

Yucca Mountain Transportation Security Issues: Overview and Update

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ABSTRACT

This paper examines four aspects of transportation security planning for the proposed geologic repository at Yucca Mountain, Nevada. The authors review the transportation sabotage consequence assessments prepared over the past five years by the United States Department of Energy (DOE), and the State of Nevada Agency for Nuclear Projects (NANP). The authors identify five critical uncertainties in the repository transportation system being developed by DOE, and assess the implications of these uncertainties for shipment security. The authors compare the security findings and recommendations of the recent National Academy of Sciences study of high-level nuclear waste transportation, with the State of Nevada petition for rulemaking (PRM 73-10) filed with the United States Nuclear Regulatory Commission (NRC) in 1999. The authors summarize recent trends in global terrorism and recommend research on alternative assumptions for threat assessments, and recommend that Federal agencies consider social-science based counterterrorism strategies, such as precursor analysis, and the “Day After” methodology developed by the Rand Corporation.

INTRODUCTION

More than five years after the September 11, 2001, terrorist attacks in New York, Washington and Pennsylvania, many questions remain unanswered about the security of spent nuclear fuel and high-level radioactive waste shipments.¹ At present, such shipments occur relatively infrequently in the United States. The current situation would change dramatically with the

¹ This introduction is based on a paper by the authors, “Planning for an Unpredictable Event: Vulnerability and Consequence Reassessment of Attacks on Spent Fuel Shipments,” revised version of a paper presented at Waste Management 2005. The revised paper was not included in the conference proceedings, but it is available on line at <http://www.state.nv.us/nucwaste/trans.htm>. The majority of the contractor reports cited in the references can be found at the same website. However, most reports dealing specifically with transportation terrorism and sabotage issues must be requested in writing from Mr. Joseph Strolin, Administrator, Agency for Nuclear Projects, Office of the Governor, 1761 E. College Parkway, Suite 118, Carson City, NV 89706.

opening of a centralized repository or interim storage facility. Every day, for three or four decades, loaded casks of spent nuclear fuel and high-level radioactive waste would be moving somewhere within the United States. The resulting large-scale and long-distance shipments would create new opportunities for terrorism, sabotage and other human initiated events (hereafter referred to as terrorism).

Concern about the terrorist threat to repository shipments led Nevada's Attorney General to file a petition for rulemaking with the NRC in June 1999.² In the petition, Nevada documented the vulnerability of shipping casks to high-energy explosive devices. Nevada also submitted evidence that shipments to a national repository would be dramatically different from past shipments in the United States and that these differences would create greater opportunities for terrorist attacks and sabotage. The petition requested a general strengthening of the current transportation safeguards regulations and a comprehensive reexamination of the consequences of radiological sabotage.

The NRC published Nevada's petition (Docket PRM-73-10) in the *Federal Register* on September 15, 1999, and accepted public comments through February 2000. The Western Governor's Association endorsed Nevada's petition on behalf of 18 western States. Five other states (LA, MI, OK, VA, and WV) also endorsed all or part of the petition.³ Almost seven years after the close of the Nevada Petition comment period and five plus years after the 9/11 attacks, the NRC has still not officially responded to the Nevada petition.

The NRC recently notified the Nevada Attorney General: "The NRC has completed its security assessments and is now in the process of resolving your petition. The petition resolution will be addressed in a Federal Register notice. The NRC will also notify you of its decision."⁴ As of December 29, 2006, the NRC has provided no further information about any regulatory or administrative decisions regarding the Nevada petition.

CONSEQUENCE ASSESSMENTS

For more than two decades, the consequences of a successful terrorist attack using explosives against a shipping cask have been debated. The NRC first imposed safeguards restrictions, including physical protection requirements, on spent fuel shipments in 1977. Based on a series of contractor studies, the NRC concluded in 1984 that that the expected consequences of a successful attack in "a heavily populated area such as New York City would be no early fatalities and less than one (0.4) latent cancer fatality." NRC then issued a proposed rule eliminating physical protection requirements (10CFR73.37) for most spent fuel shipments. (1) State governments, environmental groups, and some nuclear industry sources objected to the proposal. Three years later NRC terminated the proposed rule without explanation, but throughout the 1990s the NRC continued to downplay attack consequences in its public information pamphlets. (2, 3, 4)

² The petition is available at <http://www.state.nv.us/nucwaste/news/ag990622b.htm>.

