[Revised Final Draft 8-14-03]

Spent Nuclear Fuel Shipments As Terrorist Targets

Robert J. Halstead, Lindsay Audin, James David Ballard, Merritt Birky, Fred C Dilger, Jim Hall, and Marvin Resnikoff

The recent article by D M Chapin, et al, "Nuclear Power Plants and Their Fuel as Terrorist Targets," (Science, Vol 297, September 20, 2002), contained a number of serious factual errors and misrepresentations regarding potential spent nuclear fuel shipments to the proposed Yucca Mountain repository The "facts about the safety of nuclear shipments" as presented in this article are misleading and give a false sense of security regarding shipping risks.

These misleading facts include: [1] the status of cask certification and testing: [2] the radiological hazards of spent fuel; [3] the vulnerability of casks to attacks involving explosives, and [4] the potential consequences of a successful attack Additionally, the authors have ignored publicly available impact analyses conducted by the U.S. Department of Energy (DOE), and they have failed to mention the State of Nevada's 1999 petition to the U.S. Nuclear Regulatory Commission (NRC) for rulemaking. Both the DOE and Nevada documents are directly applicable to this matter

Cask Certification and Testing

The Chapin article asserts that shipping casks have been "tested against collisions, explosives, fire and water " In fact, none of the shipping casks currently used in the United States, and none of the casks that could be used for waste shipments to Yucca Mountain, has been subjected to full-scale tests.

According to the NRC, seven spent nuclear fuel truck cask designs and nine rail cask designs are currently certified for use in the United States. NRC does not require full scale testing of these casks, and none of them have been tested full-scale to demonstrate their ability to survive severe accident conditions or terrorist attacks. (1)

Instead of full-scale testing, the NRC relies upon scale model testing and computer analysis to assess cask performance under hypothetical accident conditions However, many experts believe that such simulations must be validated with full scale testing before reliance can be placed in computer analysis based on scale models To date, none of the casks that could be used for waste shipments to Yucca Mountain has been subjected to full-scale tests (1) This is in addition to the fact that the NRC has no specific cask performance standards regarding terrorist attacks. (2)

Radiological Hazards

The Chapin article implies that spent nuclear fuel is not very dangerous "Before shipment, the fuel elements have been cooled for several years, so the decay heat and short-lived radioactivity have died down " In fact, irradiated reactor fuel remains

dangerously radioactive for many decades.

According to DOE, irradiated reactor fuel contains a large inventory of dangerous radionuclides, including the fission products strontium-90 (half-life 28 years) and cesium-137 (half-life 30 years). Even after 50 years of cooling out of the reactor (less than 2 half-lives for cesium-137), the surface dose rate of the typical spent fuel assembly is in excess of 8,000 rem/hour, (3) an exposure rate that is sufficient to deliver a life-threatening, acute radiation dose in less than 5 minutes. (4) While fuel cooled for as little as 5-10 years could be shipped to the repository, DOE estimates that the average cooling time would be 23 years prior to shipment. Each rail cask of spent fuel shipped to the repository would contain, on average, 816,000 curies of Cesium-137, and each truck cask, about 136,000 curies of Cesium-137. (5) A release of less than one-percent of such a large inventory of Cesium-137 in a respirable form could have disastrous human health and economic consequences

Cask Vulnerability

Referring to shipping casks, the Chapin article asserts: "Only the latest antitank artillery could breach them, and then the result was to scatter a few chunks of spent fuel onto the ground." In fact, twenty years of tests and studies have demonstrated the vulnerability of casks to a broad range of potential terrorist weapons.

