

**Yucca Mountain Transportation Planning:  
Lessons Learned, 1984-2009**

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**ABSTRACT**

This paper reviews the 25-year-long debate over the transportation program for the now-terminated Yucca Mountain repository project, and identifies lessons learned which might be applied to future spent nuclear fuel and high-level radioactive waste shipments to geologic repositories or centralized storage facilities in the United States.

**INTRODUCTION**

Over the past two and a half decades, the U.S. Department of Energy (DOE) proposal to construct and operate a geologic repository for spent nuclear fuel (SNF) and high-level radioactive waste (HLW) at Yucca Mountain, Nevada, generated a broad range of transportation controversies. These controversies include the national scope of nuclear waste storage and transportation impacts, the lack of rail access to the Yucca Mountain site, the assessment of transportation impacts as part of the repository licensing process, the widespread concern about transportation safety, the vulnerability of shipments to terrorism and sabotage, the effort to maximize use of rail transportation, and the selection of cross-country rail routes. While the Yucca Mountain project has now been terminated, the same or similar issues and controversies can be expected to arise in the context of any future large-scale SNF and HLW transportation effort.

Yucca Mountain transportation analyses conducted by DOE and the State of Nevada provide a rich source of lessons learned for future SNF and HLW shipments in the United States. [1-22, 30-32] Yucca Mountain transportation lessons learned include the licensing proceeding contentions admitted by the Nuclear Regulatory Commission (NRC) Atomic Safety and Licensing Boards in May 2009; the NRC package performance study cask testing proposal; current NRC proposals for enhanced transportation safeguards regulations, extended at-reactor storage, and integrated regulation of SNF storage and transportation; and the waste confidence final decision. [23-29, 33] The lessons learned also include the findings and recommendations of the National Academy of Sciences (NAS) 2006 report, Going the Distance? The Safe Transport of Spent Nuclear Fuel and High-Level Radioactive Waste in the United States. [34]

**FUTURE SHIPMENTS WILL BE A MATTER OF NATIONAL CONCERN**

While important details about the future nuclear waste management system are uncertain, transportation analyses conducted by DOE and Nevada with regard to the now-terminated Yucca Mountain project indicate that SNF and HLW shipments to a future national repository or central storage site would be dramatically different than current shipments. The amount of waste shipped, the number of shipments, and the total shipment miles would greatly increase. Cross-country nuclear waste shipments would occur weekly, or even perhaps daily, for four or five decades, or more. The number of affected congressional districts, States, Indian Tribes, and local governments would create enormous potential for political controversy.

Assuming no new reactors, and license extensions for all operating reactors, the current SNF inventory will grow by about 2,000 MTU (metric tons uranium) per year. Once regular shipments to centralized storage, geologic disposal, and/or reprocessing begin, annual shipments of at least 3,000 MTU seem likely. At that rate, assuming mostly rail (95 percent) transportation of commercial SNF, and all rail transportation of DOE SNF and HLW, there would likely be about 7,000 train shipments (3-5 casks per train) and 5,000 truck shipments (one cask per truck) over about 50 years. That works out to about 100-150 train-load shipments and 100 truck shipments every year in the future, compared to about 10-15 train-loads and 10-15 truck shipments per year currently. Put another way, under a mostly rail scenario, assuming a total SNF and HLW inventory of about 150,000 MTU, there would be about 7-10 times more shipments each year, using larger capacity casks, carrying 50 times more spent fuel annually.

However, the DOE mostly rail scenario may be unrealistic. Even marginally greater reliance on legal-weight truck (LWT) or over-weight truck (OWT) shipments could significantly increase the number of shipments. If 20 percent of the projected inventory were to be shipped by LWT or OWT, an additional 9,000 to 15,000 truck shipments would likely be required, for a total of 14,000 to 20,000 truck shipments. Shipping 35 percent by LWT or OWT could easily bring the total to more than 23,000 truck shipments, an average of more than one truck shipment per day, every day, for 50 years.

Shipments to a national repository or centralized storage facility would impact an extraordinary number of people, communities, and political jurisdictions. There are currently 76 storage sites in 34 states. The “representative routes” identified by DOE, from these sites to Yucca Mountain (see Figure 1), would have traveled 22,000 miles of railways and 7,000 miles of highways, traversing 44 states, the District of Columbia, 33 Indian nations, and about 836 counties with a population of about 161 million. (2005 Census estimates) Between 10 and 12 million people live within one-half mile (800 meters) of these rail and highway routes. And these routes would have affected most of the nation's congressional districts (330 in the 110th Congress). [18, 31, 32]



Fig.1. “Representative” Rail and Truck Routes to Yucca Mountain (DOE, 2008)

**TRANSPORTATION REQUIREMENTS MUST BE ADDRESSED IN FACILITY SITE SELECTION**

One important lesson from the DOE repository program is that critical transportation requirements, such as mainline rail access and interstate highway access, must be addressed in the earliest phases of site selection for storage and disposal facilities. Direct rail access to the national rail network is highly desirable in siting a geologic repository or centralized storage facility. Without direct rail access, delivery of SNF and HLW to a national facility would require either tens of thousands of cross-country over-weight truck (OWT) shipments or many thousands of heavy-haul truck (HHT) shipments from an intermodal transfer facility. Access to the interstate highway system is also highly desirable, for delivery of SNF and HLW and repository construction materials and supplies, and for access by workers and emergency services. In the 2002 Final Environmental Impact Statement (FEIS) for Yucca Mountain, DOE identified rail as the preferred mode of transportation, nationally and in Nevada, based upon the "smaller number of shipments" and "the correspondingly reduced environmental impacts." [8]

But Congressional selection of Yucca Mountain as the only repository candidate site in 1987 ignored known problems with rail access construction and impacts, as well as challenging highway access. DOE's 1986 Environmental Assessments (EAs) for the first repository showed that Yucca Mountain had the most difficult rail access, the most difficult interstate highway access, and most adverse overall transportation system impacts, of the five candidate sites studied (Table I).

