Application No.: 04-02-026
Exhibit No. :
Date: December 13, 2004
Witness: Gordon Thompson

BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

Application of Southern California Edison Company (U 338-E) for Authorization: (1) to replace San Onofre Nuclear Generation Station Unit Nos. 2 & 3 (SONGS 2 & 3) steam generators; (2) establish ratemaking for cost recovery; and (3) address other steam generator replacement issues.	Application A.04-02-026 (Filed February 27, 2004)

TESTIMONY OF GORDON THOMPSON ON BEHALF OF CALIFORNIA EARTH CORPS

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For: CALIFORNIA EARTH CORPS

December 13, 2004

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I. INTRODUCTION

Q. Please state your name, business address, and professional affiliations.

A. My name is Gordon R. Thompson. I am the executive director of the Institute for Resource and Security Studies (IRSS), a nonprofit, tax-exempt corporation based in Massachusetts. The IRSS 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. In addition to working at IRSS, I hold an appointment as a research professor at the George Perkins Marsh Institute, Clark University, Worcester, MA.

Q. Please describe your professional and academic background.

A. I received an undergraduate education in science and mechanical engineering at the University of New South Wales, in Australia. Subsequently, I received a Doctorate of Philosophy in mathematics in 1973 from Oxford University, for analyses of plasmas undergoing thermonuclear fusion. During my graduate studies I was associated with the fusion research program of the UK Atomic Energy Authority. My undergraduate and graduate work provided me with a rigorous education in the methodologies and disciplines of science, mathematics, and engineering. Since 1977, a significant part of my work has consisted of technical analyses of safety, security and environmental issues related to nuclear facilities. These analyses have been sponsored by a variety of non-governmental organizations and local, state and national governments, predominantly in North America and Western Europe. Drawing upon these analyses, I have provided expert testimony in legal and regulatory proceedings, and have served on committees advising US government agencies. My Curriculum Vitae is provided here as Appendix C.

Q. Please summarize your experience that is relevant to this testimony.

A. My analyses of security threats to nuclear facilities, and of options for defending these facilities, have withstood critical scrutiny and affected policy in Europe and the USA. For example, my assessment in 1978-1979 of security threats and defense options related to the proposed Gorleben facility in Germany was accepted by the licensing authority, leading to new design standards that remain in effect. Similar assessments that I conducted in relation to the Sellafield site in the UK and the La Hague site in France, at various times between 1977 and 2000, have led to new design standards and government policies. My analyses of security threats and defense options related to storage of spent fuel from US nuclear power plants are currently influencing the development of national policy.

Q. What are the purposes of your testimony?

A. My testimony has two purposes. The first purpose is to show that, given present trends, it is reasonable and prudent to assume that the two operating units of the San Onofre nuclear generating station (SONGS) -- Unit 2 and Unit 3 -- and their spent fuel will receive an enhanced defense during the coming years. By enhanced defense, I mean the implementation of defensive measures additional to those currently required by the US Nuclear Regulatory Commission (NRC).[1] The testimony's second purpose is to provide an estimate of additional costs to Southern California Edison (SCE) and other owners of SONGS that could arise from the provision of the enhanced defense. SCE has not included such costs in its application to the California Public Utilities Commission (CPUC) to replace steam generators at SONGS Unit 2 and Unit 3. Consideration of these costs would affect cost/benefit analyses related to replacement of the steam generators.

Q. Please briefly summarize your testimony.

A. This testimony has nine sections. After this introduction (Section I), Section II describes SONGS. Section III discusses the defense of nuclear power plants in the context of US national security. Section IV reviews NRC's present requirements for defense of nuclear power plants. That review is followed, in Section V, by a discussion of the risk of attack on nuclear power plants and their spent

[1] Here, I use the term "defense" in its military sense. In a military context, the term "defense in depth" refers to a set of mutually-supportive but independent measures that protect a facility from external or internal attackers. Some safety experts in the nuclear power industry have appropriated the term defense in depth to refer to the provision of multiple safety systems. I use the term in its original, military sense.

fuel. In this context, the concept of risk encompasses vulnerability to attack, and the probability and consequences of attack. Section VI describes trends that are leading toward enhanced defense of US nuclear power plants and spent fuel. Section VII describes the type of enhanced defense of SONGS Unit 2 and Unit 3 and their spent fuel that, I believe, it is reasonable and prudent to assume will be implemented in the future. The costs of implementing the additional defensive measures are estimated in Section VIII. My conclusions are set forth in Section IX. Nine tables are part of this testimony but are collected, for convenience, in Appendix A. A bibliography to support this testimony is provided in Appendix B. Literature cited in the testimony appears in the bibliography. Appendices A, B and C are parts of the testimony.

Q. Does your testimony contain information that is sensitive from the perspective of security?

A. This testimony discusses potential destructive attacks, at SONGS and other nuclear facilities, that could cause great public harm. No information is contained in the testimony that could assist the perpetrator of such an attack. Accordingly, this testimony is appropriate for general distribution.

II. CHARACTERISTICS OF SONGS

Q. Please describe the SONGS site.

A. The SONGS site is on land leased from Camp Pendleton, a Marine Corps base.[2] The total area of the site is approximately 220 acres, the site being in two separate portions. One portion, covering 84 acres, lies between the Interstate Route 5 freeway and the Pacific Ocean. Three nuclear generating units were built on this portion. The other portion of the site – known as the Mesa – lies inland of Interstate 5. At the Mesa are a warehouse, training facilities and other facilities to support plant operations.[3] The portion of the site where the generating units are located is comparatively small,

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[2] For an introduction to Camp Pendleton and its security issues, see: Bice, 2001.
[3] SCE, 2002a; CCC, 2000; SCE, 2004a.

and heavily-used roads and public beaches are in close proximity. These characteristics make the SONGS site more difficult to defend than many other nuclear-power-plant sites.

Q. Please describe the nuclear generating units at SONGS.

A. Unit 1 of SONGS was shut down in 1992, and its decommissioning is well advanced.[4] Units 2 and 3 continue in operation. Selected characteristics of these two units are provided in Table 1. Each unit employs a pressurized-water reactor (PWR). Each reactor has two steam generators, which SCE proposes to replace.

Q. How is spent nuclear fuel managed at SONGS?

A. An independent spent fuel storage installation (ISFSI) has been established at the site, near to SONGS Unit 1. This facility will accommodate Unit 1 spent fuel that has previously been stored in the spent-fuel pools at Units 1, 2 and 3. SCE plans to expand the ISFSI in increments, so that it can accommodate spent fuel from Units 2 and 3 when their spent-fuel pools become full. As shown in Table 1, SCE expects that the Unit 2 and Unit 3 pools will become full in 2007 and 2008, respectively. Each of these pools employs high-density racks. The ISFSI employs the NUHOMS dry-storage system made by Transnuclear, Inc. In this system, the fuel is contained in a cylindrical canister that is stored horizontally inside a concrete enclosure. During this testimony I refer to the combination of a canister and its enclosure as a storage module. The canisters to be used in the ISFSI at SONGS can hold up to 24 fuel assemblies per canister.[5]

Q. Was SCE aware of the need for additional onsite, spent-fuel storage capacity when NRC approved construction of the SONGS units?

A. No. The long-term, onsite storage of spent fuel at SONGS was never considered because SCE assumed that this waste would be transported to an offsite facility.

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[4] NRC, 2004c.

Q. Please describe the hazardous radioactive material that arises from the operation of SONGS Unit 2 and Unit 3.

A. Each fuel assembly that has generated power in a reactor contains a variety of radioactive isotopes, but one isotope -- cesium-137 -- is especially useful as an indicator of the potential for radiological harm. Cesium-137 is a radioactive isotope with a half-life of 30 years. This isotope accounts for most of the offsite radiation exposure that is attributable to the 1986 Chernobyl reactor accident, and for about half of the radiation exposure that is attributable to fallout from the testing of nuclear weapons in the atmosphere.[6] Cesium is a volatile element that would be liberally released during the melt-down of a reactor core or during a fire in a drained spent-fuel pool. The inventory of cesium-137 in the SONGS Unit 2 or Unit 3 reactors, their spent-fuel pools and the ISFSI can be estimated. Table 2 provides such estimates. In that table I assume that one third of the reactor core is discharged after each 18 months of operation. Also, I assume that the full loading of a spent-fuel pool would be 1,325 fuel assemblies, which would allow for discharge of a full reactor core – 217 fuel assemblies – without exceeding the pool's capacity of 1,542 assemblies. From Table 2 one sees that each reactor contains about 7.7 million Curies (85 kilograms) of cesium-137, while a fully-loaded spent-fuel pool would contain about 68 million Curies (750 kilograms) and one ISFSI module would contain about 1.2 million Curies (13 kilograms). As a comparison, the Chernobyl reactor accident of 1986 released about 2.4 million Curies (27 kilograms) of cesium-137 to the atmosphere. That release represented 40 percent of the Chernobyl reactor core's inventory of 6 million Curies (67 kilograms) of cesium-137.[7] Atmospheric testing of nuclear weapons led to the deposition of about

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[5] CCC, 2000; CCC, 2001; SCE, 2002a.
[6] DOE, 1987.
[7] Krass, 1991.

