SLOMFP Subpart K
Presentation: Exhibit 3

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE COMMISSION

In the Matter of:	:		
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PACIFIC GAS & ELECTRIC CO.	:	Docket No. 72-26 - ISFSI	
(Diablo Canyon Nuclear Power Plant	:		
Unit Nos. 1 and 2)	:		

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SECOND DECLARATION OF DR. GORDON R. THOMPSON ON BEHALF OF SAN LUIS OBISPO MOTHERS FOR PEACE IN SUPPORT OF CONTENTION 2 REGARDING THE CONSTRUCTION AND OPERATION OF THE DIABLO CANYON INDEPENDENT SPENT FUEL STORAGE INSTALLATION

I, Gordon R. Thompson, state the following:

I. Introduction

I-1. I am the executive director of the Institute for Resource and Security Studies (IRSS), a nonprofit, tax-exempt corporation based in Massachusetts. Our office is located at 27 Ellsworth Avenue, Cambridge, MA 02139. IRSS was founded in 1984 to conduct technical and policy analysis and public education, with the objective of promoting peace and international security, efficient use of natural resources, and protection of the environment.

I-2. I am an expert in the technical analysis of safety, security and environmental issues related to nuclear facilities. Information about my relevant experience and expertise, together with an attached copy of my curriculum vitae, are provided in my declaration of 27 June 2007 in this matter.[1] That declaration accompanied a report that I prepared for San Luis Obispo Mothers for Peace (SLOMFP).[2] My declaration and report supported contentions submitted by SLOMFP in this matter.[3]

I-3. Here, I set forth facts, data and arguments to support SLOMFP Contention 2.

I-4. SLOMFP's contentions responded to the publication by the Staff of the US Nuclear Regulatory Commission (NRC) of a Supplement to the Environmental Assessment (EA) for a proposed Independent Spent Fuel Storage Installation (ISFSI) at the Diablo Canyon

[1] Thompson, 2007d.
[2] Thompson, 2007b.
[3] SLOMFP, 2007.

site. The EA Supplement was published in draft and final versions, in May 2007 and August 2007, respectively.[4]

I-5. The remainder of this declaration consists of narrative discussion set forth in Sections II through VII, together with a bibliography and three tables. All citations in the footnotes and the tables are to documents listed in the bibliography. Some additional, relevant documents also appear in the bibliography.

II. SLOMFP Contention 2 and Its Context

II-1. SLOMFP Contention 2 states as follows:[5]

> "The EA Supplement fails to satisfy NEPA because the NRC's decision not to prepare an EIS is based on hidden and unjustified assumptions."

II-2. In setting forth the basis for Contention 2, SLOMFP provided examples of the EA Supplement's reliance on hidden and unjustified assumptions. A notable example was the EA Supplement's apparent assumption that the environmental impacts of an attack on a spent-fuel-storage module would be insignificant if the attack does not result in early fatalities. That assumption can be inferred because the EA Supplement, in discussing the consequences of a release of radioactive material arising from an attack on an ISFSI, provided only one direct indicator of an adverse outcome, namely "the potential for early fatalities".[6] It should be noted that the NRC uses the terms "early fatalities" and "prompt fatalities" interchangeably.

II-3. My report in support of SLOMFP's contentions shows that the potential for early fatalities is an inappropriate indicator of the environmental impacts of an attack. Other consequences of an attack, especially land contamination and its sequelae, would have considerably greater significance. A credible attack on the Diablo Canyon ISFSI could release to the atmosphere tens of percent of the inventory of cesium-137 in affected spent-fuel-storage modules. Deposition of cesium-137 from that release could render thousands of square kilometers of land uninhabitable. Sequelae would include contamination of food and water, cancers and other adverse health effects that would be manifested years after the release, relocation of populations, abandonment of real estate, and various economic and social impacts. Economic losses could amount to tens of billions of dollars.[7]

II-4. The NRC Commissioners have admitted Contention 2 into this proceeding, in regard to the scope of the consequences considered in the EA Supplement.[8] I address that issue here, in its appropriate context. The scope of the consequences of a potential attack on the Diablo Canyon ISFSI could only be properly understood as part of a

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[4] NRC, 2007b; NRC, 2007a.
[5] SLOMFP, 2007, page 10.
[6] NRC, 2007b, page 6. An equivalent statement appears at: NRC, 2007a, page 7.
[7] Thompson, 2007b, pages 17 and 37.
[8] NRC, 2008a, pp 20-21.

comprehensive assessment of the environmental impacts of such an attack. SLOMFP does not have the funds needed to conduct such an assessment, nor does SLOMFP have the duty to do so. Nevertheless, SLOMFP fully understands the steps needed to conduct such an assessment, and has constructed its contentions accordingly. My report in support of SLOMFP's contentions, and this testimony, reflect that understanding. Both documents provide illustrative analyses to support their arguments. Neither document purports to provide a comprehensive assessment of environmental impacts.

