Section 4.3c High Burnup Fuel). Another useful source regarding nuclear shipments is Dr. Marvin Resnikoff’s book, *The Next Nuclear Gamble*, 1987.

There have been highly questionable nuclear waste transport campaigns under the cover of secrecy. Elsewhere, NIRS (Nuclear Information and Resource Service) [reports](#) that in 2003 a Michigan utility shipped a reactor vessel from Big Rock Point nuclear power plant for burial as low level radioactive waste Class C in Barnwell, SC. The vessel contained mixed oxide uranium-plutonium fuels and was chemically scrubbed to reduce high levels of contamination in order to allow it to be buried as LLRW. It was estimated to contain over 13,000 curies. The weight was over 290 tons and travelled by rail at just 5 miles an hour, due to deteriorated rail tracks, to reach the main line. It suffered a broken axle while traveling over a river bridge, but eventually reached its destination. Just two days later a 30-car rail derailment occurred in Grand Blanc, MI. The local fire chief believed the derailment resulted from degradation of the tracks due to the previous heavy shipment. The nation’s existing infrastructure could make such events a frequent occurrence given the heavy weights associated with the SNF transport casks.

The NIRS report and these incidents raise questions about whether serious transport-related incidents are being adequately reported, documented, and appropriately investigated. Considerably more information is needed regarding all incidents that may be related to transportation and the adequacy of pre-transport review, documentation, and safeguards.

In the US major funding is allocated to the National Transportation Safety Board (NTSB), which conducts investigations of many transportation accidents, including those involving loss of life and severe environmental consequences. The NTSB also regularly publishes reports and makes detailed recommendations regarding transportation safety. It is long overdue for radioactive materials to be included within NTSB authority in order to develop a regulatory system to ensure that appropriate safeguards are employed, a monitoring and reporting system is established and

detailed investigations are utilized to improve radiological standards. It is completely unacceptable for this single area — nuclear and radiological safety -- to be excluded from NTSB authority and control, given their long-standing expertise. Nuclear agencies could provide support to the NTSB but should not be in charge of this effort.

One factor to keep in mind is that, for the majority of past SNF shipments, the quantity of SNF was considerably less than anticipated in proposed shipments of SNF from nuclear reactor sites to a permanent repository or to a CIS. The sheer number of shipments anticipated in the transportation of SNF to CIS facilities will be several orders of magnitude larger than the cumulative experience thus far.

Recent DOE transport decisions are cause for concern. Inadequate review and planning occurred in the case of DOE's decision to transport high-level radioactive waste (highly enriched uranium) in liquid form from Chalk River, Canada to Savannah River, South Carolina ([started in 2017](#)). Highly enriched uranium also poses criticality concerns. Criticality can occur when sufficient fissionable material is available to sustain fission, initiating a sustained nuclear reaction. Since liquid high-level radioactive waste had never been transported before, a full environmental impact statement should have been required for these potentially dangerous shipments.

On January 30, 2019 the [federal government revealed](#) it secretly shipped a half metric ton (~1,102 pounds) of plutonium from South Carolina to Nevada sometime before November 30, 2018. Nevada state lawyers were working to challenge the proposal when DOE took action to ship the material in secret. Such ill-considered actions by DOE undermine public trust in the federal government and cause concerns about the whole process of dealing with nuclear waste.

4.3 High Burnup Fuel and Transportation

While the transport of all SNF is a hazardous undertaking, high-burnup fuel (HBF) poses additional safety concerns (see the section on HBF in this report). HBF, now widely used in American nuclear reactors, is used for a longer time in the reactor core and is more radioactive than normal low burnup fuel. High burnup fuel has 3-4 times the number of curies that low-burnup fuel (LBF) has, thus increasing the potential danger of a radiological release. We know that HBF experiences more radiation, hotter temperatures, and higher pressures in a reactor and that the fuel rods experience 2-3 times more oxidation and hydrides than LBF, causing embrittlement and thinning of the metal cladding. As a result, there are major concerns about the ability of HBF fuel rods to withstand the routine shocks and jolts that are part and parcel of transportation. Thus, HBF increases the likelihood that transportation will damage the fuel in transit and arrive at a CIS facility damaged, and it increases the amount of radiation released in the event of an accident.

The NRC and DOE are currently planning to transport SNF, not to a permanent repository, but to a CIS facility. This means that if a permanent repository is developed, transport would occur twice, along with transfers and human handling, and that SNF and its containment will undergo prolonged degradation before reaching a final destination in a permanent repository.

Alternatively, the waste will not be moved a second time resulting in CIS constituting permanent, not interim storage, but in the absence of permanent safeguards. Both these factors increase the risk, especially when HBF is part of the mix.

4.3a Two containment barriers are necessary for defense-in-depth

Transportation packaging must ensure that radioactivity is contained for the entire transportation route until it reaches its destination. In [Draft NUREG-2224](#) (p. 2-1), NRC stated: “The sealed canister or cask cavity serves as the primary barrier in a dry storage system (DSS) or transportation package for protecting against the release of radioactive solid particles or gases from the loaded SNF to the atmosphere. The SNF cladding also serves as a confinement or containment barrier for preventing radioactive solid particles and fission gases from being released into the interior cavity of the DSS or transportation package. The cladding not only provides a barrier for preventing the release of radioactive material but also prevents fuel reconfiguration during storage and transport operations. Therefore, the integrity of the cladding is an essential component of a defense-in-depth strategy to protect the public health and safety.”

NRC discussed weakening for two containment issues in Draft NUREG-2224: 1) non-leak-tight containment and 2) cans for damaged-fuel. The result would be no defense-in-depth.

NRC advanced the possibility of non-leak-tight containment. However, this poses significant risks, especially for HBF, because the fuel cladding is likely to be embrittled by oxides and hydrides and therefore more susceptible to damage from transportation vibrations and jolts. In the case of damaged fuel cladding, using containment that is non-leak-tight would mean there would be no barrier remaining to prevent a radiological release. Damaged fuel could occur during transportation, even though there was no damage when leaving a reactor site.

If fuel damage is known, the damaged fuel is placed in cans with screening on either end. The screening only keeps solid pieces of the fuel pellets within the can, so the can is not a barrier to fission gases. The Holtec MPC-37 canister allows the loading of 12 cans for damaged fuel. Damaged-fuel cans do not provide a barrier. Thus, the only containment is the canister itself. Other countries require placement of damaged fuel in a sealed container, called a quiver. The US does not use this precaution. This situation allows for a serious radioactive release to occur if the canister is damaged.

4.3b Research on HBF is not adequate

The US Nuclear Waste Technical Review Board voiced serious concerns in its [2010 report](#) with the fundamental lack of knowledge about HBF as well as the nation’s current reliance on research information based solely on a single examination of LBF. As a consequence, the NWTRB made extensive recommendations for more research on HBF including ongoing inspection and monitoring by opening canisters to observe cladding and any signs of degradation over time. However, almost none of that research has even been launched. Therefore, it is a possibility that if HBF is allowed to be transported without filling these knowledge gaps, it could be extremely vulnerable to transport damage. The NWTRB renewed its concerns in a [letter to John Kotek](#), Acting Assistant DOE Secretary for Nuclear Energy, dated May 23, 2016, about the lack of knowledge on HBF and urged additional research.

The abstract of the NWTRB report of 2010 noted: “Once the used fuel is eventually shipped to either a repository or a waste processing facility, it is not clear that the used fuel will arrive undamaged, so the

possibility exists that special precautions will need to be taken prior to opening the sealed canisters, most likely in hot cells.” (p. 16)

A hot cell is a shielded nuclear radiation containment chamber. In NRC’s 2014 Continued Storage Rule, the agency talked about a Dry Transfer System (DTS) to provide shielding if repackaging of the SNF is needed. Thus, a hot cell and a DTS are conceptually similar facilities.

DTSs are not common in the nuclear industry. They are used in order to safely deal with a gamut of radioactive materials, from low-level radiation of medical equipment to high-level radiation of SNF. They exist in various sizes and with varying amounts of shielding. The amount of shielding for radiation will depend on the type of radioactive material to be treated in the DTS. Analysis of SNF in a DTS would of course require a high degree of shielding. A DTS can also be used to isolate a damaged canister and prevent radiation releases. While fuel damage may be more common, criticality, a situation of an ongoing, sustained, uncontrolled nuclear reaction, is an extremely serious event. Embrittled HBF cladding could fracture allowing fuel reconfiguration to create the potential for a criticality event. A criticality could occur if the fuel is released from the fuel rods and a sufficient amount accumulates in one area of the canister, allowing a self-sustaining fission reaction to be initiated.

Holtec Intl. is applying for a permit to operate a CIS facility in New Mexico and assumes that SNF will arrive in good condition with no need for any special precautions. However, if the shipment is in poor condition, it will merely be returned to the sender. Clearly a criticality would preclude a return-to-sender plan. Other damage short of criticality would raise risks of a return trip, thus doubling the transportation risks. In contrast, the NWTRB foresaw the risks and recommended that CIS facilities should be prepared for the need for special radiological handling of SNF canisters within a hot cell or DTS.

The General Accounting Office (GAO) reported in 2014 ([GAO 15-141](#)) that “DOE officials stated that their strategy would not involve transportation of large amounts of high burn-up fuel until at least 2025 and that, even then, there is likely going to be enough low burn-up fuel to ship for the first several years, giving more time for the research (on HBF) to yield results.” This research has begun with the so-called "[Sister Rod Tests](#)." Unfortunately, currently planned research cannot address the extensive research needs for HBF identified by the NWTRB in 2010, and stressed again in its [letter of 2016](#).

GAO also identified HBF as posing significant problems related to its higher temperatures and radiation levels as well as its possible degradation in storage, which may render HBF non-transportable. For example, transport guidelines do not allow temperatures above 85 degrees C or 185 degrees F because the transport will involve public infrastructure. (See the Standard Review Plan for Transportation Packages of SNF, [NUREG-1617](#), 2000.) Higher radiation levels could also limit the transport of HBF, which should release no more than 10 mrem at 6.5 feet from the transport package.

4.3c The Presence of Inert Gas is Essential for Transport

All spent nuclear fuel transport requires the presence of inert gas in canisters. Inert gas is even more important in the case of HBF, because it is hotter and more radioactive. In 1980 a severe contamination event occurred at Battelle Memorial West Jefferson Facility in Ohio when a failed fuel assembly from the Connecticut Yankee nuclear reactor was sent for evaluation with only air as the gas in the canister ([Idaho National Laboratory Report, 2005](#)). The temperature of the assembly reached 430 degrees C and fuel oxidation of uranium dioxide to U_3O_8 occurred. Oxidation increases the bulk or volume of the uranium fuel causing the rupture or unzipping of fuel rods. Upon arrival at Battelle, the cask was loaded into the pool and flooded with water, generating steam and spreading the fuel, now as a fine powder, over the entire pool area of the building, as well as a number of other radionuclides. Limited information about this serious incident is available, because court records were sealed. As the NRC reports, they determined subsequent to these occurrences that just 4 days are needed for 15% of rods to unzip at 400 degrees C ([Idaho National Laboratory Report, 2005](#)). This phenomenon was previously unknown and caused the NRC to revise all SNF cask certificates to require the use of an inert gas (helium, argon or nitrogen) as a cover gas in all SNF shipments.

NRC is reviewing applications for SNF arrival at two CIS facilities currently. It has indicated that confirmation of the presence of inert gas would be done only upon arrival of a shipment at a CIS facility. Unfortunately, inspection upon arrival of the casks is too late to provide for transportation safety. It would represent a significant change from previous NRC shipping requirements. SNF at nuclear reactors may have been in dry storage for 20 years or more. In the absence of confirmatory testing that inert gas is still present at required levels, there is no way to know that the gas has not leaked from failing welds or corrosion cracking of the canisters. Any leak of inert gas would allow air to enter, leading to rapid oxidation of the fuel, increased volume and pressure in the rods, and unzipping of the fuel rod cladding. This situation could lead to a dangerous radiological release. It is essential to confirm the presence of inert gas prior to any shipments, consistent with current requirements.

4.3d Potential for increased heat loads to impact later transport

Higher temperatures must be regularly monitored and managed for HBF. Temperature limits were set by NRC during drying of assemblies when they are removed from a pool and prepared for dry storage (400 degrees C maximum with temperature elevations between drying cycles of 65 degrees C). However, the factual basis of these limits should be reviewed, as researchers have identified increased solubility of hydrogen at higher temperature, making more hydrogen available for precipitation as hydrides ([DOE, 2013](#)). Beyond the fuel and cladding it should be noted that some components such as neutron absorbers and polymer seals degrade at temperatures well below 400 degrees C. Even lead shielding, if present, can change shape and slump, thereby creating a potential hazard.

NRC is allowing early transfer of HBF to dry storage under relaxed heat-load requirements. Technical specifications in 10 CFR 72.236 include minimum acceptable cooling time of SNF prior to storage in a cask, maximum heat designed to be dissipated, and maximum loading limit. Temperature monitoring for dry-storage systems must continue at air outlets of those systems.

NRC is decreasing SNF cooling time in pools and allowing early transfer to dry storage systems. These changes are happening at individual reactors with no opportunity for public comment and

detailed consideration of the technical basis. For example, the heat load for dry storage has been raised to just under 30 kW per canister at the San Onofre Nuclear Generating Station (SONGS), roughly doubling the heat load of the previous canisters loaded. Exterior monitoring of the dry storage canisters' temperature is currently done at ISFSI sites by an inspector with a temperature gauge at the outer cask's air outflow location.

Holtec Intl. is now suggesting it plans to bid on decommissioning nuclear reactors, moving all irradiated nuclear fuel out of fuel pools within 3 years to dry storage. What are the implications of these plans on the temperatures of HBF assemblies? If this results in temperatures exceeding 400 degrees C, what will the likely impacts be of later transport to a CIS facility or a permanent repository? Changed management practices related to HBF are of more concern because of the lack of basic research on HBF. There is presently no evidence that reduced time in cooling pools and subsequent transportation is a safe practice.

4.3e Research must address the substantial unknowns associated with HBF

The NRC should address the substantial unknowns associated with HBF by preparing a detailed research plan that includes thorough inspections of a representative sample of HBF assemblies in storage for various time periods. For cladding, most research has focused on Zircaloy-4 cladding with few studies of newer claddings. A single [10-year study](#) by DOE of HBF fuel rods is now underway, but the results will not be available until 2025. Much more research should be launched to answer the questions identified by the NWTRB in their 2010 report before HBF is transported.

Additional research is especially needed on fuel rods with high oxides and hydrogen levels to evaluate embrittlement and determine that transportation will pose few problems.

[Results of a Multimodal Transport Study](#) were presented at a Nuclear Waste Technical Review Board Meeting in fall 2018 by DOE. (See Appendix VI of this document for a more in-depth discussion of this study.) The transport study was supposed to evaluate the stresses and shocks experienced by fuel rods during transport. Unfortunately, surrogate and dummy fuel rods were used that could not represent actual fuel rods. They failed to even use unirradiated new fuel rods, let alone actual used irradiated rods. This was likely a costly study, but given the limitations, it does not provide much valid or useful evidence.

4.4 Canister Integrity and Corrosion Cracking

Canister integrity is impossible to determine. Dry-storage systems require that canisters be encased in concrete casks for the necessary shielding of gamma and neutron radiation. Lead may also be used for shielding. This casing creates a problem: how to easily inspect the exterior of the steel canisters for corrosion, cracking or other damage, while protecting workers from radiation.

As a result, NRC has allowed substitutes for real inspections; such substitutes provide little validity or confidence in the results. ISFSI managers can utilize findings of surrogate demonstration programs, even though the surrogates may not represent valid, similar environmental conditions. The other option is to choose one canister for inspection from among all the others at the site -- 1 out of 50 or 80 or

more. The NRC does not require managers to select HBF canisters for inspection. Thus transport of such HBF fuel canisters would be risky and the outcomes unknown.

Visual observation of the exterior of the canister could identify obvious corrosion or welding damage, but workers would be exposed to high levels of radiation. Moreover, it is not technically possible to actually determine that microscopic cracking has not occurred in the relatively thin steel canisters that are only 5/8 inches thick. The loss of inert gas, however, would be an indication of a canister leak.

It is likely that a shipment to a CIS facility will have been in storage for 20 years or more without an actual visual inspection, thus posing risks of transporting a canister that may be damaged. The decommissioning of nuclear reactors will require relatively long transportation campaigns. An ideal time to actually inspect the exterior of steel canisters is just prior to shipment. A radiation- shielded DTS system would provide the ability to inspect canister exteriors and even facilitate repackaging, while protecting workers.

The NWTRB has called for this problem to be addressed: “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. 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.” ([NWTRB 2019](#), p. 80)

Sandia National Laboratory is working to identify non-destructive techniques to be able to identify microscopic cracking and other canister damage. See their [Gap Analysis to Guide DOE R&D in Supporting Extended Storage and Transportation of Spent Nuclear Fuel: An FY2019 Assessment \(Final Report\)](#).

4.5 Human-Induced Disasters and Accidents

Human error can occur at all stages of nuclear reactor decommissioning, and during SNF cooling, storage, and transportation. Human error can also occur in response to emergency situations. This does not mean that workers themselves are primarily responsible for a particular accident. It could mean that government budgets were cut and therefore routine inspections were cut, or repairs on infrastructure were delayed because funding was cut or procedures were inadequate. Potential human-induced problems can involve the entire system associated with oversight including maintenance, undetected structural deficiencies associated with bridges and overpasses, infrequent inspections, budget cuts, and failure to carry out recommendations for corrective measures. Many untoward events involve multiple factors. This is illustrated by the investigations of accidents by the National Transportation Safety Board.