20 million Curies (220 kilograms) of cesium-137 across the land and water surfaces of the Northern Hemisphere.[8]

III. NUCLEAR POWER PLANTS AND NATIONAL SECURITY

Q. Please describe the security threat to nuclear power plants and their spent fuel.

A. The National Strategy for The Physical Protection of Critical Infrastructures and Key Assets, which was published in February 2003, identifies nuclear power plants as key assets, defined as follows:[9]

> "Key assets represent individual targets whose destruction could cause large-scale injury, death, or destruction of property, and/or profoundly damage our national prestige, and confidence."

Prominent officials, such as the Chair of the National Intelligence Council, Robert Hutchings, have concurred on the security threat posed by nuclear power plants:[10]

> "Targets such as nuclear power plants, water treatment facilities, and other public utilities are high on al-Qa'ida's targeting list as a way to sow panic and hurt our economy. . . . Just this past year, al-Qa'ida attacks in Kenya, Saudi Arabia, and Turkey have demonstrated the group's impressive expertise to build truck bombs, and we are concerned it will try to marry this capability to toxic or radioactive material to increase the damage and psychological impact of an attack. . . . I have already detailed the terrorist threat and feel it is important to point out that according to State Department statistics, more businesses are targeted in terrorist attacks than all other types of facilities combined. US interests both abroad and at home, as well as US citizens working abroad, are prime targets for terrorist groups seeking to damage the US economy and affect our way of life. High-profile facilities such as nuclear power plants, oil and gas production, and export and receiving facilities remain at risk; moreover al-Qa'ida and other terrorist groups' targets and methods may be evolving."

Q. In your opinion, is the concern expressed by Chairman Hutchings justified?

A. Yes. Nuclear power plants and their spent fuel are, in my opinion, likely targets in a sophisticated attack on the US homeland, for both symbolic and practical reasons. An important symbolic reason is the connection of nuclear power plants with nuclear weapons. The US government justified its March 2003 invasion of Iraq in large part by the possibility that the Iraqi government might have

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[8] DOE, 1987.
[9] White House, 2003, page 7.

acquired a nuclear weapon. Yet, our government flaunts its own superiority in nuclear weapons and rejects the constraint of its weapons by international agreements such as the Non-Proliferation Treaty.[11] As an approach to international security, this policy has been criticized by the director general of the International Atomic Energy Agency as "unsustainable and counterproductive".[12] It would be prudent to assume that this policy will motivate terrorist groups to respond asymmetrically to US nuclear superiority, possibly through an attack on a US nuclear power plant and/or its spent fuel. From a practical perspective, nuclear power plants and ISFSIs are large, fixed targets. At present, as shown below, these facilities are lightly defended. In the eyes of an enemy, they can be regarded as pre-deployed radiological weapons that could release large amounts of radioactive material.

Q. What types of attacker should we consider?

A. An attack on a US nuclear facility would be either an act of insanity or an act of malice. An insane attacker would have no political purpose, but a malicious attacker would be pursuing the political objectives of a domestic or foreign constituency. Currently, concern about attack is focused on foreign enemies and their domestic sympathizers. These groups are not the only sources of threat, but they deserve special consideration because their objectives relate to US foreign policy and military campaigns.

Q. What general actions can be taken in response to the threat of a foreign-origin attack?

A. There should be a mixture of offensive and defensive actions. "Offensive" refers to efforts to destroy or incapacitate attackers before they attack, and "defensive" refers to protecting ourselves from attack. The need for a balance between offensive and defensive actions was recognized by a

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[10] Hutchings, 2004.
[11] Deller, 2002; Scarry, 2002.
[12] ElBaradei, 2004, page 9.

high-level task force convened by the Council on Foreign Relations. In an October 2002 report, this group stated:[13]

> "*Homeland security measures have deterrence value*: US counterterrorism initiatives abroad can be reinforced by making the US homeland a less tempting target. We can transform the calculations of would-be terrorists by elevating the risk that (1) an attack on the United States will fail, and (2) the disruptive consequences of a successful attack will be minimal. It is especially critical that we bolster this deterrent now since an inevitable consequence of the US government's stepped-up military and diplomatic exertions will be to elevate the incentive to strike back before these efforts have their desired effect".

Q. How would you describe the current level of defensive action at nuclear facilities?

A. NRC requires only a light defense for civilian nuclear facilities. It does not require security measures that reflect the actual security risks. In effect, NRC rejects the advice of the Council on Foreign Relations' task force that I quote above. An explicit rejection of this type of advice was articulated by the NRC chair, Richard Meserve, in late 2002:[14]

> "If we allow terrorist threats to determine what we build and what we operate, we will retreat into the past – back to an era without suspension bridges, harbor tunnels, stadiums, or hydroelectric dams, let alone skyscrapers, liquid-natural-gas terminals, chemical factories, or nuclear power plants. We cannot eliminate the terrorists' targets, but instead we must eliminate the terrorists themselves. A strategy of risk avoidance – the elimination of the threat by the elimination of potential targets – does not reflect a sound response."

Q. Do you agree with this statement?

A. No. To deter attack, the nation need not scrap every modern technology or infrastructure asset. Instead, potential targets can be ranked by their attractiveness as targets for attack. Then, each target can receive a level of defense that is commensurate with its attractiveness. The chosen level of defense would aim to reduce the likelihood of a successful attack and the consequences of an attack. In instances where the cost of providing the chosen level of defense appears prohibitive, the target can be replaced by another, more defensible, facility or activity that serves the same purpose.

Q. What is the significance of NRC's approach to security at nuclear facilities?

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[13] Hart et al, 2002, pp 14-15.
[14] Meserve, 2002a, page 22.

A. Without any public debate, and apparently without any analysis of strategic risks, NRC has chosen to rely primarily on US offensive capabilities to protect nuclear power plants.

Q. Do you believe that this is an adequate approach?

A. No. As discussed above, defensive capabilities are equally important. In addition, the US government's offense-dominated response to terrorism has proven to be costly in terms of fracturing alliances and arousing hostility worldwide. If anything, this offensive approach has increased the risks of terrorist attack in the US. Drawing a balance between defending key assets and pursuing security through offensive actions is a crucial, but not always understood, aspect of homeland-security policy.

IV. PRESENT NRC REQUIREMENTS FOR DEFENSE OF NUCLEAR POWER PLANTS

Q. Briefly describe the history of government regulation of security at nuclear power plants.

A. NRC's basic policy on the protection of nuclear facilities from attack is set forth in 10 Code of Federal Regulations (CFR) § 50.13. This regulation was originally promulgated in September 1967 by the US Atomic Energy Commission (AEC), the predecessor of NRC. It states:[15]

> "An applicant for a license to construct and operate a production or utilization facility, or for an amendment to such license, is not required to provide for design features or other measures for the specific purpose of protection against the effects of (a) attacks and destructive acts, including sabotage, directed against the facility by an enemy of the United States, whether a foreign government or other person, or (b) use or deployment of weapons incident to US defense activities."

Q. Has this policy changed over time?

A. Regulation 10 CFR 50.13 remains in effect.[16] Nevertheless, experience has forced NRC to increase licensees' obligations to defend nuclear facilities. A series of events, including the 1993 bombing of

[15] Federal Register, Vol. 32, No. 186, 26 September 1967, page 13445.

the World Trade Center in New York, forced NRC to introduce a rule in 1994, requiring licensees to defend nuclear power plants against vehicle bombs.[17] The terrorist events of September 11, 2001 have forced NRC to require additional measures, described below. Yet, as shown below, NRC currently requires only a light defense of nuclear facilities.

Q. What was NRC's response to the events of September 11, 2001?

A. After the events of September 11, NRC concluded that its requirements for nuclear-facility security were inadequate. Accordingly, NRC issued an order to licensees of operating plants in February 2002, and similar orders to licensees of decommissioning plants in May 2002 and reactor-site ISFSI licensees in October 2002, requiring "certain compensatory measures", also described as "prudent, interim measures", whose purpose was to "provide the Commission with reasonable assurance that the public health and safety and common defense and security continue to be adequately protected in the current generalized high-level threat environment".[18] The additional measures required by these orders were not publicly disclosed, but the NRC chair stated that they included:[19]

(i) increased patrols;

(ii) augmented security forces and capabilities;

(iii) additional security posts;

(iv) vehicle checks at greater stand-off distances;

(v) enhanced coordination with law enforcement and military authorities;

(vi) additional restrictions on unescorted access authorizations;

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[16] Regulation 10 CFR 50.13 does not preclude the US government from defending nuclear power plants. Indeed, the NRC chair has stated (Meserve, 2002a, page 22) that defense of nuclear plants against air attack would, if required, be a task for the US military.

[17] Final Rule, Protection Against Malevolent Use of Vehicles at Nuclear Power Plants, 59 Fed. Reg. 38,889 (1 August 1994).

[18] The quoted language is from page 2 of NRC's order of 25 February 2002 to all operating power reactor licensees. Almost-identical language appears in NRC's orders of 23 May 2002 to all decommissioning power reactor licensees and 16 October 2002 to all ISFSI licensees who also hold 10 CFR 50 licenses.

[19] Meserve, 2002b.

(vii) plans to respond to plant damage from explosions or fires; and

(viii) assured presence of Emergency Plan staff and resources.

NRC also established a Threat Advisory System that warns of a possible attack on a nuclear facility. This system uses five color-coded threat conditions ranging from green (low risk of attack) to red (severe risk of attack). These threat conditions conform with those used by the Department of Homeland Security.