II-5. A comprehensive assessment of environmental impacts, as discussed in the preceding paragraph, would begin by identifying and characterizing a range of credible attacks. Then, for each type of attack, the assessment would estimate the release of radioactive material to the environment. In the case of an attack on an ISFSI, the most significant mode of release would be to the atmosphere. Next, the assessment would model the dispersal of radioactive material in the environment. That step would include site-specific factors that significantly affect the behavior of atmospheric plumes. Then, the assessment would estimate human exposure to the released radioactive material by all significant pathways. Finally, the assessment would estimate the health, environmental, social and economic impacts, both direct and indirect, that arise from the potential for attack-induced release of radioactive material.

II-6. The NRC Staff has not conducted a comprehensive assessment, as specified in the preceding paragraph, for the Diablo Canyon ISFSI. Analysis that the Staff has conducted is reviewed in subsequent sections of this testimony. The requirements of a comprehensive assessment provide a framework for that review.

III. NRC Staff Position Regarding the Potential for Early Fatalities

III-1. As stated in paragraph II-2, above, the EA Supplement provided only one direct indicator of an adverse outcome of an attack on an ISFSI, namely the potential for early fatalities.[9] Thus, SLOMFP has inferred that the NRC Staff, in preparing the EA Supplement, assumed that the environmental impacts of an attack on an ISFSI would be insignificant if the attack does not result in early fatalities. Information subsequently provided by the NRC Staff in this proceeding has confirmed SLOMFP's inference. That information relates to research reactors and related facilities, and to ISFSIs, as described in the following paragraphs.

III-2. In the document, SECY-04-0222, dated 24 November 2004, the NRC Staff submitted to the NRC Commissioners a proposed decision-making framework for vulnerability assessments for materials and research and test reactors.[10] SECY-04-0222 stated, at page 3:

> "Several methodologies for conducting and evaluating comprehensive VAs [vulnerability assessments] for different types of assets are currently under

[9] The EA Supplement also discussed the estimated radiation dose to an individual, which is an indirect indicator of an adverse outcome. That issue is discussed here in Section IV.
[10] Reyes, 2004.

> development. In particular, the ASME, in cooperation with numerous stakeholders, is funded by DHS to develop the RAMCAP methodology. This methodology is designed to inform the allocation of resources to protect infrastructure components."

SECY-04-0222 went on to state, at page 4:

> "As discussed in this paper, the consequences considered are prompt fatalities from radiation exposure and those chemical effects associated with radioactive material processes (i.e., UF_6). Past Commission policy and practice has varied with respect to consideration of consequence criteria. The proposed VA decision-making framework uses only prompt fatalities as a consequence criterion.
>
> It is also recognized that other guidance, such as the draft RAMCAP methodology, uses other consequence criteria. For example, RAMCAP uses criteria such as economic, environmental, national security, symbolic and sociopolitical impacts, and loss of output or production capability as metrics for national level screening.
>
> Other related radiological consequence criteria that could be incorporated in the framework include latent fatalities, land contamination, and chemical risks due to plant conditions which affect the safety of radioactive materials [words redacted]. Including some of these consequence criteria may also be consistent with the goal, in the NRC's Strategic Plan, to ensure protection of public health and safety and the environment, and also with the section on commercial nuclear reactors in the National Infrastructure Protection Plan. There are various points of view within the staff on the need for additional criteria, e.g., land contamination.
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> The staff also recognizes that exposure to certain radioactive materials [words redacted] would not result in a prompt fatality or the need for additional measures. However, using other consequence criteria (e.g., land contamination) may require additional security measures."

III-3. The NRC Commissioners subsequently provided a written response, dated 19 January 2005, to the recommendations proffered by the Staff in SECY-04-0222.[11] The Commissioners stated, at page 1:

> "The Commission specifically approves, as recommended by the staff, the use of prompt fatalities as the consequence analysis in the decision-making framework for this activity."

The Commissioners went on to state, at page 3:

[11] Vietti-Cook, 2005.

> "As a separate issue from the vulnerability assessments conducted under the decision making framework, the staff should not be independently developing criteria and standards for other consequences (such as land contamination and economic impacts) at this time. Rather, consistent with the US government programs for homeland protection and security, the staff should continue to support the separate vulnerability assessment reviews being conducted under the leadership of the Department of Homeland Security (DHS). These activities include the consideration of consequences other than prompt fatalities."

