

Memo

To: R Halstead
From: M Lamb and M Resnikoff
Date: 01/21/00
Re: Comment Summary – Yucca Mtn Draft EIS, Expanded version

Summary

After reviewing DOE/EIS-0250D, *Draft 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* (July, 1999), with emphasis on the transportation of spent fuel to the proposed repository, a number of questions have been raised which need answer. Below is an outline summarizing some of the key deficiencies of the EIS. Many of the comments listed below follow a central theme: the EIS uses outdated experimental data and improper mathematical models to arrive at unbelievable estimates of health consequences due to incident-free transportation and accident scenarios. No new experiments have been performed to assess shipping cask response to postulated accident conditions or sabotage scenarios, even though the current generation of casks bear little resemblance to the casks used in experiments cited by the current EIS. No new estimation of the frequencies of severe accidents is made, even though rail and highway conditions, such as speed limits, have changed since the cited studies were performed. Computer models estimating release fractions in a terrorist strike are used which cannot properly model the casks involved. When the deficiencies in the EIS's treatment of transportation are assessed, it becomes clear that new experimental studies are necessary to provide a realistic assessment of the costs of transportation. These new experiments must involve an updated Modal Study, new experiments concerning modern cask response to sabotage events, and new traffic surveys estimating the frequency of severe accidents. In addition, the inadequate treatment of transportation in this analysis points to the glaring need for NRC to perform an updated EIS on the transportation of spent nuclear fuel. The outlined points below are just brief summaries, and detailed analyses of each point will be provided at a later date.

1. Use of data from the Modal Study to estimate accident severities and probabilities of severe accidents

1.1. Use of “mid-lead” temperature as parameter determining accident severity

1.1.1. Lead (MP 621°F) will stabilize the inner core temperature in the event of a fire until it is completely melted. This has the affect of insulating the inner core from temperature increases for an extended period of time. Uranium and/or steel, with a much higher melting point, will not melt, resulting in an inner core temperature that will rise constantly with heat input. Therefore, inner cores of newer casks are expected to have higher temperatures during a fire of a given intensity.

1.1.2. The use of mid-lead temperature results in grouping of all fires with temperature greater than 1050°F into one consequence category, since lead-nickel alloying occurs here, weakening the integrity of the older casks. Since uranium and/or stainless steel will behave differently under temperature duress, new classifications based on its properties must be used for categorizing fire intensities.

1.2. Use of “reference cask” containing a water jacket neutron shield

The Modal Study used as its reference cask one using a water neutron shield. This shield was assumed to evaporate in event of fire. The resulting dead air space was modeled to cut the heat transfer rate into the cask by over 70% (Modal 6-36). Given a 1475°F fire transferring heat at a rate of 17,000 BTU/hr-ft², this had the effect of reducing the heat actually absorbed by the cask to 5,000 BTU/hr-ft². This reduction was assumed when the melting times were calculated. However, newer casks no longer use water jackets, and the thermal insulation device assumed in the Modal Study is no longer present. Therefore, the heat transfer rate absorbed by the cask is expected to be much closer to the thermal output from the fire itself, since it cannot be assumed without testing that the polypropylene shield will behave like a water jacket. Since the time to reach lead melt is proportional to the rate of thermal input, the absence of the dead air insulator would have the effect of reducing the time required to melt the lead shielding from 1.09 hours to about 20 minutes. (Audin, 18) For the uranium and/or stainless steel shield, this means quicker increases in temperature than those postulated by the Modal Study, resulting in a reduction in the fire severity needed to cause a given accident condition.

1.3. “Lead cask bias” used to select most appropriate measurement parameter

The decision to use strain on the inner cask wall as the primary measure of cask response is based on lead’s tendency to “slump” when subjected to high loading, resulting in high strains on inner cask wall. However, uranium and/or stainless steel are strong and rigid and thus will not slump. Rather, the force from impacts will be transferred to the joints and welds of the cask, likely resulting in a greater force being applied to them than those in a lead cask. The choice of strain as the sole measurement parameter for physical duress

will likely lead to an underestimation of the damage caused to newer casks through rupture of welds and seals in the event of an accident. Therefore, new experiments must be performed to model this behavior.

1.4. Incorrect use of “distribution” and “frequency” of velocities

The EIS states that, even though the average speed limit on national interstates has increased since the Modal Study, the distribution of accidents, and the frequency distribution of accidents, on the highways is not likely to change (EIS, J-66). However, there is no evidence cited to support this statement. The National Highway Safety Traffic Administration (NHTSA 1998), along with numerous other agencies, have provided evidence that increases in speed limit lead to more accidents, more fatalities, and a greater proportion of vehicles traveling at higher speeds. All of these suggest that the DOE is incorrect in claiming that increased speed limits will not affect accident severity distributions.

In one study assessing the change in Interstate fatalities in states which raised the speed limit in 1995, the NHSTA discovered that “Interstate fatalities experienced a statistically significant increase in those states that raised their posted speed limits late in 1995 or early in 1996.” (NHTSA 1998) Further, the Insurance Institute for Highway Safety reported that distributions of travel velocities do indeed change with increased speed limits, stating that “in general, higher speed limits lead to greater proportions of cars travelling at very high speeds.” (Institute) For example, the Institute cited traffic statistics in New Mexico, finding that “the proportion of motorists exceeding 70mph grew from 5 percent shortly after speed limits were raised [from 55 to 65 mph] to 36 percent.”(Institute)

These studies seem to contradict the statement made in the EIS. Unless the DOE can obtain credible evidence to back its assertion that changing the speed limit will not affect the distribution of velocities or accident severities, it must be assumed that the NHSTA and the Insurance Institute are correct in concluding that increased speed limits do lead to higher proportions of persons traveling at high speeds. This means that the Modal Study’s accident distribution is an underestimate of the true probabilities of severe accidents. This again is evidence that a new study must be performed. To accompany a new Modal Study, the NRC should also conduct an updated EIS on spent fuel transportation which accounts for modern speed, traffic, and accident conditions.

1.5. Improper assumptions regarding the location of severe accidents

The Modal Study findings are used to estimate the amount of radioactive material released as a function of accident severity, using strain on the inner cask wall and mid-lead temperature as the two variables to estimate this release. Also used is the Modal Study finding that in 99.4% of all rail and truck cask accidents, no cask contents would be released.