Q. What types of defensive measures does NRC require?

A. Present NRC requirements for the defense of nuclear facilities are focused primarily on site security, which NRC discusses under the heading "physical protection". As described in Section VII, below, site security is one of four types of measures that, taken together, could provide a defense in depth against acts of malice or insanity. The other three types of measures are: facility robustness; damage control; and emergency response planning. With some limited exceptions, these measures are ignored in present NRC requirements for nuclear-facility defense.[20]

Q. What is meant by "physical protection" in terms of NRC security requirements?

A. At a nuclear power plant or an ISFSI, NRC requires the licensee to implement a set of physical protection measures. According to NRC, these measures provide defense in depth by taking effect within defined areas with increasing levels of security. Within the outermost physical protection area, known as the Exclusion Area, the licensee is expected to control the area but is not required to employ fences and guard posts for this purpose. Within the Exclusion area is a Protected Area encompassed by physical barriers including one or more fences, together with gates and barriers at points of entry. Authorization for unescorted access within the Protected Area is based on background and behavioral checks. Within the Protected Area are Vital Areas and Material Access

Areas that are protected by additional barriers and alarms; unescorted access to these locations requires additional authorization. Associated with the physical protection areas are measures for detection and assessment of an intrusion, and for armed response to an intrusion. Measures for intrusion detection include guards and instruments whose role is to detect a potential intrusion and notify the site security force. Then, security personnel seek additional information through means such as direct observation and closed-circuit TV cameras, to assess the nature of the intrusion. If judged appropriate, an armed response to the intrusion is then mounted by the site-security force, potentially backed up by local law-enforcement agencies and the FBI. The design of physical protection areas and their associated barriers, together with the design of measures for intrusion detection, intrusion assessment and armed response, is required to accommodate a "design basis threat" (DBT) specified by NRC.

Q. What is a DBT?

A. A DBT is a set of characteristics of a potential attack on a nuclear facility. It provides a basis for the design and assessment of defensive measures. At a nuclear power plant such as SONGS, the major sources of hazard are the reactors and the spent-fuel pools. In theory, both of these items receive the same level of protection against attack, but in practice the reactor has been the main focus of attention. The DBT for an ISFSI is less demanding than that for a nuclear power plant, as discussed below.

Q. What is the DBT for a nuclear power plant?

[20] For information about NRC's requirements -- expressed in regulations, rules and orders -- for nuclear-facility defense, se the NRC website (www.nrc.gov); NRC, 2004a; Markey, 2002; Meserve, 2002b; Meserve, 2003; NRC, 2002.

A. In April 2003 the DBT for a nuclear power plant was revised, but NRC announced that the features of the revised DBT would not be published. The previously-applicable DBT had the following features:[21]

> "(i) A determined violent external assault, attack by stealth, or deceptive actions, of several persons with the following attributes, assistance and equipment: (A) Well-trained (including military training and skills) and dedicated individuals, (B) inside assistance which may include a knowledgeable individual who attempts to participate in a passive role (e.g., provide information), an active role (e.g., facilitate entrance and exit, disable alarms and communications, participate in violent attack), or both, (C) suitable weapons, up to and including hand-held automatic weapons, equipped with silencers and having effective long range accuracy, (D) hand-carried equipment, including incapacitating agents and explosives for use as tools of entry or for otherwise destroying reactor, facility, transporter, or container integrity or features of the safeguards system, and (E) a four-wheel drive land vehicle used for transporting personnel and their hand-carried equipment to the proximity of vital areas, and
> (ii) An internal threat of an insider, including an employee (in any position), and (iii) A four-wheel drive land vehicle bomb."

In announcing the revised DBT in April 2003, NRC stated:[22]

> "The Commission believes that this DBT represents the largest reasonable threat against which a regulated private security force should be expected to defend under existing law."

Q. What is the DBT for an ISFSI?

A. NRC's April 2003 order revising the DBT did not mention ISFSIs.[23] Nor was there mention of a revised DBT in an August 2004 NRC order requiring additional security measures at ISFSIs.[24] Thus, it can be inferred that the previous DBT continues to apply to ISFSIs.[25] For an ISFSI, the previous DBT was the same as for a nuclear power plant except that it did not include the use of a

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[21] 10 CFR 73.1, Purpose and Scope, from the NRC web site (www.nrc.gov).
[22] NRC Press Release No. 03-053, 29 April 2003.
[23] Collins, 2003.
[24] Federline, 2004.
[25] A September 2004 NRC document stated (NRC, 2004a, page 22) that NRC has conducted vulnerability assessments for dry-storage modules used at ISFSIs, specifically evaluating two different threat scenarios: "a large aircraft impact similar in magnitude to the attacks on September 11, 2001, and ground assaults using expanded adversary characteristics consistent with the DBT for radiological sabotage". This statement is consistent with retention of the previously-applicable DBT for ISFSIs.

four-wheel-drive land vehicle, either for transport of personnel and equipment or for use as a vehicle bomb. This was true whether the ISFSI was at a new site or a reactor site.[26] Thus, an ISFSI at a reactor site would be less protected than the reactors and spent-fuel pools at that site. At a reactor site or a new site, an ISFSI may be vulnerable to attack by a vehicle bomb.[27]

Q. If the current DBT for nuclear power plants is not published, how can one know what it contains?

A. Its general characteristics can be inferred with reasonable confidence. Four major considerations support such an inference. First, the new DBT must be consistent with 10 CFR 50.13. Second, the DBT does not exceed the capabilities of a "regulated private security force". Third, there is a well-documented history over the past two decades, showing vigorous resistance by the nuclear industry to measures that enhance site security, and reluctance by NRC to contest that resistance.[28] Fourth, available information shows only incremental change in practices of site security.[29] To illustrate the fourth consideration, if a credible defense against air attack -- as is discussed for SONGS in Section VII of this testimony -- had been deployed, aspects of the air defense would be discernible by the public. The absence of visible change indicates that a credible air defense has not been deployed. Also, the additional costs of site security that have been reported by nuclear-plant licensees indicate that site security has undergone only incremental change.

Q. In your opinion, what is the general nature of the new DBT?

A. The new DBT remains focused on a ground assault by a comparatively small group of lightly-armed attackers. The most destructive instrument included in the DBT is probably a vehicle bomb. The new DBT probably does not allow for aerial or multi-modal attack by a commando-type force. It probably does not allow for anti-tank missiles or lethal chemical weapons. There is probably no provision for an attack using a commercial or general-aviation aircraft, with or without a load of fuel

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[26] 10 CFR 73.1, Purpose and Scope, from the NRC web site (www.nrc.gov).

[27] An ISFSI at a reactor site may receive some additional security protection as a result of its proximity to operating reactors on the site. This additional protection will not apply if the ISFSI is located far from the reactors or on a different portion of the site.

[28] Hirsch et al, 2003.

[29] POGO, 2002; Brian, 2003.

or explosive. There is no provision for attack using a nuclear weapon. The insider threat probably does not include carefully-planned, sophisticated interventions by key employees. Also, the new DBT does not apply to ISFSIs, so it can be assumed that ISFSIs continue to receive a lesser degree of protection than nuclear power plants. Finally, the scale of the presumed attack is such that backup for the licensee's site-security force continues to be provided by local law-enforcement agencies and the FBI, rather than the US military.

Q. You have discussed NRC requirements for defense of nuclear power plants and spent fuel, including your understanding of the general nature of the current DBT. Please summarize your conclusions regarding these requirements.

A. At present, NRC requires only a light defense of nuclear power plants and spent fuel. These requirements are inadequate in view of the nature of the threat and the need to balance offensive and defensive means of protecting the nation.

V. RISK OF ATTACK ON NUCLEAR POWER PLANTS AND SPENT FUEL

Q. What are the factors that should be considered in defending a nuclear facility against the threat of an attack?

A. Before deciding upon the level and type of defense of a nuclear power plant and its spent fuel against the threat of an attack, a decision maker should assess the risk of a successful attack. In this context, the concept of risk encompasses vulnerability to attack, and the probability and consequences of attack. In assessing risk, one should assume that attackers are technically sophisticated and possess considerable knowledge about individual nuclear facilities. For decades, engineering drawings, photographs and technical analyses have been openly available for every civilian nuclear facility in the US. This material is archived at many locations around the world. Thus, a public discussion, in general terms, of potential modes and instruments of attack will not assist attackers. Indeed, such a discussion is needed to ensure that appropriate defensive actions are taken.[30]

Q. Are nuclear power plants and spent-fuel-storage facilities designed to resist attack?

A. No. It is possible to design a nuclear power plant to resist attack, an example being the proposed PIUS design.[31] However, no US civilian nuclear facility has been designed to resist attack. Any capacity that a facility has in this respect is a byproduct of designing to account for other factors (earthquake, fire, equipment failure, human error, etc.).

Q. What are the points of vulnerability of a nuclear power plant?

A. The safe operation of a US commercial reactor and its associated spent-fuel pool(s) depends upon the fuel in the reactor and the pool(s) being immersed in water. Moreover, that water must be continually cooled to remove fission heat or radioactive decay heat generated in the fuel. Various systems are used to ensure that water is available and is cooled, and that other safety-related functions -- such as shutdown of the fission reaction when needed -- are performed. Some of the relevant systems -- such as the electrical switchyard -- are highly vulnerable to attack. Other systems are located inside reinforced-concrete structures -- such as the reactor auxiliary building -- that provide some degree of protection against attack. The reactor itself is inside a containment structure. At some plants, but not all, the reactor containment is a concrete structure that is highly reinforced and comparatively robust. Spent-fuel pools have thick concrete walls but are typically covered by lightweight structures.