III-4. The Staff's recommendations in SECY-04-0222, and the Commissioner's written response to those recommendations, did not explicitly cover ISFSIs. However, a subsequent Memo sent from one Staff office to another did explicitly link SECY-04-0222 with ISFSIs.[12] The Memo, dated 9 December 2005, stated at page 1:

> "In response to Chairman Meserve's memorandum, "Response to Terrorist Acts", dated September 28, 2001, and in accordance with SRM-SECY-04-0222, "Decision-Making Framework for Materials and Research and Test Reactor Vulnerability Assessments", the Spent Fuel Project Office (SFPO) staff performed framework assessments for spent fuel storage casks and transportation packages and radioactive material transportation packages for various potential terrorist threats."

III-5. From that statement, it is evident that the NRC Staff, in performing framework assessments of the vulnerability of ISFSIs to attack, acted "in accordance with" the approach set forth in SECY-04-0222. It follows that the Staff, in considering the consequences of an attack on an ISFSI, limited its consideration to the potential for early fatalities.

III-6. The Government Accountability Office (GAO) reviewed, in a January 2008 report, NRC's assessment of the vulnerability of research reactors to attack.[13] GAO's general conclusion is evident in the report's title, *Nuclear Security: Action May be Needed to Reassess the Security of NRC-Licensed Research Reactors*. GAO noted NRC's reliance on the potential for early fatalities as the sole indicator of the consequences of attack. GAO used the term "immediate fatalities", which is equivalent to "early fatalities". The GAO report stated, at page 8:

> "NRC used the number of immediate fatalities caused by radiological release resulting from an attack at a research reactor as its criterion to measure consequences and assessed [assess] the adequacy of the security at NRC-licensed reactors."

III-7. In preparing the above-mentioned report, GAO obtained independent advice on the vulnerability of research reactors to attack, and on the consequences of such an attack,

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[12] Strosnider, 2005.
[13] GAO, 2008.

and reviewed the findings of the US Department of Energy (DOE) and Sandia National Laboratories (SNL) on these matters.[14] Analysts at Idaho National Laboratory (INL) and the Department of Homeland Security (DHS) advised GAO that a credible attack on a research reactor could cause a release of radioactive material substantially larger than NRC assumes. An INL analyst advised GAO that the consequences of an attack could include significant land contamination. GAO noted that DOE has determined that the consequences of an attack at some of its research reactors could be severe, potentially involving the dispersion of radioactive material over many square miles. GAO also noted that SNL had, under contract to NRC, assessed the vulnerability of research reactors. SNL concluded that some credible attacks could be successful. NRC disagreed, and concluded that radiological consequences of credible attacks would be minimal.

III-8. The NRC Commissioners' response of 19 January 2005 to SECY-04-0222 stated, at page 1:[15]

> "The Commission continues to support its earlier direction that Sandia National Laboratories' draft vulnerability assessments not be shared with industry and should not be released to anyone outside the agency."

III-9. From that statement, it appears that the Commissioners sought to suppress a differing professional opinion that was developed by SNL while working under contract to NRC. The existence of that differing opinion was not publicly known until the publication of GAO's report in January 2008. Moreover, as shown in paragraph III-3, above, the Commissioners ordered the Staff to refrain from independently developing criteria and standards for attack consequences other than early fatalities. These actions by the Commissioners were taken with direct application to research reactors and related facilities. As shown by paragraphs III-4 and III-5, above, it appears that these actions also apply to ISFSIs.

III-10. From the preceding paragraphs, it can reasonably be concluded that NRC has made a policy choice to consider only one category of environmental impacts of an attack on an ISFSI, namely the potential for early fatalities. Also, in the context of research reactors and related facilities, NRC has made policy choices to not consider attack scenarios that SNL and other authorities have determined to be credible, and to not consider environmental impacts other than the potential for early fatalities. A motive for the latter choice can be inferred from an NRC Staff statement quoted in paragraph III-2, above, that "using other consequence criteria (e.g., land contamination) may require additional security measures". Additional security measures would involve additional costs. Thus, by not considering environmental impacts such as land contamination, NRC may have allowed licensees to avoid additional costs. It can reasonably be inferred that NRC has taken essentially the same approach in the context of ISFSIs.

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[14] GAO, 2008, pp 14-18.
[15] Vietti-Cook, 2005.

IV. NRC Staff Estimation of Radiation Dose to an Individual

IV-1. As noted in subsequent paragraphs, the NRC Staff has released a succession of documents that discuss its estimation of the radiation dose to an individual following an attack on the Diablo Canyon ISFSI. Each successive document contains additional information, but the publicly available description of the Staff's assumptions and analyses remains incomplete. For example, the Staff has not disclosed the composition of the atmospheric release for which it estimates a radiation dose.