For the prediction of where along routes accidents may occur, the RADTRAN4 computer program was used. This method assumes that accidents could occur at any location along routes, with their frequency of occurrence being determined by the accident rate characteristic of the states through which the route passes and the number of shipments that travel the route. Important to note is that *state-specific*, and not city- or county-specific, accident rates were used. Thus, the “urban” accident rate is an average of the rates of all defined urban areas in a given state. In determining maximum effects of accidents, the methodology used was as follows:

The analysis assumed maximum reasonably foreseeable accident scenarios could occur anywhere, either in rural or urbanized areas. The probability of such an accident would depend on the amount of exposure to the transportation accident environment. In this case, exposure would be the product of cumulative shipment distance and the applicable accident rates. (J-61)

It appears that what was done was take the probabilities of *any* accident, which were state-specific for each population group, and multiply by a generic probability of a given accident being of a certain severity. That is, it is assumed that accident severity is randomly distributed between population zones. Using this assumption, it is concluded that “because of the large differences in the distances traveled in the two types of population areas, a severe accident scenario that might be reasonably foreseeable in a rural area might not be reasonably foreseeable in an urban area.” (J-61)

However, it seems questionable that severe accidents are randomly distributed. Resnikoff analyzed 38 “extra severe” accidents to determine their location. Analysis of the rail accidents included in these 38 accidents showed that most high-speed impacts occur at downgrades, particularly if curves are present. Downgrades are as likely to occur in suburban as rural areas. In addition, the commission only based its estimation of “severe” accidents on impacts, not on fires or fire duration. Most of the truck accidents analyzed occurred in urban areas. Thus, the frequency distributions used by the EIS seem incorrect.

1.6. Improper Exclusion of most severe accident scenarios

1.6.1. The Modal Study used as its “average highway conditions” a stretch of Interstate 5 in Los Angeles and Orange counties. For example, it tallied the number, height, and geographic conditions of the bridges on this stretch and used these to estimate the number of bridges of a certain height. This was then used to estimate how many tall bridges existed in the entire nation for spent fuel trucks to cross. Using this, it was determined that an accident involving a truck falling off a high bridge was not “reasonably foreseeable” and its consequences were not determined. Since this stretch of highway is dominated by urban areas, the distribution of bridge types is biased in favor of small, short bridges, like the ones that cross over other roads. This is not representative of national conditions and leads to the unnecessary exclusion of a potentially disastrous consequence. After searching the FHWA and the DOT web sites for information regarding the frequency and heights of bridges, it seems that there exists no national database tracking bridge heights, although a national

inventory of bridge frequencies does exist. The number of bridges per mile of highway assumed in the Modal Study does seem to be reasonably representative of national tendencies after reviewing information on the National Bridge Information database. However, the bridge heights assumed are likely to be underrepresentations of national highway statistics.

As a minimum, the EIS on Yucca Mountain should report on the likely consequences involving a train or truck carrying spent nuclear fuel falling off a tall bridge. This estimation should include cleanup costs associated with any decontamination of water supplies which might be needed in the event of a fall into a water body. Unless a national database is available which provides information on the distribution of bridge heights across the country, the possibility of a fall off a tall bridge cannot be ignored, and the consequences must be assessed.

- 1.6.2. The Modal Study assumes that the probability of train accidents involving the falling off of a bridge is the same as that for the highway scenario, with the geographic conditions also taken from the highway estimations. More clearly, the Study used data taken from Interstate 5 to estimate the geographic conditions of national train routes, including bridge heights. Thus, the same argument given for the highway scenario (point 1.6.1) holds here, but more so since there is no proof that highway and rail conditions are similar.
- 1.6.3. The method of rejecting accidents having a yearly probability less than one in 10 million is arbitrary and incorrect when performing a probabilistic risk assessment. The product of the probability and the likely consequences are what determine significance in a risk assessment.
- 1.6.4. DOE consistently offers estimations of health effects due to transportation without giving a range of likely effects in the event of an accident. This is based on the assumption that the effects given are “conservative.” However, the points raised here show that the studies are not conservative: unless new studies are performed, a range of possible health effects should be given.
- 1.6.5. If the DOE insist on using the “reasonably foreseeable” criteria of 1 in 10 million mentioned above, improper accident distribution data, unknown cask response to accident conditions, and improper estimation of accident probabilities (all mentioned above) will make some circumstances not deemed “reasonably foreseeable” in the Modal Study “reasonably foreseeable.” These events must be considered in any acceptable consequence analysis.

Some final notes on the Modal Study, and on the Modal Study II

It is interesting to note that, in a review of the Modal Study (Plooster et al, 1986) conducted for the NRC, the analysts remarked that:

“Some current literature suggests that lead casks are on their way out. If this is so, then most of the work in this report will be obsolete when the next generation of shipping casks hits the rail/road.” (b.1)

Similarly, the Modal Study itself comments on the usefulness of the results if new cask designs are implemented or transportation conditions change:

“New designs using alternative design principles and materials, or changes to regulations such as the imposition of a 75 mph national speed limit, could affect the results and conclusions of this study.”(xx)

So, we are merely agreeing with the Modal Study and its review in stating that the current study is obsolete and that a new study needs to be performed before any of its conclusions can be used. Recently, the NRC and Sandia National Laboratory have begun the process of developing an updated Modal Study to address many of the objections raised above. Public hearings on this plan are set to begin on November 17th in Bethesda, Maryland. It would be proper for DOE to use the updated Modal Study as part of a larger EIS on spent fuel transportation. Additionally, the updated Modal Study public hearings should be used as a venue to address the need for a new transportation impact analysis concerning Yucca Mountain as the destination for the nation’s spent nuclear fuel and high-level radioactive waste.

2. Deficient Treatment of Sabotage

There are a number of points of contention with the current treatment of sabotage by the DOE in the Draft 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 (DOE/EIS-0250D, 1999) and referenced documents. In order to establish the need for a reevaluation of the analysis of sabotage used by DOE in preparation of the EIS most clearly, only the most significant problems will be addressed. The final conclusion of this section is that the DOE does not adequately address the threat of sabotage, nor does it prove that concerns about the affects of such an event are unwarranted.

2.1. Inadequate selection of Reference Weapons and Reference Cask

The type of shaped charge used in the Sandoval experiments and cited in Luna as the device offering the maximum impact of a sabotage attack is the M3A1 military shaped charge. This charge, when tested against a full-scale GE IF-200 cask, was capable of penetrating one cask wall, penetrating 42 cm (16.5 inches) into the cask, damaging 50% of the spent fuel rods, and releasing more than 1% of the total fuel. Sandoval also says that a survey of attack devices was performed in this study, with the devices selected based on their availability to the perpetrator and their potential to breach truck casks. The details of this evaluation are classified.

In order to better understand exactly what devices were considered for possible use as the reference weapon, it is necessary to understand the restrictions placed on this analysis. In 10 CFR 73.1.a.1, “radiological sabotage” is defined as:

- (i): a determined violent external assault, attack by stealth, or deceptive actions, of several persons with the following attributes, assistance, and equipment:
 - a. well-trained (including military) and dedicated individuals
 - b. inside assistance, passive or active
 - c. suitable weapons, up to and including hand-held automatic weapons, equipped with silencers and having effective long-range accuracy
 - d. hand-carried equipment, including incapacitating agents and explosives for use as tools of entry or for otherwise destroying reactor, facility, transporter, or container integrity or features of the safeguard system
 - e. a four-wheel drive land vehicle used for transporting personnel and their hand-carried equipment to the proximity of vital areas
- (ii): an internal threat of an insider, including an employee
- (iii): a four-wheel drive land vehicle bomb

This provides the parameters by which the assessment of possible weapons was made. The definition of “hand-carried equipment” is unclear. It appears that such anti-tank artillery as the Milan Anti-Tank Missile and the US TOW 2 Anti- Tank missile, reported to have armor-penetrating capabilities of greater than 1000mm (39.4 inches) and greater than 700 mm (28.5 inches), respectively, have not been considered as plausible sabotage weapons. In contrast, the M3A1 is reported as having armor-penetrating capabilities of at least 20 inches. This means that either of the anti-tank missiles will penetrate deeper into a spent fuel cask, likely completely through, drastically increasing the amount of material released. Anti-tank missiles of this sort must be analyzed in a credible sabotage analysis. Both devices can be transported by a few persons, or a vehicle, and thus should be considered “hand-carried.”