Table I. Rail and Highway Access Conditions at Potential Repository Sites

Condition	Davis Canyon, Utah	Deaf Smith, Texas	Hanford, Washington	Richton, Mississippi	Yucca Mountain, Nevada
Nearest Mainline Railroad (miles)	74	25	51	17	100
Nearest Alternative Railroad (miles)	Not Identified	40	101	26	265
Rail Access New Construction (miles)	39	26	3	26	100
Rail Access Cost (Million 1985 Dollars)	142	21	6	16	151
Nearest Interstate Highway (miles)	89	14	28	26	100
Nearest Alternative Interstate (miles)	198	200	72	84	208

Ref. 1, 3

Yucca Mountain lacked the favorable conditions for rail access spelled out in the 1984 repository siting guidelines: short distances; low construction costs; absence of need for Federal condemnation to acquire rights-of-way; absence of need for cuts, fills, tunnels, and bridges; absence of steep grades or sharp curves; and bypass of local cities and towns. Yucca Mountain presented three potentially adverse conditions: relatively high construction costs; relatively difficult terrain; and local conditions (proximity to military facilities and potential military aircraft over-flights) "that could cause the transportation-related costs, environmental impacts, or risk to public health and safety from waste transportation operations to be significantly greater than those projected for other comparable siting options." [1]

DOE's 1986 Yucca Mountain EA assumed rail access could be attained by constructing a 100-mile railroad, originating in the Las Vegas area, at a cost of \$151 million (1985\$). By 2008, DOE was proposing construction of the circuitous Caliente rail alignment (Figure 2), a 300-plus-mile railroad, longer than the distance between Washington DC and New York City, crossing 8 mountain ranges, at a cost of \$2.7 billion or more. [22] Even if built, the Caliente rail line to Yucca Mountain would not have eliminated rail shipments through downtown Las Vegas, a major concern in Nevada. Additionally, Yucca Mountain had

poor access to the national interstate highway system, which led DOE to propose routing all legal-weight truck shipments to Yucca Mountain through the Las Vegas Valley (Figure 3).

Studies prepared for the State of Nevada estimate that at least 95,000 residents of Clark County live within one-half mile of the Union Pacific rail route DOE would have used for shipments to Yucca Mountain via Caliente, and at least 113,000 residents of Clark County live within one-half mile of the highway routes DOE would have used for truck shipments. A large portion of the world-famous Las Vegas “Strip” and more than 34 hotels with 49,000 hotel rooms are located within what would have been the one-half mile region of influence along the rail route. Nevada estimates at least 40,000 nonresident visitors and workers in Clark County would have been located within one-half mile of the highway and rail routes at any hour of the day. Virtually all of Clark County’s 1.8 million residents live within what would have been the 50-mile radiological region of influence for transportation accidents and sabotage.[19] None of this was considered in the early site selection process and failure to do so, contributed significantly to the accumulating problems with Yucca Mountain.

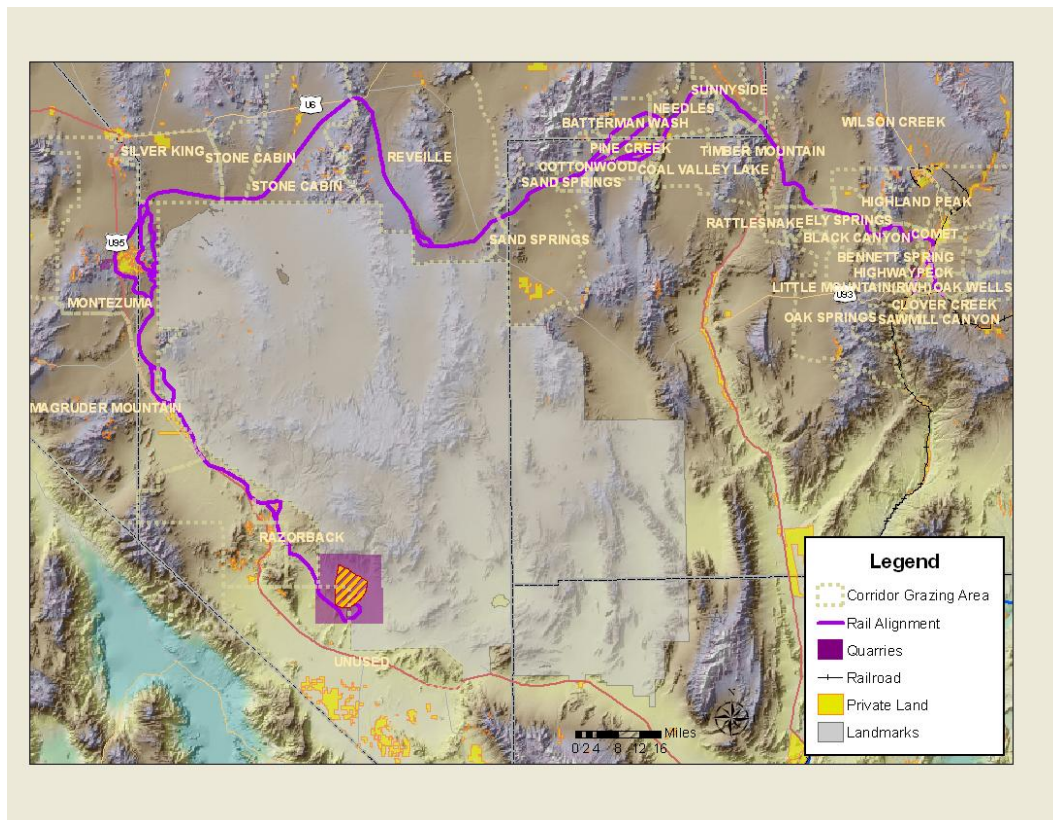
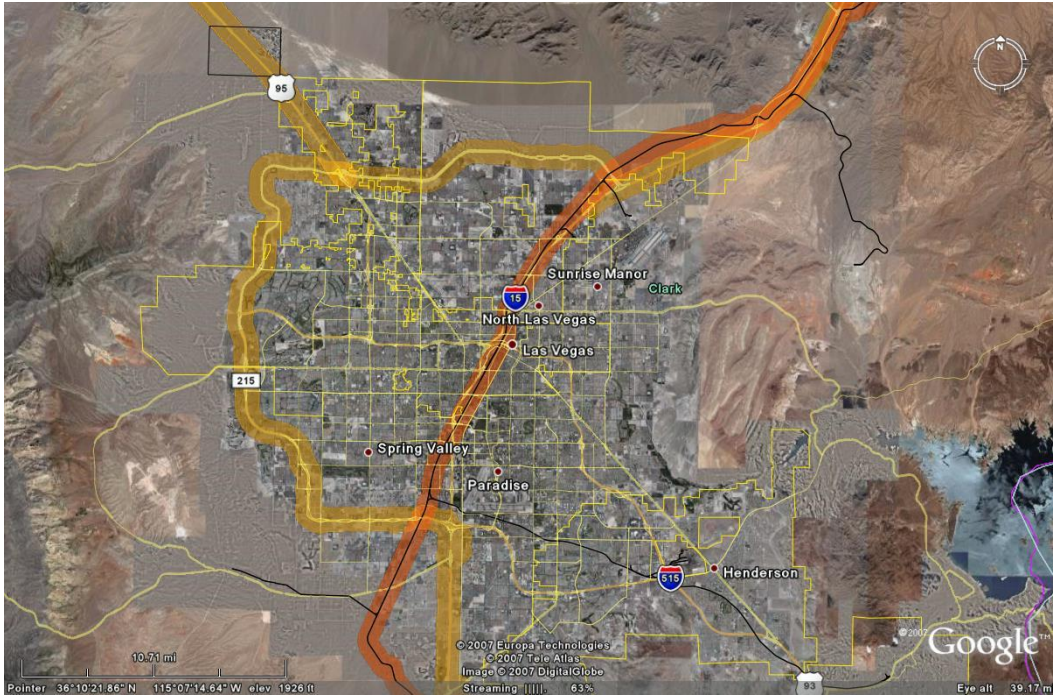