³ The comments submitted to the NRC are available on the web at http://3/26/01/ruleforum.llnl.gov/cgi-bin/rulemake?source=NV_PETITION.

⁴ "SUBJECT: STATE OF NEVADA PETITION FOR RULEMAKING (PRM-73-10)," Letter from S.W. Moore, Chief, Rulemaking and Guidance Branch, Office of Nuclear Material Safety and Safeguards, US NRC, to Mr. G. J. Chanos, Attorney General, State of Nevada, August 11, 2006.

In 1995, the State of Nevada urged DOE to evaluate successful terrorist attacks and sabotage incidents as part of the environmental impact statement (EIS) for Yucca Mountain. DOE acknowledged that shipping casks are vulnerable to terrorist attack in both the 1999 Draft EIS and in the 2002 Final EIS. (5, 6) In support of the Draft EIS, DOE sponsored a 1999 study of cask sabotage by Sandia National Laboratories (SNL). (7) According to the Draft EIS, the SNL study demonstrated that high-energy devices (HEDs) were "capable of penetrating a cask's shield wall, leading to the dispersal of contaminants to the environment." The 1999 SNL study also concluded that a successful attack on a truck cask could release more radioactive materials than an attack on a rail cask, even though rail casks would contain, on average, up to six times more SNF than truck casks.⁵

In the Final EIS, DOE updated its sabotage analysis, assuming more highly radioactive spent nuclear fuel (SNF), a larger respirable release, and a higher future average population density for U.S. cities. The Final EIS estimated that a successful attack on a GA-4 truck cask in an urbanized area under average weather conditions would result in a population dose of 96,000 person-rem and 48 latent cancer fatalities. For a successful attack on a large rail cask, DOE estimated a population dose of 17,000 person-rem and 9 latent cancer fatalities.⁶ In neither case did DOE evaluate any environmental impacts other than health effects, and ignored the economic impacts of a successful act of sabotage. While the DOE did not specifically estimate cleanup costs after such an attack, the Final EIS states that clean-up costs following a worst-case transportation accident could reach \$10 billion.⁷

Analyses prepared for the state of Nevada by Radioactive Waste Management Associates (RWMA) calculated that sabotage impacts could be considerably greater than those estimated by DOE. RWMA replicated the DOE Final EIS sabotage consequence analyses, using the RISKIND model for health effects and the RADTRAN model for economic impacts. This reanalysis used the SNL study average and maximum inventory release fractions, a range of credible values for the gap inventory of Cesium-137, and a range of population densities and weather conditions. RWMA concluded that an attack on a GA-4 truck cask using the same common military demolition device assumed in the DOE analysis could cause 300 to 1,820 latent cancer fatalities, assuming 90% penetration of the cask by a single blast. For the same device used against a large rail cask, RWMA estimated 46 to 253 latent cancer fatalities, again assuming 90% penetration.

The RWMA study further estimated that the major radiological health impacts of an attack would be caused by the downwind dispersion of respirable material (mainly particles with a diameter less than 10 microns) that could be ejected from the damaged cask. Depending upon the meteorological conditions present at the time of an attack, the respirable aerosol of radioactive materials could affect an area of 10 square kilometers (3.9 square miles) or more. RWMA

⁵ DOE addressed the impacts of acts of sabotage in Ref. 5, pages 6-33 to 6-34. "The estimated impacts would be greater for an act of sabotage against a legal-weight truck shipment than against a rail shipment, even though the amount of spent nuclear fuel in a rail cask would be as much as six times that in a truck cask, The greater impacts would be a result of the estimate that an event involving the smaller truck cask would release greater quantities of radioactive materials (Luna, Neuhauser, Vigil 1999, all)."

⁶ DOE addressed the impacts of acts of sabotage in Ref. 6, pages 6-50 to 6-52.

⁷ Accident cleanup costs are discussed in Ref. 6, Appendix J, page J-73

estimated cleanup costs ranging upward from \$668 million for the rail incident, and \$6.1 billion for the truck incident, to more than \$10 billion.⁸ Full perforation of the truck cask, likely to occur in an attack involving a state-of-the art anti-tank weapon, could cause as many as 3,000 to 18,000 latent cancer fatalities, and cleanup and recovery costs could far exceed \$10 billion.⁽⁸⁾

The consequence assessments prepared by DOE and NAMP assumed single-phase attack scenarios. None of these consequence assessments have evaluated the effects of an attack involving the simple impact-exacerbating tactics identified by the U.S. Army peer review report more than two decades ago: combined use of a breaching device and a dispersal device, or use of multiple breaching devices.⁽⁹⁾ None of these consequence assessments have incorporated insights⁹ obtained from the 1998 testing sponsored by International Fuel Containers,