Failure to consider arson coupled with missile strike as credible reference weapon and reference attack

A very significant factor to note when analyzing the results of the Luna report is that missile strikes accompanied by fires have not been considered. In section 3, the following statement is made:

“[U]nlike tanks and other typical targets of armor-piercing weapons, nuclear waste casks contain no explosive or combustible materials that could be touched off by the HEDD penetration, so little secondary damage is expected. In other words, only penetration and swept volume of spent fuel disrupted determine the magnitude of the damage that can be inflicted by an attack on a cask, not penetration depth *per se*.”

This shows a hidden assumption in the assessment of sabotage. The Luna study assumes that there will be no fire coupled to a missile strike in the event of sabotage. Luna makes this assumption noting that the casks themselves are not combustible. However, this does not account for the potential of saboteurs to deliberately set a fire, or for the fact that the casks will be in proximity to combustible materials while being transported. Shipping casks are designed for transport on trucks or trains that are powered by highly flammable, combustible materials. These casks are also very likely to spend a significant portion of their travel in proximity to other trucks, rail cars, pipelines, etc. containing combustible or explosive materials. Further, potential saboteurs must be assumed to have knowledge that engulfing a target in flames in addition to striking it with a missile will be very likely to

cause extensive damage. All of these factors lead to the conclusion that “secondary damage” cannot be ignored, as it has in this study.

Heat input to a cask will weaken the areal density of the metal shielding layers. If potential saboteurs were to first weaken the shipping casks via thermal input before missile strike, this could significantly increase the damage caused by such an event. In a series of experiments testing resistance of shipping containers to puncture conducted for the NRC by Lawrence Livermore National Laboratory and published in 1980, the impact of increasing temperature on cask strength was addressed (NUREG/CR-0930). One experiment in this study concentrated on the effect of temperature on the ultimate “punch force” required to completely penetrate a shipping cask wall. From this test it was determined that “the force at failure decreases with increasing temperature,” (NUREG/CR-0930, pg 32). This study used three temperatures for this determination: room temperature, 200°F, and 400°F. Since this study shows there is a correlation between the force required to penetrate a shipping cask wall and the temperature of the cask, it is very important that these effects be considered in a proper evaluation of sabotage scenarios. Further, the temperatures involved in deliberately set, engulfing fires will be able to raise the cask outer wall temperature to levels much beyond this range. In the Modal Study, it is commented that the rail and truck casks used in their analysis “can be exposed to a regulatory fire (1475°F, engulfing) for over 1 hour” (6-43) before the temperature at the mid-lead thickness of the cask wall reaches 500°F. The problems with the use of the Modal Study are detailed in section 1 of this report, and the use of the above statement in no way endorses the validity of the Modal Study’s conclusions or methodologies. What this statement does show is an acknowledgement that the regulatory fire will raise the temperature of a shipping cask wall over the 400°F temperature estimate used in NUREG/CR-0930. This leads to the conclusion that in extreme fire situations, such as those deliberately set as part of a sabotage attempt, the temperature of the shipping cask will rise. This will lessen the force required to completely penetrate the shipping cask wall, as was discovered in NUREG/CR-0930, resulting in greater damage to a fuel cask in the event of a subsequent missile attack.

In addition, not addressing the effects of heat input on spent fuel respirable release in the event of a breach ignores the ability of temperature to increase the percentage of spent fuel released in respirable form. For example, the conversion of UO_2 to U_3O_8 is exothermic at slightly elevated temperatures, and results in the formation of a fine powder of respirable size (Aronson). Coupling a fire with a cask breach will expose the spent fuel inside the cask to elevated temperatures, resulting in thermodynamically favorable conditions for the above reaction. The importance of this term needs to be addressed in an assessment of sabotage consequences.

By failing to include thermal effects in its assessment of sabotage, the DOE has provided an insufficient treatment of sabotage consequences in the Yucca Mountain EIS. This needs to be remedied before the true impact of a successful event can be analyzed.

2.2. Improper extrapolation of previous experiments to current cask designs

2.2.1. Swept Volume

In the Luna report, it is acknowledged that the cask design used in the 1980-1981 tests examined in the Sandoval report is outdated, and an attempt is made then to correlate the data collected in these experiments to a computer simulation of a newer-design cask impact by two HEDD devices. In particular, Luna suggests an “alternative” means of analyzing the test results in the Sandoval report which “enables evaluation of the magnitude of the potential source term in other situations based on calculated hole volumes.” (Luna 2.2.6)

To do this, Luna attempts to correlate the experimentally determined ratio of respirable aerosol produced to the mass of fuel released in an event to a calculated ratio based on the mass of swept fuel. The equation is (Luna 2.2.6):

$$MS = (\pi/4) \times NP \times NL \times NR \times PL \times PD$$

NP:

An estimate of the amount of fuel assumed to be affected longitudinally in the pin at the center of the hole. Assumed to be the number of pellets in the missing length rounded up to the next whole pellet. Operationally defined as L/L_p , the missing length of pin divided by the pellet length [unitless].

NL:

An estimate of the affected number of pins laterally. Assumed to be the number of pins within the hole diameter rounded up to the next integer. Operationally defined as L/PP , rounded to the next integer, giving it units of $[\text{length}^2]$

NR:

Defined by Luna as “number of rows of pins along the disruption path/PP,” thereby giving it units of [length].

PL:

Depth of penetration of pin disruption. Operationally defined by Luna as NR/PP , giving it units of $[\text{length}^2]$

PD = pellet density, giving it units of $[\text{mass}/\text{length}^3]$

Thus according to Luna, the equation works out to be:

$$MS[\text{mass}] = (\pi/4)[\text{unitless}] \times NP [\text{unitless}] \times NL [\text{length}^2] \times NR [\text{length}] \times PL [\text{length}^2] \times PD [\text{mass}/\text{length}^3],$$

$$[\text{mass}] = [\text{mass} \cdot \text{length}^2]$$

The inconsistent units definitely need explanation by the Sandia researchers responsible for the report. The numerical values obtained using this equation were duplicated by independent calculations, assuming that the number of rows of pins along the disruption path was 6 for the full-scale test (see attached spreadsheet). This suggests that either the units are listed incorrectly in the document, or that the equation used to estimate swept mass is invalid. Until this discrepancy is addressed, the DOE’s use of the Luna report in the Yucca Mountain EIS is suspect.