Q. Could attackers exploit points of vulnerability?

A. Yes. Knowledgeable attackers could obtain a large release of radioactive material from a nuclear power plant or its spent fuel by applying force in a targeted manner. To minimize the need for brute

[30] For more detailed discussion of nuclear-facility vulnerability, see: Thompson, 2003; Thompson, 2002a.

Compare to SCE witness Hotmes

force, knowledgeable attackers would seek to unleash sources of energy (radioactive decay heat, stored thermal energy, energy of chemical reactions, etc.) that are already present in the facility. In their planning, attackers could benefit from the large published literature of probabilistic risk assessment (PRA) in the context of nuclear power plant accidents.[32] Attackers could hinder damage-control efforts by incapacitating plant personnel through means that include a release of short-lived radioactive material from a reactor core.

Q. Is SONGS unusual in its robustness or vulnerability?

A. SONGS Unit 2 and Unit 3 are typical representatives of the PWR nuclear generating units that are common in the USA. The two reactor containments are comparatively thick-walled concrete structures. My understanding is that the two spent-fuel pools are partially sunk below grade level. These design features provide some protection against attack. Nevertheless, SONGS has several points of vulnerability that will be evident to informed readers of PRA literature.

Q. Are you concerned about the hazard posed by the spent-fuel pools at SONGS Unit 2 and Unit 3?

A. Yes. The vulnerability of the Unit 2 and Unit 3 spent-fuel pools deserves special consideration for two reasons. First, each pool now contains an amount of long-lived radioactive material that is substantially larger than the amount in a reactor core. As shown in Table 2, a full pool will contain nine times the amount of cesium-137 that is in an operating reactor. Second, the potential for a spent-fuel-pool fire exists because the pools have been equipped with high-density racks. Loss of water from a pool could cause some or all of the fuel in the pool to self-ignite and burn, releasing a large amount of radioactive material to the atmosphere.[33] This potential exists because high-density

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[31] Hannerz, 1983.

[32] The state of the art for reactor PRAs is illustrated by: NRC, 1990.

[33] NRC has published a variety of technical documents that address spent-fuel-pool fires. The most recent of these documents is: Collins et al, 2000. For more recent analyses of spent-fuel-pool fires, see: Alvarez et al, 2003; Thompson,

racks have a closed structure in which, to suppress criticality, each fuel assembly is surrounded by solid, neutron-absorbing panels.[34] In the absence of water, this configuration allows only one mode of circulation of air and steam around a fuel assembly -- vertically upward within the confines of the neutron-absorbing panels. This mode of circulation provides less effective transfer of radioactive decay heat than would occur in a low-density, open-frame rack. Moreover, the upward flow of air or steam could be blocked by residual water or debris. Thus, across a broad range of conditions, loss of water from a high-density pool will cause the temperature of the fuel cladding to rise to the point where a self-sustaining, exothermic oxidation reaction of the cladding with air or steam begins. Other exothermic oxidation reactions can also occur. For simplicity, the occurrence of one or more of the possible reactions can be referred to as a pool fire.

Q. Does the proximity of a spent-fuel pool to a reactor create a special hazard?

A. Yes. The combination of a pool and a reactor, as exists at each of SONGS Unit 2 and Unit 3, poses a greater risk than is posed by either item separately. The presence of the reactor increases the risk posed by the pool, in two ways. First, an attack on the reactor could release a large amount of short-lived radioactive material that precludes access by personnel to provide cooling or water makeup to the pool, thereby contributing to the initiation of a pool fire. Second, at each refueling of the reactor, the pool receives spent fuel with a comparatively high level of heat output from radioactive decay. Under attack conditions, the presence of this fuel could lead to comparatively rapid evaporation of pool water and/or ignition of exposed fuel, thereby increasing the conditional probability of a pool fire. Conversely, the presence of the pool increases the risk posed by the reactor, because the release

2003; and Thompson, 2002a. The NRC Staff stated in March 2003 (NRC, 2003, page 10) that it has completed an "integral analysis of a spent fuel pool accident scenario", but this analysis has not been published.

[34] Criticality is a situation in which a nuclear fission reaction becomes self-sustaining.

of radioactive material from a pool fire could preclude access by personnel whose presence is needed to keep the reactor in a safe condition.

Q. Could an attack on part of SONGS lead to a cascading sequence of events?

A. Yes. A focused attack at one or more locations could trigger a sequence of events that would, at worst, involve large releases of radioactive material from both of the operating reactors and both spent-fuel pools. Compare to SCE witness

Q. Do you believe that an attack on a civilian nuclear facility is possible?

A. Yes. I believe that a determined and sophisticated attack on a US nuclear power plant and/or its spent fuel is a realistic possibility. There is a large amount of publicly available information on the design of commercial nuclear power plant facilities, as well as the amount, location, and method of storage of radioactive materials at each plant. Much is known about the nature of the security measures at each plant, including the fact that there are no security measures designed specifically to address attacks from the air. Not only does the nuclear-plant defense currently required by NRC not address the full spectrum of potential threats, but I believe that the US government's current policy of addressing terrorism through an offense-dominated strategy is increasing the threat of terrorist attack.

Q. Would an effective attack require weapons not generally available to civilians?

A. Not necessarily. A nuclear power plant or an ISFSI could be attacked using one or more of a variety of modes and instruments. Table 3 shows a selection of potential modes and instruments, summarizes their key characteristics, and describes the defenses that are currently mounted against them. One of the potential instruments of attack shown in Table 3 is an explosive-laden smaller aircraft. In this connection, it is noteworthy that the US General Accounting Office (GAO) expressed concern, in September 2003 testimony to Congress, about the potential for malicious use of general-aviation aircraft. The testimony stated:[35]

> "Since September 2001, TSA [the Transportation Security Administration] has taken limited action to improve general aviation security, leaving it far more open and potentially vulnerable than commercial aviation. General aviation is vulnerable because general aviation pilots are not screened before takeoff and the contents of general aviation planes are not screened at any point. General aviation includes more than 200,000 privately owned airplanes, which are located in every state at more than 19,000 airports. Over 550 of these airports also provide commercial service. In the last 5 years, about 70 aircraft have been stolen from general aviation airports, indicating a potential weakness that could be exploited by terrorists."

Q. Is there a form of explosive that causes you special concern?

A. Yes. I am especially concerned that a shaped charge might be used in an attack on a nuclear facility. Shaped charges have many civilian and military applications, and have been used for decades. They are used, for example, as human-carried demolition charges or as warheads for anti-tank missiles. The largest known shaped charge was the German MISTEL, developed late in World War II. This device was 2 meters in diameter, had a mass of 3,500 kilograms and contained 1,700 kilograms of explosive. It was carried in the nose of an un-manned bomber aircraft. The Japanese used a smaller version of this device, the SAKURA bomb, for kamikaze attacks against US warships.[36] Recently, a US government laboratory has developed, and described in a published report, a shaped charge specifically intended to penetrate large thicknesses of rock or concrete.[37] This device is intended for mounting in the nose of a cruise missile. The charge is a cylinder with a diameter of 71 cm and a length of 72 cm. It has a total mass of 410 kilograms and contains 270 kilograms of Octol explosive. When tested in November 2002, this device created a hole of 25 cm diameter in tuff rock to a depth of 5.9 meters. The charge's purpose is to be the first stage of a "tandem" warhead, opening a hole in rock or concrete so that the second stage can penetrate deeply into the attacked structure before

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[35] Dillingham, 2003, page 14.

exploding. This charge, by itself or in a tandem configuration, would be within the payload capacity of many general-aviation aircraft. In illustration, a Beechcraft King Air 90 will carry a payload of up to 990 kilograms at a speed of up to 460 km/hr.[38] A used King Air 90 can be purchased in the USA for $0.4-1.0 million.[39]

Q. Can the probability of a successful attack on a US nuclear power plant be estimated?

A. There is no statistical basis for such an estimate, because there has been no determined attack on a US plant. It is prudent to assume that an attack on a US nuclear power plant, with a substantial conditional probability of success, is a realistic possibility. This conclusion arises from the following qualitative considerations. First, the scale of the planning and resources needed to mount an attack on a nuclear power plant, with a substantial conditional probability of success, would be comparable to the scale of preparations for the attacks of September 11, 2001, and it is prudent to assume that similar efforts will be mounted in the future. Second, senior officials in the US government have repeatedly acknowledged that nuclear power plants are prime potential targets. Third, groups like al-Qa'ida seek high-stakes objectives such as political control of Saudi Arabia and its oil fields, and history tells us that confrontations over such objectives have frequently involved high levels of violence. Fourth, the experience of the 20th century, during which the US homeland suffered only limited attacks, will not necessarily be repeated during the 21st century.

Q. What is your estimate of the potential release of cesium-137 from SONGS in the event of an attack?

A. As shown in Table 2, each of the two spent-fuel pools at SONGS will contain, from 2007 or 2008 forward, about 68 million Curies (750 kilograms) of cesium-137. Each of the Unit 2 or Unit 3 reactor cores contains about 7.7 million Curies (85 kilograms) of cesium-137. A typical dry-storage

[36] Walters, 2003.
[37] I have withheld this citation.
[38] Raytheon Aircraft Company, "Technical Data, Beechcraft King Air C90B", 16 June 2004.
[39] The website www.aircraftdealer.com, accessed 6 November 2004.

module at the ISFSI will contain about 1.2 million Curies (13 kilograms) of cesium-137. During a spent-fuel-pool fire, the fractional release of cesium-137 to the atmosphere could range from 10 to 100 percent.[40] A similar range of release fractions can be assumed for attack-induced atmospheric releases from reactor cores or dry-storage modules. An attack on SONGS could lead to an atmospheric release of radioactive materials from one or both of the operating reactors, and/or one or both of the spent-fuel pools, and/or the ISFSI. Thus, the atmospheric release of cesium-137 following an attack on SONGS could exceed 100 million Curies. The actual magnitude of the release would depend on the attack scenario.