Fig. 2. Caliente Rail Alignment



**Fig. 3. Potential Rail and Highway Routes through Las Vegas**

### **TRANSPORTATION WILL BE CONSIDERED IN FACILITY LICENSING**

The role of transportation in future NRC licensing proceedings for disposal and storage facilities may well have been established by the May 2009 Memorandum and Order issued by the NRC Atomic and Safety Licensing Boards (ASLBs) considering the DOE license application for Yucca Mountain. The key paragraph reads:

Transportation of nuclear waste is a foreseeable consequence of constructing a nuclear waste repository. As California persuasively argues, “[w]ithout transportation of the waste to it, Yucca Mountain would be just a very large, fancy, and expensive hole in a mountain.” The Commission, for example, has stated that there can be “no serious dispute” that the NRC’s environmental analysis in connection with licensing nuclear facilities should extend to “related offsite construction projects – such as connecting roads and railroad spurs.” Likewise, there can be no serious dispute that the NRC’s NEPA responsibilities do not end at the boundaries of the proposed repository, but rather extend to the transportation of nuclear waste to the repository. The two are closely interdependent. Without the repository, waste would not be transported to Yucca Mountain. Without transportation of waste to it, construction of the repository would be irrational. Under NEPA, both must be considered. [24]

Applying this reasoning, the NRC ASLBs admitted 46 NEPA [National Environmental Policy Act] contentions or challenges related to transportation: 17 submitted by the State of California, 16 submitted by the State of Nevada, 8 submitted by California and Nevada Counties, 3 submitted by the Nuclear Energy Institute, and 2 submitted by the Timbisha Shoshone Tribe. These admitted contentions address virtually every aspect of repository transportation, including: selection and design of shipping containers; modal options (rail, legal-weight truck, over-weight truck, heavy-haul truck, and barge); route selection for rail and truck shipments to Nevada, and within Nevada; selection of the Caliente rail alignment to Yucca Mountain; environmental impacts of rail line construction and operation; routine radiation exposures to workers and the public; consequences of severe transportation accidents; consequences of transportation terrorism and sabotage; and emergency response capabilities. [24]

The admitted NEPA contentions regarding transportation safety and security deserve particular attention. The DOE SEIS for Yucca Mountain acknowledged transportation radiological impacts in four categories: (1) routine exposures to members of the public residing near transportation routes, cumulative total up to 2,500 person-rem dose and 1.5 latent cancer fatalities, and in certain special circumstances (for example, 0.016 rem to a person in a traffic jam); (2) routine exposures to transportation workers such as escorts, truck drivers, & inspectors, cumulative total up to 13,000 person-rem and 7.6 latent cancer fatalities (by administrative controls, DOE would limit individual doses to 0.5 rem per year; the allowable occupational dose is 5 rem per year); (3) release of radioactive material as a result of the maximum reasonably foreseeable transportation accident (probability about 5 in one million per year), involving a fully engulfing fire, 34 rem dose to the maximally exposed individual, 16,000 person-rem population dose and 9.4 latent cancer fatalities in an urban area, and cleanup-costs of \$300,000 to \$10 billion; and (4) release of radioactive material following a successful act of sabotage or terrorism, using a high-energy density device, resulting in 27-43 rem dose to the maximally exposed individual, 32,000-47,000 person-rem population dose and 19-28 latent cancer fatalities in an urban area, and cleanup costs similar to a severe transportation accident. [Ref 12, Pp.6-15 to 6-27, 8-41, G-56, CR-467]

NRC staff reviewed and accepted the DOE SEIS transportation impact analysis in the Yucca Mountain licensing docket. The State of Nevada and other parties have challenged the DOE SEIS consequence estimates for transportation accidents and sabotage. Nevada argued that the consequences of a severe accident could be significantly greater if DOE had considered different radiological characteristics of SNF, different environmental conditions, and exacerbating human errors. Nevada argued that the consequences of a successful act of sabotage could be significantly greater if DOE had considered an attack using two weapons, one to breach the cask and another to disperse the cask contents. [23] The NRC licensing board has accepted Nevada's contentions, and if the licensing proceeding should resume, these matters would be further explored in great detail.

#### **TRANSPORTATION PLAN MUST ADDRESS SAFETY CONCERNS**

Spent fuel remains lethally radioactive for at least fifty years after removal from a reactor.<sup>1</sup> Spent fuel transportation involves potential radiological risks to health, safety, and the environment, and social impacts resulting from public perception of radiological risks. In 2009 the DOE Office of Civilian Radioactive Waste Management (OCRWM) published a National Transportation Plan (NTP) for the proposed Yucca Mountain repository that ignored the radiological hazards of spent nuclear fuel, and failed to explain how DOE would manage the safety and security of spent fuel transportation. [20] The NPT contrasted sharply with the approach taken in the 2006 NAS Report on spent fuel transportation safety, and even with the approach taken by DOE in the 2008 SEIS for Yucca Mountain.