Even if the unit discrepancy is a mere typographical error, equating the mass of swept fuel with the respirable release fraction fails to consider such factors as number of holes of penetration (2 for full penetration) and differences in thermal properties of HEDD devices. First, it was assumed that, because the Sandoval full-scale test and the computer modeled test in Luna predicted shaped charges to penetrate only one side of a shipping container, the amount of released respirable material could be described as proportional to the “swept volume” of the fuel pins. However, it was also acknowledged that having multiple holes (for example, an exit and entry hole, or multiple entry holes caused by multiple device strikes) would significantly increase the fraction of respirable material released, since multiple holes will allow outside air to flow through the cask. Because the DOE assumes that a terrorist strike will result in only one hole into a shipping container, it is assumed that this air flow will not be generated, thus leading to the correlation between affected mass and respirable release.

However, it is necessary to consider the event of a full cask penetration (or multiple-hole penetration) event. Under these circumstances, there will be a continual supply of oxygen provided to the inner core of the cask. This oxygen will then react with the uranium dioxide spent fuel, oxidizing it to U_3O_8 . This process is exothermic at slightly elevated temperatures, and results in the formation of a fine powder of respirable size. Further, this air flow, when coupled with elevated temperatures resulting from fire (as would be reasonable in the event of a crash or deliberate arson) would heat the core of the cask without having to first heat its surrounding shields. This will result in a quick elevation of the spent fuel temperature, providing more oxidation and thus more respirable aerosol production. Because the DOE assumed that all sabotage events would at most penetrate a shipping cask with one hole, this mechanism was ignored.

In review of the testing performed at Sandia and Batelle laboratories in the 1980s, it is stated that the M3A1 charge used would completely penetrate certain shipping casks such as the NFS-4 (Dietrich & Walters, 1983 pg. 5). If this type of cask were used in destructive testing, the benchmark forming the basis for the Luna results could be drastically different. This shows the need to consider the effects of a complete penetration event. In the case of a complete penetration, according to the review cited above, “the entrainment of particles in the jet’s wake would enhance release at the jet exit hole. Further, two holes should vent more rapidly than one and perhaps capture higher initial concentrations in the efflux” (5). By referencing a flawed computer evaluation of cask resistance to HEDD impact, the EIS has improperly limited the discussion of impacts associated with sabotage events to single-hole, incomplete penetrations. This results in an incomplete estimate of the true effects of a successful sabotage event.

The Luna report acknowledges that the existence of multiple holes results in significant increases in aerosol release fractions. In section 2.2.5, the report states that “the total effect of a full penetration event may be to increase aerosol release by approximately 10 times the aerosol release fraction from partial penetration.” If we use this factor of 10 to figure out a new % respirable release and account for the difference between spent fuel and surrogate fuel, the % respirable release is greater than 1%. Below is outlined the % respirable release fractions assuming 10X greater release than was estimated in the Sandoval tests. Also, three different spent fuel-surrogate fuel correction factors are used (see section 2.2.3) to show how they affect the results.

	Release fraction from Sandoval tests	New release fraction, assuming 10x Sandoval result
Aerosolized fraction of surrogate fuel mass released from pins	0.000537	0.00537
% aerosolized fraction of spent fuel mass released from pins, using SFR of 3	0.1611%	1.611%
% aerosolized fraction of spent fuel mass released from pins, using SFR of 5.6	0.300%	3.00%
% aerosolized fraction of spent fuel mass released from pins, using SFR of 12	0.644%	6.44%

More analysis needs to be performed before a swept fuel mass can be used as a correlation factor predicting masses of respirable fuel released in the event of a high-energy impact.

In using Swept Volume as a surrogate for respirable release, the analysis is making the assumption that all potential devices used in a terrorist attack will behave the same as the M3A1 charge. Its conclusion rests on the assumption that, given a certain swept volume size, a certain respirable mass fraction will be released, regardless of other factors, such as differences in thermal heat evolution. Further, the computer code used to estimate release fractions of other casks was calibrated using only two test results. When it was found that the code underestimated the hole size by a factor of two, the calibration simply multiplied by 2 to obtain a correlation. Without an experimental validation of the ability of the SCAP code to effectively model the newer-generation casks, this approach is unacceptable.

2.2.2. Respirable Aerosol Production

Luna addressed a mechanism for additional respirable aerosol release due to the pressurized nature of actual spent fuel rods which was not addressed by the Sandoval tests using unpressurized rods. The report states that in the Sandoval experiments there was a “significant amount of surrogate fuel aerosol created within the cask by the HEDD that remained inside and was ultimately deposited on the inner surfaces of the cask.” Some or all of the unaccounted material in the Sandoval tests (which

Sandoval concluded “could not have been respirable”) is likely to be made up of this material. Luna states that, given a mechanism to create flow of gas out of the cask, this could become an additional respirable aerosol source.

The Luna study addresses the fact that real fuel rods are pressurized, and that rupture of these rods allows gas to escape, producing a flow that will carry aerosol into the environment. In every test subjecting shipping casks (real or modeled) to a HEDD explosion, the fuel rods used were not pressurized, and there was never a direct measurement of the actual quantity of respirable aerosol within the cask that would comprise this contribution from “blowdown.” Luna then attempts to estimate the amount of respirable material generated via this pathway by using a brittle fracture study conducted at Argonne National Laboratory (Jardine et al, 1982. “Final Report of Experimental Laboratory-Scale Brittle Fracture Studies of Glasses and Ceramics,” Report No. ANL-82-39, Argonne National Laboratory, Argonne, IL.)

Jardine developed experimental data on the amount and size distribution of particulate material produced by calibrated hammer impacts on brittle materials. His work developed a linear relationship between energy density in the material from the impact of a calibrated hammer on brittle materials and the mass of particulate material with geometric diameter less than $10\mu\text{m}$ over 2 orders of magnitude in energy. Important to note is that Jardine used materials that were sufficiently refractory to ensure that melting and vaporization were not a factor. Thus, one problem with correlating this study for use in tests involving high density devices is that thermal properties are not considered. This is incorrect for missile penetrations, especially when they are coupled with fire (deliberate or otherwise).

Next, Luna takes the relationship found by Jardine for particles of $10\mu\text{m}$ geometric size and says that this analysis is not interested in these particles. Luna states that “of interest to this study is the quantity of particles that are of respirable sizes. For uranium dioxide pellets with a density of 10.5 g/cm^3 , this corresponds to a geometric size of about $3\mu\text{m}$.” The use of $3\mu\text{m}$ particle size is unsubstantiated, since particles of size $10\mu\text{m}$ are airborne and will contribute to overall dose in the event of an explosion. Further, $10\mu\text{m}$ particles are generally considered the maximum size for respirable aerosols. Therefore, this is the size that should be used in determining the aerosol fraction released in sabotage tests.