Q. Are there studies on the consequences of a large release of cesium-137?

A. Yes. For example, some of the consequences of a large, atmospheric release of cesium-137 have been estimated in a recent paper by three of my colleagues.[41] They assumed releases of 3.5 or 35 million Curies of cesium-137 at each of five nuclear-power-plant sites (not including the SONGS site), and estimated the offsite economic damage. For a release of 35 million Curies, the 5-site average economic damage was found to be about $400 billion. The costs considered were: (i) compensation for loss of contaminated real estate and other property; (ii) relocation costs; (iii) decontamination costs; and (iv) costs of disposing of wastes generated during decontamination. A simple analytic process was used, and the authors relied heavily on a 1996 study done for Sandia National Laboratories. That study identified factors that could bias its cost estimates downward, including: (i) its neglect of administrative and support costs that could double the cost estimates; (ii) its neglect of litigation costs; and (iii) its neglect of impacts on downtown business and commercial districts, heavy-industrial areas, and high-rise apartment buildings. Consideration of these factors would increase the $400 billion estimate of economic damage. In examining human health effects,

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[40] Alvarez et al, 2003.

my colleagues estimated that, for a release of 35 million Curies of cesium-137, the 5-site average of additional cancer deaths would be about 6,000 deaths. These deaths were valued at $4 million each, yielding a cost of $24 billion. If the release also included short-lived radioactive isotopes, as would occur if a reactor core were involved in the release incident, there could be additional cancer deaths.

Q. Could there be additional, indirect costs?

A. Yes. My colleagues considered only direct costs arising from contamination of the environment with cesium-137. There would be many additional, indirect costs arising from a successful attack on a US nuclear power plant, including the following five types of cost. First, the attack would probably lead to temporary or permanent shutdown of other nuclear power plants across the nation, leading to additional costs for electricity supply. Second, domestic and foreign markets for US agricultural products and other goods would be depressed by customers' fear of radioactive contamination. Third, the attack would be perceived internationally as a major blow to the USA, thereby affecting capital flows, exchange rates, and market valuations. Fourth, the attack would probably lead to a reduction of civil liberties, potentially including a period of martial law, with long-term negative effects on the economy. Fifth, there would probably be large, additional US expenditures on homeland security and, potentially, on offensive military operations. In considering potential indirect costs, note that in 2003 the US gross domestic product was $11,000 billion, exports were $1,300 billion, and imports were $1,800 billion.[42]

Q. How is the above analysis relevant to this proceeding regarding SONGS?

A. Analysis could be performed to estimate the direct costs of an atmospheric release of cesium-137 from SONGS. Also, the accompanying indirect costs could be analyzed. In the absence of such

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[41] Beyea et al, 2004.

[42] Bureau of Economic Analysis website (www.bea.doc.gov), accessed 27 September 2004.

analyses, it is prudent to assume that the direct and indirect economic consequences of a successful attack on SONGS could exceed $1,000 billion.

VI. TRENDS TOWARD ENHANCED DEFENSE OF NUCLEAR POWER PLANTS AND SPENT FUEL

Q. What is the likelihood that there will be more stringent requirements for defense of nuclear power plants in the United States?

A. As stated in Section IV, above, NRC has increased licensees' obligations to defend nuclear facilities in the aftermath of terrorist attacks. One important step was the adoption in 1994 of a rule requiring licensees to defend nuclear power plants against vehicle bombs. Other, similar steps have been taken since September 11, 2001. Present trends suggest that the NRC and/or other arms of the federal government will, over the coming years, require and/or provide further enhancement of the defense of nuclear power plants and spent fuel. These trends are evident in the general area of homeland security, and in the specific area of nuclear-facility security.

Q. Please describe the trends in homeland security.

A. An important indicator of overall homeland-security trends is the level of total expenditure in this area. Reliable data on total expenditure are lacking, so estimates must be made. One estimate of total US homeland-security expenditure – by federal, state, local and private entities – shows annual expenditure growing from $5 billion in 2000 to $85 billion in 2004, with anticipated growth to $130 billion, or perhaps as high as $210 billion, in 2010.[43] A recent incident illustrates the increased attention now given to homeland-security threats. On June 9, 2004, an aircraft carrying the governor of Kentucky approached Washington, DC, without a functioning transponder. Detection of this approach triggered a rapid evacuation of the Capitol building and surrounding office buildings. Two patrolling F-15 fighter planes were directed to intercept the aircraft, but did not reach it in time to shoot it down if it had proceeded toward the Capitol. In discussing this incident, officials noted that the federal government provides a layered defense of Washington that includes ground-based anti-aircraft missiles.[44] An aspect of the war in Iraq illustrates the challenge of defending energy infrastructure, and holds lessons for homeland security. Offshore terminals are part of Iraq's infrastructure for the export of oil. At these terminals, oil is transferred from underwater pipelines to tankers. Two of these terminals were attacked, but not extensively damaged, by boat-bomb suicide missions on April 24, 2004. Currently, the terminals are defended by US, UK and Australian warships, and by gun emplacements on the terminals. Radar and optical imagery are used to detect approaching boats. An exclusion zone of 2,000 meters is maintained. Gunners are authorized to fire at boats approaching within 500 yards. During the April 2004 attacks, gunfire from Iraqi security forces caused two of the three attacking boats to explode prematurely.[45]

Q. Please describe the current trends in nuclear-plant security.

A. Increasingly, citizens and public officials across the USA have called upon the federal government to re-think its approach to the defense of US nuclear power plants and spent fuel. For example, in October 2002 the Attorneys-General of 27 states sent a letter to the majority and minority leaders of the US Senate and House of Representatives.[46] The letter called for "passage of legislation this year to protect our states and communities from terrorist attacks against nuclear power plants and other sensitive nuclear facilities". Special attention was drawn to the vulnerability of spent-fuel pools.

[43] Barami, 2004.
[44] Solomon, 2004.
[45] Glanz, 2004.
[46] Letter from the Attorneys-General of Arizona, Arkansas, California, Colorado, Connecticut, Georgia, Hawaii, Iowa, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Montana, Nevada, New Jersey, New Mexico, New York, North

Congress has not yet acted on this letter. As another example, the Attorneys-General of California, Massachusetts, Utah and Washington, as well as San Luis Obispo County and the citizen group San Luis Obispo Mothers for Peace, have joined in litigation before the US Court of Appeals, seeking a full evidentiary hearing to examine the threat posed by potential acts of malice or insanity at the planned ISFSI at the Diablo Canyon nuclear power plant.

Q. Have Congressional leaders expressed concern about the vulnerability of civilian nuclear facilities?

A. Yes. For example, David Hobson, Chair of the House Appropriations Subcommittee on Energy and Water Development, addressed this issue in an August 2004 speech. The primary focus of his speech was US policy on nuclear weapons. In that context, he stated:[47]

> "I don't believe that pursuing new [nuclear] weapons initiatives contributes anything to our national security in the near future. However, continuing to store spent fuel all over the country, often near major population centers, poses a much greater risk to our national security."

Representative Hobson argued that rapid development of the proposed Yucca Mountain radioactive waste repository would be the best way to reduce the risk to which he alluded. It is likely, however, that continued slow development or suspension of the Yucca Mountain project will convince Representative Hobson and other members of Congress to support enhance defenses at the sites of nuclear power plants. In this connection, it is noteworthy that publications by other authors and me helped to influence Congress to request from the National Academy of Sciences (NAS) an independent, classified study on the security of spent-fuel storage. Congress was motivated to take this action by concern that the NRC was not properly considering the threat to spent fuel.[48] The study began in January 2004, and a classified report was provided to Congress in late June or early July 2004. Release of an unclassified version of the report is expected in late December 2004 or

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Carolina, Ohio, Oregon, Pennsylvania, Rhode Island, Vermont, West Virginia, Washington and Wisconsin to the Senate Majority and Minority Leaders, the Speaker of the House and the House Minority Leader, 8 October 2002.

[47] Hobson, 2004.

early in 2005. Congress has requested the NRC to "take recommendations of the final NAS report seriously and to take actions to address these recommendations at the earliest possible date".[49] There is speculation that NAS recommendations for enhancing the security of spent-fuel pools include: (i) distributing fuel in a pool so that hotter and cooler assemblies are separated; and (ii) installing spray equipment to cool spent fuel in the event that water is lost from a pool.

Q. Are other arms of the US government involved in debate or action regarding the defense of nuclear facilities?

A. Yes. Another illustration of the trend toward enhanced defense of nuclear facilities is the pressure upon the US Department of Energy (DOE) to improve the security of Category I special nuclear material -- plutonium and highly-enriched uranium. At a Congressional hearing in April 2004, a GAO witness and the chair of the committee holding the hearing pointed out that DOE's present DBT -- promulgated in May 2003 -- for Category I material was developed too slowly, will be implemented over too long a period, and is inadequate to meet the threat. A Postulated Threat to the security of Category I material has been articulated by the intelligence community.[50] For sites that handle nuclear weapons, DOE's present DBT represents the lower range of the threat identified in the Postulated Threat. For other Category I sites, the present DBT is significantly smaller than the Postulated Threat.[51] It is likely that DOE will come under increasing pressure to rectify these deficiencies. As another example, the final version of the Coast Guard Authorization Act, which passed the US Senate in late July 2004, includes a provision that requires the Coast Guard to assess the vulnerability of US nuclear power plants to attack from adjacent bodies of water. The Coast Guard must complete this assessment within one year and report the findings to Congress.