Particularly vulnerable locations at which accidents occur involve SNF transfers to an additional mode of transportation. If only dedicated trains are used, where there is interaction with other train lines or where roads and trains cross, vulnerabilities will occur. A clear route or path with no interaction with other hazardous materials transport is optimum for safety, but may not be logistically or technically feasible. Congested rail hubs and long waiting times can increase hazards.

Transportation planning for SNF should take into account the possibility of accidents arising from human mistakes and failure of human-built infrastructure. Many of these possibilities can be identified quickly from past experience and records, but many may need to come from “thinking outside the box” and anticipating possible vulnerabilities. Many people involved with potential accidents may lack the experience to understand these possibilities and may respond inappropriately to emergencies.

To provide some examples, we suggest three credible accidents that could affect the shipment of SNF:

Bridge Collapse. The [ASCE infrastructure report](#), described above, raises concern that there is the probability of a bridge collapse somewhere in the US. The probability is surely increased by the enormous weight of proposed SNF shipments, 286,000 lbs. Additionally, aging infrastructure and extreme weather associated with climate change may result in damaged bridges, increasing their vulnerability. We have had rainfalls across the US that exceed 20 inches in 24 hours. As a result extreme flooding can occur, with fast moving water at unusually high levels, increasing strain on bridge supports.

Train Collisions. Until a system is in place on all trains that would eliminate the possibility of collisions, human mistakes could cause an accident that involves a train with a SNF shipment. Train collisions and derailments nationally are a relatively common news story.

Avoidance Accident. A driver of a truck carrying a SNF shipment may cause a rollover accident in attempting to avoid hitting a school bus or another truck at an intersection.

The above do not include terrorist acts which may be sufficiently destructive to cause a radiation release. Such threats are real and the nation and states have a vast network of security personnel to address and prepare for such threats. Unfortunately, the public is not provided with information about what security risks have been analyzed and the safeguards employed. There should be greater efforts to provide more safety assurance.

A major concern for human-induced events relates to adequate funding. GAO identified increasing environmental liabilities related to nuclear waste cleanup as "high risk" for the nation in 2016 for the first time. Presently, the backlog stands at \$377 billion, yet we are anticipating a massive transportation program for the most dangerous nuclear wastes that will need billions of dollars in funding for infrastructure and planning, partly due to an infrastructure repair backlog. Additionally, if the transportation program is not fully funded, with attention to all aspects of planning including personnel training and public involvement, the likelihood of transportation accidents could increase dramatically. This outcome is not acceptable with such a hazardous substance as SNF and the potential for large numbers of people to be impacted by a radiological release.

4.6 Natural Disasters

Natural disasters during the shipment of SNF are a major concern. It is important to note that the NWTRB identified in 2010 the fact that requirements for storage of SNF included the

consideration of natural hazards while, surprisingly and disturbingly, transportation requirements did not.

4.6a Regulatory Context

The following regulations apply to the siting of nuclear reactors and dry storage, 10 CFR 72.122(2)(i):

“(i) Structures, systems, and components important to safety must be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, lightning, hurricanes, floods, tsunamis, and seiches, without impairing their capability to perform their intended design functions. The design basis for these structures, systems, and components must reflect:

- A) Appropriate consideration of the most severe of the natural phenomena reported for the site and surrounding area, with appropriate margins to take into account the limitations of the data and the period of time in which the data have accumulated, and
- B) Appropriate combinations of the effects of normal and accident conditions and the effects of natural phenomena.”

The NWTRB urged correction of inconsistencies so that natural hazards would be evaluated for transportation as well. ([NWTRB, 2010](#), p. 15). (For dry storage facilities, see the Section 2.4 Natural Disasters in this report.)

We examined five reports for their treatment of natural disasters. This series of reports is built on a [1977 NRC environmental impact statement](#) (EIS) on risks of transportation and addressed many questions that have come up since that EIS. The words earthquake, hurricane, tornado, wildfire, rockslide, landslide, mudslide, avalanche, sinkhole, and flood do not appear in this report.

1) [Spent Fuel Transportation Risk Assessment, Final Report \(NUREG 2125, 2014, 517pp.\)](#)

The first report states that “Risk is usually defined by answering the questions posed by the risk “triplet,” which is identified below:

- a) What can happen (the scenario)?
- b) How likely is it (the probability)?
- c) What is the outcome if it happens (i.e., how bad is the consequence)?

Unfortunately under the first question, “what can happen”, the occurrence of natural hazards is not addressed in the entire report.

2) [Regulations for the Safe Transport of Radioactive Materials, 2018 Edition \(190 pp.\)](#)

This document, from the International Atomic Energy Agency (IAEA), of which the United States is a member, establishes safety standards for the safe transportation of nuclear materials, including SNF. As with the NRC report above, none of the words earthquake, hurricane, tornado, rockslide, landslide, mudslide, avalanche, sinkhole, and flood appear in this report.

3) [Going the Distance?—The Safe Transport of Spent Nuclear Fuel and High-Level Radioactive Waste in the United States, National Academies Press, 2006, 355 pp.](#)

This report was developed by the National Research Council Committee on Transportation of Radioactive Waste to consider transport of SNF to a Yucca Mountain repository. It is a fairly thorough report on some substantial transportation risks. However, again, none of the words earthquake, hurricane, tornado, rockslide, landslide, mudslide, avalanche, and flood appear in this report.

4) [Yucca Mountain Transportation Issues, slide presentation by Fred C. Dilger, consultant and UNLV faculty, Nevada Agency for Nuclear Projects, 2015.](#) (see [NIRS archives](#))

This presentation details how the State of Nevada has treated the transportation issue. When Yucca Mountain was being considered for a permanent repository for HLW, Nevada devoted significant resources to evaluate the transportation and health impacts. The Nevada Agency for Nuclear Projects (NANP) developed a broad line of inquiry into the transportation issue as it would affect Nevada. This particular presentation does not, however, include any mention of natural hazards, even earthquakes. This seems to be clear oversight in a state which has the 3rd highest seismic hazard in the US (Alaska and California being one and two, respectively).

5) [Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada - Readers Guide and Summary, DOE/EIS-0250, 2002, 118 pp.](#)

This is the summary introduction to the complete final environmental impact statement (FEIS), which is thousands of pages in length. The summary contains “earthquake” several times, mostly in conjunction with the safety of the repository site itself. There is one short mention of earthquakes as possibly causing a transportation accident. Other natural hazards -- hurricane, tornado, rockslide, landslide, mudslide, avalanche, sinkhole, and flood -- do not appear in this summary and constitute a major omission.

Clearly, these major government documents have largely ignored natural hazards and disasters as threats to the transportation of SNF. One priority for Sierra Club and its chapters should be to request greater consideration of potential natural disasters associated with the transportation of SNF.

4.6b Examples of Credible Natural Hazards Affecting Nuclear Waste Transport

Below are listed five hypothetical natural hazards that would have major and potentially catastrophic impacts on SNF transportation.

1. A quickly spreading wildfire in a forest area, like those seen frequently in the last few years, overtakes a railway and prevents a nuclear waste train from proceeding. Erratic flames finally engulf the entire train, destroying the track bed. Damage to the train and tracks is sufficient to require weeks of in-situ repairs, with exposure to significant radiation for workers, before it's able to continue. A radioactive release could occur as a result of the fire or a collapse of the track bed, with a vertical fall causing the release.

2. A nuclear waste transport truck is on an aging bridge just as a magnitude 7 earthquake strikes in California. The bridge collapses, pitching truck and waste into a canyon where the force of impact on canisters causes a radioactive release in a location posing difficult access. Any accident posing difficult response circumstances would likely result in a significant delay in emergency response, increasing radioactive exposures to the environment and the public.

3. A rockslide or mudslide on a steep slope outside a town halts a train carrying nuclear waste, derailing the engine and the SNF car. A long and hazardous waste cleanup is required potentially exposing residents and workers to significant radiation.

4. A severe ice storm on mountain pass causes a truck carrying nuclear waste to slide down the highway, smashing several cars and trucks on the way, and to pitch over guardrail and come to rest at the bottom of a lake. A criticality event is a possibility.

5. An earthquake's strong ground motion derails a train. The 1906 San Francisco magnitude 7.9 earthquake actually caused a locomotive to topple off the tracks north of San Francisco. The accident was analyzed with computer modeling in a [2019 paper](#).

4.6c Likelihood for Specific Natural Hazards to Affect Transportation of Nuclear Waste

Earthquakes. [Hazard maps](#) exist for earthquakes across the US. Almost every state has regions where, in the timeframe of moving all the SNF to Yucca Mountain or another central repository, an earthquake could occur with associated ground motion sufficient to directly affect the shipment of nuclear waste (e. g., toppling of a rail car with a canister) or to adversely affect the structures which lie along the transportation corridor (e. g., bridges, overpasses, on/off ramps). Underground high-volume disposal wells have increased the prevalence of earthquakes in areas of the eastern and central US where they were very uncommon. Extensive studies on the risks to cities from large earthquakes have already been conducted, so it seems important to do similar studies to assess the risks to waste shipments in transit.

Tsunamis. Tsunamis are a significant threat confined to coastal regions of the US, more likely the western coast of the US, although seiches (freshwater tsunamis) have been observed occasionally on large lakes. The San Onofre nuclear power plant site (now being decommissioned but with onsite storage) on the beach in Southern California is of great concern and is often compared to Fukushima for tsunami threat. The recurrence time for a tsunami that would breach the retaining wall at San Onofre has not been estimated due to the large number of source areas possibly [generating a tsunami](#), but an estimate would likely measure in hundreds of years (as reported in a presentation to San Onofre Community Engagement Panel.) The [largest historical tsunami height](#) measured in California is 4.5 meters in the San Francisco Bay region in 1868. Ideally, one would have the hazard expressed in probability of occurrence of a given wave height per given number of years (for instance, 1% probability in 100 years of a 10-meter wave). That probability may be extremely difficult to quantify; but, if it could be reliably quantified, in conjunction with the extent of the possible damage to humans and infrastructure, then meaningful risk assessment could be done. At San Onofre, for instance, the hazard is apparently of low probability but the risk is extremely high due to the nature of SNF and its proximity to major metropolitan areas. We note that dry-storage canisters at Fukushima in 2011 were not breached in a much higher tsunami which [measured 13 meters](#) at the Fukushima plant and overflowed the containment walls meant to prevent

tsunami damage. However, this is because their dry storage was inside a building. Nonetheless a risk exists for a number of nuclear power plants on the coasts. The type of canister should also be considered. The Fukushima canisters were approximately 10 inch thick steel while, for instance, the San Onofre ones are only 5/8-inch steel. If such an event occurred during the loading or transport of SNF, the danger could be substantial.

Rockslides or mudslides. Numerous roadways and train tracks in the US run through canyons, pass by rock cliffs, or are located on high earthen slopes prone to slides, especially after rainfalls. Rocks or mud on tracks or highways is not an uncommon occurrence, leading to hours or days of traffic delays. These phenomena can sometimes carry enormous masses of earth or rock, enough to threaten the heavy loads contained in SNF shipments. Derailments of rail cars and damage to SNF casks and even burials of transport vehicles is possible.

Hurricanes. Good warning systems exist for hurricanes in the US and today provide at least several days notification. This advance warning should generally be sufficient to stop transport of nuclear waste into any zone which might be gravely affected by hurricanes and their aftermath of flooding. Already we know that Hurricane Michael blew an entire freight train in Florida off the tracks in 2018; and also in 2018, Hurricane Florence derailed a CSX train in North Carolina. What is the possibility that hurricane-force winds could topple a rail car or truck with a SNF waste canister over 100 tons? This question needs computer modeling to quantitatively estimate its probability.

Tornadoes. It is possible that tornado-force winds could topple a rail car or truck with a heavy waste canister. FEMA [reports](#) that an EF2 tornado with winds exceeding 111 mph would topple a train off a track. No report to our knowledge has examined this possibility for train cars carrying heavy nuclear waste canisters. Computer modeling or actual simulations could probably determine whether this is likely or not. Certainly, fairly heavy freight trains have been derailed dozens of times in the last decades by tornadoes or hurricanes.

Wildfires. These are unexpected and often rapidly developing natural hazards, becoming more and more common in the Western US. However, the early detection systems for wildfires are improving — satellite and land-based imaging. The likelihood of a wildfire entrapping a train or truck carrying nuclear waste is undoubtedly fairly low, and some estimate for the probability of this happening can be extrapolated from current data on numbers of vehicles caught in wildfires on roads or railways. Increasing wildfire events in California and around the West are making this threat more credible every year. A major fire could cause a radiation release, but also could reduce effectiveness of shielding. Waste canisters from the transportation corridor can present serious problems if they end up in streams, lakes, or canyons. The daunting task of removing a canister from a deep canyon is not an accident that responders are likely to be able to handle quickly.

Sinkholes. Sinkholes most often arise from the dissolving of limestone, gypsum, or salt underground. This dissolution occurs when formations are subject to current or prior water saturation. Sinkholes may also arise when soil is simply washed away under a structure. Sinkholes may exist undetected beneath the surface but then be suddenly revealed by a collapse of the ceiling, or they may have long-standing surface openings. The former are more dangerous because they lie hidden from roadway or railway construction and other infrastructure. Roadway and railway collapses over sinkholes are well documented, and the problem will certainly be exacerbated with

the large weight of nuclear waste shipments, often exceeding usual weight limits for shipments on rails or roads.

Floods. While floods on major river systems can be fairly well predicted based on precipitation data on a time scale of hours of warning, flash floods offer a significant and credible threat to transportation of nuclear waste. Both likely have a good body of experience from which to draw inferences for nuclear waste transportation. Minor flooding on streams and small rivers is usually of relatively short duration. Major flooding on large rivers, although perhaps lasting many days, can often be predicted such that transportation has the ability to adjust. The more important concern may be the damage to transportation infrastructure, often hidden from view, which may have occurred during the flooding cycle, no matter its duration. Commonly, train tracks and even entire trains are partially submerged in a flood posing a risk to the train as well as the underlying infrastructure. Dam breaks can cause flooding to occur much more quickly.

Combination of various natural hazards. The combination of two or more natural hazards cannot be ruled out. For instance, damage to rail lines due to flood-water erosion under tracks during a hurricane could lead to increased risk of high winds from the hurricane toppling transportation railcars on the tracks. Similarly, the shock of a major earthquake combined with a tsunami could magnify risks to a railroad or highway.

Combination of natural hazards and human infrastructure. A possible scenario in this category might be a dam break following a major rain event. Another scenario of this type is that flood-water or earthquake damage to infrastructure may not be exhaustively assessed, leading to later infrastructure failure along transportation routes. Dry-storage sites for SNF should be evaluated for credible natural disasters which, when combined with human-induced hazards, present high risks. For instance, a major natural hazard at the Indian Point, New York, nuclear reactors is from an earthquake. FERC approved a large diameter gas pipeline for underground construction across the reactor property on the basis of a faulty safety analysis, review, and approval by NRC. Now there are interacting hazards -- an earthquake could rupture the high-pressure, large-diameter pipeline and result in a blast and fireball endangering the SNF cooling pool. This new hazard was human-induced by the NRC approval and FERC decision. (See US NRC [Office of Inspector General Report](#), Indian Point Nuclear Plant, Inquiry Pertaining to Gas Transmission Lines, Case # 16-024.)

Effects of climate change. The pervasive nature of climate change is affecting our ability to make predictions regarding weather-related events and their magnitude, though clearly the intensity of weather-related events is increasing. Even transportation infrastructure in good repair may not be designed to handle extreme rainfall and flooding. In most cases, predictive natural-hazard models will probably lag in the need to incorporate the latest climate modeling and even the latest available historical records.

4.7 Radiation Exposures, Releases and Health Effects

4.7a Background on Radiation Exposures and Health Effects

Materials that are radioactive are unstable (i.e., the nuclei in the atoms of the material possess too much energy or mass) and transform spontaneously (decay) through the emission of radiation.

This radiation may be in the form of energetic particles, such as alpha particles (contain 2 protons and 2 neutrons equivalent to a helium nucleus), beta particles (electrons), neutrons; or energy may be emitted in the form of gamma rays or X-rays. Collectively these emissions are known as ionizing radiation because they are sufficiently energetic to damage living cells they travel through. The cell may die, repair itself, or multiply incorrectly. This can lead to cancer or birth defects. For adults there can be a long latency period of 10-20 years or more before a cancer occurs. In infants and children this cancer latency period can be much shorter. However, while cancer is most often discussed, there are other non-cancer effects of radiation such as a weakened immune system. Many children exposed to radiation from the Chernobyl disaster have heart problems. There is no safe dose of radiation for adults or children. See the [National Academy of Sciences report](#) entitled *BEIR 7: Health Risks from Exposure to Low Levels of Ionizing Radiation*. The NAS concluded that any radiation exposure, no matter how slight, carries a risk of causing cancer or other health effects.

The *rem* is one of the two standard units used to measure the effective dose, which combines the amount of energy (from any type of [ionizing radiation](#) that penetrates human tissue), along with the medical effects of the given type of radiation. The *sievert* (Sv) is the other unit used. 1 Sv = 100 rem. Most often we measure exposure in millirems, because a rem is a relatively large exposure. 1 rem = 1000 millirems. Workers in the nuclear industry are supposed to receive no more than 5 rems (5000 millirems) of exposure over an entire year of work. A [lethal dose](#) of radiation is 400-450 rems.

For [beta](#) and [gamma](#) radiation, the [effective dose](#) is the same as the [absorbed dose](#). By contrast, the effective dose is larger than the absorbed dose for [alpha](#) and [neutron](#) radiation, because these types of radiation are more damaging to the human body. Thus the effective dose for alpha and neutron radiation must be multiplied by the “radiation [weighting factor](#)” for this more damaging radiation. For alpha particles this factor is 20. The former term “quality factor” has now been replaced by “radiation weighting factor”. (See Appendix III in this document for a table of weighting factors.)