⁸ Ref. 8, pages 2-3, provides the following explanation:

In the RISKIND and RADTRAN calculations presented later in this report, we calculate the consequences of the release of these fractions of respirable aerosol and gas, and their subsequent downwind dispersion and intake. However, we neglect the contribution of the non-respirable fraction of the cask inventory which will be released from the protection of the fuel rods and/or the cask, but will not be small enough to disperse far downwind. If we were to include this fraction, there would be a significantly higher level of contamination modeled close to the damaged container, resulting in a higher dose to the MEI and population dose to those closest to the cask location. Therefore, it is important to keep in mind that the above release fractions are only for those particulates having a diameter less than 10 microns, leading to an underestimate of the dose to persons closest to the event.

⁹ The 1998 test is recorded in a videotape available from International Fuel Containers, Inc., (ICFI), New York, NY. Part of the test footage was shown on a national television broadcast of CBS 60 Minutes on October 26, 2003. The broadcast was repeated on July 25, 2004. IFCI conducted two tests with identical warheads, one with the cask in its transport mode, and a second test with the cask in its storage mode, protected by a concrete jacket. In its storage configuration, the cask suffered only superficial surface damage from the second TOW warhead explosion. IFCI believes the test clearly demonstrated that the CASTOR cask in a protected storage installation would survive a missile attack, with no release of radioactive material. The CASTOR cask in its concrete jacket would, in the authors' opinion, represent a hardened target consistent with our previous recommendations for a shelter-in-place approach to protecting at-reactor storage facilities and centralized storage facilities. The authors have not been able to obtain any of ICFI's written documentation regarding the tests. Our assessment is based on interviews with ICFI and Army personnel, analysis of the videotape, and information derived from publicly-available, unclassified literature.

ICFI's use of static warheads rather than actual missile strikes has resulted in additional technical debate. Critics of the IFCI test argue that use of a perfectly placed, static warhead, resulted in optimal weapon performance, and caused more damage to the cask in its transport mode, than would be expected from the same warhead delivered by a missile fired under real world conditions. Other viewers believe that damage to the cask in its transport mode would have been greater, due to the kinetic energy delivered by the fast moving projectile, and that the cask and its contents would have suffered greater damage due to internal cask gas and explosive overpressures that could be generated from the missile impact. This debate suggests the need for additional weapon-specific testing, using a full-scale cask, and development of specialized software that can account for multiple breach points and other tactical contingencies.

Incorporated, at the U.S. Army Aberdeen Test Center.(10, 11) Most significantly, none of these consequence assessments have evaluated any of the impact-exacerbating tactics studied by counter-terrorism experts in the post-September 11 environment. Credible hijack and control scenarios, specialized truck bomb scenarios, and/or concealed weapons (like improvised roadside devices) scenarios, coupled with suicide tactics, could potentially result in radiological consequences far greater than those previously estimated by DOE or the State of Nevada's NANP.

DOE has continued to evaluate terrorism consequences since 2002. The DOE 2004 Record of Decision regarding Yucca Mountain transportation states that in addition to developing a security plan in cooperation with other Federal agencies, DOE is “exploring the use of armed Federal agents as escorts for all shipments” and other operational techniques and equipment designs “to further mitigate the potential threat of a terrorist act.” Through international programs, DOE is “exploring opportunities to enhance the physical protection of casks.”(12) DOE is also developing a transportation-specific design basis threat, information classification guidelines, and information protection protocols. In its most recent Federal Register notices regarding Yucca Mountain transportation impact assessment, DOE invited public input regarding: “The potential radiological impacts to workers and the public from sabotage of transportation and repository operations.”(13)

PLANNING UNCERTAINTIES

Despite public declarations that transportation risks matter and that the DOE and NRC will do whatever they can to reduce these, the fact remains that agency decisions being made about transportation program planning leave serious programmatic uncertainties unresolved. These uncertainties have direct, significant implications for security planning.

