SPENT FUEL AND HIGH-LEVEL RADIOACTIVE WASTE
TRANSPORTATION RISKS AND IMPACTS

Background

The transport of spent nuclear fuel and high-level radioactive waste to the proposed Yucca Mountain repository site in southern Nevada has the potential to dramatically and significantly impact communities throughout Nevada and across the nation. Depending on assumptions about the mix of shipping modes, handling and shipping capabilities at points of origin (e.g., reactor sites), size of the shipping canister or cask, and other factors, a Yucca Mountain repository, if constructed and opened, would receive between 23,500 and 96,300 shipments of spent nuclear fuel (SNF) from civilian nuclear power plants and high-level radioactive waste (HLW) from DOE weapons facilities. The repository would also receive an unknown number of shipments of so-called "miscellaneous wastes requiring geologic disposal," adding to the overall number of radioactive materials shipments that would be required.

Studies by the State of Nevada and DOE indicate that 43 states would be directly impacted by SNF and HLW shipments to the proposed Yucca Mountain repository. A study by DOE identified 109 cities with populations over 100,000 that would be affected by such shipments. The DOE report parallels an analysis done by State researchers in 1995 and updated in 1996. The Nevada report examined shipping routes, both rail and highway, in relation to the impacts various alternatives would have on communities nationwide. The State’s analysis shows that many of the reactors that would ship waste during the first 10 years of repository operations will likely use truck transport regardless of the availability of rail access to Yucca Mountain, thereby impacting a larger number of cities and communities than reflected in the DOE report.

Transportation issues are critically important to the State and local Nevada communities. Nuclear waste transportation will be the most visible and dramatic "driver" of potential repository impacts for Nevada. Despite this fact, DOE has done almost nothing to evaluate

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14 Under a scenario where most of the waste is shipped using legal weight trucks, there would be 96,000 truck shipments plus 300 Naval spent fuel shipments that would have to come by rail from Idaho National Engineering and Environmental Laboratory, due to the size and configuration of the Navy packaging. Under a scenario where most waste is transported by rail, there would be 19,800 rail shipments plus 3,700 truck shipments from reactors that are not rail capable. (Both of these shipment scenarios are taken from DOE’s Draft Environmental Impact Statement for the Yucca Mountain Repository project, which was release in August, 1999.) Due to the fact that there is no rail access to Yucca Mountain or the Nevada Test Site and the cost of constructing such access could exceed $1 billion, the State of Nevada considers it much more likely that spent fuel and high-level waste would be transported to the site by legal weight truck.

impacts, either in Nevada or nationally. The few feeble attempts that DOE has made to address the transportation issue, as in the draft Yucca Mountain EIS, have been wholly inadequate and designed to obfuscate risks and impacts rather than deal with them forthrightly.

This is especially true in the national arena, where DOE has actively sought to downplay impacts of radioactive materials transportation related to the repository program. DOE went so far as to purposely mislead citizens and communities in other parts of the country when hearings on the draft Yucca Mountain EIS were held in late 1999 and early 2000. Instead of advising people in areas where the hearings were held of transportation routes, numbers and types of nuclear waste shipments through their communities, and the impacts that could be expected, DOE noticed the meetings as if they involved only a proposal for a repository facility in southern Nevada. In fact, the transportation issue was ignored in every public notice DOE issued on the draft EIS hearings.

The State’s transportation impact assessment efforts over the past 14 years have resulted in numerous disturbing findings with respect to spent fuel and high-level waste transportation and its impacts on the Nevada and the nation.

**The Historical Record - Cause for Concern About Safety**

DOE and the commercial nuclear power industry are eager to point to the past history of commercial spent fuel transportation as hard and fast evidence that repository shipments can be accomplished safely. Such assurances are disingenuous at best. The fact is that there will be more spent fuel shipments in the first year of repository operations alone than in the last 40 years of commercial utility shipments combined. The shipping campaign needed for Yucca Mountain will be larger, of much longer duration, more complex, and far riskier than anything ever attempted in the United States or anywhere else in the world.