Radioactive isotopes can also be more harmful to humans if they are inhaled or ingested. A tiny amount of inhaled plutonium can cause lung cancer. Radioactive strontium is treated like calcium by the body and is taken up in bone tissue, where it irradiates bone and blood-forming activity in the bone marrow, potentially leading to leukemia or other cancers.

According to an [NRC webpage](#) on dosage, Americans receive a radiation dose of 620 millirems yearly. Half of this is from natural background radiation. The other half is from medical procedures and commercial and industrial sources.

The most common unnatural radiation exposure is via gamma rays or X-rays. Protection from this type of radiation involves 3 methods—distance, time, and shielding. In most cases keeping people at a distance from a source of gamma rays and limiting the time of exposure to a few minutes provides adequate protection. Most medical and dental X-rays, a type of gamma ray, last just a few seconds for example. X-ray technicians are potentially exposed multiple times a day, so they are also provided with the shielding of a wall while taking an X-ray. Sometimes the patient is provided with a lead apron as a shield. A key question prior to X-rays is: Are you pregnant or could you be? The reason for this is the vulnerability of the fetus to radiation. Babies and young children are also more vulnerable to radiation than adults because of their rapid growth and development. (See

Appendix VII for information on childhood radiation exposures.) Excluding childhood exposures, adult women are 50% more vulnerable than adult men to the adverse effects of radiation.

4.7b Transportation Exposures

The 2006 [National Academy of Sciences report](#) has important background information on transportation accidents and exposures; it states:

“Spent nuclear fuel shipments in the United States are usually made under the USNRC’s or DOT’s exclusive use regulations (10 CFR 71.47(b)). Such shipments can be transported using public road and rail systems in the United States only if they do not exceed the following dose limits (p. 119):

- 2 millisieverts (mSv) per hour (200 millirem [mrem] per hour) on the external surface of the transport package and at any point on the outer surface of the vehicle.
- 0.1 mSv per hour (10 mrem per hour) at any point 2 meters (6.5 feet) from the outer lateral surfaces (but not the top or bottom) of the vehicle.
- 0.02 mSv per hour (2 mrem per hour) in any normally occupied space. This provision does not apply to private carriers if exposed personnel under their control wear approved radiation dosimetry devices.”

The middle value, 10 mrem per hour, is the most important for assessing population exposures, except for workers who are exposed more frequently. Compare this figure to the 620 mrem that the average American receives per year from natural and human-made sources. Workers and inspectors would need to be aware of the higher exposures near the transport package and would likely need monitoring equipment and radiation badges to monitor their personal exposure.

The 2006 NAS study further noted that (p. 119):

“U.S. agencies do not collect records of radiation exposures resulting from the transportation of irradiated nuclear fuel as is done for radiation exposures to personnel in nuclear power plants. Private carriers will keep records for those workers who use radiation monitoring devices in accordance with regulations, but these records are not published. Consequently, the doses received by workers and the public associated with spent nuclear fuel shipments in the United States are not precisely known, although the committee judges that they are likely to be relatively small given the external dose limits allowed by regulations combined with the small numbers of shipments that have been made to date.”

Four levels of possible exposures associated with rail transportation are discussed in the following subsection, since rail has been identified as the primary transport method for SNF . If trucks are used for more than very short trips to a railhead, more evaluation would be needed because trucks would need to make stops for fuel and servicing, in addition to addressing driver needs.

i) Minor Exposures

The majority of transportation exposures will be exposures to gamma rays. The shipment casks are shielded by design to some degree. However, gamma rays, which can pierce all but extremely thick

shielding, will still be emitted from transport packages of SNF, and thus workers and the public will receive doses of radiation, often referred to as radioactive shine.

Potentially minor exposures for the public may relate to situations where trains are held on sidings due to traffic, a needed repair, or some incident ahead on the line. If passengers are potentially exposed at train station stops or on sidings for an unknown time period, it should be possible to have passengers move to other cars or locations where they are not directly adjacent to the rail car carrying spent nuclear fuel. Our understanding is that a single dedicated freight train will have only one rail car carrying SNF with buffer cars on both sides. Actual transportation plans have not yet been proposed by the relevant agencies.

ii) Moderate Exposures

In congested urban areas that surround rail stations, it is possible that SNF rail traffic may be held waiting for a lengthy period to be given a departure time. In such situations there should be an evaluation of the presence of facilities and institutions in proximity that might house vulnerable populations for 8 hours or more per day. Nearby (within 10 or 20 meters), institutions where people are housed for as much as 24 hours per day should be evaluated. Priority consideration should also be given to health services for pregnant women, infants and children, nursery schools, elementary schools, and day care facilities. The impact of short-term exposures to gamma rays are as a result multiplied by the time exposed and the number of times in a given year. Operational changes to rail yard practices for SNF hazardous loads, use of concrete shielding, and even relocation of facilities should be considered. Congested rail yards also must make a defined separation of other hazardous materials — toxic gases and liquids as well as flammables — from SNF.

iii) Routine Radiation Exposures

Some amount of radiation in the form of gamma or X-rays will be continuously released from the shipment of nuclear waste. Workers involved with securing the shipment and monitoring it will be most exposed and will need to have their exposure monitored. Workers may also wear shielded clothing. Maintaining distance from the source and limiting the time in close proximity are the most important radiation reduction measures. If a minor incident backs up traffic, priority should be given to clearing pregnant women and young children from the immediate area. Situations should be avoided where nuclear transport trains and passenger trains are held stationary in close proximity due to rail traffic.

iv) Contamination of Exteriors of Shipping Casks

Shipping casks have been observed with significant levels of exterior surface radioactive contamination. The most serious multi-year exterior contamination occurred in France (see *No. 6/7 Issue: Transport* under Bulletins of the [Wise-Paris online publication](#)). A full 25% to 33% of Areva's irradiated nuclear fuel shipments into its La Hague reprocessing facility were externally contaminated for years on end, above "permissible" levels. On average, the shipments were giving off radiation dose rates 500 times the "permissible" level; in one instance, a shipment was emitting radiation 3,300 times the "acceptable" level. This affected hundreds of shipments over the course of several years. An industry document indicated that on average 26% of the spent fuel casks and 36% of the "transports" (rail cars or trucks) were contaminated.

Of the total of 192 casks and transports surveyed in France, 50 were identified as contaminated up to some 200 Bq/cm² (Bq = [Becquerel](#), a unit of radioactivity). Specific limits had been established for external surface contamination ranging from .04 Bq/cm² to 4 Bq/cm².

Inspections found that a large area of the surfaces accessible to the public were contaminated in a uniform fashion at a level of several hundred Bq/cm². Mycle Schneider of WISE-Paris interviewed transport personnel who appeared to know nothing about radioactive contamination. ([Transport Special- Plutonium Investigation](#)). Transport workers may have received heavy doses of radiation related to this level of contamination which was worsened by their lack of awareness about the contamination and related danger. Moreover, they could easily have spread the contamination to other areas such as passenger areas, shops, cafes, and homes.

Surface contamination of shipments has occurred in the US as well. Robert Halstead, Director of the Nevada Agency for Nuclear Projects, identified [49 surface contamination incidents](#) that occurred in the US between 1949-1996. Unfortunately, there are no details about the extent of contamination.

It is imperative that shipping casks be inspected for external surface contamination prior to leaving a reactor site. A surface sample should be collected and sent to a lab. When the SNF is placed on a railcar, rail workers should have monitoring equipment to confirm that exterior contamination is not present. Any contamination could expose rail workers to harmful doses of radiation as they conduct their duties, and their work could spread the contamination to other trains and require extensive cleanup. Such contamination could include alpha particles, which have a greater biological impact if inhaled or ingested — 20 times that of gamma rays. When such surface contamination is detected, thorough cleanup is necessary prior to shipping.

4.7c An Accident That Involves a Radioactive Release from the Shipping Cask

A recent DOE report on the transportation of SNF is presented in: [A Historical Review of the Safe Transport of Spent Nuclear Fuel, ORNL/SR-2016/261, Rev. 1, Department of Energy, 2016, 88 pp.](#) This recent report covers the past history of nuclear waste transport accidents in the US and in the world. It reports (at p. v of Executive Summary):

“In general, there have been few transportation accidents worldwide in the history of transporting SNF, and none have had significant radiological consequences.”

It estimates there have been over 4,300 shipments of SNF around the US and over 20,000 in the world, respectively, up to about the year 2010. It claims that getting accurate counts in many countries is difficult, which is the case for the US in earlier years of the nuclear age, and that the world number in particular is probably higher. So these estimates are underestimates of the actual number. However, there is limited experience with moving commercial SNF. The Navy probably has the most experience with SNF shipments and has a reasonably good safety record. DOE and NRC seem to discount the potential for serious radiological releases from SNF shipments. A number of serious scenarios require planning:

- Vibrations and jolts associated with transportation could alter the stability of fuel in its container. In a worst case scenario, instability could cause a criticality.
- Generally, the NRC operates under the assumption that two barriers for containment of the SNF are functioning (cladding and canister), which it identifies as defense-in-depth. However, NRC has allowed exceptions. Multiple damaged fuel cans are allowed in each multi-pack canister. Damaged fuel means the cladding is no longer serving as a primary barrier. Damaged fuel cans have only screening on each end, and thus are not sealed like other canisters. There is recognition of this problem, for instance, at the decommissioned San Onofre nuclear reactor, the damaged fuel from Unit 1 will wait to be moved in 2030 and will be packaged separately for transportation. The question is whether this will actually provide a two-barrier system.
- No inspections are required of the steel canisters in dry storage for evidence of corrosion prior to shipment. The licensee is allowed to utilize surrogate demonstration canisters from elsewhere to assess suitability for transport, although local environmental conditions may be different than those experienced by surrogates. If a surrogate is not available, additional safety analyses are required. A main issue of concern is whether reconfiguration of the fuel has occurred in storage, affecting the transportability of the fuel (see [Draft NUREG-2224](#), Dry Storage and Transport of High Burnup SNF). These methods are highly questionable in the case of HBF, as there is so little relevant research to use for transportation modeling and safety analysis.
- A severe accident, a criticality, or an engulfing fire of long duration involving multiple tanker cars with flammable materials, could lead to a radiological release ([NUREG-1617](#) Standard Review Plan for Transportation Packages for Spent Nuclear Fuel). Packages must have adequate structural integrity to satisfy 10 CFR 71 requirements for subcriticality, containment, shielding, and temperature.
- Emergency responders may be required to allow the fire to burn out in order to avoid an explosion and worsening of the situation.
- Recently under [draft NUREG-2224](#), NRC entertained the possibility of allowing non-leak-tight confinement boundaries on canisters, thus eliminating defense-in-depth.
- Appropriate equipment to contain the release of radiation, to protect workers, to monitor for radiation, and to lessen impacts may not be nearby. Radiological release equipment is not widely available for emergency responders, increasing the risks for the public. This is particularly true for local responders who may be poorly equipped and not trained for radiation accidents.
- Personnel with the needed expertise may not be immediately available.

Any severe accident that exerts a force on the shipping container could result in damage that releases radioactive gases and particles. An engulfing fire that cannot be quickly extinguished can also result in a radioactive release. While the NRC issued [NUREG-2125](#) in 2014, essentially claiming that the risk of harmful doses from accidents such as these is extremely small, a need for emergency response planning still exists.

In the event that an actual release is identified, it is essential for people to quickly move as far away as possible from the accident. Accurate information about the extent of the release may not be immediately available. Emergency responders will summon trained personnel to handle such an incident. There could be a delay before qualified radiological expertise is available to assess the situation. In the absence of detailed information from those in charge of the emergency, the public should put distance between the accident and themselves and seek refuge in a building at some distance away, until more information is available.

4.7d The 2000 Halstead Report

In the [2000 report](#) entitled *Radiation Exposures from Spent Nuclear Fuel & High-Level Nuclear Waste Transportation to a Geologic Repository or Interim Storage Facility in Nevada*, Robert Halstead, Director of Nevada's Agency for Nuclear Projects, evaluated the future routine radiation exposures to the population related to shipping to the Yucca Mountain repository. The Halstead report is probably the most extensive assessment of transportation risks to date and was based on extensive DOE and NRC work cited in the report. Some of the considerations raised in that report are discussed here in the following paragraphs.

i) Exposures and Doses Resulting from Routine Transportation Operations

Halstead noted that the [Sandquist 1985 report](#) to DOE analyzed exposures resulting from routine (non-accident) transportation and focuses on radiation doses received by:

- (A) workers conducting safety inspections of casks and vehicles;
- (B) individuals residing, working, or institutionally confined at locations near shipping routes; and
- (C) drivers and passengers of vehicles in traffic gridlock incidents who may be stranded for an extended period of time near an undamaged shipping cask.

The routine shipments consisted of truck and rail casks containing five-year-old, medium-to-high burn-up SNF. Specific fuel characteristics, cask designs, and cask capacities are less important for estimating routine exposures than the emission rate allowed under NRC regulations, 10 mrem/hour at 2 meters from the cask surface. Cask designs being developed for shipments to a repository assume the 10 mrem/hour emission rate. (DOE considered and rejected the idea of limiting new cask design emissions to 2 mrem/hour at 2 meters, which would have cut the payload for the new truck casks in-half). Sandquist's evaluation proceeded from the 10 mrem emission rate per hour at 2 meters from the cask surface.

A key question will be whether 10 mrem/hour emission rate will be used by NRC and DOE for transportation today or in the future. More assemblies are now being packed in multipack canisters and loaded at higher heat loads, including high burn-up fuel which has 3-4 times the number of curies of low burn-up fuel. Will the fuel being transported today meet the 10 mrem per hour emission rate at 2 meters from the cask surface? Or will these agencies relax the standard? The shipping casks should be tested for their emission rate and the presence of any surface

contamination before leaving a reactor site and comply with the most stringent standards for transport.

ii) Exposures to Members of the Public Residing, Working, or Institutionally Confined at Locations near Shipping Routes

Individuals who reside, work, attend school, or are institutionally confined at certain locations within 6 to 40 meters (20 to 130 feet) of a nuclear waste highway route, or within 6 to 50 meters (20 to 160 feet) of a nuclear waste rail route, could potentially receive yearly radiation doses equal to a significant percentage of, or even in excess of, average annual background doses (nominally 310 mrem). Such exposures could occur under circumstances where:

- (A) residences, workplaces, or certain institutions (especially schools, prisons, or long-term health care or retirement facilities) are located near route features or segments that would require nuclear waste trucks or trains to stop and start again, or travel at very slow speed.
- (B) the number of shipments is high enough, one to several casks per day, that opportunities for exposure occur frequently at the same locations.
- (C) individuals residing, working, or confined at near-route locations are regularly present to be exposed to a significant portion (if not all) of the shipments which occur annually.

Sandquist conducted detailed evaluations related to Nevada routes for shipments to Yucca Mountain, Nevada. Similar work could be applied to other routes elsewhere in the country. Using the PATHRAE model to estimate exposure rates (in microrem/minute) at various distances (in meters) from the cask center, Sandquist specified exposure times (in minutes) and distances (in meters) for various events (such as slow transit through residential areas), and calculated maximum individual exposures (in millirems) per event. We don't provide the detailed results here, but those results should be consulted by those attempting to protect public safety when considering proposed plans for shipping SNF.

It is possible that locations exist along highway routes in Nevada where exposure times could average 6 minutes per truck shipment. It is likely that there are locations where exposure times could average 2 minutes per truck shipment. Depending upon the number of truck shipments and distance from the route, maximally exposed individuals near highway routes could potentially receive annual doses ranging from 6 mrem to 960 mrem, equivalent to 2% to 266% of the average annual background radiation dose for Americans, which was set at 310 mrem at the time of Sandquist's study. Further study of route-specific details is necessary for more precise dose estimates.

It should be noted that buildings themselves provide some radiation dose reduction, especially if concrete or brick. Wood houses provide almost no dose reduction. However, walking outside along the route, shopping, or doing errands would increase radiation exposures.

iii) Rail interchange/transfer points

Estimation of exposures from rail transportation is more difficult, primarily because of uncertainties about service options (dedicated trains versus general freight service), number of casks per shipment, and continuous rail shipment or intermodal transfer to heavy-haul trucking.

Maximally exposed individuals located within 20 meters (66 feet) of rail interchange/transfer points could potentially receive annual doses in the range of 150 mrem, assuming 500 rail cask/shipments per year and an average exposure time of 10 minutes per rail cask received.

iv) Traffic Gridlock Incidents

In response to inquiries from the US NWTRB, DOE personnel in 1990 prepared an analysis which concluded that the maximum dose from a gridlock incident could be as high as 40 mrem (equivalent to 10 chest X-rays). DOE provided the following assumptions to the NWTRB:

Group located 1 meter from vertical plane of trailer

People in vehicles closest to trailer

Gridlock lasts 2-4 hours

No remedial action to move group members

Exposure rate to group, 5-10 mrem/hr

The result was excessive radiation in such a scenario — up to 40 mrem.

v) Severe Accident Assessment

Halstead critiqued the accident modeling done by Sandquist. The modeled accident is a high-speed impact followed by a long-duration, high-temperature fire fed by some external source of petroleum fuel. The inventory of the severe accident involved 14 pressurized-water reactor (PWR) assemblies, 5 years out of the reactor. Total curies are 1,380,000. All SNF inside the cask is assumed to be oxidized, and a pathway created either by a valve failure, failure of the cask closure seal, or a small breach caused by a fine stress crack in the cask shell is also assumed. The impact and burst rupture creates a pathway of only 1 square inch for the release. As a result of the very small pathway, the release amounts to just 4/1000th of the entire inventory or 0.4%, a relatively small hypothetical release. However, the public health impact would be significant.