The "principal finding" of the NAS report on transportation safety, was that spent fuel transportation "is, from a technical viewpoint, a low-radiological-risk activity with manageable safety, health and environmental consequences when conducted in 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."

The NAS report [34] explained further:

FINDING: There are two potential sources of radiological exposures from transporting spent fuel and high-level waste: (1) radiation shine from spent fuel and high-level waste transport packages under normal conditions; and (2) potential increases in radiation shine and release of radioactive materials from the transport packages under accident conditions that are severe enough to compromise fuel element and package integrity. The radiological risks associated with the transportation of spent fuel and high-level waste are well understood and are generally low, with the possible exception of risks from releases in extreme accidents involving very-long-duration,

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<sup>1</sup> Assumes a surface dose rate of 8,640 rem/hour, for 50-year cooled SNF typical of utility discharges in the 1970s, based on US DOE, DOE/NE-0007, 1980, and lethal acute dose of 600 rem. See Ref. 21, p.9.

fully engulfing fires. While the likelihood of such extreme accidents appears to be very small, their occurrence cannot be ruled out based on historical accident data for other types of hazardous material shipments. However the likelihood of occurrence and consequences can be further reduced through relatively simple operational controls and restrictions and route-specific analyses to identify and mitigate hazards that could lead to such accidents.

**RECOMMENDATION:** Transportation planners and managers should undertake detailed surveys of transportation routes to identify potential hazards that could lead to or exacerbate extreme accidents involving very-long-duration, fully engulfing fires. Planners and managers should also take steps to avoid or mitigate such hazards before the commencement of shipments or shipping campaigns.”

The NAS further cautioned: “The finding that spent fuel transportation risks are ‘generally low’ at present does not necessarily mean that such risks will continue to be low in the future. Future risks depend on a number of factors (e.g., the care taken in fabricating transport packages and executing transportation operations). Ongoing vigilance by regulators and shippers will be essential for maintaining low-risk programs in the future, especially during the scale-up and operation of large-quantity shipping programs.” And the NAS emphasized the importance of identifying and managing “social risks.” “Such risks, which can result in lower property values along transportation routes, reductions in tourism, and increased anxiety, have received substantially less attention than health and safety risks, and some are difficult to characterize.” [Ref. 34, Pp. 7-11]

In the National Transportation Plan (NTP), the public face of the DOE transportation program, DOE failed to address these issues in a substantive manner. In the NTP, DOE downplayed the radiological characteristics of spent fuel, was silent about the potentially severe radiological impacts identified by DOE in the SEIS, and ignored national policy on radiation protection, failing to even mention the NRC requirement for maintaining radiation exposures as low as reasonably achievable (ALARA). The NTP made only limited and self-serving references to the NAS report, arguably the most important public document ever published about spent fuel transportation.<sup>2</sup> The NTP seriously damaged the credibility of the DOE OCRWM transportation program, and missed an opportunity to establish a consensus about safety and security among transportation stakeholders.

The NAS report provided separate findings and recommendations on transportation safety and security. Security issues are addressed later in this paper. The NAS divided the safety issues into current concerns and future concerns. Taken together, the NAS current and future safety concerns provide a template for organizing the risk management elements of a national transportation plan for SNF and HLW.

**Any future national transportation plan should implement the recommendations of the NAS report, or explain why they should not be implemented:**

- **Undertake detailed surveys of transportation routes to identify potential hazards that could lead to or exacerbate extreme accidents involving very-long-duration, fully engulfing fires, and mitigate such hazards before the commencement of shipments; [p.10]**
- **Expand membership and scope of existing DOE advisory group (TEC) to obtain outside advice on social risk, including impact and management; [p.11]**
- **Establish transportation risk advisory group explicitly designed to provide advice on characterizing, communicating, and mitigating the social, security, and health and safety risks of transportation; [p.11]**
- **Undertake additional analyses of very long duration fire scenarios, develop measures to prevent shipments from encountering such fires; [Pp.13-14]**
- **Use full-scale package testing as part of integrated package performance program (testing to destruction should not be required); [Pp.14-15]**

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<sup>2</sup> The DOE NTP makes two references to the NAS report, one regarding the general level of risk (p.2) and the other regarding the process for selecting shipment routes (p.25).

- **Continue involvement of states and tribal governments in routing and scheduling of foreign and DOE research reactor spent fuel shipments; [p.15]**
- **Ensure state designation of highway routes are supported by sound risk assessments, and affected states fulfill their regulatory responsibilities; [p.16]**
- **Implement mostly rail option, using intermodal transportation to allow the shipment of rail packages from plants that do not have direct rail access, and avoid extended truck transportation program; [p.17]**
- **Publicly identify DOE suite of preferred highway and rail routes to a federal repository as soon as practicable, with involvement by states and tribes; [p.18]**
- **Fully implement DOE dedicated train decision before commencing the large-quantity shipments to a federal repository (avoid general trains); [Pp.18-19]**
- **Negotiate with commercial spent fuel owners to ship older fuel first, except where storage risks at specific plants dictate otherwise; if negotiations prove to be ineffective, Congress should consider legislative remedies; [p.20]**
- **Immediately begin to execute DOE emergency preparedness responsibilities defined in section 180© of the NWPA, and include emergency responders in program planning and communication with affected communities; [Pp.20-21]**
- **DOE, DHS, DOT, and NRC Develop criteria for protecting sensitive information about transportation, and commit to open sharing of information that does not require such protection, and facilitate timely access to open information; [p.21]**
- **Examine options for changing the organizational structure of the DOE repository transportation program. [p.21]**

Even though the potential for new rail construction particular to Yucca Mountain has been rendered moot, by DOE's decision to terminate the project, the authors of this paper disagree with the NAS recommendation that "DOE should fully implement its mostly rail decision by completing construction of the Nevada rail spur." [Pp. 17, 217] Rather, what the failed Yucca Mountain experience teaches us is that selecting a future disposal, storage or waste treatment site without fully considering transportation requirements, and then trying to correct the lack of rail access later, can have disastrous consequences for the waste program.