According to studies sponsored by DOE and NRC in the 1980s, an off-the-shelf, Korean War-era, military demolition charge could breach the wall of a truck cask, deeply penetrate the cask interior, and eject one-percent of the spent fuel cargo, including a small but dangerous respirable release (6)

U.S. Army peer review of these studies confirmed the findings. The Army reviewers added that the reference weapon would completely perforate current-generation truck casks (which have thinner walls than the obsolete cask that was used during this test) and that the use of two explosive devices, one to breach the cask wall and another to disperse the cask contents, could significantly increase the amount of radioactive materials released. (7)

Other reviewers commented that commercial shaped charge explosives and military antitank weapons could cause equal or greater damage to a cask and its contents, and that the release and dispersion of radioactive materials could be greatly increased if coupled with the use of incendiary devices. (8)

In 1999, DOE sponsored a study of cask sabotage by Sandia National Laboratories (SNL) in support of the Draft EIS for Yucca Mountain (9) SNL re-evaluated the earlier tests, and conducted additional simulations and analyses, but did not perform any additional full-scale or scale model tests. This research concluded both truck and rail casks could be breached, by military shaped charges and by antitank weapons SNL concluded that the respirable release would be six times larger than previously reported, due mainly to blowdown from the pressurized fuel rods. The SNL study also found that if the weapon

used fully perforated the cask, the amount of respirable radioactive material released could be ten times greater than even these new release estimates (10)

In 1998, an additional test of cask vulnerability was sponsored by a private company, International Fuel Containers, at the U.S. Army Aberdeen Test Center In that test, U S Army experts demonstrated that a TOW missile warhead could breach a large, nodular cast iron cask, of the type currently used for rail transport in Europe (11) While the European cask that was tested is not certified for transport use in the U.S., it is similar to the new U S rail casks in its overall design, wall thickness, and capacity

A study prepared for the State of Nevada compared vulnerability of cask walls constructed of iron, steel, and steel-lead-depleted uranium That study concluded the new U S casks being designed for rail shipments to Yucca Mountain would be equally vulnerable to an attack using a TOW missile, and that the TOW missile would be expected to completely perforate the truck cask design assumed for Yucca Mountain shipments (12)

Consequences of Attack

Regarding the consequences of a successful terrorist attack on a shipping cask, the Chapin article asserts: "There seems to be no reason to expect harmful effects of the radiation any significant distance from the cask." In fact, studies sponsored by DOE, (10) by NRC, (6) and by the State of Nevada, (13) all indicate that the major radiological health impacts would be caused by the downwind dispersion of respirable material (mainly particles with a diameter less than 10 microns) that had been ejected from the cask Depending upon the meteorological factors 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 The larger fragments - those "chunks of spent fuel" referred to by Chapin, et al - would contaminate the area within 100 meters of the attack site (about 8 acres), but are not included in the consequence assessments, although they would also be highly radioactive. (13)

Further, Chapin et al cite DOE's Final Environmental Impact Statement (FEIS) for Yucca Mountain regarding descriptions of shipping casks and spent fuel, but they ignore DOE's analysis of the impacts of acts of sabotage against repository shipments DOE estimated that a successful terrorist attack on a truck cask in an urban area would result in a population dose of 96,000 person-rem, and 48 latent cancer fatalities. While the DOE did not specifically estimate cleanup costs after such an attack, the FEIS states that clean-up costs following a worst-case transportation accident could reach $10 billion. (14)

Analyses prepared for the state of Nevada by Radioactive Waste Management Associates (RWMA) estimated sabotage impacts would be considerably greater than DOE's estimate RWMA replicated DOE's Final EIS sabotage consequence analyses, using the RISKIND model for health effects and the RADTRAN model for economic impacts, 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. (13)

RWMA concluded that an attack on a GA-4 truck cask using the same common military demolition device used in the DOE's analysis could cause 300 to 1,800 latent cancer fatalities, assuming 90% penetration of the cask by a single blast Full perforation of the cask, likely to occur in an attack involving a state-of-the art anti-tank weapon, could cause 3,000 to 18,000 latent cancer fatalities. This more realistic study estimated that cleanup and recovery costs would exceed $10 billion (13)