The reality is that there have been less than 2,600 spent fuel shipments nationwide since 1964. While there have been no documented cases of radioactive releases involving these shipments, a number of transportation and unloading accidents have occurred, and there have been instances of equipment failure that could have resulted in more serious accidents under the right circumstances. In addition, at least one case of attempted sabotage of a shipment is known to have occurred. These accidents and incidents occurred even though past shipments have been made under extraordinarily strict and controlled conditions - conditions that were much more stringent than can be expected for the tens of thousands of shipments needed to move waste to a repository.

There is no reason to expect that the commercial nuclear industry's past experience is a good predictor of the safety of future DOE shipments to Yucca Mountain. U.S. utilities have had relatively little experience with long-distance rail shipments. By contrast, the lowest estimate of
the amount of spent fuel to be shipped to Yucca Mountain (63,000 MTU) is more than thirty times the total amount of waste shipped in this country between 1964 and 1990. The average length of shipments to Yucca Mountain would be about 2,000 miles, compared to an average distance of about 550 miles for previous utility shipments (if only past rail shipments are considered, the average distance was 327 miles), creating additional opportunities for human error and equipment failure. Moreover, DOE's track record as a self-regulated shipper of spent nuclear fuel includes instances of risk-taking that would be unacceptable or illegal if committed by an NRC licensee. For example, DOE knowingly used a cask with questionable safety margins (the M-1A) for shipments of research reactor fuel through the New York metropolitan area.  

Another factor that makes it impossible to compare a DOE sponsored Yucca Mountain shipping campaign with past spent fuel shipments is DOE's plan for a “market driven” transportation system that will rely on up to three regional contractors and an unknown number of subcontractors to be selected on the basis of lowest bids and to be operated in a for profit manner. Incentives under this type of arrangement will be for the contractors to seek to operate the transport system in such a way to minimize cost and maximize profits. In the case of historical utility shipments of spent fuel, most of which have been individual shipments handled in a one-of-a-kind manner, extraordinary and even extra-regulatory precautions have been taken to minimize risk, even if these precautions resulted in greater costs.

Radiological Health Effects of Routine Shipments

Spent nuclear fuel is extremely radioactive and very deadly. It requires extraordinary precautions and shielding in order to safeguard the public and others from its lethal effects. A person standing one yard away from an unshielded, 10 year old fuel assembly, for example, would receive a lethal dose of radiation (500 rem) in less than three minutes and would incur significant damage within seconds.

The surface dose rate of spent fuel is so great (10,000 rem/hour or more) that shipping containers with enough shielding to completely contain all emissions are too heavy to transport economically. Consequently, NRC regulations allow a certain amount of neutron and gamma radiation to be emitted from shipping casks during routine operations and transport (1,000 mrem/hr at the cask surface and 10 mrem/hr 2 meters from the cask surface). While the significance of human exposure to low levels of radiation, which may cause health effects less obvious than cancer or birth defects, is not fully understood and is the subject of much controversy in the medical and health physics communities, there is a risk of serious adverse health effects from routine emissions (i.e., without accidents occurring or radioactive materials being released from the shipping casks) to train crews due to emissions from rail casks.

especially on dedicated trains; to truck drivers and others involved in truck transport of the waste; to inspectors dealing with large numbers of shipments over long periods of time; and to members of the public from truck casks during gridlock incidents. Another aspect of this issue is the excessive level of surface contamination (the so-called "weeping" phenomenon) on casks loaded in wet storage pools.

State of Nevada researchers, using DOE’s shipment number figures and computer models, have estimated that the Yucca Mountain shipping campaign, even without a radiological accident occurring, would result in the following exposures:

- Truck safety inspectors would receive 2,500 millirems per year (mrem/yr);
- Occupants of a vehicle next to a spent fuel truck in a traffic situation lasting one to four hours would receive 10 - 40 mrem per person per incident;
- Members of the public along potential legal weight truck routes in Nevada could receive between 150 - 260 mrem/yr.

Such exposures could add up to substantial amounts of radiation when multiplied over the 28 - 35 year duration of a Yucca Mountain shipping campaign. People exposed repeatedly, over long periods of time, to such spent fuel and high-level waste shipments could experience serious and even life threatening radiation-induced health effects.