The first of these uncertainties results from the current lack of rail access. DOE has stated its intent to begin rail construction in 2009, complete the rail line in 2014, and begin receiving SNF & HLW shipments in 2017. DOE is already behind schedule for preparation of the rail access environmental impact statement (RA EIS). (14, 15) Preliminary estimates indicate that cost of constructing a railroad spur along the preferred Caliente corridor may reach or exceed \$2 billion (compared to the original estimate of about \$800 million), primarily due to failure to plan for the difficult terrain that exists along the corridor. Determined stakeholder opposition along the Caliente corridor seems likely to delay construction. DOE is evaluating the feasibility, costs, and institutional constraints of a potential alternative rail route (Mina), which would traverse an Indian reservation. (16) The feasibility report for the Mina route estimates the construction cost at about \$1.6 billion. (17)

The second uncertainty results from the DOE decision to adopt an integrated transportation, aging, and disposal (TAD) canister system that is significantly different from the transportation systems evaluated in the Final EIS for Yucca Mountain.(13) In addition to technical considerations, the future of the TAD concept is uncertain because of utility financial concerns. Moreover, up to 20 percent of the potential repository inventory appears to have been already committed to at-reactor dry storage systems incompatible with TAD.

The third uncertainty grows out of the DOE decision to adopt the TAD canister system, namely the radiological characteristics of the spent nuclear fuel to be transported in the TAD system. The technical specifications recently released by DOE would allow shipment of irradiated reactor fuel with initial enrichment up to 5 percent, reactor burn-up up to 80 GWdt, and cooling time of 5 years.(18) Such fuel would be significantly hotter (thermally) and more highly radioactive than the representative fuels evaluated in the Final EIS for Yucca Mountain. The consequences of radiological sabotage against shipments of such fuels would be significantly greater.

The fourth uncertainty results from the need to accommodate 23 reactor sites which will have difficulty shipping spent fuel to Yucca Mountain by rail. DOE has variously proposed servicing these sites by direct legal weight truck (LWT) shipments, some combination of LWT casks and rail transport to an intermodal transfer station in Nevada, and heavy haul truck and/or barge transport and intermodal transfer of large rail casks.(6) The 23 shipping sites without direct rail access account for almost one-third (32.3 percent) of the total 63,000 MTU of commercial spent fuel that would be shipped to the proposed repository over the first 24 years of operation, and for almost one-half (47.6 percent) of the spent fuel that DOE would likely ship in the first five years of operation. (19) Even if most of these sites can eventually use rail casks, at least 10 percent of the potential repository inventory will likely be transported to Yucca Mountain in LWT casks.

The fifth uncertainty results from the need to integrate Yucca Mountain transportation planning with current proposals for a Global Nuclear Energy Partnership (GNEP) based on reprocessing. (20) A compounding uncertainty regards the compatibility of the proposed TAD system and a waste management system based on reprocessing of SNF.

NAS STUDY FINDINGS AND RECOMMENDATIONS

In February 2006, the National Academies' (NAS) Committee on Transportation of Radioactive Waste released a comprehensive report on spent fuel transportation.(21) The study's most important findings and recommendations agreed with the major recommendations made by the State of Nevada over the past two decades.

The general conclusions of the NAS study were:

1. There are no fundamental barriers to safe transportation, but social and institutional challenges to repository transportation require expeditious resolution, and the challenges of sustained implementation should not be underestimated; and
2. Malevolent acts (terrorism, sabotage, and theft) are a major technical and societal concern. Regarding malevolent acts, the NAS urged that an independent examination of security should be carried out before the commencement of repository shipments; and that objective information about security risks and countermeasures should be shared with elected officials and the public to the fullest extent possible.

The study endorsed a number of specific measures for managing transportation risks:

1. Risks can be reduced by shipping the oldest fuel first, maximizing use of rail transportation, using dedicated trains, and minimizing truck shipments;
2. DOE should identify and make public preferred highway and rail routes for repository shipments as soon as possible;
3. Most significant transportation accident risks would likely involve long-duration, fully-engulfing fires; additional steps must be taken to reduce the likelihood of such accidents;

4. Potential adverse social and economic impacts of repository shipments are important; for many members of the public, social and economic impacts (often referred to as perceived risk impacts) are as important as health and safety impacts; special government efforts will be needed to manage these social and economic impacts.

The NAS concluded that serious consideration should be given to taking the transportation program out of the DOE repository program, and perhaps out of DOE altogether. While Nevada staff and consultants agree with most of the NAS concerns about the DOE institutional structure, Nevada has not endorsed this NAS recommendation because taking the transportation program out of DOE might result in less governmental oversight and less program accountability.