IV-2. As explained in Section VI, below, it appears that the Staff's process of estimating the radiation dose to an individual has been fundamentally shaped by NRC's policy choice to consider only one category of environmental impacts of an attack on an ISFSI, namely the potential for early fatalities. That policy choice has led the Staff to confine its analysis of radiological consequences to a particular category of radiation exposure, and to refrain from considering potential releases of radioactive material that are significant in regard to other categories of radiation exposure. In other words, NRC's policy choice has precluded a thorough, science-based assessment of the environmental impacts of a credible attack on the Diablo Canyon ISFSI.

IV-3. The NRC Staff's May 2007 EA Supplement for the Diablo Canyon ISFSI discussed, at page 7, the factors relevant to radiation dose arising from an attack at the ISFSI, concluding:[16]

> "Based on these considerations, the dose to the nearest affected resident, from even the most severe plausible threat scenarios – the ground assault and aircraft impact scenarios discussed above – would likely be below 5 rem."

IV-4. That claim was further elaborated in the Staff's August 2007 EA Supplement, which stated at page 7:[17]

> "More specifically, NRC staff performed a dose calculation using source term and meteorology inputs from the generic assessments. This resulted in a projected dose of less than 5 rem for the nearest resident. Using the Diablo Canyon site-specific meteorology, as opposed to the generic meteorology, reduces the projected dose consequences by a factor of 10 to 100."

IV-5. In a subsequent response to SLOMFP discovery in this proceeding, the Staff provided additional, but still incomplete, information regarding its estimation of the radiation dose to an individual resident.[18] The Staff stated that dose was calculated as total effective dose (TED) including inhalation, external exposure from the plume, and 4 days of external exposure from deposited material. Presumably, the Staff actually calculated total effective dose equivalent (TEDE). As a first step, the Staff used the

[16] NRC, 2007b.
[17] NRC, 2007a.
[18] NRC, 2008b, pp 15-17.

Hotspot code assuming a release height of 1 meter, no plume rise, a wind speed of 4.0 meters per second, and atmospheric stability of D (neutral). Given those assumptions, dose was calculated for an individual at an unstated distance. As a second step, the Staff compared the Hotspot-modeled plume dispersion with dispersion estimates provided in the licensee's Environmental Report for the location of the nearest resident to the Diablo Canyon ISFSI, at a distance of 2,414 meters. That step yielded a dose 1 or 2 orders of magnitude lower than did the first step.

IV-6. Hotspot is a code developed by Lawrence Livermore National Laboratory (LLNL). It is a conventional Gaussian straight-line dose assessment model. In describing Hotspot, LLNL says:[19]

> "Users requiring more sophisticated modeling capabilities, e.g., complex terrain; multi-location real-time wind field data; etc., are directed to such capabilities as the Department of Energy's NARAC computer codes."

IV-7. The Diablo Canyon site is on the coast, with substantial topographic relief (hills) in landward directions. An atmospheric plume released at such a location can exhibit complex behaviors. The NRC Staff did not attempt to model those behaviors, relying instead on the Hotspot code. The findings of that code could be highly misleading. For example, a study conducted for NRC in 1983 stated, regarding plume behavior in coastal zones:[20]

> "The direct application of a conventional Gaussian straight-line dose assessment model, initialized only by on-site tower data, can potentially produce highly misleading guidance as to plume impact locations."

The same study also stated:[21]

> "For sites located within a coastal zone the following are just some of the transport phenomena routinely encountered:
>
> (1) surface wind flow reversals due to mesoscale frontal passages,
> (2) the return of effluents onshore that had previously drifted over water during the prior night's land breeze,
> (3) trajectory curvature due to Coriolis and other forces,
> (4) plume bifurcation from multi-stack releases due to extreme vertical wind shears,
> (5) transport of near surface plumes to higher altitudes due to chimney-like updrafts in convergence zones,
> (6) encapsulation of plumes in return flow layers aloft,
> (7) second trip fumigation from recirculating plumes."

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[19] LLNL, 2008.
[20] Lyons et al, 1983, page 3.
[21] Lyons et al, 1983, pp 5-6.

IV-8. A comprehensive assessment of the environmental impacts of potential attacks on the Diablo Canyon ISFSI would consider the range of plume behaviors that can be exhibited at this particular site. The NRC Staff chose, instead, to use a simple, stylized model of plume behavior – the Hotspot code – despite its known limitations. That approach is consistent with a preconceived view that the environmental impacts of potential attacks are insignificant. A similar approach is evident in the Staff's consideration of attack-induced releases of radioactive material, as discussed in Section VI, below.

V. Attack-Induced Atmospheric Release of Radioactive Material from a Spent-Fuel-Storage Module: Background Discussion

V-1. There is a published, technical literature that relates, directly and indirectly, to attack-induced atmospheric release of radioactive material from a spent-fuel-storage module of the type that would be used at the Diablo Canyon ISFSI. Also, general attributes of such a release can be estimated from professional knowledge of engineering and related disciplines. In the following paragraphs, these sources are used to discuss the range of attack-induced atmospheric releases that could occur at the Diablo Canyon ISFSI. In Section VI, below, that range is compared with the releases considered by the NRC Staff.