The NEPA issues raised in Nevada's 2005 legal challenge to DOE's selection of the Caliente rail corridor have not yet been finally decided. Nevada's challenges to the DOE Caliente rail line proposal are still pending before the NRC and the U.S. Surface Transportation Board (STB). Further legal actions are expected by affected landowners and land users in the affected Nevada counties. The potential adverse impacts within and outside Nevada, and the massive cost uncertainties associated with new rail construction, threaten to undermine any future "mostly rail" transportation option, and should serve as a cautionary reminder for any future facility siting effort

### **PHYSICAL PROTECTION OF SHIPMENTS WILL BE A MAJOR CONCERN**

Potential threats to spent nuclear fuel shipments include theft, diversion, sabotage, terrorism, induced accidents, and violent protest demonstrations. Over the past decade, concern has focused on acts of sabotage or terrorism intended to release and disperse radioactive material, including attacks using military explosives and anti-tank missiles. The frequency, predictability, and symbolic value of repository shipments would be dramatically different from current shipments. Operation of a national repository or centralized storage facility would result in frequent (perhaps daily), highly-visible, long-distance shipments of SNF, to a single destination.

The State of Nevada brought its concerns about physical protection of current and future SNF shipments to the NRC in a 1999 petition for rulemaking (PRM-73-10). [25] DOE addressed the vulnerability of repository shipments in the 1999 Draft EIS for Yucca Mountain. NRC delayed its response to Nevada's petition after the September 11, 2001 terrorist attacks. DOE acknowledged the vulnerability of shipping casks to terrorism and sabotage in the 2002 Final EIS for Yucca Mountain. [8] The NRC commissioned a

series of classified threat and consequence assessments in response to the 9/11 attacks and Nevada's petition, and in response to congressional direction. [25]

The NAS report also addressed this issue:

**PRINCIPAL FINDING ON TRANSPORTATION SECURITY:** Malevolent acts against spent fuel and high-level waste shipments are a major technical and societal concern, especially following the September 11, 2001, terrorist attacks on the United States.

**RECOMMENDATION:** An independent examination of the security of spent fuel and high-level waste transportation should be carried out prior to the commencement of large-quantity shipments to a federal repository or to interim storage. This examination should provide an integrated evaluation of the threat environment, the response of packages to credible malevolent acts, and operational security requirements for protecting spent fuel and high-level waste while in transport. This examination should be carried out by a technically knowledgeable group that is independent of the government and is free from institutional and financial conflicts of interest. This group should be given full access to the necessary classified documents and Safeguards Information to carry out this task. The findings and recommendations from this examination should be made available to the public to the fullest extent possible. [Ref. 34, Pp. 8-9]

In its petition to the NRC, and in comments to the DOE and the NAS, Nevada cited more than 20 years of tests and analyses, reported in unclassified literature, indicating that SNF shipping casks could be breached by a range of weapons, including Korean War-era military demolition charges, and Vietnam War-era anti-tank weapons. In 2008, in its SEIS for Yucca Mountain, DOE revised its earlier assessment of impacts of an act of sabotage, increasing its estimate of health and economic consequences. [12] However, DOE continued to assume that an attack would utilize a single weapon, which would deeply penetrate, but not fully perforate, the shipping cask.

The SEIS estimated that a single-weapon attack, penetrating one wall of the cask, could result in a 32,000-47,000 person-rem population dose and 19-28 latent cancer fatalities in an urban area, and cleanup costs similar to a severe transportation accident, in the range of \$300,000 to \$10 billion. [12] A DOE-sponsored study estimated that a single-weapon attack that fully penetrated the cask, creating an exit hole, could increase the amount of radioactive material released as an aerosol by about 10 times, compared to the one-hole penetration. [35] A Nevada-sponsored study estimated that a multiple weapon attack, which created an exit hole, would increase the release of radioactive cesium by 100 times or more. The resulting population dose was estimated to be 55-202 times greater than the SEIS estimate; the dose to the maximally exposed individual was estimated to be 555-1,615 times greater; and cleanup costs were estimated to be hundreds of billions of dollars(2008\$) in an urban area. [36]

As of January 2011, the NRC has extended the comment period for its 2010 proposed rule, which would significantly strengthen physical protection of SNF in transit. The proposed rule incorporates regulatory clarifications and security enhancements requested in Nevada's 1999 petition for rulemaking, findings of NRC and DOE consequence analyses, and agency and licensee experience gained since the terrorist attacks of September 11, 2001. However, DOE SNF shipments would continue to be exempt from the NRC physical protection regulations. [26]

The State of Nevada recommends the following measures to enhance physical protection of future spent fuel shipments and mitigate the consequences of potential sabotage events: ship the oldest fuel first; minimize number of shipments and shipment-miles; maximize use of rail, requiring dedicated trains; adopt NRC proposed amendments to 10 CFR 73.37 for all shipments; assess implications of federal regulations for cross-country rail shipments; require full-scale testing of shipping casks; adopt DOE-SRG WIPP transportation protocols for accident prevention and emergency response; and implement a comprehensive human factors management program.

## **MAXIMUM USE OF RAIL MAY NOT BE FEASIBLE GIVEN EXISTING WASTE STORAGE AND TRANSPORTATION SYSTEM CONDITIONS**

There is virtually unanimous agreement among nuclear waste transportation planners that rail is the preferred mode for repository shipments. The NAS report summarizes the major reasons that favor the “mostly rail” option:

- It reduces the total number of shipments to the federal repository by roughly a factor of five, which reduces the potential for routine radiological exposures, conventional traffic accidents, and severe accidents.
- Rail shipments have a greater physical separation from other vehicular traffic and reduced interactions with people along transportation routes, which also contributes to safety.
- Operational logistics are simpler and more efficient.
- There is a clear public preference for this option. [34]

An additional development favoring rail transport is the growing number of at-reactor SNF dry storage systems utilizing large dual-purpose (transportable storage) canisters, which would be shipped off-site in loaded transport packages weighing more than 110 short tons. This trend is expected to continue.

Transportation planners confront three questions: What is the maximum share of SNF shipments that can reasonably use rail transport to a repository? What would it cost to maximize the rail share of SNF shipments? What are the larger national implications, particularly in terms of impacts on highly populated areas, and compliance with new rail security regulations, of maximizing use of rail for repository shipments?