Nevada strongly disagreed with the NAS recommendation that DOE should proceed to construct “the Nevada rail spur” along the Caliente corridor. The NAS ignored Nevada concerns regarding engineering feasibility, adverse safety conditions, and unacceptable environmental impacts. The NAS ignored evidence presented directly to the study committee that selection of Caliente would likely route significant numbers of rail shipments through downtown Las Vegas, less than one-mile from the Las Vegas Strip, resulting in unique adverse social and economic impacts, and requiring extraordinary planning and training for shipment security, accident prevention, and emergency response.

RECENT TRENDS REGARDING THREAT ASSESSMENT

NANP has previously recommended alternative assumptions for threat assessments, such as combined use of a breaching device and a dispersal device, or use of multiple breaching devices. NANP has also recommended an integrated, systems approach to risk reduction, including primary reliance upon rail transport; mandatory use of dedicated trains; shipment of oldest fuel first; security-conscious route selection and shipment scheduling; and enhanced physical protection measures in transit. Current NANP activities discussed herein include: review of recent rail security assessments in the United Kingdom (London Assembly report); the Large and Associates review of British shipment vulnerabilities; NATO and subsequent research on attacks scenarios; updated threat assessment reflecting use of improvised explosive devices in Iraq, and tandem warhead missiles in Lebanon; and concluding with an evaluation of social-science based counterterrorism strategies, such as precursor analysis and “day after” methodologies..

London Assembly Report

The 2001 London Assembly document is one example of emerging literature focusing in on the transportation of SNF in international contexts. The focus of this report is on emergency response in the event of a radiological release from a train carrying SNF casks(s) in an urban area of London. The report questions the readiness of emergency response assets and also bring into the debates on SNF transport the need for and availability of technical support from the energy industry. This report focuses upon potential trackside contamination, based on the assumption that any release would be limited to these geographic areas and thus the plume limited in scope and reach. (22)

The London Assembly report makes very familiar recommendations to those working in the field of SNF transportation. The report notes specific issues with: 1) routing and alternatives that minimize risks; 2) risk assessment issues; 3) the serious issues associated with integrated emergency preparedness; 4) the need for proactive monitoring in the event of routine and non-routine transport; 5) the need for better inspections and enforcement of statutory compliance; 6)

the necessity of prearranged information protocols in the event of an incident; and finally 7) trackside security issues. (22)

Large Report (Greenpeace UK)

The 2006 Large and Associates Report, sponsored by Greenpeace UK, assumed that a threat exists for nuclear facilities, SNF shipments, and waste storage facilities. The report makes the analogy that SNF could be used as a dirty bomb, and shipments, if attacked, equated to a radiological dispersion device (RDD). (23)

This report identifies systematic vulnerabilities for fixed site and rail shipments in Great Britain. One observation is that terrorists would be intelligent enough to conduct secondary bomb or dual purpose attacks, the first attack being on SNF shipments directly and the second to delay response assets from addressing the incident scene in order to ensure maximum distribution of the radioactive plume. Such secondary attack discussions are not given in detail but do represent a validation of the potential three phase attack scenarios developed by NATO researchers and the multiple phase attacks previously posited by Nevada in analysis of transportation vulnerabilities, based on United States Army research.

The Large report specifically notes a two stage primary attack methodology, one to breach the cask and the second to disperse the contents, again very reminiscent of the NATO work and previous scholarship by Nevada and U.S. Army researchers. The Large report notes additional terrorist attacks tactics like the potential use of armour piercing munitions, shaped charges, and the threats posed by engulfing fire as risks for SNF shipments. While not a complete enumeration of potential cask threats, these three do represent a modest consensus in the scholarship on the subject. The Large report also notes that fires can be created in tunnels and under what terms “fire circumstances” could be enhanced, perhaps a reference to the tactical use of termite and/or other fire educating chemicals in a similar fashion to both bodies of previous scholarship noted.

The tactical discussion notes that there are times when vulnerability is heightened, along high density transportation corridors, for example. The report also notes that security is minimal for said shipments, trains carrying SNF are not staffed by specially trained security operatives, and that stops of hours in duration are not uncommon in transit. Additionally the report also suggests systematic vulnerability since the routes, times, and trains themselves are identifiable to the casual observer. Lastly, the report notes that regulations are behind the times, conceived in a pre-9/11 world and not focused on the terrorism threat that exists now and for the foreseeable future. The advancement of ordnance technology and availability of advanced munitions was noted in this report and may be indicative of the level of threat that is underplayed in the regulations. The final tactical consideration is that advanced military training, knowledge and technology are more readily available than in years past and as a result of world wide experience in battlefield conditions.