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[48] Inside NRC staff, 2003.
[49] Weil, 2004.
[50] A Postulated Threat is a hypothetical threat that can be used for planning purposes and is, in effect, a suggested DBT.
[51] Schwartz, 2004.

Q. Have there been recent policy-level developments relevant to NRC's DBT for nuclear power plants?

A. Yes. During the course of litigation before the US Court of Appeals, NRC committed in September 2004 to commence a formal rulemaking to establish a DBT.[52] The currently-prevailing DBT was issued by NRC without any rulemaking. A properly-conducted rulemaking would increase pressure on NRC to consider the full spectrum of potential threats, which would almost certainly lead to requirements for enhanced defense of nuclear power plants and their spent fuel. Another recent development was Congressional testimony by GAO in September 2004.[53] GAO's testimony showed that NRC cannot currently assure that nuclear power plants are protected against the prevailing DBT. Also, GAO stated that "certain potential vulnerabilities, such as airborne assaults, are currently being addressed outside of the DBT".[54] Finally, GAO stated that the DBT specified by NRC is similar to that of DOE, and that DOE intends to revise its DBT.[55] These statements reinforce my judgment that NRC will be obliged, by events and by pressure from Congress and elsewhere, to require an enhanced defense of nuclear power plants and spent fuel.

Q. How has the nuclear industry reacted to the trends you describe?

A. Within the nuclear-power industry internationally, there is growing recognition that the industry will be obliged to respond to public demands for enhanced defense of nuclear power plants and spent fuel. In illustration, a group of owners of nuclear power plants in Germany has contracted with the armaments company Rheinmetall to install smoke-generating machines at their plants, to hinder the approach of hostile aircraft. A system of this kind has been tested successfully. It is said that full

[52] Public Citizen, Inc., and San Luis Obispo Mothers for Peace had initiated proceedings against NRC in the US Court of Appeals (DC Circuit). On 17 September 2004 the Court suspended the proceedings, directing the parties to: "file motions to govern future proceedings within 30 days after a rulemaking proceeding has commenced but in no event later than 120 days from the date of this order".

[53] Wells, 2004.

[54] Wells, 2004, page 4.

[55] Wells, 2004, page 4.

deployment could occur within one year.[56] As another example, in April 2004 the Holtec company asked NRC to provide expedited generic approval of partial-underground placement of casks for dry storage of spent fuel. This system would employ the Holtec HI-STORM 100 cask, the type of cask that is to be used, for example, at the planned ISFSI at the Diablo Canyon nuclear power plant. The top of the cask would project about 2 feet above ground. Holtec has described this system as offering "the next level of protection against terrorist attacks".[57]

VII. A POTENTIAL PLAN FOR ENHANCED DEFENSE OF SONGS UNIT 2 AND UNIT 3

Q. What are the implications for SONGS of the trends that you have described above?

A. It is reasonable and prudent to assume that SONGS Unit 2 and Unit 3 and their spent fuel will receive an enhanced defense during the coming years. In order to estimate the additional costs to SCE and other plant owners that could arise from the provision of an enhanced defense, it is necessary to articulate a plan for enhanced defense. Here, I set forth a potential plan that could be required by NRC and/or other arms of the federal government. All aspects of the plan would be implemented if the Unit 2 and Unit 3 reactors continued operating through their present license terms or beyond. The plan would be partially implemented if the reactors were shut down at an earlier point.

Q. What are the features of the potential plan?

A. I assume that the plan would employ the principles of defense in depth, and would encompass four categories of defensive measures: (i) site security; (ii) facility robustness; (iii) damage control; and (iv) emergency response planning.

Q. Please describe the additional site-security measures.

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[56] Reuters, 2004.

A. Site-security measures are those that reduce the potential for implementation of destructive acts of malice or insanity at a nuclear site. Two types of measures -- "generic" measures and "site-specific" measures -- fall into this category. Generic measures are implemented at offsite locations, and protect multiple sites. The implementing agencies might have no direct connection with a particular site. Airline or airport security measures are examples of generic measures. Site-specific measures would be implemented at or near a nuclear site. Implementing agencies would include the licensee, NRC, and other entities such as the National Guard. The physical protection measures now required by NRC, as discussed in Section IV, above, are examples of site-specific measures. Additional, generic, site-security measures are not discussed here. The lack of such a discussion does not imply that present measures of this kind are adequate or optimal. The focus here is on site-specific measures, because these measures are directly relevant to the economics of SONGS. I believe that the following set of additional site-security measures is representative of what would be required for the SONGS site under an enhanced-protection plan:

(i) <u>Establishment of a mandatory aircraft-exclusion boundary around the site.</u>

(ii) <u>Deployment of an aircraft-detection system that triggers security alerts as the exclusion boundary is approached and crossed.</u>

I assume that the Sentinel system -- a portable, phased-array radar system -- would be used to detect approaching aircraft.[58] Two units of Sentinel should suffice. The units would be owned and operated by the military, perhaps the National Guard or the Marine Corps, but SCE and other plant owners would bear the costs of their deployment and operation. The objective of deploying Sentinel would be to provide continuous detection, tracking and identification of aircraft near to and within the mandatory aircraft-exclusion boundary. This information would be conveyed to SONGS by

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[57] Conley, 2004.

secure, redundant communication links. As an approaching aircraft reached specified distances from the plant, with specified vectors, Sentinel would trigger a succession of security alerts.

(iii) Deployment of an automated system to destroy aircraft at short range if they are closing on the plant.

I assume that the Phalanx system -- an automated gun -- would be used for this purpose.[59] Originally designed to intercept anti-ship missiles, Phalanx has been modified to intercept a range of fast- and slow-moving targets including missiles, fixed-wing and rotary-wing aircraft, and sea-surface targets. At SONGS, two Phalanx units could provide reliable coverage. As for Sentinel, the units would be owned and operated by the military, but SCE and other plant owners would bear the costs of their deployment and operation. At nuclear-power-plant sites that have a large land area with limited public access -- such as the Diablo Canyon site -- Phalanx could be activated at most times and could be programmed to have a wide field of fire. The SONGS site is small, and is adjacent to public beaches, the Interstate Route 5 freeway and Camp Pendleton. At SONGS, therefore, Phalanx would probably be activated only at times of anticipated danger, and its field of fire would be limited. These constraints would reduce the effectiveness of Phalanx at SONGS.

(iv) Expansion of the DBT, beyond that now specified by the NRC, to include additional intruders, heavy weapons, aircraft attack, lethal chemical weapons and more than one vehicle bomb.

(v) Provision at the ISFSI of protection equivalent to that provided for the nuclear generating units.

The additional defensive measures in (iv) and (v), above, would require an expanded defensive perimeter to accommodate the ISFSI, might require strengthening of vehicle barriers to resist more than one vehicle bomb, and would require a larger and more capable guard force. Note, as discussed below, that in this plan the ISFSI modules serving SONGS Unit 2 and Unit 3 would be located

[58] FAS, 2000a; DSCA, 2002; Raytheon, 2001.

inland of Interstate Route 5. A partial model for the upgraded guard force could be the force that protects DOE's most sensitive sites. GAO has described the protection of these sites as follows:[60]

> "While specific measures vary from site to site, all protective systems at DOE's most sensitive sites employ a defense-in-depth concept that includes sensors, physical barriers, hardened facilities and vaults, and heavily armed paramilitary protective forces equipped with such items as automatic weapons, night vision equipment, body armor, and chemical protective gear."

The set of measures described in (i) through (v), above, reflects the threat of attack from the air, and the present lack of defense against air attack. Measures to enhance defense against ground or sea attack are also included. The measures I describe would seek to accommodate separate or combined attacks from air, land or sea, together with actions by insiders.

Q. Please describe the second category of additional defensive measures, namely "facility-robustness measures".

A. Facility-robustness measures are defensive measures that improve the ability of a nuclear facility to experience destructive acts of malice or insanity without a significant release of radioactive material to the environment. An integrated set of additional facility-robustness measures that I believe could be required for SONGS is as follows:

(i) <u>Automated shutdown of the reactors upon initiation of a specified alert status at the plant, with provision for completion of the automated shutdown sequence if a control room is disabled.</u>

Automated shutdown of the reactors would serve two purposes. First, it could increase the time interval between reactor shutdown and onset of damage to safety systems, thereby reducing the level of decay heat that would have to be removed from the reactor by degraded safety systems. Second, it could increase the probability that a reactor would be brought to a safe-shutdown condition if the control room were disabled. The second of these purposes is probably the most significant from a

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[59] FAS, 2003; Raytheon, 2003; USN, 1999; Friedman, 1991.

risk-reduction perspective. To achieve the second purpose, the automated-shutdown system would have to be located apart from the control room, with redundant communication links to the control room, plant safety systems, and offsite facilities. The automated-shutdown system would be designed to detect a loss of capability in the control room, and would thereupon assume command of the shutdown process.

(ii) Permanent deployment of diesel-driven pumps and pre-engineered piping to be available to provide emergency water supply to the reactors and the spent-fuel pools.