Particles of size in the range of $10\mu\text{m}$ are small enough to be dispersed quite far from an implosion scene. In addition, they can be deposited in the nasal region of the respiratory tract. While it is rare that particles of this size penetrate into the lungs, they will contribute to overall radiological dose. In addition, many of the particles deposited in the nasal region will be ingested, contributing to continued dose inside of the body. Ignoring particles greater than $3\mu\text{m}$ thus leads to an underestimate of the true radiological health effects of a postulated terrorist event.

To estimate the impact energies expected from HEDD1, Luna takes the estimated HEDD1 kinetic energy and divides it by the estimated swept volume of the disrupted fuel. Luna then makes two estimates: “the highest energy represents no attenuation of the HEDD energy by penetrating the wall. Since the HEDD action penetrated about equal amounts of mass per unit area passing through the wall and passing through the fuel, the residual energy deposited in the fuel is likely to be one-half to one-third of the initial energy density. This is shown by the low end of the range indicated on the plot.” In fact, the lower energy is 1/3 of the higher energy. Luna then states that the correlation, using a particle diameter of 3 μ m and an energy density of 1/3 the estimated initial energy density, approximates that 5% of the unaccounted mass will be respirable.

There are a number of things seriously wrong with this conclusion. First, the Jardine study that the entire relationship is based on does not take into account thermal effects when estimating the correlation between energy density and respirable aerosol production. The correlation used was obtained from a test involving a calibrated hammer, not a high-temperature explosive device. As was mentioned earlier, Luna comments that “all materials were sufficiently refractory to assure that melting and vaporization were not a factor in the tests.”(22) This suggests that the correlation is leaving out the importance of temperature in creating additional respirable particles, which if included would certainly increase the fraction of respirable aerosol production.

Second, the UO₂ and spent fuel data points obtained from other studies (MacDougall et al, 1987. “Site Characterization Plan Conceptual Design Report, Volume 4, Appendices F-O,” Report No. SAND94-2641, Sandia National Laboratories, Albuquerque, New Mexico), (Alvarez et al, 1982. “Waste Forms Response Project Correlation Testing,” Report No. EGG-PR-5590, Idaho National Engineering Laboratory, Idaho Falls, Idaho), which Luna states act to validate the use of the Jardine results for spent fuel, are inconclusive. The data from the MacDougall study is in the very low energy density range, and they cannot be used to demonstrate any correlation without more data points taken in the higher energy density range. The Alvarez study appears (the graph in Luna is hard to read) to provide respirable percents from 2%-40% at an energy density approximately 7 times smaller than the density estimated for the HEDD. Regardless of any of these uncertainties, the Luna study assumes one value for the respirable fraction produced and places no uncertainty boundaries on it.

Third, Luna assumes that the HEDD will have an energy density of 1/3 that estimated based on the swept volume and kinetic energy of the device. It is argued in the Luna study that since the device penetrated about equal amounts of mass per unit area penetrating the wall of the cask as it did penetrating the fuel rods, the energy available for action on the fuel rods is likely “to be 1/2 to 1/3 of the initial energy density.” However, this assumes that the HEDD action on the cask wall does not

impart an energy to the fuel rods. Because of this fact, Luna's use of 1/3 of the initial assumed energy density is an underestimate (using 1/3 instead of 1/2 is an underestimate in itself). Without actual knowledge of the amount of respirable aerosol produced (as in a properly sampled test), the energy density should be assumed to be 100% of the initial.

In order to check the effect of the assumptions made by Luna in correlating the Jardine data to the sabotage benchmark, we calculated the likely aerosol release ignoring all of the objections raised here except for the use of 3 µm particles (see attached spreadsheet). Instead, we used Figure 2 from the Luna report to obtain a % respirable production in the energy range given by Luna for the HEDD penetration assuming 10µm-sized particles. Using this, the Jardine correlation estimates that 50-100% of the fuel impacted by the HEDD will be respirable, as opposed to the 5% assumed by Luna. This changes the respirable surrogate fuel aerosol produced estimate from .19kg (Luna) to 1.91-3.82 kg.

Without any direct measurement of the respirable aerosol produced by HEDD penetration, the 5% assumption used is neither conservative nor grounded in reality. Unless experimental studies are conducted that specifically measure this term, a more conservative approximation of 50-100% respirable production must be used.

2.2.3. Spent Fuel to Surrogate Fuel Aerosol Ratio

The Luna report also proposes a reduction in the spent fuel to surrogate fuel aerosol ratio used to estimate spent fuel releases using data obtained with DUO₂. Luna lists several experimental estimates of the (spent fuel release/ surrogate fuel release) which vary over two orders of magnitude : .53, 5.6, .71, .42, 3, 2.8, 2.5, 3, 12. The Sandoval report used the value of 5.6, obtained for the analysis using a wet sieve technique. However, Luna questioned the validity of this technique, and concluded that a value of 3 was a more valid ratio, largely based on the only spent fuel aerosol point obtained from any experiments. Again, it is difficult to see how this can be substantiated. For the most conservative approach, the ratio should be the highest one experimentally estimated, which is 12.

In order to determine the effect of using different ratios on the estimation of the source term for a spent fuel release, we recalculated the estimated amount and percentage of fuel released from the truck cask used in the Sandoval experiments in the manner done by Luna in table A-1. We calculated this term while varying this ratio from 3 to 12, in addition to varying the estimated respirable aerosol production from 5% - 100%. The results are summarized below.

Respirable aerosol production percentage	Spent fuel-surrogate fuel correction factor	Respirable spent fuel produced (kg)	Percentage of total spent fuel in cask
5	3	0.574	0.29%



50	3	1.071	0.53%	Luna's result
100	3	2.294	1.14%	
5	5.6	5.736	2.85%	
50	5.6	10.708	5.33%	
100	5.6	22.945	11.41%	
5	12	11.472	5.71%	
50	12	21.415	10.65%	
100	12	45.890	22.82%	

Clearly, the 0.29% release calculated by Luna is not conservative. This is important because the same assumptions about spent fuel-surrogate fuel ratios and respirable aerosol productions are used when estimating the effects of HEDD impact on newer-generation casks. As is shown above, these assumptions are incorrect and lead to highly incorrect results. Because of this, it is recommended that experimental tests be performed subjecting new generation shipping casks to HEDD impact, rather than to rely on an incorrect computer simulation.

2.3. SCAP computer code used without sufficient benchmarking

The Luna study attempts to utilize a computer model as a replacement for actual experimentation in order to determine the possible damage caused by two HEDD's on state-of-the-art shipping casks. However, the code that they use admittedly does not model multi-layered targets well. The Luna study “benchmarks” the SCAP code against the Sandoval full-scale test and determines that the code predicts penetration depth well, but underestimates the size of the hole created by the penetration. In an attempt to remedy this, the Luna report multiplies the predicted hole size by a factor of 2.0 to obtain “correct” results, then proceeds to do the same when modeling other cask designs. This approach is seriously incorrect. It assumes that the code will consistently model all cask layer or shell arrangements, including different numbers of layers, which is incorrect. Important to this analysis is understanding the reasons why the SCAP code underpredicts the hole diameter. According to Luna, “underestimation is believed to be a result of some secondary effects, such as the dispersive layered nature of the targets, the relatively unfocused nature of the HEDD1, and the near one-dimensional nature of the flow dynamic of the code.” (23) The SCAP user’s manual addresses the problems in applying the model to predict penetration characteristics on multi-layered targets, stating that “there may exist interface phenomena not modeled by the code which could result in serious difficulties in comparing SCAP modeling output and experimental data. For a *limited number of interfaces* the code should still be useful.” (27, emphasis added).