V-2. One example of relevant published literature is a 2001 paper by Lange et al, discussing an experiment to simulate an attack on a cask used for storage or transport of spent fuel, using a shaped charge.[22] The authors described a test, done in 1992, in which a shaped charge penetrated a shortened CASTOR cask containing shortened fuel assemblies in which the pellets were made of depleted uranium. The fuel rods were internally pressurized to 40 bar to simulate real spent-fuel rods. The shaped charge was intended to represent an anti-tank weapon. Each of two shots yielded a release of 1.0 grams of uranium in the aerodynamic equivalent diameter (AED) class of less than 12.5 micrometer, and 2.6 grams in the AED class 12.5 to 100 micrometer. Using these test results, the authors estimated the downwind radiation dose for an equivalent attack on a real cask containing real spent fuel. They estimated that the inhalation dose at a distance of 50 meters would be below 50 mSv (5 rem) for the most severe (i.e., dose-enhancing) weather conditions. The inhalation dose would be dominated by actinides, such as plutonium isotopes.

V-3. There is an International Working Group for Sabotage Concerns of Transport and Storage Casks. This Working Group links SNL, DOE, NRC and organizations in Germany, France and UK. The Working Group conducts an experimental program whose findings are published periodically. One of those publications, dated October 2006, stated at page 3:[23]

"This program provides source-term data that are relevant to some sabotage

[22] Lange et al, 2001.
[23] Molecke et al, 2006.

> scenarios in relation to spent fuel transport and storage casks, and associated risk assessments."

The same publication stated at page 15:

> "This experimental program is designed to measure several important features of the interaction of a HEDD (conical shaped charge, CSC) jet with spent fuel or surrogate material pellets contained within a Zircaloy-4 cladding tube."

The term HEDD refers to a high-energy-density device, in the form of a shaped charge. It is clear that the primary focus of the Working Group's experimental program is to examine the creation by an HEDD of respirable aerosol. Information about the release of respirable aerosol is needed to estimate the inhalation dose accrued by an individual downwind of an attacked cask.

V-4. The NRC Staff argues that the radiation dose to a downwind resident following an attack on the Diablo Canyon ISFSI would not exceed 5 rem. Exposure of a person to a dose of 5 rem would require only a small release of radioactive material from a spent-fuel-storage module, as discussed in the report I prepared to support SLOMFP's contentions.[24] That report showed, for example, that creation of a hole in a module's multi-purpose canister (MPC) would yield a dose of 6.3 rem to an individual located 900 meters downwind if the hole had an equivalent diameter of a mere 2.3 mm. Most (95 percent) of the dose would be attributable to the release of two-millionths (1.9E-06) of the MPC's inventory of radioisotopes in the "fines" category. The dose of 6.3 rem would be the committed effective dose equivalent (CEDE) arising from inhalation. CEDE would make up most of the total dose (TEDE) and is a sufficient approximation to it.

V-5. The experiments discussed in paragraphs V-2 and V-3, above, simulated mechanical damage to the interior of a container containing spent fuel assemblies. The damage would encompass some or all of the rods in affected fuel assemblies, and some of the pellets in those rods. These experiments did not investigate the potential for ignition of the zirconium alloy (zircaloy) cladding of the rods, or the implications of that ignition for the release of radioactive material to the atmosphere. Similarly, the calculations summarized in paragraph V-4 did not consider zircaloy ignition. As shown in the following paragraph, ignition of zircaloy cladding could lead to a substantial atmospheric release of cesium-137, causing severe radiological impacts of the type discussed in paragraph II-3, above.

V-6. Table 1 shows that the energy released by combustion of zircaloy cladding in air would be ample to raise the temperature of adjacent fuel pellets well above the boiling point of cesium, which is about 690 degrees C. Sustained combustion inside a spent-fuel-storage module would require the free ingress of air and egress of combustion products. If those conditions prevailed, combustion of cladding could propagate to many of the

[24] Thompson, 2007b, page 33 and Table 4-1.

rods inside the module, and the release of radioactive material to the atmosphere could include tens of percent of the module's inventory of cesium-137.