The Sandquist estimate is that the maximally exposed individual receives 10.2 rem of radiation, and there is no health impact even though the exposure is by inhalation. (Inhalation of alpha particles could cause cancer.) In addition to limiting the size of the radioactive release, Sandquist fails to consider the consequences of the loss of shielding. Though Sandquist modeled water jackets as shielding, borated polyethylene could be used and would slump or melt in a fire and leave the cask partially or totally unshielded in places. Five-year-old SNF from a PWR (pressurized water reactor) has a very high surface dose rate, as high as 25,000 to 50,000 mrem/hour. Workers unaware of the loss of shielding could receive a fatal dose of 500 rem (500,000 mrem) working on the accident.

Halstead also notes that the averaging of exposures across a large population tends to wipe out or hide the fact that some individuals, such as emergency responders and others supervising the shipment, will be exposed to much higher doses. As a result, those maximally exposed receive higher doses and are more likely to develop health impacts. We need to be aware of this when reading and interpreting population-dose estimates, which fail to identify individuals that likely received higher radiation exposures. The risks in the Halstead report may be altered by a number of factors resulting in greater risk.

Current inventory projections for transport will have higher SNF burn-up levels. Larger cask capacities and higher burn-up result in more curies and more gamma and neutron-emitting fission products. Greater cooling time reduces total curies and reduces gamma and neutron emissions from the fission products with shorter (less than ten years) half-lives. As a result, risk may be greater depending on these factors.

Given that DTS technology exists and that several commercial companies offer this technology, it is not unreasonable to deploy this technology in determining whether SNF rods, assemblies, and canisters are degraded after prolonged dry storage or whether SNF components may have been damaged due to an accident. Although cost estimates would need to be procured based on exact requirements, it is unlikely that a DTS component added to a consolidated interim storage (CIS) facility or to a reactor site would significantly increase the already large overall cost of the transportation program. Unfortunately, this technology cannot be rapidly deployed to an accident site due to their extreme weight and need for careful assembly. Following radiological accidents, other means of containing a release are necessary.

4.7e Cask Response to Fire Accidents

In an accident involving fire it is important to consider the temperature limit of SNF casks. The following information was taken from the 2013 [NUREG-2125](#) study, p.71.

“The thermal response of each cask is compared to two characteristic temperature limits: the rated seal temperature (350 degrees C (662 degrees F) for elastomeric seals used in the Rail-Lead cask and the Truck-DU cask and 649 degrees C (1,200 degrees F) for the metallic seal used in the Rail-Steel cask) and the fuel rod burst rupture temperature (750 degrees C (1,382 degrees F) for all casks (Lorenz, 1980)). These temperature limit values are the same as those used in [NUREG/CR-6672](#), *Re-examination of Spent Fuel Shipment Risk Estimates*, for the elastomeric seal and fuel rod burst temperature. The Rail-Steel cask seal temperature limit is obtained from Table 2.1.2 and Table 4.1.1 in the HI-STAR 100 safety analysis report (SAR) (Holtec International, 2000). Section 7.2.5.2 in NUREG/CR-6672 explains that 350 degrees C (662 degrees F) is a conservative temperature limit the spent nuclear fuel (SNF) transportation industry typically uses for elastomeric seals. Section 7.2.5.2 of NUREG/CR-6672 also provides the rationale for the use of 750 degrees C (1,382 degrees F) as the fuel-rod rupture temperature. These temperature limits are used in this study to determine if the cask seals or fuel rods would be compromised under any of the accident scenarios analyzed. If only the seals are compromised, a crud-only release ensues (“crud” is colloquial for “corrosion and wear products”). If the fuel rods and seals are both compromised, a release of crud and SNF constituents would ensue. In either case, the consequences of the release would have to be evaluated.”

The fuel for the fire is proportional to the size of a rail fuel tanker -- 30,000 gallons -- or the tank on a heavy-duty truck -- 9000 gallons. Even though this fuel would not stay in a pool approximately 10 feet in diameter around the cask (it would run off), modeling focused on a 30-minute engulfing fire. Uniform 800 degree C heating is assumed for the cask. Surprisingly, the evaluation assumed that large areas inside the cask would be starting at relatively low temperatures -- 42 to 313 degrees C -- despite the presence of SNF. It was concluded that the leaden rail cask is

capable of protecting the fuel rods from burst rupture and of maintaining containment when exposed to the severe fire environments that were analyzed, even when the neutron-shield material is conservatively assumed to be absent during the fire accident. However, some reduction of gamma shielding is estimated to occur.

Again, from [NUREG-2125](#):

“Nevertheless, no release of radioactive material is expected if this cask was exposed to any of these severe thermal environments because the elastomeric seals did not reach their temperature limit. This ensures the cask is capable of maintaining containment (i.e., preventing any radioactive material from getting out of the package) under any of the fire environments analyzed.”

Two unique assumptions occurred with this analysis. First, the fuel assemblies, fuel baskets, and interior of the casks are assumed to be homogeneous materials. And second, the temperatures assumed for the interior of the casks were relatively low prior to the fire. These two potentially incorrect assumptions could have altered the results of the fire analysis, which showed no effect on the elastomeric seals when they would quite possibly have been degraded. Thus, we have seen multiple fire analyses which assume burning of only the fuel on board a train or truck, roughly no longer than a 30-minute fire. It has been reported that in a Sandia 1970 test the lead shielding melted in a shipping container at the end of 30 minutes and spurted out. (personal communication, Kevin Kamps, of Beyond Nuclear) Given the standard used of just 30 minutes in a fire, in any accident involving fire, workers should assume that loss of shielding is a possibility and take appropriate precautions.

However, even if dedicated trains are employed for SNF, there is not any guarantee that SNF will be free from interactions with a flammable tank car. The NTSB has documented multiple engulfing fires (non-nuclear shipments) that burned for longer than 24 hours. Certainly, it is hoped that the new standards for hazardous and flammable tank cars will be fully implemented on all SNF transport routes.

4.8 Emergency Response

Emergency responder preparedness is an essential element of safe and effective programs for transporting SNF and high-level waste. Emergency responder preparedness has so far received limited attention from DOE, states, and tribes for the proposed transportation program to interim or permanent repositories. DOE has the opportunity to be innovative in carrying out its responsibilities for emergency responder preparedness.

The Environmental Working Group examined potential accident scenarios associated with the transport of high level nuclear waste to the proposed Yucca Mountain Repository. While the Yucca repository project was subsequently abandoned by DOE, the report, “[Marks the Spot: Accident Scenarios](#),” is still relevant today. The report models accident scenarios of moderate severity, as opposed to worst case ones, for a number of US cities as well as a national one.

DOE at the time predicted 100 accidents over 38 years of national transport by rail and truck to Yucca, while the State of Nevada predicted 400 accidents. Radiation, primarily in the form of cesium, escapes as a result of a broken seal in the shipping cask and a subsequent modest fire. A worst-case scenario

involving puncture or penetration of the cask, a severe fire, or a major explosion were not considered in these evaluations.

Transporting high-level nuclear waste was identified as a major security risk and following the September 11, 2001, attacks on NYC and Washington DC, the Secretary of Energy temporarily halted all shipments of high-level nuclear waste.

[Another study in 2001](#) by Radioactive Waste Management Associates (RWMA) for the State of Nevada investigated accidents (p. 12) identified as severe, credible accidents, not worst case ones. This study speaks to a radioactive release that can reach emergency responders at a firehouse, before they learn of the incident and to hotels that aren't advised to shut off building ventilations systems to prevent the internal spread of radioactive emissions soon enough. The economic analysis addresses the high costs of extensive decontamination that can delay cleanup and result in longer-term public exposure and health impacts. The study also identified potential for a rural accident to have widespread impacts -- in this case, contamination of a river that is a drinking water resource.

4.9 Storage vs. Transport?

Transportation is the necessary interface between dry storage of SNF and its placement in a permanent repository, or perhaps a CIS site. This creates a dilemma: continued on-site dry storage presents problems due to the fact that such on-site storage was never designed and built for the long-term while transportation raises its own set of serious risks. Moreover, current dry-storage requirements do not provide for the means to accurately assess the risks in continuing dry storage on-site, and so there are considerable unknowns regarding the status of the SNF across the US and its containment within storage canisters. These unknowns will only increase with time. Transport before degradation of the dry-storage containment is certainly desirable, but by what criteria is that degradation to be judged and what thresholds will be placed? As the SNF now in dry storage ages, it seems evident that thorough monitoring of its condition becomes ever more crucial. This must be balanced against known, and unknown, risks in transportation, and especially in transportation of possibly degraded canisters and contents. Merely moving SNF already in dry storage to another dry storage location without a major change in the conditions of storage, so that they are substantially improved, is highly problematic.

The [NWTRB 2010 Report](#) was specifically geared to addressing long-term storage; but it found a lack of basic information and research, and could not provide needed answers. It recommended significantly increased research. Thus we are left with two imperfect locations for storage and insufficient knowledge to assess the comparative advantages and disadvantages.

In September 2019, the US NWTRB released its report, [Preparing for Nuclear Waste Transportation](#), which identified numerous serious issues that require a significant amount of work, over at least 10 years, to be accomplished. A total of 30 technical issues were identified by the NWTRB for resolution, many of which require significant and lengthy efforts to prepare for safe transportation.

4.10 Guidance

Introduction

The federal government and its nuclear agencies have not produced even a draft plan for the transport of SNF, one of the most hazardous substances known to humans. The loss of containment poses the most serious and likely radiological risks for the public. If transportation of SNF is to be undertaken at all, it requires a comprehensive and detailed plan that has been subject to extensive review and comments. Shortcuts to a legitimate process are not acceptable in a democracy and should provide a large warning sign to elected members of Congress and state and local officials. Numerous recommendations follow.

1. DOE, NRC and DOT must commit to extensive public involvement in transportation planning, including a thorough NEPA (National Environmental Policy Act) review process.

The NRC is currently reviewing applications for two CIS facilities; unfortunately, transportation issues have been separated from the review of the facilities themselves. NEPA requires environmental review of transportation issues. The GAO identified societal challenges as posing the greatest difficulties to overcome in siting CIS facilities or repositories and in planning for transportation. A sustained effort of public involvement is essential to successful and safe transportation. Surprisingly, DOE has not yet focused on the development of detailed transportation plans. In 2018 funding for DOE transportation planning was cut, and a core planning meeting had to be cancelled. The public has not been seriously engaged in transportation planning. As a result there is enormous uncertainty regarding future transportation plans and their adequacy, which demand public input and advocacy.

2. Transportation planning must involve multiple federal, state and local agencies as well as the private sector and members of the public.

A possible model for such a coordinated effort is the work done by the Western Governors Assoc. in planning transport of nuclear waste to WIPP. Transportation also requires experienced personnel since there are multiple, complex safety issues and requirements. Training of personnel for key roles at federal, state, and local levels is essential, in planning routes for safety, in conducting inspections, and in training personnel at all levels for emergency response. Personnel with in-depth understanding of local hazards and areas that must be protected are essential to identify the best transportation routes. The entire process requires a coordinated effort so that all standards and requirements are met, all possible accidents are anticipated, and each agency knows all the responsibilities and capabilities of the other agencies. Local agencies also have knowledge of current projects likely to impact transportation infrastructure; e.g., replacement of a rail bridge, reconstruction of a rail station, a major industrial project affecting local traffic, etc. The public must be engaged early and regularly in these planning efforts.

3. The Public has a “Right to Know” about SNF shipments.

The public's "right-to-know" about potential hazards is embodied in the federal Community Right to Know Act (1986), which supports local emergency planning. This right-to-know includes the public's ability to find out what planning has been done in their own communities to prepare for these shipments and potential incidents. Whether or not the structure in a community involves a Local Emergency Planning Committee (LEPC) or another official body, communities along proposed SNF shipping routes must have the opportunity to be consulted and to give input on specific local conditions and circumstances that should be factored into the planning of shipments. The public along the entire shipping route must be informed of the risks specific to their community and how those risks will be lessened in the finalized plan. This is especially important in communities where emergency responders are volunteers and have limited training regarding hazardous materials.

4. Involved agencies must confirm the use of dedicated freight trains, carrying SNF only and no other cargo.

DOE has contracted for the design and fabrication of rail cars to transport SNF. One rail car will now undergo actual testing. As of June 2020 there is still a need to confirm that freight trains will be dedicated to SNF only. The total number of transport casks on a single train should also be limited.

5. Transportation infrastructure requires a substantial increase in funding to address existing infrastructure repair and replacement. Route choices should be made only after confirming via inspections that the infrastructure for the entire route is in excellent condition.

6. A comprehensive system of accident and incident reporting as well as investigation is needed for all SNF and other radiological shipments, led by the National Transportation Safety Board. Radiological shipments must have an official regulatory system with monitoring, reporting and investigations of incidents and accidents, associated with adverse outcomes.

The system should cover transport preparation/planning/and documentation at a fixed location, transport itself, any transport events or problems, and final arrival at a destination with any significant observations at that time. This reporting system should also involve the use of an emergency number to report accidents and/or incidents and obtain appropriate emergency and technical assistance. Detailed investigation of significant incidents and reporting enables all "Lessons Learned" to be widely shared.

7. Older SNF should be shipped first.

If a Transportation Plan is eventually approved, the Nuclear Waste Policy Act specifies that older fuel should be shipped first and we concur. The National Academy of Sciences Committee study in 2006 generally supported this plan; however, it recommended a "pilot program" involving relatively short, logistically simple movements of older fuel from closed reactors to demonstrate the ability to carry out its responsibilities in a safe and operationally effective manner. DOE should use the lessons learned

from this pilot program to initiate its full-scale transportation program from decommissioned reactors. Moreover, older fuel should be given a priority, because it is less likely to include high burnup fuels, which are more likely to be damaged during transport.

8. Confirmation of the presence of inert gas immediately prior to transport for every canister must be required and certified.

NRC is currently reviewing applications for two CIS facilities. The NRC has indicated that confirmation of the presence of inert gas would be done only upon arrival of a shipment at a CIS facility. This is a dangerous practice that fails to provide in advance for transportation safety. NRC actually requires inert gas as a shipping requirement. SNF in storage at nuclear reactors may have been in dry storage for 20 years or more, and a slow leak may mean little inert gas remains to prevent fuel oxidation and rupture of fuel rods.

9. Potential exterior surface contamination of a shipping cask should be tested prior to leaving the dry storage SNF site.

These exposures are more serious because of the potential to inhale alpha and beta particles.

10. Surface contamination of canisters should be checked by rail lines upon arrival to document cask condition and prevent workers from exposure and accidentally spreading contamination to other rail cars and public facilities.

11. Only stainless steel canisters that have undergone an actual inspection should be eligible for shipment to another location.

Stainless steel canisters holding fuel assemblies are inserted into outer large metal casks for transportation. The only way to do a visual inspection of the exterior of the canister is to remove the canisters from the outer storage casks. This creates a problem because, when the storage cask is removed, so is the radiation shielding. Workers are then exposed to high radiation levels. NRC has permitted ISFSIs to rely on NRC data from surrogate canisters or to inspect one canister on-site as representative of all on-site canisters. This is insufficient for canisters in storage for 20 years or more.

Each site engaged in a shipping campaign could use a Dry Transfer System, a room-sized radiation-shielded facility to remotely inspect the canister prior to shipment. NRC planned for DTSS to be at all ISFSIs, at reactors, and at CIS facilities in its 2014 Continued Storage Rule. This would provide important information about evidence of corrosion or damage to welds. Visual information prior to transfer would provide basic information on canister condition. Unfortunately, at this time there is no satisfactory method to identify microscopic through-wall canister cracks.

12. Safe transportation of SNF must include two NTSB priorities, Positive Train Control (PTC) and the replacement of older tank cars for flammable and hazardous materials.

Both these recommendations have been made by the National Transportation Safety Board (NTSB):

- a) PTC employs a collision avoidance technology that was to be installed by December 31, 2018 for all passenger trains and trains handling hazardous or flammable materials. PTC precisely locates a train along the railroad and enforces signal and speed restrictions. PTC is a proven technology that prevents train-to-train collisions, excess speed derailments, and unauthorized train movement.
- b) Replacement of older tank cars with newer versions provides protection against catastrophic release of hazardous and flammable materials. There is no deadline for this improvement. A deadline of 2025 should be set for full replacement to be complete.

13. Restore electronic braking systems for all trains carrying SNF.

The American Association of Railroads recently removed the requirement for trains carrying SNF (Model S-2043) to have electronically controlled braking systems. The Federal Railroad Administration continues to support the benefits of these braking systems. When SNF is being shipped, all systems must be state-of-the art; and that certainly applies to braking systems.

14. Route choices for SNF should include evaluation of the volume of non-nuclear hazardous materials being transported along a given route and the extent to which the newer tanker cars are in use for these shipments.

Large volumes of hazardous and flammable materials on the same route as SNF shipments should be avoided and the use of only the new safer tanker cars deployed.

15. All rail routes used for the transportation of hazardous materials, including SNF, should receive heightened inspection, repair, and maintenance programs.

The NTSB has called for focused attention on maintenance, inspection, and repair of all routes handling hazardous materials, as well as improved oversight and enforcement. Sierra Club chapters should get clarification that route findings indicate appropriate maintenance, inspection, and repair for all infrastructure. Many rail hubs have extensive storage facilities immediately adjacent to rail lines. Such storage, with its inherent hazards and proximity to active rail lines, should be included in comprehensive inspection reports.

16. Any and all plans for transportation via truck or barge must be developed in detail and available for review by elected officials and the public well in advance of implementation in order to identify hazards, make corrections, and receive input from emergency responders.