**Spent Nuclear Fuel and High-Level Radioactive Waste Accidents**

While there is uncertainty over the long-term effects of exposure to lower doses of radiation, there is no disagreement about the health impacts of a major radiological release. State of Nevada researchers have estimated that a credible, worst case accident involving a spent fuel rail shipment would result in between 356 to 432 latent cancer fatalities, if the accident occurred in a populated area. In addition, there would be thousands of people who would suffer non-lethal effects such as cancers, genetic damage, nervous system disorders, etc.

Such an accident, if it occurred in an urban area, would have economic impacts of between $63 and $108 billion, excluding any costs resulting from lost business or opportunity costs resulting from the stigmatizing effects of such an accident.\(^\text{17}\)

\(^{17}\) Estimated economic costs include clean up and decontamination; razing and reconstructing contaminated buildings, infrastructure, etc.; environmental damage; public health and safety costs; and other costs associated with the response to and remediation for such an accident.
**Probability of Severe Accidents**

Despite DOE and nuclear industry claims of infallibility, accidents involving spent fuel and high-level waste shipments can and will happen, and it is very possible that at least some of these accidents will be severe enough to result in the release of radioactive materials. An estimate of the number of accidents likely to occur during spent fuel shipments to a repository can be obtained by multiplying the historical anticipated accident rates by the anticipated cumulative shipment miles. If all spent fuel were to be shipped to the repository by truck in large-capacity casks, requiring about 96,000 shipments and over 100 million shipment miles, 129 accidents and over 1,900 incidents would be expected over the operating life of the repository. Under the mostly rail shipping scenario, about 440 accidents and almost 1,000 incidents would be expected.

Overall accident rates could be considerably higher depending on the accident histories of the actual routes to be used. None of DOE’s risk assessments consider unique local conditions along specific route segments that could increase the probability or the consequences of severe accidents. Nor has DOE considered potential changes in the transportation environment that may significantly influence future accident rates: higher highway speed limits; higher average train speeds and the introduction of high-speed passenger trains; industry deregulation and profitability; higher rates of infrastructure failure; urban freeway congestion and gridlock; and other factors. Perhaps the single most important factor, and the most difficult to assess, is human error. None of DOE’s risk estimates has encompassed the full spectrum of human factors. Organizational and individual error will significantly affect not only the probability of severe accidents, but also the accuracy of efforts to estimate the probability and consequences of severe accidents.

**Shipping Cask Performance in Severe Accidents and Sabotage or Terrorism Incidents**

The assumption by DOE, NRC, and the nuclear power industry that shipping casks will survive the most severe accidents, sabotage, or terrorist incidents without loss of shielding or containment is not only unsubstantiated, but dangerously irresponsible. Agency-sponsored research indicates that the NRC cask performance standards do not reflect credible worst-case accident or attack scenarios. None of the casks currently in use have been physically tested to determine if they comply with current standards because full-scale testing is not required by the NRC. DOE has no plans for full-scale testing of the new cask designs that would be used for repository shipments, even though they will differ significantly from current designs. Furthermore, DOE has not adequately considered human factors in all phases of cask

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18 Casks to be used for repository shipments are being designed to hold much more spent fuel than current casks. The new casks will be less heavily shielded; manufactured with new, different, and lighter weight materials; and mass-produced in large quantities instead of being hand built like existing casks.
development and deployment. Human error may affect cask performance in the design phase, in fabrication, in licensing, in operations, and in maintenance. DOE's consideration of human factors in cask design has been inadequate, as documented in the Agency’s review of the preliminary design reports for the GA-4/9 and BR-100 casks. Human factors management will be especially important in DOE’s transportation system because the large cask fleet will require mass production and large-scale maintenance operations.

In addition, none of the casks to be used to ship spent fuel and high-level radioactive waste are required to be physically tested. NRC allows manufacturers to use computer simulations to demonstrate compliance with safety regulations. State researchers and others have strongly criticized not only the lack of physical testing for casks, but also the NRC cask safety regulations themselves as being too lenient and not representative of real world accident conditions.