Beyond attacking a cask with explosives, terrorists might commit radiological sabotage by causing a devastating transportation accident. Last year's Baltimore rail tunnel accident demonstrates the potential consequences of a very severe accident. This train fire burned for more than three days with temperatures as high as 1500°F. While full details of the fire history are not known, there is evidence that the fire may have burned at 1500°F for 7 to 24 hours, and the temperature may have reached 2000°F. Even at 1500°F, a prolonged fire could have caused cask seal failure and fuel pellet oxidation, resulting in a substantial respirable release of radioactive cesium, and wide dispersion of radioactivity by way of the fire smoke plume and concurrent meteorological conditions (15)

An analysis prepared for the State of Nevada by RWMA estimated that the release from a single rail cask in such an accident could have contaminated an area of 32 square miles. Cleanup of the contamination would cost an estimated $13.7 billion and failure to do so would cause 4,000 to 28.000 cancer deaths over the next 50 years. Even though cleanup would mitigate long term risks, between 200 and 1,400 latent cancer fatalities would be expected from exposures during the first year. (15)

The Baltimore rail tunnel fire is still being investigated, and full details of the fire history may never be known. Nonetheless, terrorism risk assessments must consider the possibility that an intentional, human -initiated event could cause a fire environment equal to, or even exceeding, the Baltimore fire characteristics estimated in the RWMA study

Nevada Petition for Rulemaking

Well before the terrorist suicide attacks of September 11, 2001, 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 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. (16)

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. Two and one-half years after the close of the comment period, and more than a year after the 9/11 attacks, the NRC has still not officially responded to Nevada's petition. (17)

Lessons Learned from 9/11

The tragic events of September 11, 2001 clearly indicate that a thorough reconsideration of potential terrorist attack scenarios is necessary. In addition to the changes recommended in Nevada's petition for NRC rulemaking, spent fuel transportation risk assessments must also consider such emerging factors as: suicide attacks involving large groups of well-trained adversaries; terrorist infiltration of trucking and railroad companies; coordinated use of hijacked vehicles; and attacks at locations with a highly symbolic social, political, or economic value.

The post-September 11th recovery efforts in New York and Virginia demonstrate the importance of addressing standard socioeconomic impacts, including cleanup and disposal costs and opportunity costs to affected individuals and business, and economic losses resulting from public perceptions of risk and stigma effects. The necessity of addressing impacts on emergency responders and recovery workers is now also clear.

Finally, the events of September 11th underscore the importance of immediately adopting a national policy to shelter in place the spent nuclear fuel currently stored at commercial nuclear power plants. Current wet and dry storage facilities will require protection from terrorist attack for the operating life of the plants and well beyond the onset of decommissioning efforts. This need for on-site security and storage will be true regardless of current proposals for centralized storage or geologic disposal. (18)

Physical protection of spent fuel at existing facilities is a straightforward task and well within the mandate of the security forces already assigned to those facilities. Current technologies and proven counter-terrorism tactics can readily turn wet and dry storage installations into hardened targets.

Physical protection of spent fuel shipments is a much more difficult matter. From the standpoint of target attractiveness and vulnerability, shipping spent nuclear fuel to a national repository or centralized storage site will only increase the risk of terrorism and sabotage. And even if such shipments were to begin within the next decade, it would still be necessary to protect both the storage facilities and the shipments for four decades or more.

References

(1) "Table of Commercial Spent Fuel Transport Casks," Enclosure 1, Correspondence from R.A. Meserve, NRC Chairman, to The Honorable H. Reid, United States Senate, April 2, 2002; and Meserve to Reid, April 24, 2002.

(2) The accident performance standards are stated in the Code of Federal Regulations, Title 10, Part 71, Subpart E The NRC regulations contain no comparable standards for cask performance following terrorism or sabotage incidents.

(3) U.S. Department of Energy, Statement of Position in the Matter of Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (Waste Confidence Proceeding), Docket PR-50, 51 (44 FR61372), before the U.S. Nuclear Regulatory Commission, DOE/NE-0007, April 15, 1980.