17. Security and terrorism risk must be also be incorporated into transportation risk assessment.

Security and terrorism risks and detailed analyses need not be shared with the public, but must be shared with state and local homeland security officials and appropriate emergency response officials.

18. National Security concerns should not be exercised related to the transport of SNF to hinder the public's legitimate "right-to-know", as expressed in the Community Right to Know Act. Basic information about all the terror threats that have been evaluated should be available to the public and their elected officials, along with information about preparedness and appropriate emergency responses.

19. Shipment routes should be considered in a manner that minimizes risks to people and is consistent with the Sierra Club's policies on environmental justice.

This most often means identifying routes away from populated or congested areas and away from locales where traffic stoppages are likely. Documentation related to route selection should include evaluation of area housing, environmental justice concerns as well as other critical environmental concerns, such as storage of hazardous materials.

20. As part of transportation planning, each state/region of the country should develop a Natural Hazard Inventory working with state and local officials related to the transportation of SNF in the region in order to evaluate the risks and safety considerations along proposed routes for SNF.

The natural hazard inventory should include and carefully examine both hazards with well-developed, credible risks, such as earthquake hazards, as well as those that have never been evaluated. Because various transportation routes pose different natural hazards, the analysis of safety in view of natural hazards should be specific to actual corridors and particular risks. Different natural hazards will change with actual points along a route; for instance, a rockslide in a canyon may be a very spatially limited threat affecting only a small portion of a given route, while earthquakes may threaten a much larger portion. Determination of the need for specificity can be regulated in a programmatic manner. Climate change is likely to accelerate the onset and severity of some of these hazards, so it should be considered in safety evaluations.

21. For all credible potential natural disasters along proposed routes, transportation planning should include an analysis of the emergency response and equipment that may be needed.

It is likely that some natural disasters will entail abnormal situations not found with other routine accidents and will present difficult challenges to responders. Nonetheless planning should include an effective response to any potential situation

22. The evaluation of natural hazards in any particular area of the US must include not only the likelihood of any of these events for that area, but also whether there will be adequate warnings, in order to stop the transport or to alter the transport schedule and to advise residents of their next action.

For instance, following the large 2018 fires in California, officials and weather forecasters were warning of mudslides in the burned areas when heavy rains were expected. Hurricanes usually have ample, days-long warnings. However, earthquakes and tornadoes usually occur with no or limited warning.

23. Additional research on High Burnup Fuel (HBF) should be conducted to increase confidence that transportation will not damage fuel rods.

HBF research should address the comments of the 2010 NWTRB study and provide a firm foundation for future decision-making. This research is urgent as NRC is considering future use of even higher burnup fuels than those that are presently used.. The [NWTRB in 2010](#) voiced serious concerns about the fundamental lack of knowledge about HBF as well as the nation's current reliance on research information based solely on a single examination of low-burnup fuel. As a consequence, the NWTRB made extensive recommendations for more research on HBF including ongoing inspection and monitoring by opening canisters to observe fuel assemblies and cladding for any signs of degradation. The necessary research has not yet been undertaken. Instead NRC has approved increased uranium enrichment to aid the economics of small modular reactors.

24. It is especially important to study HBF and cladding with high oxides and hydrogen content to understand embrittlement of cladding that may result in damage during transport.

25. Initial transport of SNF should be limited to low-burnup fuel (LBF) exclusively for the first 8 years or so. This limitation should include not permitting the mixing of LBF and HBF in the same shipping canister. Both limitations should be subject to additional research being conducted on HBF, but it must first be launched.

GAO reported in 2014 that “DOE officials stated that their strategy would not involve transportation of large amounts of high burn-up fuel until at least 2025 and that, even then, there is likely going to be enough low-burnup fuel to ship for the first several years, giving more time for the research (on HBF) to yield results.” ([GAO report 15-141](#)) Transportation planning could take a decade. The nation could thus postpone the transport of HBF to enable additional research to be completed, including internal inspection of fuel assemblies as recommended by the NWTRB in 2010.

26. Containment of radioactivity is a vital issue during transportation. This is particularly important for HBF, given that the fuel is more brittle and it contains 3-4 times as many curies as low-burnup fuel (LBF). (See [Alvarez Memo dated Dec.17, 2013](#)).

The NRC and DOE need to substantively address the implications of weakening defense-in-depth by allowing non-leak-tight containment. The magnitude of potential radiological releases during transport should be calculated for HBF and the public health impacts evaluated.

27. Defense-in-depth is essential, not optional, for transportation. Redundant containment barriers are necessary for transport, including for damaged fuel.

The NRC has advanced a plan to eliminate defense-in-depth for radioactive containment prior to the development of a massive national transportation plan for SNF. ([Draft NUREG -2224](#)) This plan must be reconsidered and withdrawn.

28. State and local health departments should be engaged in evaluating potential health exposures from radiation along the transportation route, providing recommendations to limit

routine exposures, and identifying the equipment and personnel needed in the event of an accident and making certain such equipment is available 24 hours a day and 7 days a week.

Routine expected exposures from transportation from gamma rays or “radioactive shine” are relatively small doses. At 6.5 feet from the shipping cask this amounts to 10 mrem per hour, a relatively small dose. Most members of the public will not even be that close to the cask. A situation could occur with an SNF train and a roadway, where both are affected by a traffic halt. Those managing the traffic situation could direct car passengers closest to the cask to leave their vehicle and wait at a greater distance (20-30 ft.) until traffic is freed up in order to reduce exposures.

29. Additional equipment should be staged at regular intervals along the route to enable emergency responses within a reasonable time frame.

Most SNF shipping campaigns will be relatively long term. As a result, in order to accommodate other freight and passenger trains, SNF may not be moved every day. Planning for adequate emergency response equipment would involve coordination with other states and localities to plan for and stage appropriate equipment at regular intervals to enable a response within a reasonable time period.

30. A set of basic emergency and protective equipment should be carried on one of the buffer cars surrounding the SNF railcar.

A railcar carrying SNF will have 2 buffer cars -- one on each side of the SNF rail car. Emergency contact numbers, required paperwork, and protective equipment could be carried on one of the buffer cars.

31. Since many rail lines are used for freight as well as passengers, basic information cards and posters should be made available explaining radioactive waste transport, what they should expect to see, and what to do if their rail car is parked adjacent to a rail car with a SNF cask for any length of time.

If a passenger rail car is halted adjacent to an SNF cask, the message to passengers should instruct them to relocate to other rail cars with available seats with priority given to pregnant women, infants and children. It is anticipated that traffic delays will occur especially in congested areas.

32. Satellite monitoring of the SNF train should be considered in addition to planning for redundant communication capacity to enable rapid response for an emergency.

33. In the event of a transportation accident, a key priority is providing information to the public so they can take appropriate action to protect themselves.

Of the many accidents that might occur, two situations have the potential to be serious: 1) release of radioactive contents from a damaged transport cask; and 2) a fire or threat of a fire, which could

lead to a radioactive release. A rapid response is important, however accurate assessment may be difficult and the necessary equipment and personnel for the situation may take time to arrive.

Local emergency responders can immediately provide essential information about the possibility of a release and advise the public to put substantial distance between themselves and the accident, if appropriate. Sheltering in place for nearby homes and businesses should include closing windows and doors and shutting off ventilation systems to prevent radioactive exposures inside buildings. Prior identification of community emergency shelters can also facilitate moving the public away from harm.

34. We join the US NWTRB in recommending full-scale testing of transportation casks in likely accident scenarios.

The Nuclear Waste Technical Review Board believes modeling and less-than-scale tests of potential accidents do not provide sufficient information to ensure that cask integrity will be maintained. As a result, the risk to the public from accidental releases may be underestimated by Federal agencies and the industry. (See recommendations in the [NWTRB 2010 Report](#), p. 16 and 123.)

35. In the event of a radiation release, the public should be evacuated from the area, putting substantial distance between the accident and potentially exposed individuals. Covering the mouth and nose will reduce inhalation of radioactive particles.

In the event of a radiological release, radioactive emissions will increase, and workers accompanying the shipment should be able to monitor emissions and identify the increased emissions as a release.

36. Following a radiation release, the public should receive detailed information about the doses received by workers and various members of the public, based on their individual circumstances.

A population-based average radiation dose estimate does not supply adequate information for those maximally exposed to the release. Averaging the exposure across the population of a town does not tell us anything about those most exposed. It is necessary to know the highest doses received and how many people were exposed at that level.

37. Dry Transfer Systems aka Hot cells are needed at all SNF dry storage facilities to conduct inspections prior to transport. They are also needed at CIS facilities to be prepared for possible adverse events such as the arrival of damaged SNF containers, or a radioactive leak.

Some industry and government plans for CIS facilities make the assumption that nothing will ever go awry, despite plans to transport large quantities of very hazardous SNF and despite their own record of documented adverse handling of SNF.

Even if adverse events occur with only 1 in 1,000 shipments, preparation for adverse events should include DTSSs. There is no way to know how frequently adverse conditions and events will arise,

where containment of the SNF has been compromised posing a threat to local communities. In addition, given the lack of a substantial knowledge base related to HBF, it may arrive in a severely damaged condition, requiring the use of a DTS, because “return to sender” would pose significant increased hazards to the population along the route.

38. Given the diverse background of emergency responders and the unique hazards posed by radioactive materials, it is critically important to plan for the necessary emergency response training along transportation routes well in advance of actual transport of SNF.

Emergency responders have various types of training backgrounds -- police, fire, and medical personnel -- in addition to full-time employees versus volunteers. This wide variation in backgrounds becomes more acute when considering incidents involving radioactive materials. Understanding of radioactive materials by first responders is limited. This situation must be adequately recognized by transportation planners in order to plan for the necessary training well in advance of actual transport of SNF.

39. Detailed plans for a rapid response should be developed for a critical event in which radiation is released.

Response time is far more critical in the event of a radiological release than in other types of accidents, so plans must be developed that enable an immediate response.

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Section 5 - Community Engagement and Informed Consent

5.1 Introduction to Consent-Based Processes

The "right to informed consent" is among the Principles of Environmental Justice adopted in 1991 at the First National People of Color Environmental Leadership Summit. Informed consent should be utilized in public decisions regarding the transportation and storage of extremely toxic and long-lived radionuclides in spent nuclear fuel (SNF) from nuclear power plants and in other high-level wastes

(HLW) from other nuclear activities. We narrow our focus on “informed consent” and what exactly it means in the context of a highly technical national problem that presents significant risks for public health and catastrophic damage.

In order for the public to give “informed consent”, it is necessary that extensive details about the project must be available to the public, including the inherent hazards and the regulatory requirements that will isolate radioactive materials from humans and the biosphere for millions of years. The government must provide a long-lasting guarantee that adequate safeguards will be employed and, if those safeguards fail, the government will step in to reinforce or improve those safeguards to protect public health and safety.

We realize that consent was not often sought from US citizens in the siting of nuclear power plants and their associated cooling pools and dry-storage areas although the risks of such nuclear facilities were often pointed out. Nuclear energy was a national policy goal, and the nuclear industry grew around that with little emphasis on explaining the risks and gaining acceptance on the basis of clear, full knowledge. Indeed, most citizens were never asked in any meaningful way to consent to the building of nuclear power plants or storage. Licensing of dry-storage areas has been especially problematic as the life of these facilities will, in most cases, go beyond their original licensing period with no permanent storage solution in sight. Risk, growing incrementally with time, has had no process of consent to lessen it.

Most of the public is familiar with informed consent as applied to medical, legal, and sexual issues. Normally, these involve only one or two individuals; but large groups, as in medical trials, may be involved, in which cases each individual expresses consent. The extension to nuclear waste transportation and storage is reasonable, but there are practical considerations. One needs to examine how exactly it is applied, or intended to be applied: by representative government decisions, by individual consent forms, by popular vote, etc. The exact instrument of consent may skew that consent or even make it meaningless. What would fully informed and properly executed consent look like for nuclear waste? The US has some case histories involving consent at some level, and we examine them below.

5.2 Available Literature

A number of excellent articles, white papers, and government documents exist on the subject of consent for SNF. We do not aim to repeat or summarize that material here. We simply provide here a possible reading list, annotated briefly, of recent work. The articles here are chosen to be after the report of the Blue Ribbon Commission in 2012, and they contain many references to earlier work.

[Report of the Blue Ribbon Commission on America’s Nuclear Future, 2012. Chapter 6: A Consent-Based Approach to Siting and Developing Future Facilities for Nuclear Waste Management and Disposal.](#) This part of the report focuses on consent issues and how to develop a meaningful consent process.

[Designing a Process for Consent-Based Siting of Used Nuclear Fuel Facilities – Analysis of Public Support, 2012.](#) Published in *The Bridge*, a National Academy of Sciences publication, this article discusses surveys of the public on the issues of consent surrounding SNF.

[Informed consent: What communities need to know about interim nuclear waste storage, 2016.](#) This article in the *Bulletin of Atomic Scientists* addresses many issues surrounding both interim and permanent SNF storage and refers to the Blue Ribbon Commission’s report.

[Response to DOE’s Invitation for Public Comment To Inform the Design of a Consent Based Siting Process for Nuclear Waste Storage and Disposal Facilities, 2016.](#) This Natural Resources Defense Council (NRDC) comment letter was intended to provide input to the preparation of the DOE 2017 consent-based siting draft. It is rather thorough on history and status of a consent- based process for SNF.

[Real Consent for Nuclear Waste Management Starts with a Free Market, 2016.](#) This article in *The Backgrounder*, a Heritage Foundation publication, gives a free-market view of SNF consent- based solutions while pointing out the failures of consent approaches thus far.

[Department of Energy Draft: Consent-Based Siting Process for Consolidated Storage and Disposal Facilities for Spent Nuclear Fuel and High-Level Radioactive Waste, 2017.](#) This is essentially the DOE’s response to the Blue Ribbon Commission’s Recommendations and was opened for public comment. The status in 2020 is uncertain.

[Reset of America’s Nuclear Waste Management: Strategy and Policy, 2018.](#) This report from Stanford U. contains a sizable chapter on consent-based siting of nuclear waste.

5.3 World Survey of Consent Regarding Nuclear Waste

The following table was compiled from information available on the website of the [World Nuclear Association](#). For 18 countries with multiple nuclear power plants, it summarizes the status of long-term and interim storage of SNF and whether consent was required or not. A “yes” or “no” for consent in each case takes a fair amount of explanation, but in all the “yes” cases, there was a multiyear process to obtain consent; and they can be considered as informed consent, although with reservations. The degree of consent (majority, unanimity, etc.) and the means of executing consent varies with country.

long-term and interim spent nuclear fuel policies – 2018@

country*	number of reactors^	long-term storage			interim storage		
		long-term storage method	site identified	consent required	consolidated interim storage	site identified	consent required
Belgium	7	geologic repository	no	TBD	no	N/A	N/A
Canada	19	geologic repository	no	yes	no	N/A	N/A
China	36	geologic repository	no	no	yes	yes, Lanzhou, in use	no
Czech Republic	6	geologic repository	no	TBD	no	N/A	N/A
Finland	4	geologic repository	yes, Olkiluoto	yes	no	N/A	N/A
France	58	geologic repository	yes, Bure	no	N/A#	N/A	N/A
Germany	8	geologic repository	no	yes	yes	yes, Gorleben, in use	no
India	22	TBD	N/A	N/A	no	N/A	N/A
Japan	43	geologic repository	no	yes	yes	yes, Mutsu, in use	no
Korea (South)	25	geologic repository	no	yes	yes	no	no
Russia	36	geologic repository	yes, multiple	no	no	N/A	N/A
Spain	7	geologic repository	no	TBD	yes	yes, Villar de Canas	no
Sweden	10	geologic repository	yes, Forsmark	yes	yes	yes, Oskarshamn, in use	no
Switzerland	5	geologic repository	no	no	yes	yes, Würenlingen, in use	no
Taiwan	6	TBD	N/A	N/A	no	N/A	N/A
United Kingdom	15	geologic repository	no	yes	yes	yes, Sellafield, in use	no
Ukraine	15	geologic repository	no	TBD	no	N/A	N/A
United States	99	geologic repository	yes, Yucca Mt.	no	no	no	yes
@majority of information taken from World Nuclear Assoc. website at http://www.world-nuclear.org/information-library/country-profiles.aspx							
* only countries with > 4 nuclear plants considered here, except Finland							
^ IAEA, 2016							
# France uses reprocessing, and reprocessing sites are somewhat like consolidated interim sites							

5.4 History of Consent-Based Approach to Nuclear Waste in US

5.4a 1987 Nuclear Waste Policy Act Amendments and aftermath — Yucca Mountain, NV

In 1987 the Congress passed an act which designated Yucca Mountain, NV to be studied as the sole permanent repository for SNF from commercial reactors in the US. A meaningful consent process was avoided, but the act allowed the Governor of Nevada to “veto” the repository, subject to a subsequent nullification by Congress. President Bush recommended to Congress that Yucca Mountain be developed as the SNF repository in 2002. Nevada exercised its veto in that year, but it was overridden by Congress also in that year. Preparations for developing the repository continued until 2010 when President Obama removed all funding for it in the budget. In the context of this guidance, Yucca Mountain was not a consent-based process.

5.4b Blue Ribbon Commission of the DOE and followup

President Obama, upon defunding Yucca Mountain, set up the *Blue Ribbon Commission on America’s Nuclear Future*. It was managed under the Department of Energy and released a comprehensive report in 2012. One chapter of the BRC report took a pragmatic and considered approach: “Experience in the United States and in other nations suggests that any attempt to force a top-down, federally mandated solution over the objections of a state or community—far from being more efficient—will take longer, cost more, and have lower odds of ultimate success.” They proposed an approach honoring 6 principles (Chapter 6), the first of which is “consent-based”.