A 1985 DOE contractor report concluded that a maximum severe, credible accident involving a single, current-generation rail cask (one that holds considerably less spent fuel than the casks proposed for repository shipments) could result in the release of a significant amount of radioactive materials to the environment. The study assumed a severe impact followed by a fire fed by large quantities of fuel. According to the study, the release of only a small fraction of the cask's contents would be sufficient to contaminate a 42 square mile area. The costs of cleanup after such an accident in a rural area would exceed $620 million, and the cleanup effort would require 460 days. An alternative analysis by a State of Nevada researcher estimated cleanup costs for the same rural accident that ranged from $176 million to $19.4 billion, depending primarily upon permissible post-accident soil concentrations of cobalt-60, cesium-134, and cesium-137, and upon regulatory requirements for disposal of the contaminated soil. Cleanup after a similar accident in a typical urban area would be considerably more expensive and time consuming (between $62 and $108 billion).

**Terrorism Risks in High-Level Waste Transportation**

State of Nevada research into the potential risks associated with terrorism or sabotage against repository shipments indicates that such risks are substantial and grossly underestimated by DOE, NRC, and the nuclear industry. Years of relative quiet on the national scene with respect to nuclear facilities and nuclear shipments have fostered complacency and what one researcher called an “atrophy of vigilance.” Research conducted by the State indicates that past NRC and DOE evaluations of the terrorist threat are deficient with respect to the terrorist threat in the 21st century. The type of terrorism (domestic as well as international), the methods that might be employed, and the weapons that are available to terrorist groups have changed markedly

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over the past 20 years. As a result, the risks of terrorist action and the consequences of such action against spent fuel or HLW shipments may be much greater than current estimates indicate.

The outcome of a terrorist attack on a SNF or HLW shipment will vary according to the type of attack, the weaponry used, the location, and other variables. The armor penetration capability of currently available weapons that could be used to attack a shipping cask is considerably greater and more effective than the capability that was assumed in the DOE and NRC assessments of the 1970s and 1980s. Guerrilla armies around the world are known to be equipped with older anti-armor missiles such as the Soviet RPG-7 and the American M72. With the ability to penetrate up to 10 - 14 inches of armor plate, these weapons pose a considerable threat to a nuclear waste shipping cask. Terrorists could conceivably obtain one of the dozen or more antitank weapons currently capable of penetrating 12 - 30 inches of tank armor.\(^{20}\)

DOE’s draft Yucca Mountain EIS includes an analysis of acts of sabotage against spent fuel shipping casks. DOE acknowledges that high-energy explosive devices available to terrorists are “capable of penetrating a cask’s shield wall, leading to the dispersal of radioactive contaminants to the environment.” [page 6-33]. DOE estimated that a successful attack on a truck cask in an urban area could release enough material to cause 15 latent cancer fatalities.

State of Nevada staff and contractors have replicated DOE’s accident and sabotage consequence analyses, using the RADTRAN and RISKIND models, and have evaluated DOE’s accident and sabotage scenarios using credible alternative assumptions. Nevada believes that the Draft EIS underestimates the impacts of a successful terrorist attack on a truck cask by at least a factor of 10. The population dose from the postulated attack could be at least 310,000 person-rem, resulting in at least 150 fatal cancers. Adverse economic impacts, including business losses and cleanup costs, could be as high as $20 billion.

Nevada’s Attorney General filed a petition for rulemaking with the NRC in June 1999. The petition requests amendments to the current transportation safeguards regulations and a comprehensive reexamination of the consequences of radiological sabotage against SNF/HLW shipments. In September 1999, the NRC accepted and published for public comment Nevada’s Petition for Rulemaking. The Western Governors’ Association endorsed Nevada’s petition, as did nine individual states. As of December 2000, NRC staff are still reviewing the petition and public comments.

Meanwhile, in September 2000, the National Council on Radiation Protection and Measurements (NCRP) published a draft report on radiation protection issues related to terrorist

\(^{20}\) In fact, one such weapon, a U.S. Army “Super Dragon” anti-tank missile launcher, was recently found in a cave in Churchill County, Nevada by hikers. Neither the Army nor the Nevada National Guard could account for the weapon.
activities intended to disperse radioactive material. (Radiation Protection Issues Related To Terrorist Activities That Result in the Dispersal of Radioactive Materials, NCRP Draft Report No. SC 46-14, September, 2000) The NCRP report states: “Nuclear reactors, adjacent spent fuel storage depots, nuclear fuel reprocessing facilities, transport vehicles, or any high level waste site are potential targets for the use of high explosives to disperse into the atmosphere the very high levels of radioactivity associated with materials at these facilities.” [page 15].