Below is a table comparing the cask used in the Sandoval study with the casks used in the Luna model.

Cask used in Sandoval:		Truck Cask used in Luna		Rail Cask used in Luna	
Steel-lead-steel truck cask		steel-uranium-steel		steel-uranium-lead-steel	
Weight (ton)	25	weight (ton)	25	weight (ton)	125

Inner cavity diameter (cm)	69.85	Inner cavity diameter (cm)		inner cavity diameter (cm)	162.56
Length (cm)	490.22	Length (cm)	406	length (cm)	
Steel outer shell thickness (cm)	3.175	Steel outer shell thickness (cm)	3.81	steel outer shell thickness (cm)	4.60375
Lead middle thickness (cm)	16.84	Uranium middle thickness (cm)	7	lead middle thickness (cm)	1.27
Steel inner shell thickness (cm)	0.79	Steel inner shell thickness (cm)	0.9525	uranium middle thickness (cm)	5.55625
Neutron shield: water jacket, empty (cm)	11.43	Neutron shield: steel outer layer (cm)	0.3175	steel inner shell thickness (cm)	3.81
		Neutron shield: polypropylene layer (cm)	11.43	neutron shield: steel outer layer (cm)	0.635
				neutron shield: water jacket layer (cm)	15.24
1 PWR assembly		4 PWR assemblies		26 PWR assemblies	

Looking at the above table, it becomes apparent how different the three casks actually are from each other. They consist of different materials in different proportions, can carry different numbers of fuel assemblies, and have different sizes and weights. Regardless of these factors, the analysis carried out in the Luna report assumes that the correction of “2.0” to the predicted hole diameter is appropriate for all of the casks above.

As is shown on Table 1 of the Luna report (pg 34), the casks are broken down into different layers to be used as input into the SCAP code. What is important to note is that with every different layer, there exists an interface which is not modeled by the SCAP code. For the cask used in “benchmarking” the code, these interfaces were air-steel, steel-lead, and steel-PWR assembly, along with the various interactions in the assembly itself. A factor of 2 difference between the predicted hole size and the larger experimental hole was attributed to difficulties in modeling these interface phenomena, among other things. This factor of 2 was then assumed to account for the interface phenomena in the other casks listed above, even though these casks have different interfaces and different numbers of layers. There is no justification of this step.

The use of the SCAP code to model cask response to shaped charge attack without having an appropriate experimental model to calibrate with is unacceptable. The SCAP code consistently underpredicts the diameter of the hole created by the explosion of the M3A1 device against the outdated cask used in the Sandoval report. The only justification that has been given for using a factor of two to correct this underprediction is that this makes the code correlate with experimental results. Therefore, it seems necessary to conduct new experiments using the newer casks to determine how to correlate the SCAP code with these experimental results. Since the newer casks have different numbers and types of layers, and since new HEDD devices are modeled by the code, it is likely that the deviations from experiment will be significantly different from those in the Sandoval case. Therefore, the Sandoval test results must not be used to calibrate the SCAP code for new casks and HEDD’s.

Further, it appears that the PWR assemblies were modeled as having a single, uniform density which was taken as an average of the densities of the fuel rods, the uranium, and air. This leads to the false assumption that the penetration of the HEDD will be

consistently impeded by dense material, rather than using the reality that the HEDD will find a very mixed environment with respect to density inside the cask cores.

In summary, the SCAP code simply cannot be used to provide a reliable or conservative estimate of the amount of damage expected to be caused by a HEDD on a multi-layered, modern cask. Unless there is experimental evidence that confirms the estimations presented in the Luna report, they should not be used as credible indicators of the effects of a successful sabotage event. The admitted shortcomings of the SCAP code- namely that it does not accurately predict penetration phenomena into multi-layered targets- prevents this code from offering useful information, especially since there have been no actual experiments to back these predictions up. It is not sufficient to benchmark the code against experiments performed on an outdated cask having fewer and different layers. Actual experiments must be performed with potential HEDD's in order to assess the validity of the SCAP predictions. Until this is done, the results remain irrelevant.

2.4. Omission of important sabotage scenarios

2.4.1. Intermodal transfer station sabotage event

The EIS, on pg. J-95, states that section J.1.5 evaluates the effects of sabotage on intermodal transfer stations. However, there is no section J.1.5, and there is no mention of this potential sabotage event again. It is essential to perform an analysis of the likely effects of a successful sabotage event on an intermodal transfer station because of its unique conditions. For one, shipping casks at an intermodal station will be stationary. This eliminates some of the problems associated with striking a moving target optimally that were presented in the EIS. Also, this makes the possibility of a multiple-cask release possible. Third, the appeal among potential saboteurs of attacking a station rather than a truck or train must be addressed. Intermodal transfer will also occur at reactor sites without rail access. All of these factors suggest that the potential for sabotage at an intermodal station must be addressed in a comprehensive manner.

2.4.2 Barge transport sabotage event

The EIS does not consider the consequences of a possible sabotage event on a barge shipment of spent nuclear fuel. As this is one of the transportation options being considered, it is important to consider the effects of a successful sabotage event, including the breach of shipping casks and release of radioactive material into the air and water, especially near populated areas, water supplies, or natural environments. It is essential to address this concern, especially since there was no discussion of the consequences of severe barge accidents, which were determined by the EIS to be not reasonably foreseeable.

2.5. Failure to identify/profile potential “Threat Groups”

It would be helpful to provide some general profiles of potential “Threat Groups” in terms of characterizing exactly what these groups are capable of doing, and the relative likelihood of each group performing a sabotage act. This would help in determining what types of weapons, forces, expertise, etc can be expected to be utilized by different groups, providing the DOE with a better estimate of what safeguards must be put in place. The *Final Environmental Impact Statement: U.S. Spent Fuel Policy, Storage of Foreign Spent Power Reactor Fuel* (1980: DOE/EIS-0015) provides a list of “Threat Groups” to nuclear fuel storage and transportation; a similar, but updated, list would be helpful.

2.6. Improper dismissal of considering the probability of terrorist events

The EIS and the Luna report both consistently state that, since sabotage events are not randomly occurring, no estimation of their probability can be made, other than assuming they are “extremely rare.” However, some comment should be made concerning the increase in large-scale terrorist attacks and how this relates to the need for sufficient safeguards against such attacks. Even though attacks are not random events, some effort should be made to identify trends, such as the increase in attacks on American soil over the last few years. This provides a proper foundation through which to analyze the level of protection required from terrorist attacks.