Studies for the now-terminated Yucca Mountain project identified a significant challenge to future plans for rail shipments to storage, disposal or waste processing facilities at regardless of location. The DOE 2008 assessment of reactor shipping capabilities determined that 44 commercial sites could ship SNF directly by rail; 7 sites could ship truck casks only; 21 commercial sites could ship rail casks by heavy haul truck (HHT) to the nearest rail line; and 15 of the 21 HHT sites could also ship rail casks by barge. [12]

The DOE “mostly rail” transportation option for Yucca Mountain assumed that about 93 percent of the commercial SNF destined for the repository could be shipped in rail casks. Nevada analyses, based on current shipping site capabilities, found that the maximum share of SNF shipped in rail casks, could be in the range of 65-75 percent. The 7 sites that would ship by truck, and the 21 sites that would require intermodal transport of rail casks, account for about 35 percent of commercial SNF that would be shipped to a repository. [11] The NRC licensing boards accepted Nevada’s contention [NEV-NEPA-015] challenging the provision in DOE’s license application that at least 90 percent of SNF would be shipped to Yucca Mountain annually by rail in TAD canisters. The NAS report discussed this issue at length, but did not specify the percentage of rail shipments that would constitute the “mostly rail” option it recommended. [34] There no is evidence that the 93 percent “mostly rail” option projected by DOE for Yucca Mountain would be any more feasible for shipments to other future disposal or storage facilities.

The cost of maximizing rail transportation of SNF is uncertain, regardless of the destination, because of uncertainty about the cost of upgrading infrastructure at and near the originating sites. In 2008, DOE estimated the future life cycle cost of the repository transportation program at \$19.5 billion (in 2007\$), about 24 percent of the projected future total cost of the waste management system over the next seven decades. The three largest transportation cost items were cask systems acquisition (\$10.9 billion), operations execution (\$3.1 billion), and construction of the now-terminated Nevada railroad (\$2.7 billion). [22] The operations execution item presumably included the cost of using HHTs to move more than 2,100 rail casks from the 21 sites that lack rail connections. Two other potentially significant costs of maximizing rail use were not included: the cost of infrastructure upgrades necessary for use of HHTs at 21 sites, and the cost of upgrading short lines that connect 23 reactor sites with mainline railroads.

DOE plans did not provide a cost estimate for infrastructure upgrades necessary to use HHTs. These heavy haul trucks would be up to 220 feet (67.1 meters) in length, with gross vehicle weights of as much as 500,000 pounds (227,000 kilograms). The 21 HHT routes DOE proposed to use are a combination of local,

state, and federal highways, ranging in length from 2.1 miles to 150 miles, with a total distance of about 565 miles (915 kilometers). DOE provided no information on the likely cost of upgrading roads, bridges, traffic controls, and emergency response capabilities necessary to allow safe and secure HHT shipments from reactor sites to nearby railroads. [11] The DOE life cycle cost study estimates for the national transportation system did not include infrastructure upgrades. In its 2009 National Transportation Plan (NTP), DOE stated needed upgrades “within their gates” would be made by the utilities, and off-site track, highway and bridge upgrades would be made “by States, counties, and railroads.” [20]

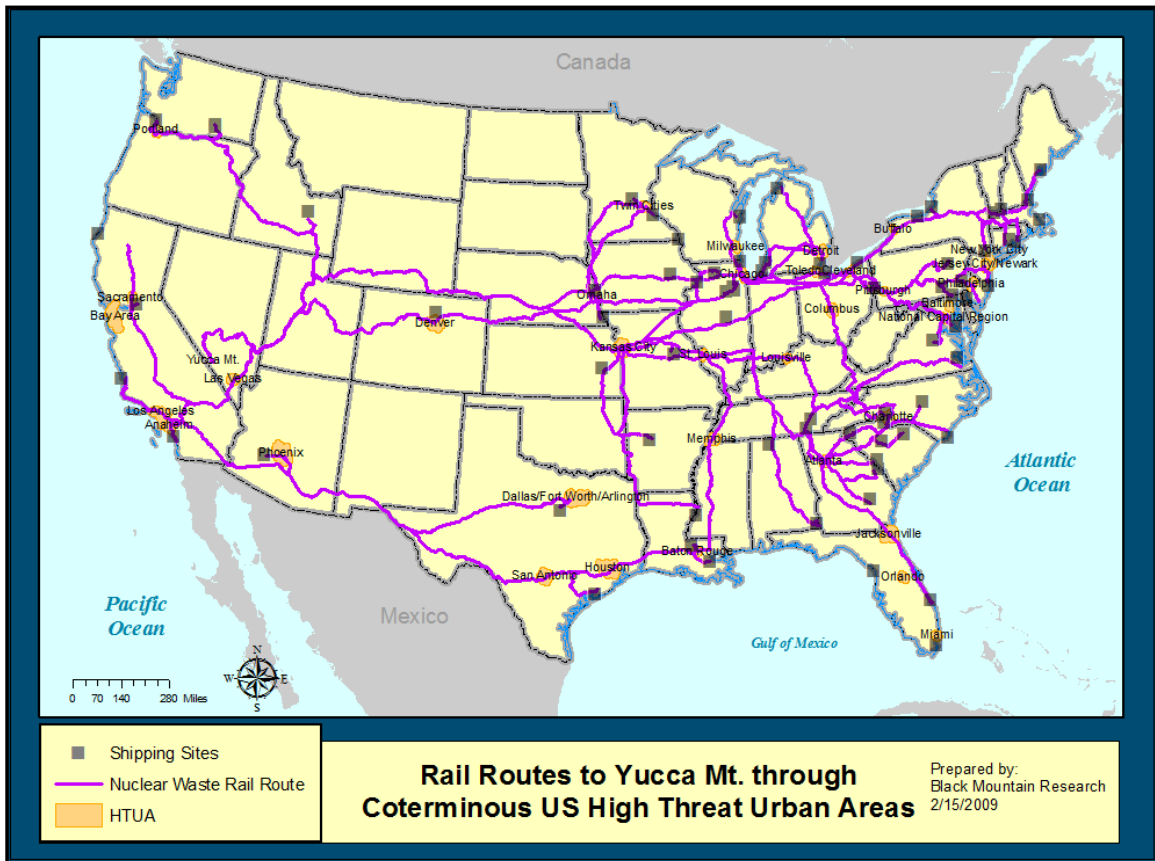
Nor did DOE plans provide a cost estimate regarding use of short lines (Class II or III railroads) to originate shipments from 23 reactor sites, 14 of which DOE classified as rail-capable. DOE assumed it could use at least 17 short line railroads, totaling more than 1,360 route miles, without assessing their financial status, infrastructure conditions, current traffic, or traffic capabilities. The Federal Railroad Administration (FRA) informed DOE of conditions that might require significant upgrading before such routes could be safely used for SNF shipments, including: class of track, rail weight, track restrictions, signals, hazardous materials registration and training, grade crossings, track conditions, sharp curves, tunnels and bridges. [11] In the NTP, DOE said it planned to “consult with” FRA about “short-line railroad track capability near reactors.” [20]