V-7. The preceding discussion shows that a thorough investigation of the vulnerability of an ISFSI to attack would devote considerable attention to the potential for ignition and sustained combustion of the zircaloy cladding inside a spent-fuel-storage module. That potential was discussed in the report I prepared to support SLOMFP's contentions.[25]

V-8. One means, among others, whereby a sub-national group could obtain combustion of zircaloy cladding would be to attack a spent-fuel-storage module using a device in which two stages are mounted in tandem. The first stage would be a shaped charge that penetrates the module's overpack and MPC. The second stage would use incendiary material, perhaps combined with explosive material, to ignite the zircaloy cladding. Table 2 shows that shaped charges capable of penetrating a module's overpack and MPC have been widely available for decades. Various types of incendiary material are available, and are described in published literature.[26] Many types of incendiary device have been developed. For example, experts at SNL have described their testing of devices that combined explosive material with combustible metals.[27] These devices yielded blast, fragmentation and incendiary effects in combination. Zirconium sponge was found to function well as an incendiary. A specific purpose of the testing was to prepare for the development of an incendiary warhead for a penetrating device. The tests led to the following conclusion:[28]

> "Our results indicate that a metalized incendiary explosive device is feasible and capable of starting massive fires at the target site."

V-9. Small, self-propelled missiles that can be equipped with tandem warheads are available on international arms markets. Consider two Russian-made examples. The RPG-29V has an effective direct-fire range of 300 meters.[29] It is said to be able to penetrate 1.5 meters of reinforced concrete. The Komet E is laser guided.[30] Its range is up to 5.5 kilometers in daylight and 3.5 kilometers at night. The manufacturer claims penetration of 1.2 meters of steel armor or 4.5 meters of concrete. A firing unit including launcher, thermal sight and one missile has a mass of 65 kg.

V-10. Arms manufacturers are continuing to develop tandem-warhead systems. For example, in January 2008 Raytheon tested the shaped-charge penetrating stage for its Tandem Warhead System.[31] The shaped charge penetrated 19 feet into steel-reinforced

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[25] Thompson, 2007b, pp 33-37.
[26] For example, Fischer and Grubelich, 1996b, provided information about various exothermic reactions. These included the "traditional" thermite reaction: 8Al + 3Fe3O4 –> 4Al2O3 + 9Fe. The heat of that reaction is 879 cal per gram, and the adiabatic reaction temperature, with phase changes, is 3,135 degrees K = 2,862 degrees C.
[27] Fischer and Grubelich, 1996a.
[28] Fischer and Grubelich, 1996a, page 11.
[29] Defense Update, 2008a.
[30] Defense Update, 2008b.
[31] Raytheon, 2008.

concrete with a compressive strength of 12,600 psi. The purpose of this new system is to penetrate a target protected by concrete, steel and rock barriers, and to cause damage inside the target. Development of the system was self-funded by Raytheon. The current version would have a mass of about 1,000 pounds in its tandem configuration. Raytheon states that it could scale the technology, which implies both larger and smaller versions.

V-11. The preceding discussion in Section V has outlined some of the types of attack-induced atmospheric release that could be experienced by a spent-fuel-storage module at the Diablo Canyon ISFSI. Table 3 provides a more complete description of potential attack-induced atmospheric releases. Four types of release are identified. Without excluding Type I and Type II releases from consideration, I focus here on Type III and Type IV releases. The differences between these releases are significant in the context of the present proceeding. Type III releases would be associated with attack scenarios such as the impact of a commercial aircraft, or the explosion of a vehicle bomb. Scenarios of that type would have a comparatively dramatic appearance, featuring noise, external fire, and smoke. By comparison, the attack scenarios associated with Type IV releases would appear less dramatic. Yet, the Type IV releases would contain much larger amounts of volatile isotopes such as cesium-137, which would be significant from the perspective of land contamination. A superficial assessment of the vulnerability of an ISFSI might lead to the conclusion that Type IV releases deserve less consideration than do Type III releases. That assessment would be incorrect. It would ignore the greater sophistication of the attack scenarios associated with Type IV releases, which would aim to maximize radiological impacts rather than the dramatic appearance of the event. Also, analysts whose attention is focused on the inhalation dose to a downwind individual could fail to appreciate the significance of Type IV releases, if they assume that the more dramatic-appearing attack scenarios associated with Type III releases would yield larger amounts of the isotopes that dominate inhalation dose.[32]

VI. Attack-Induced Atmospheric Release of Radioactive Material from a Spent-Fuel-Storage Module: Consideration by the NRC Staff

VI-1. The NRC Staff has not disclosed any information about the attack-induced atmospheric releases that it has considered in the context of the Diablo Canyon ISFSI. Some information about those releases can, however, be inferred from available sources, as described below.

VI-2. The Staff has disclosed some information about a study conducted for NRC by SNL, regarding the impact of a large aircraft on a field of HI-STORM spent-fuel-storage modules. That type of module would be used at the Diablo Canyon ISFSI. The study was described in a report.[33] Most of the content was redacted from the version of the report provided to SLOMFP. At page 7, the redacted report stated that the mass of the assumed aircraft is representative of the class of aircraft involved in the 9/11 events. At pages 24-25, the report stated that it is unlikely that a pool of fuel and a storage module

[32] Note that cesium-137 in an atmospheric plume would be significant from the perspective of land contamination, but would yield a comparatively small dose if inhaled.
[33] Smith et al, 2004.

would be co-located after the dynamic phase of the impact had concluded. Thus, a long-duration pool fire affecting a module was judged to be a non-credible event. At page C-4, the report mentioned the analytic simulation of a quiescent, engulfing fire affecting an upright module. The simulation was run for a short time – 90 to 180 seconds – consistent with SNL's judgment that a module would not be co-located with a long-duration pool fire.