2.7. Failure to present a true “worst case scenario” for consequence analysis

2.7.1. Use of “averaged” wind conditions instead of wind blowing in one direction

The inputs used by the DOE in determining health effects of a successful sabotage scenario assume generalized wind conditions. For a true worst-case scenario, the impact of a radiological release directly downwind from a large population center, such as an office building, prison, stadium, etc. must be addressed. The use of wind conditions averaged over all directions dilutes the effect of a single-direction wind event.

2.7.2. Use of “average” (neutral) weather conditions, instead of worst-case conditions

The EIS states that, because the time and place of a sabotage event cannot be predicted, average weather conditions for the entire United States must be used. However, it seems likely that potential saboteurs will, to the degree feasible, plan sabotage events around those weather conditions that are the most damaging. Thus, for a true “worst case” sabotage scenario, weather conditions leading to the greatest consequences should be used.

2.7.3. “One bullet assumption”

As has been previously discussed, the consideration of only a single HEDD strike in the simulation of a sabotage event is unrealistic. Terrorists who are serious about causing a significant release of radioactive material, and who have the means of obtaining armor-penetrating weaponry, will likely bring a complete arsenal, including several armor-penetrating devices, incendiary devices, etc. Therefore, cask response to multiple missile penetrations, especially if they are fired in succession such that missiles strike an already damaged cask, must be addressed. It is extremely likely that the damage done to an already-penetrated cask will be substantial. This has not been assessed by the DOE and must be in order for the sabotage portion of the EIS to be considered complete.

2.8. Failure to assess social, psychological, environmental, or economic costs

In order to be able to assess the consequences of a successful sabotage event satisfactorily, the full scale of effects must be studied. The DOE has commissioned studies addressing the psychological impacts of radiation accidents on the public, but similar studies have not been performed for this EIS. In addition, no consideration of the cost of cleanup of such an event is given. Below is a skeleton outline of the various factors not considered by the EIS that need considerable attention.

2.8.1. Social/psychological costs not addressed

- 2.8.1.1. Increased fear of nuclear energy, and nuclear industry
- 2.8.1.2. Fear of vulnerability to attack (see Oklahoma City bombing)
- 2.8.1.3. Susceptibility of foreign-born citizens to discrimination
- 2.8.1.4. Distrust of government that transports materials capable of such destruction

2.8.2. Environmental costs not addressed

- 2.8.2.1. Groundwater and/or surface water contamination → more human costs
- 2.8.2.2. Loss of land use near site for significant amount of time

2.8.3. Economic costs not addressed

- 2.8.3.1. Cleanup costs
- 2.8.3.2. Decontamination costs
- 2.8.3.3. Lost workdays due to radioactive contamination of roads, buildings, etc
- 2.8.3.4. Loss of tourism in Las Vegas, eg, due to contamination or fear
- 2.8.3.5. Evacuation costs
- 2.8.3.6. Relocation costs

3. Inputs to computer models predicting exposure levels

DOE relies on the validation of the RADTRAN, RISKIND, INTERLINE, AND HIGHWAY programs performed by Maheras and Pippen (DOE/ID-10511, 1995). In order to validate the RADTRAN4 and RISKIND computer codes, Maheras and Pippen compare the results of the code to the results of hand-calculations. However, the hand calculations use the same equations and assumptions as the computer code. This is not a validation of the code at all. A true validation would involve benchmarking the code against actual events. Since this is not possible, a

validation should involve analyzing the assumptions inherent in the program and not just reproducing the results of the equations used.

3.1. Use of temperature and strain as independent variables

Refer to Resnikoff, 1993. In many severe accidents, high impacts are coupled with vehicle fires. In predicting probabilities of accidents of a given severity, the probability of fire of a certain severity is multiplied by the probability of an impact of a given strain. This tends to underestimate the “true probability” of strain-fire accidents, as these two variables are not independent. This is another artifact of the Modal study needing revision.

3.2. Inconsistent assumptions made in RADTRAN4 and RISKIND

3.2.1. DOE employs RADTRAN4 for total risk, summing individual accident probabilities multiplied by consequences. RISKIND is employed to assess the maximum accident consequences. The assumptions employed should be identical, but they are not. RADTRAN4 assumes ingestion of contaminated food after an accident in rural areas in determining collective population dose; RISKIND assumes no radiological dose to populations from ingestion of contaminated food after an accident in determining maximum accident scenarios. It is unclear why these two inputs are different.

3.2.2. In calculating effects to the maximally exposed individual in an accident scenario, the EIS assumes that this person is located 360 meters (~1200 ft) from the site. In calculating effects to the maximally exposed individual in a sabotage scenario, the EIS assumes this person is 140 meters (~460 ft) from the site. It is unclear where these distances came from, or why they are different.

3.3. Incident-free exposure assumptions

3.3.1. Escorts

DOE based its estimates of annual dose to escorts on regulations that we believe are insufficient to ensure the safety of the transportation vehicles. We recommend that these requirements be increased so that there is always at least one armed escort traveling in a separate vehicle from all truck shipments, and in separate rail cars for all train shipments. This will increase the estimated dose to escorts.

3.3.2. Individuals stuck in traffic

DOE assumes that individuals exposed to radiation dose due to being stuck in traffic near a transportation vehicle will occur only once per individual. However, personal driving patterns are not random, since people (especially commuters) tend to be on

the same road at the same time of day. Therefore, persons being stuck in traffic near a transportation vehicle once are likely to be stuck multiple times.

In addition, the EIS assumes that a traffic gridlock incident will last one hour. This is contradicted by a report by Darrough. In a presentation before the US Nuclear Waste Technical Review Board, Transportation and Systems panel, the average gridlock time is taken as up to 4 hours, resulting in much higher doses for individuals stuck in transportation.

The EIS needs to consider multiple-event, 4-hour duration traffic gridlock incidents in estimating the dose received by this exposure group.

3.4. Population density

The EIS uses average population densities from the 1990 Census to estimate the “worst-case” accident and sabotage scenarios. This ignores time-dependence, such as daytime population densities in cities due to worker commuting (Manhattan’s population doubles every day), tourist population densities, special-event and localized densities. The maximum population densities used in the RISKIND code should reflect these factors.

3.5. Characteristics of spent fuel used in accident consequence estimates

3.5.1. Age of spent fuel

Simply put, the longer a given type of fuel is removed from a reactor prior to shipment, the less radioactive it is. Fuel which has cooled for a long time has had the time to undergo decay reactions, reducing its level of radioactivity.

In the Yucca Mountain EIS, DOE assumes different spent fuel ages for different analyses. For the analysis of impacts to workers during loading operations, at commercial sites, DOE used analyses documented in previous reports (Smith, Daling & Faletti 1992), (Schneider 1987) using 10 year-old PWR fuel with a burnup of 35,000 MWd/MT. For transportation accident scenarios, DOE uses PWR fuel aged 25.8 years.

The DOE assumes in its estimates a spent fuel age of 25.8 years, even though fuel is only required to be cooled for 5 years prior to transportation. This results in a reduced estimate of hazard. Unless the DOE can show through legal requirements that spent fuel will be aged 25.8 years prior to shipment, it is not appropriate to use this age in its exposure assessments for incident-free and accident scenarios.