### **RAIL SHIPMENTS MUST COMPLY WITH NEW SECURITY REGULATIONS**

The “mostly rail” option for cross-country SNF shipments requires a safety and security trade-off that generally goes unrecognized in repository impact assessments: fewer opportunities, compared with truck shipments, to route rail shipments away from highly populated areas. “The mainline rail network was designed to link, not avoid, major urban areas, and therefore traverses suburban and urban population zones. Cross-country rail routes to Yucca Mountain must traverse suburban and urban areas to access carrier interchanges. There are no Federal (USDOT) routing regulations for Yucca Mountain shipments that require rail routes to avoid highly populated areas. The Interstate highway system is constructed to allow truck shipments to either access or bypass major urban areas, and bypasses typically affect both suburban and rural population zones. Cross-country interstate truck routes to Yucca Mountain can access route interchanges at a variety of urban, suburban, and rural locations. Federal (USDOT) routing regulations (HM-164) require Yucca Mountain shipments to use interstate routes generally, and to use interstate bypass routes, where available, to avoid highly populated areas.” [30]

In late 2008, after publication of the Yucca Mountain SEIS, new Federal regulations were promulgated that would restrict rail shipments of certain hazardous materials, including SNF and HLW, through highly populated areas. The new regulations were intended to prevent “catastrophic release or explosion in proximity to densely populated areas, including urban areas and events or venues with large numbers of people in attendance. Also of major concern is the release or explosion of rail cars in close proximity to iconic buildings, landmarks, or environmentally significant areas.” [19] “Although the number of rail shipments carrying explosives and radioactive materials is relatively low, a release of these materials could cause serious and devastating harm. If terrorists detonated certain explosives at critical points in the transportation cycle, they could cause significant loss of life and damage to infrastructure, and harm the national economy through the accompanying disruption to commerce. Likewise, if terrorists perpetrated an attack against a rail car transporting certain radioactive materials, they could endanger a significant number of people as well as disrupt the supply chain as a result of contamination.” [19]

Future cross-country rail shipments of SNF and HLW will have to comply with these new security regulations adopted by the Department of Transportation’s Pipeline and Hazardous Materials Safety Administration (PHMSA) in conjunction with the FRA and the Department of Homeland Security’s Transportation Security Administration (TSA). The new rules became effective December 26, 2008, after issuance of the DOE SEIS for Yucca Mountain. [19] As a result, the “representative” rail routes to Yucca Mountain would have to be reexamined, along with the larger assumptions about the “mostly rail” scenario, for future cross-country SNF and HLW shipments.



**Fig.4. HTUAs Traversed by DOE Rail Routes to Caliente**

By way of example, DOE’s representative rail routes to Yucca Mountain would have traversed most of the “high threat areas” identified by TSA. The TSA Final Rule designated 46 high threat urban areas (HTUAs) in 28 states and the District of Columbia [49 CFR Part 1580, Appendix A]. Rail shipments of spent nuclear fuel and high-level radioactive waste through these HTUAs would be subject to new chain of custody and control and other procedures, such as designation of rail security coordinators and monitoring plans, established by the TSA Final Rule [49 CFR Part 1580, Appendix B]. [19]

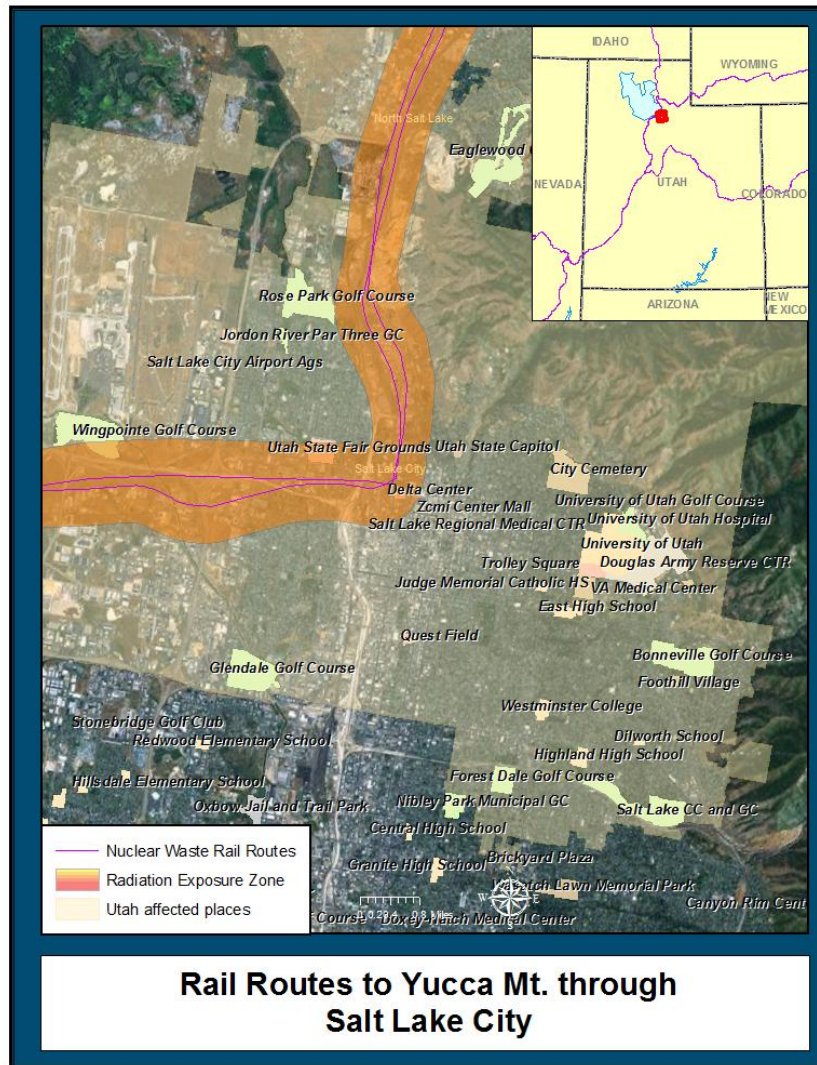
Figure 4 shows the HTUAs traversed by DOE representative rail routes to Yucca Mountain via the now-terminated Caliente rail line. Thirty HTUAs in 25 states and the District of Columbia would have been traversed by at least one DOE rail route to Caliente. Several HTUAs, including Atlanta, Chicago, Kansas City, and St. Louis are traversed by two or more rail routes. Major carrier interchanges would have occurred in HTUAs, including Chicago, Kansas City, and St. Louis. Of DOE’s 72 rail routes to Yucca Mountain, 63 would have traversed at least one HTUA, 49 would have traversed two or more HTUAs, and 28 would have traversed 3 or more HTUAs. [19]