(4) U.S. Department of Energy, Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada, DOE/EIS-0250,February 2002, p F-5. (Cited hereinafter as FEIS; available at http://www.ymp/gov/documents/feis_a/index.htm) Death can occur following acute, whole-body doses of 200 to 300 rads. Because of the predominance of gamma and beta radiation from fission products, the absorbed dose (rads) and the dose equivalent (rems) would be roughly equivalent for unshielded exposure to a spent fuel assembly.

(5) FEIS, Table J-33.

(6) R.P. Sandoval, et al., An Assessment of the Safety of Spent Fuel Transportation in Urban Environs, SAND 82-2365, 1983 See also. NRC, 10 CFR Part 73, Modification of Protection Requirements for Spent Fuel Shipments, Proposed Rule, Federal Register, Vol 49, N. 112, June 8, 1984, 23867-23872.

(7) A.M. Dietrich and W.P. Walters, "Review of High Explosive Device Testing Against Spent Fuel Shipping Casks," Prepared for NRC by U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, October 13, 1983.

(8) R.J. Halstead and J.D Ballard, "Nuclear Waste Transportation Security and Safety Issues: The Risk of Terrorism and Sabotage Against Repository Shipments," Prepared for State of Nevada, Agency for Nuclear Projects, Oct., 1997. This and other reports prepared for the Agency for Nuclear Projects, can be accessed on the web at http.//www.state.nv/nucwaste/trans htm.

(9) U.S. DOE, 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-0250, 1999, p. 6-33.

(10) R.Luna, et al., Projected Source Terms for Potential Sabotage Events Related to Spent Fuel Shipments, SAND99-0963, 1999, p.20.

(11) F Dilger, Personal Communication with E Sanderson, U S Army Aberdeen Test Center, March 7, 2002 The 1998 test is documented in a videotape, available from International Fuel Containers, Inc, New York, N Y

12) L Audin, "Assessing the Risks of Terrorism and Sabotage Against Spent Nuclear Fuel Shipments A Review of Materials and Issues in the Post-9/11 Environment," Prepared for State of Nevada, Agency for Nuclear Projects, April, 2002

(13) M Lamb, et al," Potential Consequences of a Successful Sabotage Attack on a Spent Fuel Shipping Container An Analysis of the Yucca Mountain EIS Treatment of Sabotage" Prepared by Radioactive Waste Management Associates for the State of Nevada, Agency for Nuclear Projects, April 2002.

(14) FEIS, Pp. 6-50 to 6-52, J-73

(15) M Lamb and M Resnikoff, "Radiological Consequences of Severe Rail Accidents Involving Spent Nuclear Fuel Shipments to Yucca Mountain· Hypothetical Baltimore Rail Tunnel Fire Involving SNF," Prepared by Radioactive Waste Management Associates for State of Nevada, Agency for Nuclear Projects, September 2001 For an opposing view, see Christopher S. Bajwa, "An Analysis of A Spent Fuel Transportation Cask Under Severe Accident Conditions," Prepared for U.S Nuclear Regulatory Commission, no date (ca September 2002).

(16) R.J Halstead, et al, "State of Nevada Studies of Potential Terrorism and Sabotage against Spent Fuel Shipments," WM '01, Proceedings of the Conference on Radioactive Waste Management, February 25-March 1, 2001, Tucson, AZ See also· R.J.Halstead, et al, "Nuclear Waste Transportation Terrorism and Sabotage Critical Issues," Proceedings of the 13th International Symposium on the Packaging and Transportation of Radioactive Materials (PATRAM), Chicago, IL, September 4, 2001

(17) The text of the petition and comments submitted to the NRC are available on the web at http.3/26/01/ruleforum llnl gov/cgi-bin/rulemake?source=NV_PETITION.

(18) Prepared Statement of J.D Ballard, Before the Committee on Energy and Natural Resources, United States Senate, 107th Congress, May 22, 2002.