Nevada’s petition states that three major changes have occurred in the nature of the terrorist threat that argue for a strengthening of the safeguards regulations: (1) the increasing lethality of terrorist attacks in the United States; (2) an increase in serious terrorist attacks and threats against transportation systems; and (3) renewed concerns about nuclear terrorism generally, and specifically, terrorist actions involving potential radioactive contamination.

Developments in two related areas have increased the vulnerability of spent fuel shipping casks to terrorist attacks involving high-energy explosive devices. First, the capabilities and availability of explosive devices, especially antitank weapons, have increased significantly. Second, new spent fuel shipping cask designs, developed to increase payloads without exceeding specified weight limits, appear to be more vulnerable to attacks involving past, current, and future weapons systems and commercial explosives.

Spent nuclear fuel shipments to a geologic repository and/or centralized interim storage facility will be dramatically different from past shipments in the United States. The following differences will create greater opportunities for terrorist attacks and/or sabotage against SNF/HLW shipments and may also increase the consequences of any incidents that occur:

(a) long duration, highly visible, nationwide shipping campaign;

(b) regular and predictable shipments to a single destination;

(c) large increase in amount of spent fuel shipped and increased numbers of truck and rail shipments annually, averaging several cask shipments per day, every day, for 30 years;

(d) substantial increase in number of active routes and average shipment distances, with potential implications for selection of targets and attack locations;

(e) significant concentration of shipments along certain highway and rail routes west of the Mississippi River, with implications for shipments through heavily populated areas and through locations that place shipments in significantly disadvantageous tactical positions;
(f) potential use of routes within Nevada with marginal safety design features, limited rest and refueling locations, and low likelihood of swift local law enforcement agency response; and

(g) DOE’s planned use of a “market driven” transport system (i.e., a system of regional contractors and subcontractors selected on the basis of lowest cost), thereby complicating security for shipments and potentially increasing risks.

Nevada believes that a national repository or interim storage facility may have a greater symbolic value to terrorists as a target for attack than current at-reactor storage facilities, and that the enhanced symbolic value of the facility as a target may extend to SNF shipments to such a facility. Nevada further believes that a storage or disposal facility operated by DOE, the U.S. government agency responsible for producing nuclear weapons, may have greater symbolic value to terrorists as a target for attack than commercial storage facilities and that the enhanced symbolic value may extend to DOE’s shipments of SNF and HLW to such a facility.

Combine the attractiveness of repository shipments as targets and the prominence of Las Vegas (or Reno) as a major resort area and media market, and there exists a not insignificant potential for terrorism or sabotage within Nevada. In addition, many of the geographic and terrain features in the State, such as long expanses of unpopulated rural highways and railroads, rugged mountain areas that provide ideal cover and facilitate escape, etc., also combine to increase the risks of terrorism against spent fuel and high-level waste shipments.

**Conclusion: Transportation Risks are Substantial and Unwarranted**

State of Nevada research has documented that there are substantial risks to Nevada communities and to communities in other states along potential shipping routes from the transport of spent nuclear fuel and high-level waste to a repository or interim storage facility in Nevada. These risks are significant “drivers” of many of the socioeconomic and related impacts associated with the federal program. DOE’s and the federal government’s activities in the area of transportation analysis, planning, and risk management have done little to attenuate these risks and, instead, have either obfuscated or actually exacerbate risks and their consequences.

Not only are the risks from spent fuel and high-level waste shipments potentially great, but they are also unnecessary. These materials have long been - and are currently being - stored in safe, secure locations where risks are minimized. With currently available dry storage technology, spent fuel can continue to be safely and economically stored on site for the next 100 years or more. Exposing millions of people in 43 states and thousands of communities to needless risks from the transportation of these materials is more than unwarranted - it is irresponsible and foolhardy.