To follow up on the BRC’s recommendations, the DOE developed a draft document (referenced above) elaborating on the principles and suggesting how they can be implemented and inviting comments in 2017 from individuals and organizations. Many hearings regarding a consent-based process were held around the US based on the draft document. The current status of this 2017 draft is unknown.

5.4c 2018 Congressional legislation

The 2016 election brought a new federal administration along with Republican majorities in both houses of Congress. Contrary to the previous administration, this Congress was eager to get Yucca Mountain licensed in order to receive SNF from the nation’s nuclear power plants. The House passed HR 3053 (Nuclear Waste Policy Amendments Act of 2018); but the Senate did not pass a companion bill in 2018. This bill did not impose any new consent-based process on the licensing of Yucca Mountain, NV as the permanent repository. However, the bill does allow the construction of Monitored Retrievable Storage sites (MRS; aka, Consolidated Interim Storage, or CIS), but only if the Governor of the affected state and the host community in which it will reside give approval.

There is the pertinent case of the proposed CIS in New Mexico in 2020 where the proposed facility is

only a couple miles from the Texas border. Any serious problem at the facility could affect Texas as well as New Mexico. Logically, adjoining states should be part of the consent process.

5.4d Other Congressional Options

Another option that has been put forward by NRDC is to give the EPA, and by extension the states, authority to regulate nuclear waste under the Resource Conservation and Recovery Act (RCRA).

5.5 Cases Where Consent Was (Questionably) Given in US to Store Nuclear Waste

5.5a Skull Valley Band of Goshute (Utah)

The Skull Valley Band of Goshute signed a lease with Private Fuel Storage, LLC (PFS) in May 1997 to allow them to develop a monitored retrievable storage (aka, CIS) site for SNF. This implies consent on the part of the Band, but this is controversial and has been discussed at length in the [media](#). There are apparently no actual records of the Band's proceedings prior to the lease signing in 1997. Initial application to the Nuclear Regulatory Commission (NRC) was made by PFS in 1997 for a license to build and operate the facility. The NRC actually issued a license to PFS to build the site in February 2006.

The Bureau of Indian Affairs (BIA) conducted an EIS on the project, and the FEIS was issued in December 2001. The BIA Record of Decision (ROD) was issued in September of 2006 and disapproved the project and took the no-action alternative, effectively cancelling the project approved by NRC. The Bureau of Land Management (BLM) was also involved in that rail lines would need to be constructed over federal land.

The ROD makes note of the large economic benefits that would flow to the Band from the lease of land, but they took the paternalistic stance of “... we conclude that it is not consistent with the conduct expected of a prudent trustee to approve a proposed lease that promotes storing SNF on the reservation.”

The validity of the lease itself has been questioned. Some have claimed that the General Council of the Band never approved the lease which was “authorized” by 3 tribal officers, including the Chair. Members of the Skull Valley Band filed many judicial complaints and appeals against the process by which the lease was made. The Confederated Tribe of Goshutes opposed the lease through resolutions. Tooele County signed an agreement with PFS to provide law enforcement services, but there was never any formal county resolution in favor of the MRS. The State of Utah took various actions in opposition to the proposed MRS. The newspaper referenced above points out that Utah really had no oversight because the Goshutes are a sovereign tribe.

The 2012 Blue Ribbon Commission seemed to open up the option of MRS to sites where the constituents consent to the storage. In 2012 though, [Utah media](#) reported that PFS abandoned their NRC license and that therefore the quest for the site on Goshute land was moot.

5.5b Waste Isolation Pilot Plant (WIPP, New Mexico)

The history of the Waste Isolation Pilot Plant (WIPP) can be found in the [Wikipedia article](#) or at the [website of Citizens for Alternatives to Radioactive Dumping](#). The most comprehensive history of WIPP from 1971 to 2001 is the book *Nuclear Reactions: The Politics of Opening a Radioactive Waste Disposal Site* (Chuck McCutcheon, 2002, U. New Mexico Press). Only highlights of the history are given here, especially in relation to the issue of consent.

In 1972, after the first proposed radioactive disposal site in Lyons, Kansas was rejected by state officials, a group of Carlsbad leaders (with no public notice or information) invited the Atomic Energy Commission (AEC) to examine southeastern New Mexico. In 1974, the AEC chose a site about 30 miles from Carlsbad. In 1975, that site was abandoned because of technical problems, and a new site was chosen about 26 miles from Carlsbad. Initially sought as a repository for all nuclear waste and promoted by the Department of Defense and Atomic Energy Commission to receive military waste, WIPP was explored in the 1970s. It was located in the Salado Formation salt deposits of the Delaware Basin of southeast New Mexico near Carlsbad. No legal, meaningful, consent requirements were set forth in the initial stages.

In response to concerns of public officials and citizens expressed at the time, in 1978 then Department of Energy (DOE) Secretary James Schlesinger even promised to let New Mexico have a chance to veto WIPP and to put the facility under NRC licensing. But Public Law 96-164, Section 213, authorized by Congress in 1979, constituted WIPP as “a defense activity of the Department of Energy...for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes...”. (Note: “radioactive” here is to be equated with transuranic elements, which are physically defined as those with atomic numbers 93-103 on the periodic table.) As a result, the state’s veto power was stripped as well as any licensing responsibility by the NRC. The law provided that the DOE Secretary would enter into a consultation and cooperation (C&C) agreement with the State. In 1981, after failing to negotiate such an agreement and to prevent construction of the first WIPP shaft, then Attorney General Jeff Bingaman filed a lawsuit on behalf of New Mexico. The suit was settled with the signing of a C&C agreement.

In October 1991, then DOE Secretary James Watkins announced that WIPP would open imminently. New Mexico Attorney General Tom Udall, the Texas Attorney General, three congressmen, and four citizen organizations sued to prevent WIPP’s opening. The federal district court judge ruled in favor of those bringing the lawsuits and enjoined WIPP’s opening.

In 1992, Congress passed the WIPP Land Withdrawal Act (Public Law 102-579), which required: that

WIPP comply with numerous environmental laws, including the Solid Waste Disposal Act (which requires a State of New Mexico permit); that EPA certify that WIPP would meet its 10,000-year disposal regulations; and that the volume of WIPP be limited to 6.2 million cubic feet of transuranic (TRU) waste.

TRU was defined by the WIPP Land Withdrawal Act of 1992 as

"...waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste with half-lives greater than 20 years, except for (A) high-level radioactive waste, (B) waste that the Secretary of Energy has determined, with concurrence of the Administrator of the Environmental Protection Agency, does not need the degree of isolation required by the disposal regulations, or (C) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with part 61 of title 10 Code of Federal Regulations (CFR)."

The 1992 Act brought the EPA into the discussion and provided for additional safeguards but did not return veto power to the state of New Mexico. In 1980, 1990, and 1997 DOE issued environmental impact statements, after much public comment and opposition. The State of New Mexico was then given a certain amount of oversight regarding the waste. Further Congressional action in the 1990's served to weaken the protections for the facility and to heighten citizens' concerns.

In 1998 EPA certified that the project complied with EPA standards (40 CFR 191, subparts B and C). The first shipment of TRU waste went from Los Alamos National Laboratory to WIPP on March 26, 1999, amid protesters along the route, and before the WIPP permit was formally issued.

No formal consent agreements were ever signed by New Mexico, and the state role was reduced to consultation and cooperation by the federal government. In 1981 the Attorney General of New Mexico and the DOE signed a [Consultation and Cooperation Agreement](#), which was part of a judicial settlement in response to a suit by the State of New Mexico. This document is taken by some to represent "consent" on the part of the state. Yet, in the judgement document, the state did not waive its right to bring further suits concerning WIPP. All the while, the City of Carlsbad officials continued to express formal, unwavering support for WIPP, much in the way that Nye County, Nevada has expressed formal consent to the Yucca Mountain repository. Carlsbad received sizable funding from DOE over the years, much of which went to projects unrelated to hosting of WIPP.

As of 2020, [WIPP has received over 12,000 shipments](#) of TRU waste by truck conveyance and emplaced about 3.35 million cubic feet of waste (54 percent of the legal capacity limit). A major fire accident occurred on February 5, 2014 at WIPP and a second explosion of a waste container on February 14, 2014, resulting in radiation exposure to 22 workers on the surface. The cost of the accident cleanup grew to at least \$1B and called into question the safety of the facility.

Investigation of the accident revealed that several regulatory safeguards had been systematically removed as cost-cutting measures. The final error, which was the proximal cause of the accident, was

the approval of “organic kitty litter” to be mixed with radioactive waste. This created an incompatible, reactive mixture which led to the explosion and worker exposure. That erroneous decision was made by one of our premier national laboratories involved with nuclear materials.

WIPP was, however, reopened after 3 years with plans to install a new ventilation system. The facility is slated to be closed sometime between 2025 and 2035; and it is predicted that, due to salt-formation creep, the waste will be completely isolated from the environment after 75 years. Long-term containment of nuclear wastes in salt formations still has uncertainties, and a [2012 report commissioned by the NRC](#) elaborated on remaining concerns.

Many observations on the development of public opinion in regard to WIPP are available. A notable one presented by [Sandia National Labs](#) in 2015 gives “Lessons Learned” from the long, tedious path to implementation of WIPP. One of the process faults pointed out with WIPP was that, from the beginning, the science was goal-oriented towards approving WIPP rather than being fully inclusive of alternatives, risks, and public-safety considerations. It should be added that there was no real “consent-based” element to that process and that this continues to be true.

5.5c Nye County, Nevada and Proposed Yucca Mountain Repository

With the 1987 Nuclear Waste Policy Amendment, the US Congress designated Yucca Mountain, Nevada, as the single site for the nation’s high-level nuclear waste (SNF) from commercial power reactors. This started an intense program to characterize the repository as to its suitability and safety.

While the governors of the State of Nevada and the Nevada delegation to the US Congress have consistently opposed the Yucca Mountain repository, Nye County, Nevada, the site of the repository has gradually taken a contrary view. Resolutions by the Nye County Commission through the late 1980’s and the 1990’s recognized that the repository was being located in their county without giving explicit consent. But starting in the 2000’s, the commission became more favorable to the repository; and a resolution adopted in 2007 (#2007- 48) clearly stated that Nye County was in support of Yucca Mountain. These county commission resolutions were not backed by any voter polls or ballot referendum. All along Nye County was receiving funds to participate in the scientific study of Yucca Mountain through the county’s Nuclear Waste Repository Project Office. Additional funds were also received by the county from DOE for improvements not directly related to Yucca Mountain.

The Yucca Mountain Project was defunded by President Obama in 2010 and the licensing procedure was halted. In 2011, the Nye County Commission called for NRC to restart the licensing and even started a lawsuit to force NRC to do that. The Commission issued a very positive “consent” letter to the DOE on March 6, 2012. The letter said “Nye County, Nevada hereby provides notice to you, the Secretary of Energy, that we consent to host the proposed repository at Yucca Mountain...” Again, these county commission initiatives are not backed by any voter referendum.

In 2017, the US House of Representatives took up legislation to restart the relicensing procedure for

Yucca Mountain; and the Nye County Commission again sent a letter to Congress on February 12, 2018, urging them to fund the Yucca Mountain licensing process.

It is not apparent from the record in Nye County that there has been a referendum on the Commission's consistent stance in favor of the repository. The fact that Nye County has benefited monetarily from its "consent" may have swayed many; but this should not be taken as informed consent on the issues surrounding safe, permanent storage of high-level nuclear waste. Certainly, consent in Nye County does not meet the criteria put forth by the 2012 [Blue Ribbon Commission on America's Nuclear Future](#) due to lack of engagement by DOE, to lack of meaningful public discourse, and to lack of any referendum on the issue.

Of importance to the discussion of consent for a nuclear-waste depository in Nevada is the [role of the Western Shoshone Nation](#). They have opposed the Yucca Mountain Project on the basis of historic treaties, cultural issues, and environmental concerns. In the Ruby Valley Treaty of 1863, the Shoshones did not actually cede any land to the federal government, only certain uses. A "land settlement" was made by [US Congress in 2004](#), a highly disputed authorization of payments to the Shoshones. Most Shoshone still claim sovereignty over Yucca Mountain and have therefore been very active in resistance to its development. As recently as 2019, the Shoshone Nation has conducted an [organized protest over Yucca Mountain](#). Clearly, consent for Yucca Mountain disposal of HLW has not been obtained from the Western Shoshone Nation.

5.5d Secret High-Level Nuclear Waste Shipments to Nevada

In the fall of 2018, it was brought to light that the [DOE had shipped plutonium](#) to the Nevada National Security Site (formerly the Nevada Test Site). Whether this was done "secretly" is a matter of semantics. This was done while the state was engaged in a lawsuit with the DOE over whether to allow the shipment and while the state thought it was dealing in good faith with the department. Nevada had not given consent to such shipments, although apparently no law requires such consent. However, the effective secrecy of the shipment undermines DOE's credibility in any sort of development of consent-based approaches to deal with the nation's SNF stockpile.

A second revelation of concern made by DOE was covered in a [Las Vegas Review-Journal article](#) in 2019. It was revealed that nine shipments to the Nevada National Security Site over a period of six years had high-level waste mistakenly labeled as low-level waste. Whether deliberate or accidental, the labeling allowed these shipments to come in without the normal safety scrutiny applied at the site. Nevada has not "consented" to such shipments. Regardless of whether consent was required, the mislabeling incidents strongly affect Nevada's perception of DOE operations.

5.5e Transportation of Highly Enriched Liquid Uranium from Chalk River, Canada to Savannah River Site in South Carolina

In 2017, the [DOE authorized the shipment](#) of liquid high-level radioactive waste from the Chalk River

facility in Canada to the Savannah River facility in South Carolina in over 100 truckloads. High level radioactive waste in solid form had already been shipped in the US many times previously. The liquid-form shipments contained highly enriched uranium that presented both leakage and criticality concerns. Community organizations in Canada and the US were extremely concerned about the safety of these shipments, but were given little information and almost no say in the approval process. Members of the public never gave consent to this potentially dangerous transportation plan. The environmental basis of the DOE approval of these shipments rested on a [short Supplementary Analysis](#) (SA), when an Environmental Assessment (EA) or a full Environmental Impact Statement (EIS) was more appropriate under NEPA. An SA was written by DOE; but, according to DOE regulations, it does not have to be circulated even to appropriate federal agencies and no public notice or comment period is required. The purpose of the SA is for the agency to decide whether they needed to do an EA or EIS.

A legal challenge in 2017 regarding the absence of relevant NEPA analysis was not successful. This was a severe loss for informed consent.

5.6 Where is the US on the Issue of Consent Now?

For over a year, the DOE conducted formal hearings around the country about consent-based siting for interim and final storage of SNF, asking for public comments about consent. These meetings resulted in a [draft report](#) on consent-based siting. Unfortunately, DOE never reported its final findings on consent-based siting. Instead, NRC and DOE have opted to work directly with commercial entities interested in siting nuclear waste facilities; i.e., CIS sites in New Mexico and in Texas. Consent from local communities and their public officials has not been a priority.

With the failure to site any long-term or intermediate-term facility for SNF from commercial reactors in the US, the action of the 2018 US Congress seems intent on bypassing once again public consent in this important siting process. The most recent group to examine consent-based siting is Stanford University with their above-mentioned 2018 [“Reset” report](#). In that report, it is claimed that (p. 62):

“For a consent-based siting process to succeed two conditions must be met:

- The implementer and the regulator have to establish strong bonds of trust with the local, tribal, and state governments involved and have to sustain that trust for many decades as development moves from scientific and engineering studies in support of siting through operations to closure.
- An effective mechanism has to be put in place that allows local, tribal, and state governments to exercise decisive decision-making power throughout the repository- development program.”

The “Reset” report makes strong and clear recommendations for developing a true consent process for placing high-level nuclear waste in a permanent disposal site or at an interim-storage site. True consent is treated well in the Reset report. However, readers should carefully consider some of its other recommendations such as a nuclear utility-owned implementing organization for nuclear waste

management. Canada has a utility-owned implementing organization for nuclear waste management, and it is called the [Nuclear Waste Management Organization](#) (NWMO). They intend to develop a deep geologic repository for SNF and started the site selection process in 2010. It remains to be seen whether a utility-owned organization will implement the “Reset” report consent recommendations.

Perhaps the most important takeaway here is that true consent is a long process, not just a single instance, but working through many stages. The authors call this “continuous engagement”. The DOE has made attempts to define a consent-based policy (see the DOE 2017 draft report referenced above), but this effort has been largely subverted by recent proposed federal legislation which does not advocate a consent-based process ([HR 3053](#), 2018). Furthermore, in the opinion of the “Reset” authors, the DOE earlier draft report falls short of developing a true consent process.

5.7 Radiation, Nuclear Materials & Waste Occupy a Unique Status Related to Environmental Protection

Essentially all things nuclear were exempted from federal and state environmental regulatory authority under the Atomic Energy Act and the Nuclear Waste Policy Act. Weak safeguards for nuclear waste and the release of radiation to our air and water have resulted in numerous failures across the nation that are documented extensively throughout this document. A lack of accountability and transparency by our nuclear agencies, principally DOE and NRC, has resulted in further environmental degradation and in a public unable to trust future processes or promises.

Informed consent must be directly connected to the required safeguards that address the magnitude of the hazard and the length of time the hazard will be in place. SNF poses extraordinary hazards for extremely long time periods, necessitating isolation from humans and the environment for up to millions of years. Given the duration of that level of hazard, extreme caution is necessary in the moving or siting of high-level nuclear waste.