NATO and Related Research

The vulnerability profile of the actual transport vehicles themselves, as well as the transportation casks, has been the subject of debate and criticism for decades. Recently completed, but not yet publicly available, a North Atlantic Treaty Organization (NATO) study¹⁰ assesses several updated attack scenarios and analyses of cask vulnerabilities. (24)

¹⁰ The NATO report is not currently available for public distribution. Issues referenced in this paper represent only James David Ballard's knowledge of portions of the report that he worked

Based on the NATO study and other published sources, the two-phase attack described in the U.S. Army 1983 peer review report may underestimate current technical planning knowledge and tactical capabilities of known terrorist organizations in Chechnya, Iraq, Lebanon, and elsewhere. The NATO study on the other hand divides the tactical aspects of a potential attack against nuclear waste transports into three phases: isolation events (stopping the transport vehicle – rail or highway); breach events (penetration or perforation of the cask); and dispersal events (use of a secondary device or devices to disperse cask contents). Combinations of these three phases should be expected, since they represent basic military tactics and knowledge currently available in many parts of the world, and to many adversaries, both foreign and domestic.

Clearly the range of attack scenarios that could be predicted against SNF and HLW shipments is extensive. Like the NATO study, other academic research has moved away from the primary focus on missile attack scenarios and towards potentially more disturbing and destructive tactics. For example, the Iraqi experiences of the United States military show that fully armored military grade vehicles can be breached by an IED and said devices can penetrate even the most robust transport vehicles, highway or rail. This is not the only threat emerging. Most alarming to some observers (see the Large report and Nevada studies) is the potential for the actual physical capture of a shipment, either truck or rail, and the direct application of munitions designed to breach the cask walls and disburse the contents, either in the initial attack or by means of a secondary device. Given security breaches on train shipments of wastes, the relative ease by which potential adversaries can access the shipment vehicles is alarming.

Future assessments of cask vulnerability must carefully consider both current and projected intentions and capabilities of potential adversaries. More realistic assessments must evaluate complex attack scenarios specifically designed to breach a cask and disperse its contents, especially if the perpetrators are willing to use suicide tactics and/or have insider knowledge of shipments. The current threat profile is focused primarily on foreign and Islamic sources, but this may change significantly over the decades-long time frames for transportation to Yucca Mountain or other facilities. Threat profiles must not ignore domestic terrorists, especially those who have military training combined with hostility towards Federal assets and programs. Assessments, and even potential transportation design basis threat protocols, must also be continuously updated, to ensure that they accurately reflect the best available information and contemporary threat profiles.

Weapons Capabilities

The recent (Autumn 2006) conflict between Israel and Lebanon demonstrated the widespread availability of new, more effective anti-armor technology. During that

on, researched, or authored. Ballard's views do not necessarily represent the final NATO report, the views of various team members who contributed to the NATO report, or the position of NATO.



Fig.1. Israeli tanks burning after being hit by AT 5 anti-tank missiles.

Conflict, Israeli armor casualties were extraordinarily high due to the aggressive interception of Israeli radio communications, tactical alteration by adversaries, and the use of fourth generation anti-armor warheads on anti-tank missiles. These warheads are designed to penetrate the armor with multiple charges that explode to kill the vehicle crew members.

The ready availability of the most sophisticated anti-armor weapons, that are easy to use and reliable, confirms fears about their potential use by terrorists. Perhaps even more troubling is the increasing sophistication and ingenuity of improvised explosive devices (IED's) deployed in Iraq. Emerging from the use of crude "rolling" and "daisy chained" booby traps which relied on discarded bombs or artillery shells, the IED threat has changed. Currently IED's are deployed in a wide variety of formulations that are custom tailored to the target. These new IED's range from hand grenades encased in plaster of paris figurines, to fourth generation anti-armor weapons capable of disabling or destroying a main battle tank, IED's have emerged as a primary weapon of war.



Fig.2. Anti-armor roadside improvised explosive device (IED)

Beside the new applications in IED, insurgents are deploying new kinds of armor penetration technology to defeat armored vehicles. The newest technology is the use of explosively formed projectiles (EFP) in IED's. EFP's are a relatively new type of shaped charge used against more lightly armored targets. While the penetration is generally less than a conventional shaped charge, the diameter of the hole created by these new generation charges is wider. Additionally, the caliber of the weapon necessary for initiation of the attack is smaller. Essentially, the conflict between armor protection and armor penetration that has been static since the introduction of ceramic armor thirty years ago, has become a race between protection and increasing penetration power. The implications for vulnerable shipments seem clear.(25,26,27,28,29)

Precursor Analysis

Precursor analysis is one way to address these issues in a systematic and scientific format and provides a framework for future analytical efforts like the Rand Corporation format for scenario and response development, a methodology called “next day” analysis. (30, 31) These two analytical formats provide some systematic and scientifically valid methods for addressing such a large range of uncertainties, risks, and unknown variables as those posed by the potential Yucca Mountain project.