A more likely scenario is that older fuel, already stored in storage casks at reactor sites or at the proposed PFS storage facility in Utah, will remain stored while newer fuel, stored in fuel pools, but aged more than five years, will first be transported off

the reactor site so that reactors can be decommissioned more rapidly. Currently, the proposed PFS facility in Utah is scheduled to begin accepting waste in 2002. It is likely that this will affect the age of spent fuel transported across the country. In order to move as much fuel from their sites as possible, utilities will likely ship fuel to Utah and allow it to cool there while they ship more, less-cooled fuel from their sites to Yucca Mountain. DOE has established an acceptance quota for reactor fuel, and the current regulations allow the transportation of spent fuel aged only five years. For utilities, the most advantageous use of transportation is to further reactor decommissioning. Further, DOE would have to pay the cost of casks and transportation of this newer fuel. Older fuel would then be shipped at a much later date, much of it from Skull Valley, Utah.

The consideration of older fuel in its transportation analysis serves to ignore many potentially important contributors to overall dose. As radioactive materials follow an exponential decay pattern, using longer-cooled fuel than is realistic results in serious underestimates of the risks involved with spent fuel transportation to Yucca Mountain. In a 25.8-year period, important radioactive contaminants in irradiated fuel will have decayed away. For example, Co^{60} , a main contributor to radiation dose from crud spallation, has a half-life on the order of 5 years. Concentrating on 25.8-year fuel decreases the amount of Co^{60} modeled by a factor of 2^5 , or 32, seriously reducing possible radiological effects in the event of a release.

Because the NRC has established a minimum cooling time of 5 years before fuel is permitted for transport, it is our recommendation that this be used to determine the consequences of accidents involving shipments of spent nuclear fuel. The potential ability of utilities to discharge their currently stored spent nuclear fuel to the proposed PFS site in Utah would likely result in newer fuel being shipped directly from these utilities to Yucca Mountain. The new, thinner cask designs should be assessed based on their performance when holding this young, high burnup fuel.

4. Improper attention to Intermodal Transfer Station

4.1. Crash scenarios analyzed

4.1.1. Airplane crash scenario

The airplane crash scenario assumes that the crash velocities will be those typical of takeoff and landing operations. As a worst-case scenario, the potential impact of a crashing military jet traveling at 600mph should be considered. It is also essential to consider the following in addition to airplane engines in the analysis: engine shafts, munitions (both live and dummy), and any missiles tested on site. The use of engines as the “design missile” traveling at speeds comparable with takeoff and landing procedures ignores some important crash scenarios.

5. Economic analysis of transportation costs

5.1. The EIS did not assess the costs of severe accidents when assessing the transportation costs involved in the Yucca Mountain Project. In order to aid in the adequate preparation for potential accidents, an estimate of the true cost of remedying such an accident is essential. This assessment must include, but is not limited to, the following: emergency costs, surface cleanup costs, decontamination costs (of roadways, buildings, groundwater, surface water, etc.), hospital costs to injured parties, lost workdays due to building contamination, economic losses due to fear of contamination, loss of tourism (e.g., in the event of an accident in Las Vegas), evacuation costs, relocation costs, contaminated food embargo costs, insurance costs, legal costs, governmental costs, and so forth.

The RADTRAN computer code used to determine radiological consequences of transportation accidents has an optional economic analysis contained within the program. No mention of this analysis is given in the Yucca Mountain EIS. There is no indication given as to the reasons why this analysis is not considered. Two separate economic analyses must be performed by DOE with regards to spent fuel transportation to Yucca Mountain. The first should be included with the risk assessment estimating the expected health effects of the transportation program, obtained by multiplying the consequences of each scenario by its probability of occurrence. This is essential to provide a more accurate depiction of the true costs associated with the transportation aspect of the Yucca Mountain project. The second should be included with the “maximum reasonable foreseeable action” scenario to estimate what the economic costs of a severe transportation accident would be. The RADTRAN computer code has the capability of performing estimates for both of these scenarios. These need to be included in any comprehensive risk assessment.

An economic estimate of the impacts of a plutonium-dispersal accident has been performed at Sandia National Laboratory (SAND96-0957). A similar estimate needs to be performed for spent fuel transportation to Yucca Mountain. *calculations using Transnet RADTRAN5 or our in-house RADTRAN4.*

6. Underestimation of Transportation Distances

The Yucca Mountain EIS ignores the likely possibility of intermodal transfer stations outside of Nevada. For example, A license application is pending before the NRC for the Private Fuel Storage Irradiated Spent Fuel Storage Installation at Skull Valley, Utah. If this is approved, it will likely become a “rest stop” for shipments of spent fuel from commercial reactor sites en route to Yucca Mountain. The PFS is designed to accommodate ½ of the nation’s commercial spent nuclear fuel en route to Yucca Mountain. The EIS needs to address the impacts of such a location. This will affect the number of shipments of spent nuclear fuel through the State of Nevada. For example, spent nuclear fuel from commercial reactors in Southern California will be transported through Nevada *twice* if the proposed PFS facility begins operations. This will involve the transport of spent nuclear fuel through the Las Vegas area twice. The failure of the EIS to consider the additional miles of transportation due to additional intermodal transfer and

temporary storage facilities results in an underestimation of the effects of spent fuel transportation.

Because the proposed PFS facility will operate as an integral part of the Yucca Mountain operation scheme, their effects cannot be treated separately. The existence of such a facility will directly affect the number of shipments and the transportation routes. It will also affect the average age of spent fuel being shipped. All of these factors need to be considered by DOE, and none of these factors have been.

7. Consideration of only respirable-sized particles

The Yucca Mountain Draft EIS consistently and repeatedly underestimates health effects due to severe accident or terrorist events by concentrating only on the fraction of respirable particles released during such an event. This results in a severe underestimation of the radiological effects due to inhalable particles and direct gamma dose. In the event of an accident release, particles of sizes on the order of 10 μ m or less will be dispersed readily into the environment. These particles can be deposited in the human body by deposition into the nasal cavity and subsequent ingestion. Alternately, these particles can contribute to skin contamination, increasing the dose attributable to radiological releases significantly. This has not been accounted for in the EIS treatment of sabotage or severe accident consequences.

Summary:

The above points are not exhaustive: however, they give a good indication of some of the major deficiencies in the EIS's treatment of transportation. Because of these deficiencies, it is recommended that DOE perform a completely new transportation assessment, using new experimental data. This new experimental data involves sabotage, transportation accident frequencies, and transportation accident release fractions and consequences. For the sabotage experiments, it is recommended that new tests be performed subjecting modern rail and truck casks to multiple strikes with a TOW 2 missile or its equivalent. The computer model used in the Luna report is unjustified and unacceptable. For the accident release fractions, it is recommended that the DOE perform a new Modal Study, using modern truck and rail casks and developing new parameters with which to measure accident severity and cask response. Further, modern data needs to be collected concerning the effect of speed limit on accident distributions.