Sierra Club and other leading environmental advocates believe that a valid consent process can only be achieved if the exemption for nuclear radiation is removed from environmental regulatory authority at the federal and state levels. This would then bring in the EPA to act as an independent agent in assessing important safety concerns.

5.8 Meaningful Community Engagement and Consent

Across the country, communities are host to nuclear generating plants, stockpiled nuclear waste, stored waste, or to waste transported through them. Almost none of these communities had meaningful, if any, involvement in the decisions to locate the waste in their midst and thus subject them to the associated, ongoing, and serious public health and safety risks.

All communities in a wide area near a nuclear waste storage site should have information about the risks posed to them from the nuclear waste stored there, and ongoing access to monitoring and reporting on the management of the waste and any risk management issues and incidents. Communities should be informed through local government agencies, tribal councils, traditional media, and via the internet and social media to provide clear and complete information.

All communities over a wide geographic area should have the opportunity to engage in decision-making around planning for and installation of consolidated interim storage of nuclear waste locally and/or any transportation of the waste through the community to storage in another location.

Any impacted community for which there is consideration of locating an interim or permanent nuclear waste storage facility to accept waste from other locations must have full and complete opportunity to engage in decision-making on all aspects of the proposed project. This decision-making should be informed by the recommendations (pp. 47-48) of the [Blue Ribbon Commission of 2012](#); i.e., that the process is [taken verbatim]:

- "1. Consent-based—in the sense that affected communities have an opportunity to decide whether to accept facility siting decisions and retain significant local control.
2. Transparent—in the sense that all stakeholders have an opportunity to understand key decisions and engage the process in a meaningful way.
3. Phased—in the sense that key decisions are revisited and modified as necessary along the way rather than being predetermined.
4. Adaptive—in the sense that the process itself is flexible and produces decisions that are responsive to new information and new technical, social, or political developments.
5. Standards -- and science-based -- in the sense that the public can have confidence that all facilities meet rigorous, objective, and consistently-applied standards of safety and environmental protection.
6. Governed by partnership arrangements or legally-enforceable agreements between the implementing organization and host states, tribes, and local communities.”

5.9 Guidance

1. No way forward without meaningful consent.

Given that we already have one example of a consent-based siting (Finland), such a process, tailored to US governmental structures, as well as state and tribal interests, can be designed to enable storage, transportation, and disposal of SNF. This must be based on transparency and trust and must follow an agreed-upon protocol for obtaining consent at multiple stages.

2. Ensure broadly inclusive processes.

Chapters should work to ensure that any consent process conducted within their community or state to consider the transfer of SNF is broadly inclusive, transparent, and accessible.

3. Chapters should take advantage of opportunities to advocate for ensuring state and federal environmental regulatory authority over radioactivity and nuclear waste, to ensure a truly meaningful and reliable consent process.

4. Factual and comprehensive science-based information must be developed to enable the public to have a full understanding of the potential environmental and health impacts associated with storing or transporting SNF.

The regulatory framework must provide for adequate science-based safeguards and public-health protections as well as long-term guarantees for assuring accountability.

5. Currently, unique problems are presented by the transportation of SNF, even when moving it a short distance from dangerous situations.

(See extensive discussion in the Transport section of this guidance document.) These multiple problems must be addressed in order for any transportation program to proceed. DOE, NRC and DOT must commit to extensive public involvement in transportation planning, including a thorough NEPA process. The public must be seriously engaged in a national process to address the enormous uncertainty regarding future transportation plans and their adequacy.

6. In addition, local, state and tribal communities along proposed SNF shipping routes must have the opportunity to be consulted and to give input on specific local conditions and circumstances that should be factored into the planning of shipments.

The public must be informed of the risks specific to their community and how those risks will be lessened in the finalized plan.

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Section 6 - Environmental Justice and Equity Considerations

6.1 History of environmental racism in nuclear fuel chain

An abundant literature addresses the general existence of environmental inequity, injustice and racism, in the United States and elsewhere. In [*Environmental Justice: A Reference Handbook*](#), David Newton introduces the subject as:

"...the generally accepted evidence that environmental hazards are not distributed equally among various groups of people, either in the United States or throughout the world. Instead, communities of color, and, to a lesser extent, poor people in general are exposed to hazardous and toxic wastes, dangerous working conditions, polluted air and water, and other environmental insults to a greater degree than non-colored communities and people of higher economic status." (p. 3)

Newton observes that the term "environmental inequity" refers to a geographic reality, whereas "environmental racism" explains the underlying reason for much of the distribution of the inequity. He offers the definition of environmental racism provided by NAACP Executive Director Benjamin Chavis in Congressional testimony in 1993:

"Environmental racism is defined as racial discrimination in environmental policy making and the unequal enforcement of environmental laws and regulations. It is the deliberate targeting of people of color communities for toxic waste facilities and the official sanctioning of a life-threatening presence of poisons and pollutants in people of color communities. It is also manifested in the history of excluding people of color from the leadership of the environmental movement." (p. 4)

In his analysis "[Environmental Racism with a Faint Green Glow](#)," New Mexico Environmental Law Center's Eric Jantz focuses specifically on the disproportionate impacts of the U.S. nuclear fuel cycle on poor communities of color and on how institutional failures have enabled them. Jantz lists the causes generally common to cases of environmental racism:

"People of color are often subject to housing discrimination and discriminatory zoning, which leads minority neighborhoods to disproportionately host undesirable land uses such as polluting industries. Private industry also consciously targets low-income communities of color for polluting operations because property is typically less expensive in those neighborhoods and their residents have less political and economic power than White communities to mount resistance. Weak political opposition also makes state and local governments more likely to approve polluting projects in communities of color than in White communities. Further, underrepresentation of people of color in government, the legal profession and business contributes to the disproportionate pollution burden in communities of color. Finally, because communities of color lack desirable economic development opportunities, those communities are subject to "economic blackmail"—the promise of jobs, economic development and tax revenue associated with polluting projects." (p. 249)

While implicating the entire nuclear fuel cycle, Jantz concentrates on uranium extraction, electricity generation, and nuclear waste storage stages. As Jantz details, 80-90 percent of the uranium extraction during the uranium boom of the 1950s -1980s took place on indigenous lands. While some White communities experienced exposures to radiation and toxic metal contamination from the mining, the reclamation and remediation work was more thorough and protective. By comparison, mine sites were left substantially unreclaimed in predominantly Navajo communities, resulting in ongoing exposures to surface and groundwater contamination by radioactive and other toxic pollutants. Jantz singles out the Churchrock Chapter of the Navajo Nation in particular, where portions of the population were found to have ongoing exposure to "levels of radon as much as forty-two times higher than background, ... as well as to elevated levels of gamma radiation," (p. 262) even as the NRC managed to justify approving new in situ leach mining.

The disparity occurred with uranium milling as well. Milling sites in the predominantly White communities of Durango, CO and Moab, UT and the predominantly Navajo communities of Shiprock and Churchrock were all later designated as Superfund sites. However, compared to the White communities, "the pace and adequacy of uranium milling waste contamination remediation in indigenous communities falls far behind." (p.252) And rather than being removed or effectively contained, in many cases mill tailings piles have been left in unlined pits, creating an ongoing threat to the communities.

Regarding the electricity generating stage, Jantz cites documentation that nuclear reactors are predominantly sited in proximity to poor and people-of-color communities, putting them at disproportionate risk from power-plant operational exposures, as well as to greater risk from a catastrophic accident.

Jantz briefly summarizes the experience with nuclear waste storage and observes: "In the decades of planning temporary and permanent storage locations for the nation's high-level radioactive waste, indigenous communities have usually been the first to be considered as storage sites." (p.255) Winona LaDuke provides a detailed account of the nuclear industry's repeated attempts to locate temporary nuclear waste storage sites on tribal lands in *All Our Relations: Native Struggles for Land and Life* (2016, Ch. 5 "Nuclear Waste: Dumping on the Indians.") Her description of industry efforts to court tribes and fund native consultants to promote the economic opportunity of storing nuclear waste effectively illustrates Jantz' "economic blackmail" characterization.

The nearly successful effort by the utility consortium Private Fuel Storage, a limited liability entity, to locate a storage facility on lands of the Skull Valley Band of Goshutes in Utah is a particularly stark example. [See discussion regarding the adequacy of consent in this case in Section 5.] The case involved a small economically strapped and under-resourced tribe, with a tribal government which indigenous environmental movement leader Tom Goldtooth describes as "a rare example of a Native American tribe that has willingly submitted itself to economic colonization for a price" [see Bruce E. Johansen, *Environmental Racism in the U.S. and Canada: Seeking Justice and Sustainability* (2020), pp. 274-277]. There was strong opposition from tribal members concerned about the serious environmental and public-health risks of the plan to store as much as 40,000 metric tons of HLRW for 25 years, on top of existing risks posed by multiple military-weapons testing and stockpiling sites in the vicinity. At the time, the US Bureau of Indian Affairs supported the project. Jantz notes the "NRC readily dismissed environmental justice concerns raised by tribal members." (pp. 255-256) However, strong pressure against the project arose as outside environmental groups; and, ultimately, the state of Utah joined the tribal members' efforts. Under the Obama administration a reconsideration occurred, and both the Bureau of Indian Affairs and the Bureau of Land Management denied the project.

6.2 Failure of NRC environmental justice policy

How is it that the NRC did not find environmental justice concerns in the Goshutes case? As Jantz argues, it is because the NRC's approach is fundamentally flawed and the agency's "environmental justice practices ... were and continue to be little more than window dressing." (Jantz, p. 257)

In 1994, the Clinton administration responded to demands to address disproportionate pollution burdens on poor and people-of-color communities, in particular with the issuance of [Executive Order](#)

[No. 12898](#), *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*. The order applied to executive branch agencies, but not to independent agencies such as the NRC. Nonetheless, the NRC committed to implement the order. This occurred initially, as Jantz describes, through regulatory guidance, adjudications and practice, later formalized by issuance of a [draft](#) and then [final Policy Statement](#) on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions in 2004.

The policy articulates NRC's determination to rely exclusively on NEPA law and procedure as its authority to address environmental justice concerns. To rulemaking comments calling for special attention to the nuclear industry's history of siting facilities in minority and disadvantaged communities, and on Native American homelands in particular, the final policy responds:

"The Commission continues to recognize that 'racial discrimination is a persistent and enduring problem in American society.' *LES*, CLI-98-3, 47 NRC 77, 101 (1998). However, as explained in the draft policy statement, EJ [Environmental Justice] issues are only considered when and to the extent required by NEPA. NEPA is an environmental statute, and a broad-ranging inquiry into allegations of racial discrimination goes beyond the scope of NEPA's mandate to adequately identify and weigh significant adverse environmental impacts." (p. 52045)

Eric Jantz is highly critical of the NRC's reasoning in the *LES* case referenced in, and used to underpin, the policy. It involved the proposal of the Louisiana Energy Services utility consortium (LES) to locate a uranium-enrichment facility between two almost exclusively African American communities in a Louisiana parish with a high level of poverty. In the case against the facility brought by a local citizen's group on claims of racial bias in the siting, the NRC relied exclusively on NEPA as the only basis for an environmental justice analysis. And in finding for *LES*, the NRC argued that evaluating racial bias in siting "go[es] well beyond what NEPA has traditionally been interpreted to require." (Jantz, p. 259) As Jantz notes, the NRC had used similar reasoning in the Goshutes case.

In further discussion of its implementation of the 2004 policy, Jantz details how the NRC has constrained its NEPA analysis to "willfully" ignore evidence of discrimination. He describes how the NRC's reactor-safety analysis substitutes analysis of the risks of catastrophic accidents occurring for the impacts of catastrophic accidents if they do occur. (p. 269) This is compounded by relying on generic risk assessment as opposed to site-specific analysis of the potential consequences of an accident. As Jantz observes:

"Unconsidered consequences are particularly dangerous for low-income and minority communities who are substantially more likely to lack the capacity to deal with catastrophic accidents compared to more affluent and White communities." (p. 270).

Beyond reforming its cursory approach under NEPA, the real solution, Jantz argues, is for the NRC to recognize its full authority under its implementing statute, the [Atomic Energy Act](#) (AEA), which requires the agency to protect public health and safety. He makes the case that the regulatory basis for a robust and meaningful environmental-justice policy could be established, similarly to how the EPA has used "omnibus" public health and safety language in various environmental statutes as the basis for a substantive and meaningful approach to confronting environmental racism. (p. 274) In the 2004 rulemaking, the NRC received comments urging this alternative AEA-based approach but dismissed the idea as unworkable. ([Final Policy Statement](#), p. 52044) It appears past time to revisit that conclusion.

6.3 Equity considerations for Sierra Club leaders

The issues of equity that arise in relation to managing nuclear waste are multi-dimensional. A priority is the need to ensure that the past injustices of dumping nuclear waste on already disproportionately over-burdened populations are not perpetuated. There is the need to be mindful of regional concerns; the primary nuclear waste-generating regions of the country are largely distinct from the regions that in recent years are being proposed to accept and store it. And there is the overarching consideration of inter-generational equity. How can we justify simply handing over the ever-increasing burden to future generations without a concerted and genuine effort to confront and address the problem? These are concerns that Sierra Club Chapters and other entities will need to consider as they engage on this subject.

Through a series of stepped-up change initiatives and planning processes beginning in 2014, Sierra Club has committed to becoming a more equitable, inclusive, and just organization, and to ensuring that the work we pursue centers on equity and justice. Significant strides on that journey include:

- the commitment of the organization to adhere to the [Jemez Principles for Democratic Organizing](#), and the development of associated [Practicing Jemez Principles](#) implementing guidance;
- the establishment of the Equity Department to guide the organization's journey;
- adoption of the [Multi-year Equity Plan](#) [current plan covers 2019-2022 years];
- the revision of the [Movement Organizing Manual](#) embedding equity and justice as organizing principles guiding national campaign work; and
- the issuance of the [Building Power to Win Toolkit for Changemakers](#), which provides a synthesis of guidance and a repository of tools to support all Sierra Club volunteers and staff in the fulfillment of the organization's commitment to advancing just and equitable solutions.

The above organizational commitments and resources must inform the approach of our volunteer leaders engaging in local and state decision-making around nuclear waste management. In particular, it is incumbent upon Sierra Club Chapters and volunteer activists to be proactive in applying the *Jemez Principle*, ensuring in particular that decision-making is inclusive and "relevant voices of people directly affected are heard." As the *Movement Organizing Manual* notes, "A more diverse America is an inevitable outcome; a more just America requires a more inclusive approach to environmental advocacy."(p. 60)

6.4 Guidance

1. Chapters should ensure that their representatives engaging in local and state nuclear waste generation and management proceedings and decision-making processes (1) are trained on (2) apply, and (3) are held accountable for adhering to Sierra Club equity values and the Jemez Principles in their work.

2. Chapters should advocate for robust and meaningful environmental justice policy by all federal agencies involved with nuclear waste management, radioactive materials and public exposures to ensure equal protection under the law for current and future generations.

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APPENDIX I

Book review by Don Safer of Confessions of a Rogue Nuclear Regulator by former NRC Chairman Gregory Jaczko

In January 2019, Confessions of a Rogue Nuclear Regulator, a book by former NRC Commissioner (2005 to 09) and Chairman (2009 to 12) Gregory Jaczko was released. It provides an important, troubling look at the work of the Nuclear Regulatory Commission during those years, which include the 2011 Fukushima triple meltdown of the US designed Japanese reactors. The book is accurately described on the jacket cover as “a shocking expose’ from the most powerful insider in nuclear regulation about how the nuclear energy industry endangers our lives – and why Congress does nothing to stop it”.

In the Prologue Jaczko describes the NRC as: “an agency overwhelmed by the industry it is supposed to regulate and a political system determined to keep it that way.” The book is his personal story of how he evolved from a “nuclear power moderate” concerned with nuclear safety at the start of his time on the commission to a full-blown nuclear industry critic with the message: “nuclear power will never be safe.” It is also the national story of the capture of the NRC’s work by wealthy, powerful utility and nuclear industry proponents. Robert F. Kennedy Jr. says it very well on the book’s jacket back cover: “The infuriating inside story of how a corrupt, outmoded, and inefficient nuclear industry maintains its market position against safer, more efficient forms of renewable energy by hoodwinking and corrupting Congress and co-opting the regulators.”

The book is a very important read for all interested in nuclear safety. If you are new to the questions and challenges that nuclear power poses it provides a critical look at the agency tasked with protecting the public’s safety from nuclear power’s unique immediate and incredibly long term biological and environmental threats. It should help to dispel unwarranted trust in the NRC, utilities and often uninformed elected officials.

If you are a seasoned, skeptical and even cynical veteran of many years of engagement on the issue you will be nodding your head in agreement and find your frustrating and exasperating experiences in advocating for nuclear safety and sanity explained, put into context and validated. Jaczko documents the economic and political power of the nuclear industry, its ability to control

the US Congress, and its near total capture of the NRC Commissioners. This explains the convoluted, irrational and dangerous regulatory decisions that result in mind benders like “Waste Confidence”, the multiple lives of TVA’s zombie reactors at Bellefonte, burying spent fuel rods next to the ocean at San Onofre, California and the list goes on and on and on. He also documents Congressional bullying of the NRC when the industry feels pressure from the agency to improve safety.