The many unresolved issues relevant to the safe and secure transport of SNF and HLW in the United States, coupled with the DOE's inability to articulate a clear, concise, and logical plan for SNF and HLW transport to Yucca Mountain, make a case for the application of a rigorous social science methodology. To date the makeshift forecasting and cobbled together nature of planning for potential Yucca Mountain transport efforts beg the question: Why do the responsible federal agencies fail to use readily available analytical protocols in their planning efforts, and why, if Yucca Mountain siting decisions are based on “science,” do they disregard the use of social science to plan for human initiated events like terrorism and sabotage? Some critics have charged that the culture of these agencies is stuck in cold war era philosophy of decide and defend. Other critics point out the financial interdependency of the energy industry and the federal regulatory agencies. Some critics have called for the creation of new administrative, regulatory and oversight arrangements designed to attend to threats posed by human initiated events. (2, 3, 4, 11, 21)

What is needed is a systematic survey of the existing research on this subject and the development of a social scientific method of analysis for the threats and risks involved. In some ways this methodology would mimic existing analysis done outside of controlling agencies like the NRC and DOE but most importantly it would expand on past knowledge to protect these shipments of highly radioactive materials from new threats and heretofore unrecognized risks.

The following chart example one way to approach this new SNF transportation analytical paradigm. In Figure 3, we see the four categories of issues that must be addressed prior to shipments begin to Yucca Mountain. Based on these four categories and interrelationships between sub-components therein, various analytical decision trees could then begin to address the question of three specific transportation options available to policy makers: 1) Shelter these radioactive materials in place, 2) ship materials from around the country to several regional short term storage facilities, and 3) lastly if such issues can be addressed effectively should these agencies seek a continuation of the development of the strategy for a geologic repository.