**Fig.5. DOE Representative Rail Routes Through Chicago**

Chicago illustrates the potentially heavy impact that cross-country shipments might have on HTUAs (Figure 5). About 25 percent of the DOE rail shipments to Yucca Mountain would have traveled through the Chicago area. According to the 2000 census, about 4.4 million people live in the HTUA in and around Chicago. About 585,000 people in the Chicago HTUA live within 800 meters (one-half mile) of the rail lines that would have been used for Yucca Mountain shipments. [19] Because of its role as major national rail hub, and because of its proximity to reactor sites in the Midwest, the Chicago area would likely be impacted by future SNF shipments to other destinations.

Salt Lake City represents another aspect of how the new TSA and PMSHA security regulations might impact selection of cross-country routes for SNF and HLW shipments. Salt Lake City is not a designated HTUA, but the rail routes through Salt Lake City (Figure 6) exhibit precisely the conditions of concern identified in the PHMSA routing regulations, which are designed to protect highly populated areas and iconic locations. If the 27 routing risk analysis factors [49 CFR Part 172, Appendix D] had been applied, DOE’s representative routes through Salt Lake City might not have been permissible.



**Fig.6. DOE Representative Rail Route Through Salt Lake City**

The Union Pacific mainline through Salt Lake City would have carried about 87 percent of the rail shipments of SNF and HLW to Yucca Mountain. According to the 2000 census, about 660,000 people live in the affected area in and around Salt Lake City, and about 136,000 people in the Salt Lake City area live within 800 meters (one-half mile) of the rail route. The area has a large population of day-time business and government employees, visitors and tourists. Nearby iconic buildings and landmarks include Temple Square, the State Capitol, the State Fairgrounds, and the Delta Center/Energy Solutions Arena. The Temple Square area reportedly draws up to 5 million tourists and visitors per year. The 20,000-seat Energy Solutions Arena is located within 800 meters of the Union Pacific rail line. [19] Because of its role in east-west transportation, because of its location relative to DOE HLW storage sites in Washington and Idaho, and because of its proximity to the PFS storage site in Utah, the safety and security issues associated with SNF and HLW shipments through Salt Lake City might well be revisited.

One more uncertain aspect of the new TSA and PHMSA security regulations regards potential impacts on the nation's railroads. As many as 18 rail carriers transporting DOE SNF and HLW shipments to Yucca Mountain would have been required to prepare rail transportation route analyses under the PHMSA Final Rule. The Union Pacific Railroad would likely have been required to prepare route analyses involving at least 13 designated HTUAs and at least 23 other major urban areas. The Norfolk Southern Railroad and

CSX Transportation would each likely have been required to prepare rail transportation route analyses involving at least 10 designated HTUAs and at least 11 other major urban areas. The NS and CSXT route analyses would have required coordination with those prepared by the UP for routes involving carrier interchanges, especially the large number of route interchanges in Chicago, St. Louis, and Kansas City. Dozens of other interchanges with originating and connecting carriers would also have required coordination with the analyses prepared by CSXT, NS, and UP. [19]

In addition to the HTUAs designated by TSA, the DOE representative rail routes to Yucca Mountain would have traversed 39 urban areas with 2000 census population greater than 100,000, and 12 state capitol cities. [19] Application of all 27 PHMSA route analysis risk factors could have significantly increased the number (and complexity) of the route analyses required for DOE rail shipments to Yucca Mountain.

Future planning for SNF and HLW shipments to storage, disposal or waste processing facilities at other locations around the country would likely present comparable challenges to DOE, the nuclear utilities, the national rail system, and the rail carriers that make up the national system. Considering these uncertainties, it would be prudent to reexamine all aspects of the mostly rail scenario for repository shipments.

## CONCLUSION

The Yucca Mountain repository project has now been terminated. Between 1983 and 2006, DOE expended \$780 million (in 2007\$) on transportation planning activities. [22] Between 1995 and 2008, DOE prepared three major environmental impact statements for the Yucca Mountain repository that together devoted more than 4,600 pages to transportation. [8, 12, 16]

But the Nevada component of the DOE transportation program was never able to overcome the reality that Yucca Mountain had the most difficult rail access, the most difficult interstate highway access, and most adverse overall transportation system impacts, of all the sites studied for the first repository. And even after the National Academy of Sciences provided a template for resolving public concerns about safety and security, the national component of the DOE program was unable to address the radiological risks of spent fuel transportation in a manner that could achieve stakeholder confidence. Transportation became the Achilles Heel of the DOE civilian nuclear waste repository program.

The principal lesson to be learned from the history of DOE's failed effort at Yucca Mountain is that transportation must be given equal consideration with storage and disposal, at every stage, in planning and implementing a successful national nuclear waste management program. Critical transportation requirements, such as mainline rail access and interstate highway access, must be addressed at the very beginning of site selection for storage and disposal facilities. The National Academy of Sciences recommendations on safety and security are waiting to be implemented in a national transportation plan. Risk assessment, risk management, and risk communication will be required over the entire life of operations - for storage, transportation, and disposal.

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