The information and perspective in the book about the Fukushima Nuclear Disaster is especially valuable. Jaczko experienced the terror of an out of control nuclear accident with multiple explosions and a triple melt-down. He realized the unwarranted hubris of many: “most nuclear safety professionals believed plants were effectively designed to prevent the events we were now seeing.” (p 79) He learned of all the horrifying effects and possibilities and was profoundly changed by it. He summarizes the results of three independent Japanese investigations of the cause of the meltdowns and explosions:

“the nuclear power regulators were too accommodating to those they were supposed to regulate. They worked together to create what one report called a ‘nuclear village,’ not an idyllic hamlet where business and government worked in harmony for the good of all but a corrupt, toxic environment.” (p 71)

He recognized a similar situation in the US and was shocked by the inadequacy of the US regulatory response to use what was learned to improve nuclear reactor safety in the US. He finally concluded that it is impossible to make “reactors impervious to catastrophic releases of radiation”. (p 116)

Jaczko is not the first former NRC Commissioner to become a critic of the agency and the industry, but he is the first former Chairman. Former Commissioners Peter Bradford (1977-82) and Victor Gilinsky (1974-84) are vocal critics. More common is the use of the lucrative revolving door between cooperative Commissioners and the nuclear industry (see the Aug 2, 2016 Ecologist article on the NRC). It is not a surprise that Jaczko had a very difficult time finding any employment after he was forced out of the NRC.

This book is an important addition to the works of the many critics of the Nuclear Regulatory Commission and the nuclear enterprise.

APPENDIX II

Radiological Doses

The following quantities are commonly used to characterize radiation exposures in living organisms:

Absorbed dose. The quantity of ionizing radiation deposited into an organ or tissue, expressed in terms of the energy absorbed per unit mass of tissue. The basic unit of absorbed dose is the rad or its SI (international system of units, also known as the metric system) alternative the gray (Gy; 1 Gy = 100 rad).

Equivalent dose. The absorbed dose averaged over the organ or tissue of interest multiplied by a weighting factor that accounts for the differences in biological effects (per unit of absorbed dose) for different types of radiation. The weighting factor ranges from 1 for X-rays and gamma rays to 20 for alpha particles and some neutrons. The equivalent dose is expressed in units of rem or its SI alternative the sievert (Sv; 1 Sv = 100 rem).

Effective dose. A measure of dose that accounts for the differences in biological effects of different types of radiation and for the varying sensitivity of different organs to the biological effects of radiation. Effective doses are also expressed in rem or sieverts.

Collective dose is defined as the sum of all radiation doses received by all members of a population at risk (NCRP, 1995). The units of collective dose are usually given as person-sieverts or person-rem. This concept is frequently used in radiation protection applications, both

for controlling actual exposures and for estimating potential exposure risks. The use of the collective dose for radiation protection purposely assumes the following from the National Council on Radiation Protection and Measurement (NCRP, 1995):

There is a direct proportionality between radiation dose and risk over their respective ranges of concern. Risk is independent of dose rate.

A radiation dose leads to an identical risk whether it is administered to a single individual or to a population.

APPENDIX III

Radiation Weighting factors

Radiation Type and Energy Range	Radiation Weighting Factor, W_R
X and γ rays, all energies	1
Electrons positrons and muons, all energies	1
Neutrons:	
< 10 keV	5
10 keV to 100 keV	10
> 100 keV to 2 MeV	20
> 2 MeV to 20 MeV	10
> 20 MeV	5
Protons, (other than recoil protons) and energy > 2 MeV.	2-5
α particles, fission fragments, heavy nuclei	20

[ICRU 60, 1991]

See alpha (α) particles in last row above

For more information go to: [International Commission on Radiation Units and Measurements](#)

APPENDIX IV

Minimum Safety Requirements for Dry Storage of Highly Radioactive Waste

PREAMBLE:

Irradiated nuclear fuel and other highly radioactive waste forms contain radioactive isotopes that will remain hazardous for millennia can give lethal doses unshielded, thus must be isolated from the biosphere for geological time periods.

Nuclear waste storage at reactor sites across the country poses significant risks to surrounding populations and biomes, arising from high density fuel pool storage and vulnerabilities in dry storage systems.

Transport without dealing with dry-storage vulnerabilities would pose additional risks, along transport routes and at destination sites, spreading and exacerbating the danger.

These Minimum Safety Requirements for Dry Storage are intended to address some of the vulnerabilities in dry storage.

MINIMUM SAFETY REQUIREMENTS

Radioactive waste storage systems must be designed, fabricated and maintained to **prevent** radioactive leaks, both short-term and long-term. The Nuclear Regulatory Commission does not require such prevention.

The US government must establish and enforce requirements to prevent radioactive leaks into our environment. These requirements should include, but not be limited to, the minimum requirements set forth below.

These requirements apply to highly radioactive waste including irradiated (“spent”) nuclear fuel and Greater-than-Class-C (GTCC) waste stored or planned to be stored in dry storage containers and systems.

The MINIMUM SAFETY REQUIREMENTS are:

1. Require the capability to inspect, maintain, monitor and repair all nuclear waste containers and, as needed, their contents, in order to prevent radioactive leaks at each storage site. This requirement must apply to existing and new dry storage systems.

A. Require early warning systems designed to prevent radioactive leaks. Require continuous and remote monitoring systems for early detection of degradation of containers and their contents that allow time to repair or replace parts or entire containers **before** radioactive leaks occur. Require monitoring for heat and helium to provide early warning. (For example: detection of pressure changes in lids may require a metal seal replacement.)

B. Require continuous radiation monitoring systems, including on-line, real-time radiation monitoring and publicly accessible reporting to ensure that radioactive leakage is detected immediately.

C. Require the capability to retrieve and transfer nuclear waste from one container to another at the current site. Because containers and their contents will require maintenance and could degrade or fail at any time before the waste is transferred to a permanent repository/isolation facility, the industry must deploy proven, demonstrated technologies and procedures for transferring high-level waste from a damaged or degraded container to a new

container.

2. Require secure, Hardened, On-Site Storage (HOSS). Containers must be stored in hardened facilities, as close to the point of generation as is safely possible in order to protect against environmental, health and security hazards. See *Principles for Safeguarding Nuclear Waste at Reactor Sites*.

http://ieer.org/wp/wp-content/uploads/2010/03/HOSS_PRINCIPLES_3-23-10x.pdf

A. Require capability to minimize the duration and level of radioactive release and exposure, in case of a breach. (For example, storage in a structure designed to isolate radioactivity from the environment, climate controlled with HEPA filters in the ventilation exhaust system.)

3. Require best available materials, fabrication and designs for longer, safer storage times and less risky transport. (For example: Materials must not be susceptible to corrosion and/or cracking, and structures must have no single points of failure.)

4. Fuel assemblies, fuel baskets and containers must be inspected for damage prior to transport, as required by the Nuclear Waste Policy Act and Standard Contracts.

5. Require and enforce the highest standards of independent nuclear Quality Assurance for the design, fabrication, use, maintenance, and replacement of dry storage systems.

The undersigned organizations support the above Minimum Safety Requirements for highly radioactive waste including irradiated nuclear fuel and Greater-than-Class-C (GTCC) waste stored or planned to be stored in dry storage containers. These requirements are needed to prevent reasonably foreseeable short-term and long-term radioactive leaks into the environment. Support for less dangerous, hardened dry nuclear waste storage does not constitute a statement of support for pool storage, nuclear energy or the generation of more radioactive waste.

Rev 0, November 2019 Compiled by Nuclear Information and Resource Service with input from experts, local residents, concerned organizations and individuals. www.nirs.org Contact: dianed@nirs.org

For Discussion and Sign-On

Appendix V

Atlas Railcar Phase 2 Final Report March 6, 2018

<https://www.energy.gov/ne/downloads/atlas-railcar-phase-2-final-report>

DOE has begun to work to design and fabricate railcars needed to transport SNF. The Contractor, Areva Federal Services LLC, has been hired to design the rail car. The railcar is very similar to the Navy M-290 railcar design, the only railcar to receive conditional approval to the Association of American Railroads (AAR) Standard S-2043 for transport of high-level radioactive material.

Specifications:

The rail car has 12 axles and is 10 feet 8 inches wide

The operational loads to be stenciled on the rail car will be:

Gross Rail Load -789,000 lbs.

Load Limit for payload—480,000 lbs.

Light weight load- 229,000 lbs.

The railcar cannot be completely empty. It will have to install ballast for a return trip.

Phase 2 of the project involved primarily computer modeling. The next phase will be an actual physical testing, followed by fabrication of the railcars. DOE reports in March 2019 that a single railcar has been fabricated which will now begin actual testing.

Total costs are estimated between \$107 million to \$428 million for 120 railcars and 60 buffer cars. The manufacturing cycle is estimated to take nearly nine years.

APPENDIX VI

Questions on the Validity of the ENSA Cask Multimodal Transportation Study: Don Safer's Critique

At the [Fall 2018 Nuclear Waste Technical Review Board meeting](#) there was a presentation summarizing the “ENSA Cask Multimodal Transportation Study”. [The study](#) reached the following conclusions: “The realistic stresses fuel experiences due to vibration and shock during normal transportation are far below yield and fatigue limits for cladding.” Translated into English: this study finds it is safe to transport spent nuclear fuel. Before we breathe a collective

sigh of relief at this reassuring finding it is crucial that we look a little deeper, and with a skeptical eye.

The study is a collaboration of 12 international nuclear agencies including the US Department of Energy (DOE), 3 US national labs, and Spanish and South Korean nuclear power agencies. It was conducted over 54 days of data collection, collecting 8 terabytes of data, for 4 transport modes (rail, boat, barge, truck), 9458 miles through 7 countries and 12 states, across the Atlantic Ocean and back. The cost of the study was not disclosed.

So why should the public be skeptical about the results? Could the study be fundamentally flawed and biased to find no problems? First and foremost, US DOE and the nuclear industry have earned the deep skepticism and mistrust of the American public by innumerable violations of that trust and compromises of public and worker health and safety in favor of advancing the nuclear power enterprise. Secondly, the nuclear industry has been manufacturing high burnup spent nuclear fuel for many years while many of the characteristics of this material in storage, transport and long-term disposition are still unknown and like this test, just now being studied. The DOE, the Nuclear Regulatory Commission and the nuclear industry have put the cart before the horse by creating many tens of thousands of metric tons of this material BEFORE having the knowledge that it can be safely stored, transported and isolated from the biosphere for eternity. What would they do if they find unsolvable problems or high levels of risk? Would they tell the public? Full disclosure and transparency have not been the norm in the past.

It is admittedly a challenge for interested members of the public to analyze validity and veracity of technical documents and studies such as this one, but we have learned that we must engage in these activities to enhance public safety. Public scrutiny counterbalances nuclear industry and captured regulatory authorities' tendencies to put the public at undue risk with little disclosure and often active obfuscation of the issues.

High burnup irradiated spent nuclear fuel was not actually monitored in the study. Irradiated spent nuclear fuel is too deadly and dangerous to be able to handle and monitor in the ways needed to complete this study.

Three of the 32 17 x 17 pressurized water reactor (pwr) assemblies transported in the cask were "surrogate" fuel assemblies; the remaining 29 were "dummy assemblies". The surrogate assemblies were measured for forces encountered in normal transit. Two of the surrogate assemblies were constructed tubes of Zirlo cladding filled with lead pellets, the other had 286 copper tubes filled with continuous lead rod and 3 Zircaloy-4 tubes filled with lead or molybdenum pellets. The dummy assemblies were said to be constructed to weigh and move like spent fuel assemblies.

The study contains little to no comparison between the surrogate and dummy assemblies and the real thing. There is no discussion about the physical changes and deterioration irradiated fuel

experiences in the reactor, during drying and in dry storage. This issue is covered on page 34 with the statement: “the surrogate PWR fuel assemblies simulate the mechanical and structural dynamics of irradiated commercial SNF assemblies.” There is no quantification of the burnup level simulated. There is no mention of the specific mechanical changes that cladding and fuel rods experience at high burnup levels. Those changes are just now being studied and are not fully understood. Studies have found heavy oxidation of cladding, build up of CRUD on cladding, grid to rod fretting of the cladding, pellet stack gaps, hydride reorientation in the cladding that affects strength, cladding creep from radial hoop stress, and high burnup structure in the ceramic UO₂ pellets. All of these affect the strength and structure of the fuel rods and possibly the assembly structure and spacers.

Transport casks full of actual assemblies of high burnup spent nuclear fuel will have significant differences compared to dummy assemblies or surrogate assemblies with almost all copper tubes filled with continuous lead rod. Might there be effects on actual fuel rods that were not found in the study? Are the assemblies and spacers in actual casks weaker than those used in the test? How will the high heat and radiation of actual fuel assemblies affect the integrity of the cladding during transport? Many questions remain unanswered.

The study compared the forces that the surrogates experienced to the force actual irradiated fuel rods experienced before “failure” in the limited laboratory studies conducted to date. A complete analysis would cover the details of both of those studies. Issues such as the placement of the movement monitoring sensors on the surrogate rods and the types of stresses high burnup rods were put under in those tests are beyond my expertise to critique but deserve to be fully explored.

This study did add to the knowledge necessary to confirm safe transport, but it is not enough to make a determination that it is safe to transport high burnup spent nuclear fuel.

APPENDIX VII

Low- Level Radiation Impacts on Children, Preliminary Report from the UK

A new [preliminary report](#) is available on the impacts of low-level radiation on children. The report was produced by the Low Level Radiation Campaign for the charitable organization Children with Cancer UK. The report is 81 pages long and detailed.

The article below provides a very good summary of the report.

Climate News Network

Paul Brown, ["How dangerous is low-level radiation to children?"](#)

May 22nd, 2020.

A rethink on the risks of low-level radiation would imperil the nuclear industry's future – perhaps why there's never been one.

LONDON, 22 May, 2020 – The threat that low-level radiation poses to human life, particularly to unborn children, and its link with childhood leukaemia, demands an urgent scientific reassessment.

This is the conclusion of a carefully detailed report produced for the charity [Children With Cancer UK](#) by [the Low-Level Radiation Campaign](#).

It is compiled from evidence contained in dozens of scientific reports from numerous countries over many decades, which show that tiny doses of radiation, some of it inhaled, can have devastating effects on the human body, particularly by causing cancer and birth defects.

The original reports were completed for a range of academic institutions, governments and medical organizations, and their results were compared by the newest report's authors, [Richard Bramhall](#) and [Pete Wilkinson](#). They believe they have provided overwhelming evidence for a basic rethink on so-called "safe" radiation doses.

They write: **"The fundamental conclusion of this report is that when the evidence is rationally assessed it appears that the health impacts, especially in the more radio-sensitive young, have been consistently and routinely underestimated."**

Ceaseless controversy

The pair concede this is not the first time such a call has been made, but it has never been acted upon. Now they say it must be.

What constitutes safety for nuclear workers and for civilians living near nuclear power stations, or affected by fall-out from accidents like the ones at [Sellafield in Cumbria in north-west England](#) in 1957, [Chernobyl](#) in 1986 and [Fukushima](#) in 2011, has always been highly controversial.

Bramhall and Wilkinson detail how the debate began in earnest in the 1980s, when [a cluster of childhood leukaemia cases, ten times higher than would be expected](#), was identified around Sellafield.

Government inquiries followed but reached no settled conclusion, and low-level radiation safety has been a scientific battleground ever since.

The official agencies appointed by governments are still using dose estimates based on calculations made in 1943, when Western governments were trying to develop an atomic bomb.

“The discrepancy between the number of congenital malformations in babies expected after Chernobyl and the number actually observed was between 15,000 and 50,000”

The new report highlights that this was when very little was known about how tiny doses of ingested radiation could affect the body – and when DNA was yet to be discovered.

Despite the fact that international standards are based on these scientifically ancient, out-of-date assumptions, they have not been revised. If they were, the results could be catastrophic for the nuclear industry and for the manufacturers of nuclear weapons.

The report makes clear that if the worst estimates of the damage that low-level radiation causes to children proved anywhere close to correct, then no-one would want to live anywhere near a nuclear power station.

Most would be appalled if they knew even small numbers of children living within 50 kilometres of a station would contract leukaemia from being so close.

It acknowledges that the stakes are high. If the authors’ findings are accepted, then it will be the end of public tolerance of nuclear power.

Revolution needed

Despite this long-lived institutional pushback from governments and the industry, the report says what is needed is a scientific revolution in the way that low-level radiation is considered. It compares the situation with the treatment of asbestos.

It was in the 1890s that the first evidence of [disease related to asbestos exposure](#) was laid before the UK Parliament. But it was not until 1972, when the causal link between the always fatal lung cancer, mesothelioma, and human fatality rates was established beyond reasonable doubt, that the use of asbestos was banned.

This delay is why on average 2,700 people still die annually in the UK: they were at some point exposed to and inhalers of asbestos.

Another example, which the report does not quote but is perhaps as relevant today, is [air pollution](#). It has taken decades for the scientific community to realise that in many cities it is the tiniest particles of air pollution, invisible to the naked eye, that are taken deepest into the lungs and that cause the most damage, killing thousands of people a year.

So far governments across the world have not yet outlawed the vehicles and industrial processes that are wiping out their own citizens in vast numbers.

Anxiety not irrational

The report cites many studies, with perhaps the most telling those that compare the actual numbers of cancers and malformations in babies which occurred in the aftermath of the Chernobyl accident with the numbers to have been expected if the currently accepted and out-of-date risk calculations had been used.

Despite the difficulties of getting information from reluctant governments close to Chernobyl, the report says: “The discrepancy between the number of congenital malformations in babies expected after Chernobyl and the number actually observed was between 15,000 and 50,000.”

The authors say their object “is to dispel the repeated assertion that public anxiety about the health impact of radioactivity in the environment is irrational.”

Both Wilkinson and Bramhall have considerable experience of dealing with governments, both inside official bodies as members, and as external lobbyists.

They detail how they believe the concerns of both ordinary people and scientists have been swept aside in order to preserve the *status quo*. Clearly, in sponsoring the report, Children with Cancer UK agrees. – *Climate News Network*

Paul Brown, a founding editor of Climate News Network, is a former environment correspondent of The Guardian newspaper, and still writes columns for the paper.