This capability would provide an additional supply of water, under emergency conditions, to cool the reactor cores and spent fuel in the pools. It would support the additional damage-control measures that are discussed below. If other sources of water were not available, the additional pumps would draw water from the ocean. As needed during an emergency, this new system could be manually connected to existing cooling systems such as the component-cooling system, the feedwater system, the safety-injection system, the containment-cooling system, and the fire-protection system. Also, the new system could be used to refill a drained spent-fuel pool or to spray water on exposed fuel. The existing cooling systems at SONGS Unit 2 and Unit 3 were designed to contain radioactive material and preserve the integrity of the plant in the event of an accident. By contrast, the new system would have one overriding objective – to prevent or limit the release of radioactive material to the atmosphere. In some attack scenarios, meeting that objective could involve releases of radioactive material to surface water, ground water or the ocean. Use of ocean water for emergency cooling could render the plant unfit for further operation if the plant survived the incident.

(iii) Re-equipment of the spent-fuel pools with low-density racks, excess fuel being stored in the ISFSI.

[60] Nazzaro, 2004, page 4.

Table 4 illustrates how this could be done. The table shows two options. In the base-case option, as currently envisioned by SCE, the spent-fuel inventory in each pool would rise to 1,325 fuel assemblies and remain at that level during the subsequent years of plant operation. To accommodate fuel discharged to the pool from the reactor, an equal amount of older fuel would be transferred from the pool to the ISFSI. The second option would apply if the enhanced-defense plan were implemented and the reactors continued operating. In the second option, the capacity of the pool would be reduced, over a two-year period, from 1,542 assemblies to 506 assemblies. The closed-configuration, high-density racks now in the pool would be replaced by open-frame, low-density racks, thus greatly reducing the potential for a pool fire. A steady-state inventory of 240 fuel assemblies would be held in the pool during the subsequent years of reactor operation. The second option would require more deployment of ISFSI modules in the early years than in the base-case option, but the eventual number of modules would be the same in each option.

(iv) <u>Construction of the ISFSI to employ hardened, dispersed, dry storage of spent fuel.</u>

To protect SONGS Unit 2 and Unit 3 spent fuel in the ISFSI from attack, the dry-storage modules holding this fuel would be dispersed and hardened. I have written elsewhere about the merit of hardened, dispersed, dry storage of spent fuel, and the options for providing such storage.[61] Hardening would be accomplished by the addition of concrete and steel structures, together with layers of earth and gravel, to protect the modules. Dispersal would be accomplished by increasing the distances between modules. At SONGS, dispersal would require that the modules serving Unit 2 and Unit 3 would be located inland of Interstate Route 5, at the Mesa portion of the site or on additional land leased from Camp Pendleton.

[61] Thompson, 2003.

Q. Please describe the third category of additional defensive measures, namely "damage-control measures".

A. Damage-control measures are those that reduce the potential for a release of radioactive material following damage to a facility by destructive acts of malice or insanity. Measures of this kind could be ad hoc or pre-engineered. An example of a damage-control measure is a set of arrangements for patching and restoring water to a spent-fuel pool that has been breached. It appears that NRC has required licensees of nuclear power plants to undertake some planning for damage control following explosions or fires.[62] The following are additional measures that could be taken at SONGS:

(i) establishment of a pre-planned damage-control capability at the site, using onsite personnel and equipment for first response and offsite resources for backup;

(ii) periodic exercises of damage-control capability;

(iii) establishment of a set of damage-control objectives -- to include patching and restoring water to a breached spent-fuel pool, fire suppression at the onsite ISFSI, and provision of cooling to a reactor whose safety systems and/or control room are disabled -- with accompanying detailed plans and stockpiling of needed supplies; and

(iv) provision of equipment and training to allow damage control to proceed on a radioactively-contaminated site.

Q. Please describe the fourth category of additional defensive measures, namely "emergency-response measures".

A. Emergency-response measures are those that reduce the potential for exposure of offsite populations to radiation, following a release of radioactive material from a nuclear facility. Measures in this category could accommodate releases attributable to acts of malice or insanity, or "accidental"

[62] Meserve, 2002b.

releases arising from human error, equipment failure or natural forces (e.g., earthquake). There are two major ways in which malice- or insanity-induced releases might differ from accidental releases. First, a malice- or insanity-induced release might be larger and begin earlier than an accidental release.[63] Second, a malice- or insanity-induced release might be accompanied by deliberate degradation of emergency response capabilities (e.g., the attacking group might block an evacuation route). Accommodating these differences could require additional measures of emergency response. A team based at Clark University in Massachusetts has developed a model emergency response plan that could be implemented at SONGS to significantly enhance emergency-response capability.[64] This model plan was specifically designed to accommodate radioactive releases from spent-fuel-storage facilities, as well as from reactors. That provision, and other features of the plan, would provide a capability to accommodate both accidental releases and malice- or insanity-induced releases. Major features of the model plan include:[65]

(i) structured objectives;

(ii) improved flexibility and resilience, with a richer flow of information;

(iii) precautionary initiation of response, with State authorities having an independent capability to identify conditions calling for a precautionary response[66];

(iv) criteria for long-term protective actions;

(v) three planning zones, with the outer zone extending to any distance necessary[67];

(vi) improved structure for accident classification;

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[63] Present plans for emergency response do not account for the potential for a large release of radioactive material from spent fuel, as would occur during a pool fire. The underlying assumption is that a release of this kind is very unlikely. That assumption cannot be sustained in the present threat environment.
[64] Golding et al, 1992.
[65] Golding et al, 1992, pp 8-13.
[66] A security alert could be a condition calling for a precautionary response.
[67] In the original Clark University plan, the inner and intermediate zones would have radii of 5 and 25 miles, respectively. As an example of the planning measures in each zone, potassium iodide would be pre-distributed within the 25-mile zone an

(vii) increased State capabilities and power;

(viii) enhanced role for local governments;

(ix) improved capabilities for radiation monitoring, plume tracking and dose projection;

(x) improved medical response;

(xi) enhanced capability for information exchange;

(xii) more emphasis on drills, exercises and training;

(xiii) improved public education and involvement; and

(xiv) requirement that emergency preparedness be regarded as a safety system equivalent to in-plant systems.

VIII. COSTS OF IMPLEMENTING THE ENHANCED-DEFENSE PLAN FOR SONGS UNIT 2 AND UNIT 3

Q. How have you estimated the additional costs to SCE and other plant owners that would arise from introduction of the enhanced-defense measures that you have described above?

A. As a first step, I have reviewed available data and projections on the overall operating and maintenance (O&M) expenses and capital expenses at SONGS. These data provide a baseline for considering the costs that arise from defending the plant. Second, I have reviewed available data and projections on the portions of the O&M expenses and capital expenses for SONGS that are attributable to measures for defending the plant. As a third and final step, I have estimated the additional costs of providing the enhanced-defense measures that are set forth in Section VII, above.

Q. What are the overall O&M expenses for SONGS with its present level of defense?

made generally accessible nationwide. This zonal arrangement would require adaptation to the specific circumstances of the SONGS site.

A. For the years 1996 through 2000, annual O&M expenses for SONGS Unit 2 and Unit 3, measured in constant 2000 dollars, ranged from a high of $246 million (in 1998) to a low of $195 million (in 2000).[68] In this proceeding, SCE has projected that the annual O&M expenses for 2004, in 2004 dollars, will be $284 million.[69]

Q. What are the overall capital expenses for SONGS with its present level of defense?

A. For the years 1996 through 2000, "basic" annual capital expenses for SONGS Unit 2 and Unit 3 were about $30 million.[70] SCE projected, in its 2003 General Rate Case before the CPUC, that capital cash flow, in current-year dollars, would be $82 million in 2004 and $63 million in 2005.[71] In this proceeding, SCE has projected that the annual capital expenses for 2004, in current-year dollars, will be about $145 million.[72] A possible explanation for the discrepancy between these two projections for 2004 is provided below.

Q. What portion of the overall O&M expenses for SONGS Unit 2 and Unit 3 is attributable to measures for defending the plant at the present level of defense?

A. For the years 1996 through 2000, annual O&M expenses for site security, measured in constant 2000 dollars, ranged from a high of $10.7 million (in 1998) to a low of $6.6 million (in 1996).[73] SCE projected, in its 2003 General Rate Case before the CPUC, that $13.9 million would be required in 2003 for O&M expenses for site-security functions, while $7.1 million would be required for functions in the "regulatory affairs" category.[74] The latter category includes emergency planning, fire protection, and various other functions. In this proceeding, SCE has projected that $2.0 million

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[68] SCE, 2002b, Table XVI-7.
[69] SCE, 2004b, Table IV-11.
[70] SCE, 2002a, page 2.
[71] SCE, 2002a, Table III-1.
[72] SCE, 2004b, Figure IV-7.
[73] SCE, 2002b, Table XVI-7.
[74] SCE, 2002b, pages 18 and 29.

of additional annual O&M expenses, above the previously-prevailing level, will be incurred in 2004 and subsequent years to meet NRC's revised DBT.[75]

Q. What portion of the overall capital expenses for SONGS Unit 2 and Unit 3 is attributable to measures for defending the plant at the present level of defense?

A. In this proceeding, SCE has projected that $64 million of security-related capital expenses will be incurred during 2004 to meet NRC's revised DBT.[76] This is a comparatively large capital expenditure, confirming that the SONGS site is more difficult to defend than some other nuclear-power-plant sites. This expenditure could account for a discrepancy, mentioned above, between two SCE projections of capital expenses for 2004.