VI-3. Another report described a study conducted by SNL for NRC on the response of a HI-STORM 100 module to an explosive blast.[34] Again, most of the content was redacted from the version provided to SLOMFP. At page 8 the redacted report stated:

> "The amount of explosive and standoff distance is representative of a scenario of a small truck parked directly adjacent to the cask. The scenario parameters for this event were defined by NRC design basis threat criteria and by NRC staff, where more specificity was required to define the event. This loading simulates a truck delivery of the explosive, parked adjacent to the cask."

At page 21 the report stated:

> "The charge configuration is limited to a bare TNT charge in close proximity to the cask."

VI-4. The attack scenarios discussed in paragraphs VI-2 and VI-3 would be associated with Type III atmospheric releases, using the typology set forth in Table 3. Both scenarios would have a dramatic appearance, but neither would represent a sophisticated approach to maximizing radiological impacts. Neither scenario would be likely to initiate sustained combustion of zircaloy cladding inside a module. Both scenarios would be consistent with atmospheric releases similar to those discussed in paragraphs V-2 to V-4, above. For such releases, the dominant radiological impact would be the inhalation doses accrued by persons exposed to the radioactive plume.

VI-5. The NRC Staff argues that the environmental impacts of potential attacks on the Diablo Canyon ISFSI are not significant. The Staff has not provided a comprehensive assessment to support that position.[35] Nor has the Staff disclosed all of the assumptions that underlie its position. Thus, much of the basis for the Staff's position remains hidden. Section III of this testimony provides compelling evidence that NRC has made a policy choice to consider only one category of environmental impacts, namely the potential for early fatalities. That policy choice, and other factors, could provide a four-part explanation of how the Staff reached its position on environmental impacts, as follows. First, the policy choice would have prevented the Staff from considering any category of environmental impacts other than the potential for early fatalities. Second, as an outcome of the policy choice, the Staff would have focused its attention on the inhalation dose to a

[34] Kipp et al, 2004.
[35] As discussed in paragraph II-5, a comprehensive assessment would consider a range of attack scenarios, release types, and weather conditions. It would also address site-specific issues, including the complexities of atmospheric plume dispersion at the Diablo Canyon site.

downwind individual, because that mode of radiation exposure would be most likely to lead to an early fatality. Third, as an outcome of focusing on inhalation dose, the Staff would have believed that Type IV releases do not require consideration, because the Staff thought that Type III releases would include larger or comparable amounts of the isotopes that dominate inhalation dose. Fourth, the Staff would have been misled by the comparatively dramatic appearance of the attack scenarios associated with Type III releases, leading to the false conclusion that Type IV releases would yield comparatively small environmental impacts.

VI-6. The four-part process described in the preceding paragraph is consistent with all of the information provided by the Staff in this matter. I am not aware of any better explanation of the Staff's position on environmental impacts of potential attacks. The most prominent feature of this explanation is that the Staff began its assessment of the environmental impacts of an attack on the Diablo Canyon ISFSI with a preconceived position. As a result, the Staff did not conduct a comprehensive, science-based assessment, and its conclusions were faulty. The process is reminiscent of the Staff's prolonged failure to understand the potential for ignition of spent fuel in a high-density spent-fuel pool, if water were lost from the pool.[36] In a license proceeding regarding the Harris nuclear power plant, I argued that comparatively aged spent fuel – including fuel aged 10 or more years after discharge from a reactor – could ignite if water were lost. The Staff disparaged my position, but subsequently adopted that position. For almost two decades, the Staff had failed to understand that comparatively aged fuel could ignite. The Staff's prolonged failure derived from an erroneous, preconceived position, namely that total, instantaneous loss of water would be the most severe mode of loss of water.

VII. Conclusions

VII-1. The NRC Staff has not conducted a comprehensive, science-based assessment to support its position that the environmental impacts of potential attacks on the Diablo Canyon ISFSI are not significant. Instead, the Staff conducted a limited assessment that led to an erroneous conclusion. There is compelling evidence that the assessment was shaped by a preconceived position. A major determinant of that position was an NRC policy choice to consider only one category of environmental impacts, namely the potential for early fatalities. It appears that the Staff was also misled by other factors, including the comparatively dramatic appearance of attack scenarios that the Staff chose to consider. A comprehensive assessment of environmental impacts would consider additional attack scenarios, together with a range of radiological impacts including land contamination and its sequelae.