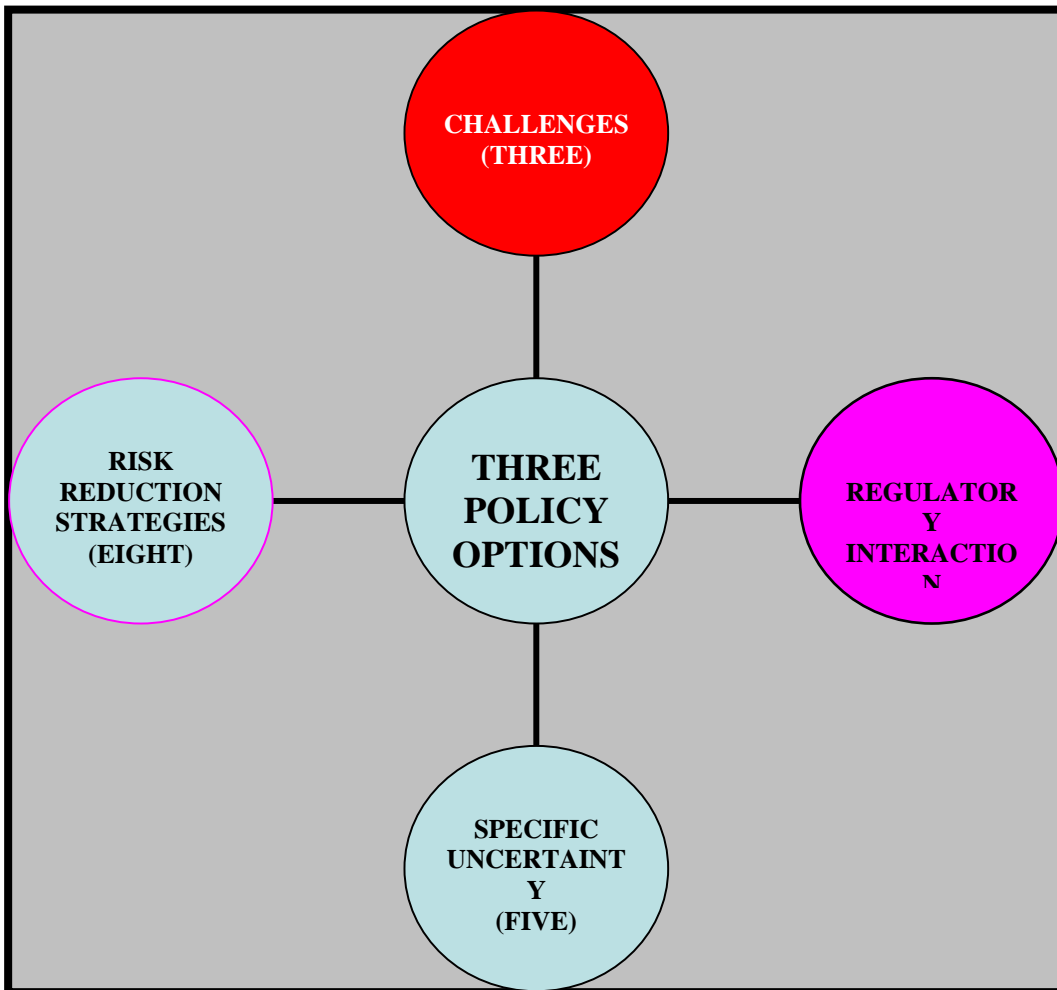


Fig.3. Example of Precursor Analysis Applied to Security Planning.

As noted above the three primary policy options include shelter in place, regional interim storage and full implementation of a geologic repository. Such decisions, especially the geologic repository option are dependent on a number of factors already identified in the literature summarized herein and as such are directly applicable to any enumeration of an analytical methodology for the transportation effort. This option is the focus of the balance of this paper.

The three challenges already noted in this document and not yet addressed effectively by transportation planners are the social, institutional and technical challenges. These three key areas will reside in the transportation program no matter the changes that the future may bring with respect to the threat environment posed by terrorism or other human initiated events. Specific items in these three categories of risks may change, for example as technology comes to play and that can address any one sub-topic, but their valiance in any analytical methodology should remain constant.

The second analytical category that will remain fairly constant over the lifespan of the program is related regulatory issues. The authorizing legislation for the program holds several agencies responsible for the transportation effort. The lack of a clear mandate and lead agency status for the total transportation effort means that turf wars between federal agencies will arise (NRC, DOT, DHS, EPA, and others) all the while Indian tribes, state agencies, regional authorities, and local governments will also be seeking a voice in the regulation of shipments.

Uncertainties resulting from radical changes in transportation planning, false starts in planning efforts, and the systemic uncertainty, indistinctiveness, and ambiguity resulting from poor regulatory assertiveness, control and leadership result in contemporary issues that should be addressed prior to shipment planning. For example this document has identified five such contemporary uncertainties: rail access, TAD usage, alternative radiological characteristics, intermodal operations, and the impact of the Global Nuclear Energy Partnership are examples.

Lastly, a series of risk reduction suggestions have been made over the years and should be addressed in order to reduce shipment risk. Eight specific suggestions are identified herein and include: shipment of oldest fuel first, identification of preferred highway and rail routes, specific fire reduction technologies and strategies incorporated into shipment protocols, analysis of health impacts based on changes instituted or under consideration, increased analytical recognition of the significance of perceived risk impacts, analysis of the choice of a full or near full reliance on rail for shipments, the use of dedicated trains for shipments, enhancement of physical protection measures along with a transportation specific series of design basis threats (DBT), and safety and security conscious route selection criteria.

Given these categories of variables and the many interactions that may be analyzed between these factors, the use of a typical precursor model – item analysis with connective relationships depicting probabilities of relationships between variables, could then be done for any number of interconnections (sub-parts) of the categorical interactions noted above. What is suggested herein is an alteration of this typically “probability” based modeling towards categorical modeling, albeit one which can handle the variations in sub-topics given the length of time the repository shipment campaign will entail.

One way to address these possibilities is the use of “day after” simulation methods where a five year future time period is posited, detailed contingencies are given to participants, a range of worse case characteristics are addressed and ultimately the study would be asked to find real world, present day solutions for the future problems found in the analysis. The suggested analysis would need to be repeated systematically to address changes in variables/contingencies

but by using established methods of analysis, the administration of any such program would be informed by science and not based on reactive policy decisions. Such combined use of accepted social science methodology and expert forecasting techniques would allow transportation planners the opportunity to get beyond the minutia of the everyday and towards more comprehensive planning, something sorely needed in the debate over a geologic repository.

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