Q. How have you estimated the additional costs of providing the enhanced-defense measures that you have described?

A. I have estimated these costs for three different scenarios for the future operation of SONGS Unit 2 and Unit 3. Each scenario begins in year X, which could be 2006 or a subsequent year. For all three scenarios, a program of enhanced defense is initiated in year X. In the first scenario, the reactors continue operating. In the second scenario, the reactors are shut down in year X. In the third scenario, the reactors are shut down in year X+3. My purpose in presenting these three scenarios is to assist evaluation of the cost-effectiveness of replacing steam generators at SONGS Units 2 and 3. The first scenario assumes that the steam generators are replaced, while in the second and third scenarios they are not. The second scenario assumes that shutdown of the reactors immediately upon initiation of the enhanced-defense program is cost-effective and/or required for other reasons. In the third scenario the reactors are shut down after a comparatively short period of operation, assumed here for purposes of illustration to be three years. For each of the three scenarios, I

[75] SCE, 2004b, Table IV-11.

estimate the additional O&M and capital costs of enhanced defense, above the costs for a base-case scenario in which no enhanced defense would be provided.

Q. Why do you assume, in the third scenario, that the reactors are shut down three years after initiation of the enhanced-defense program?

A. This assumption addresses the progressive degradation of the steam generators at SONGS. Degraded steam generators are a point of weakness in a reactor's containment system. Accordingly, regulatory requirements for enhanced defense of SONGS would logically be accompanied by the introduction of more stringent criteria for the integrity of steam-generator tubes. Studies performed by and for NRC show that degradation of steam-generator tubes increases the potential for release of radioactive material to the atmosphere in the event of an accident at a reactor that involves severe damage to the reactor core.[77] The same potential would be significant in the aftermath of an attack that damages reactor safety systems, especially if the attack creates an open pathway from the secondary side of the steam generators to the atmosphere. Also, integrity of the steam-generator tubes could be an important factor in the successful functioning of the emergency cooling system that I have identified as a likely component of an enhanced-defense program for SONGS.

Q. How does the enhanced-defense program vary among the three scenarios?

A. In the first scenario, all of the enhanced-defense measures that are described in Section VII, above, are implemented. In the second scenario, the only enhanced-defense measures that are implemented are those needed to protect spent fuel, because the risk posed by reactor operation is eliminated. In the third scenario, the risk posed by reactor operation continues for only three years. Accordingly, I assume that Sentinel, Phalanx, the automated shutdown system and the emergency cooling system

[76] SCE, 2004b, page 44.
[77] Ellison et al, 1996; SGTR Severe Accident Working Group, 1998.

are not required, but an expanded DBT and enhanced capabilities for onsite damage control and offsite emergency response are required.

Q. How do you estimate the additional costs that would arise from re-equipping the spent-fuel-pools with low-density racks and transferring excess spent fuel to a hardened, dispersed, onsite ISFSI?

A. As discussed in Section VII of this testimony, Table 4 shows two options for management of spent fuel at SONGS Unit 2 or Unit 3. The option involving a reduction in the capacity of each spent-fuel pool, over a two-year period, applies to the first and third enhanced-defense scenarios discussed above. In Table 5, I provide estimates of the capital expenses of the two options, for both operating units at SONGS. For the option that involves reducing the capacity of the spent-fuel pools, which is listed in Table 5 as the "enhanced-defense option", I include the capital expenses of an ISFSI that is hardened and dispersed. I assume that the capital expenses to transfer spent fuel to a conventional ISFSI would be $120 per kilogram of uranium, while the capital expenses to transfer spent fuel to a hardened, dispersed ISFSI would be $240 per kilogram of uranium. It has been reported that the capital expenses to place spent fuel in ISFSIs at US nuclear power plants range from $90 to $210 per kilogram of uranium.[78]

Q. What are your estimates of the additional costs to SCE and other plant owners that would arise from deployment of the Sentinel and Phalanx systems at SONGS?

A. For Sentinel, I estimate a capital expense of $15 million over an initial 2-year period to provide infrastructure support and an annual O&M expense of $8.5 million. Based on a projected sale, I estimate the cost of the Sentinel system to be approximately $3.7 million per unit.[79] I assume here that: (i) the Sentinel units at SONGS would be owned and operated by the US military, but SCE and other plant owners would bear the costs of their deployment and operation; (ii) the capital cost to the

[78] Alvarez et al, 2003, page 31.

military of deploying two Sentinel units at SONGS would be $10 million; (iii) the capital cost would be recovered from SCE and other owners over 4 years without interest; and (iv) continuous operation would require a 30-FTE crew costing, with overheads and supplies, $0.2 million per annum per person. For Phalanx, I estimate a capital expense of $20 million over an initial 2-year period to provide infrastructure support and an estimated annual O&M expense of $11 million. The same O&M assumptions discussed above for Sentinel are applied to the Phalanx system, except that the capital cost of two Phalanx units is assumed to be $20 million.[80]

Q. What is your estimate of the additional costs to SCE and other plant owners of meeting an expanded DBT and providing the ISFSI with the same level of protection as is provided for the nuclear generating units?

A. I estimate additional annual O&M expenses of $15 million to meet these requirements, assuming that SCE would need to increase the size of its security workforce by approximately 75 FTE, at a cost, with overheads and supplies, of $0.2 million per annum per person. In addition, I assume additional annual capital expenses of $3 million. For phases of a scenario where the reactors do not operate, I estimate that the additional annual O&M expenses and capital expenses in this category would be reduced by one third.

Q. What are your estimates of the additional costs of providing an automated shutdown system and a new system to supply cooling water under emergency conditions?

A. In both cases I estimate an additional capital expense of $75 million over an initial 2-year period.[81] Also, I assume that R&D costs for these new systems would be borne by NRC or another arm of the federal government, potentially with cost recovery from licensees of US nuclear power plants.

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[79] DSCA, 2002.
[80] An amateur website (Doehring, 2004) gives a unit cost of $5.6 million for Phalanx.
[81] This estimate reflects a range of $50-100 million.

Q. What is your estimate of the additional capital expenses of re-equipping the spent-fuel pools with low-density racks and transferring excess fuel to a hardened, dispersed, onsite ISFSI?

A. The bottom line of Table 5 provides my estimate of these additional expenses, above the expenses that would arise in the base case. These estimates apply directly to the first and third scenarios discussed above. For the second scenario, in which the reactors do not operate after initiation of the enhanced-defense program, the additional capital expenses would simply be those of transferring the spent fuel in the pools, at the time of shutdown of the reactors, to a hardened, dispersed ISFSI (at $240 per kilogram of uranium) instead of to a conventional ISFSI (at $120 per kilogram of uranium).

Q. What are your estimates of the additional costs of providing enhanced capabilities for onsite damage control and offsite emergency response?

A. In both cases I estimate additional annual O&M expenses of $10 million and additional annual capital expenses of $2 million. Providing the enhanced capability for onsite damage control would require an increase in the size of the SONGS workforce. I assume a 50-FTE increase. At a cost, with overheads and supplies, of $0.2 million per annum per person, this step would increase annual O&M expenses by $10 million. I assume that the same increase in personnel and annual O&M expenses would be required to provide the enhanced capability for offsite emergency response. In this instance, however, some of the additional staff would work for state and local governments. For phases of a scenario where the reactors do not operate, I estimate that the additional annual O&M expenses and capital expenses in this category would be reduced by two thirds.

Q. What is the overall additional cost of providing an enhanced defense for SONGS?

A. Tables 6, 7 and 8 summarize the cost estimates developed above, for each of the three scenarios that I have identified. Note that these costs are additional to the O&M expenses and capital expenses that SCE and other plant owners are currently incurring. To illustrate the cumulative implications of the additional costs for the three scenarios, Table 9 shows the cumulative additional costs for each scenario over a 15-year period.

Q. Are your cost estimates definitive?

A. No. My cost estimates are preliminary. More accurate cost estimates would require: (i) articulation of the enhanced-defense measures in more detail; (ii) comparison of the enhanced-defense measures with similar projects that have been recently implemented at US nuclear power plants or other security-intensive facilities; and (iii) use of the comparisons developed in (ii) to extrapolate from actual costs of recently-implemented projects.

IX. CONCLUSIONS

Q. What are your conclusions in this testimony?

A. Nuclear power plants are key national assets that are especially likely to be targeted by enemies of the US. Drawing a balance between defending key assets and pursuing security through offensive actions is a crucial, but not always understood, aspect of homeland-security policy. NRC currently requires only a light defense of US nuclear power plants and spent fuel. As a result, these facilities are vulnerable to sophisticated, determined attacks. There is a trend in decision-making circles across the USA to call for enhanced defense of US nuclear power plants and spent fuel. It is therefore prudent to assume that SONGS Unit 2 and Unit 3 and their spent fuel will receive an enhanced defense during the coming years. This testimony describes measures that I expect would be included in a plan for such a defense. These measures could be required by NRC and/or other arms of the federal government. Preliminary estimates are made here of the additional capital and O&M expenses that would be incurred by SCE and other plant owners if the measures were implemented. SCE has not included any of these additional costs in its cost-benefit analyses, assuming instead a zero probability of additional requirements for an enhanced defense during the operational life of SONGS Unit 2 and Unit 3 and their spent-fuel storage. Such an assumption is not appropriate, and the costs that I have estimated should be considered in evaluating SCE's application.