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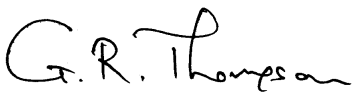
[36] Thompson, 2007d, pp 4-5.

I declare under penalty of perjury under the laws of the United States of America that the foregoing statements of fact are true and correct to the best of my knowledge and belief, and that the opinions expressed herein are based on my best professional judgment.

Executed on 14 April 2008.



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NOTE: The bibliography and the three tables that appear on the following pages are discussed in the narrative sections above, and are part of this declaration.

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Table 1
Illustrative Calculation of Heat-Up of a Fuel Rod in a PWR Fuel Assembly Due to Combustion in Air

Indicator	Affected Material	
	Zircaloy Cladding	**UO_2 Pellets**
Solid volume, per m length	1.90E-05 cub. m (OD = 1.07 cm; thickness = 0.06 cm)	6.36E-05 cub. m (OD = 0.9 cm)
Mass, per m length	0.124 kg (@ 6.55 Mg per cub. m)	0.700 kg (@ 11.0 Mg per cub. m)
Heat output from combustion of material in air, per m length	1.48 MJ (@ 2,850 cal per g Zr)	Neglected
Equilibrium temperature rise if material receives 50% of heat output from adjacent combustion, and if heat loss from material is neglected	Neglected	approx. 2,700 deg. C (enthalpy rise if UO_2 temp. rises from 300 K to 3,000 K = 1,052 kJ per kg UO_2)

Notes:
(a) Data shown in table are from: Nero, 1979, Table 5-1; Powers et al, 1994, Table 4; and files accessed at International Nuclear Safety Center (INSC), Argonne National Laboratory, <http://www.insc.anl.gov/>, in March 2008.
(b) Melting point of UO_2 is 2,850 deg. C (from INSC files).
(c) Boiling point of elemental cesium is 685 deg. C (from: Thompson and Beckerley, 1973, Volume 2, page 527).
(d) 1 cal = 4.184 J

Table 2
Performance of US Army Shaped Charges, M3 and M2A3

Target Material	Indicator	Type of Shaped Charge	
		M3	**M2A3**
Reinforced concrete	Maximum wall thickness that can be perforated	60 in	36 in
	Depth of penetration in thick walls	60 in	30 in
	Diameter of hole	• 5 in at entrance • 2 in minimum	• 3.5 in at entrance • 2 in minimum
	Depth of hole with second charge placed over first hole	84 in	45 in
Armor plate	Perforation	At least 20 in	12 in
	Average diameter of hole	2.5 in	1.5 in

Notes:
(a) Data are from: Army, 1967, pp 13-15 and page 100.
(b) The M2A3 charge has a mass of 12 lb, a maximum diameter of 7 in, and a total length of 15 in including the standoff ring.
(c) The M3 charge has a mass of 30 lb, a maximum diameter of 9 in, a charge length of 15.5 in, and a standoff pedestal 15 in long.

Table 3
Types of Atmospheric Release from a Spent-Fuel-Storage Module at the Diablo Canyon ISFSI as a Result of a Potential Attack

Type of Event	Module Behavior	Relevant Instruments and Modes of Attack	Characteristics of Atmospheric Release
Type I: Vaporization	• Entire module is vaporized	• Module is within the fireball of a nuclear-weapon explosion	• Radioactive content of module is lofted into the atmosphere and amplifies fallout from nuc. explosion
Type II: Rupture and Dispersal (Large)	• MPC and overpack are broken open • Fuel is dislodged from MPC and broken apart • Some ignition of zircaloy fuel cladding may occur, without sustained combustion	• Aerial bombing • Artillery, rockets, etc. • Effects of blast etc. outside the fireball of a nuclear weapon explosion	• Solid pieces of various sizes are scattered in vicinity • Gases and small particles form an aerial plume that travels downwind • Some release of volatile species (esp. cesium-137) if incendiary effects occur
Type III: Rupture and Dispersal (Small)	• MPC and overpack are ruptured but retain basic shape • Fuel is damaged but most rods retain basic shape • No combustion inside MPC	• Vehicle bomb • Impact by commercial aircraft • Perforation by shaped charge	• Scattering and plume formation as for Type II event, but involving smaller amounts of material • Little release of volatile species
Type IV: Rupture and Combustion	• MPC is ruptured, allowing air ingress and egress • Zircaloy fuel cladding is ignited and combustion propagates within the MPC	• Missiles with tandem warheads • Close-up use of shaped charges and incendiary devices • Thermic lance • Removal of overpack lid	• Scattering and plume formation as for Type III event • Substantial release of volatile species, exceeding amounts for Type II release