Application No.: 04-01-009
Exhibit No.: ____________
Date: August 3, 2004
Witness: Gordon Thompson

BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

Application of Pacific Gas and Electric Company (U 39 E) for Authority to Increase Revenue Requirements to Recover the Costs to Replace Steam Generators in Units 1 and 2 of the Diablo Canyon Power Plant.	Application 04-01-009 (Filed January 9, 2004)

TESTIMONY OF GORDON THOMPSON ON BEHALF OF THE SAN LUIS OBISPO MOTHERS FOR PEACE, SIERRA CLUB, PUBLIC CITIZEN, GREENPEACE AND ENVIRONMENT CALIFORNIA

Dian M. Grueneich, J.D.
Theresa Cho, Of Counsel
Clyde Murley, M.A.
GRUENEICH RESOURCE ADVOCATES
582 Market Street
San Francisco, CA 94104
(415) 834-2300
(415) 834-2310 facsimile
dgrueneich@gralegal.com
cmurley@gralegal.com

For:

SAN LUIS OBISPO MOTHERS FOR PEACE, SIERRA CLUB, PUBLIC CITIZEN, GREENPEACE AND ENVIRONMENT CALIFORNIA

August 3, 2004

TABLE OF CONTENTS

I. INTRODUCTION

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

A. I am Gordon 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 United Kingdom 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 United States government agencies. My Curriculum Vitae is provided here as Appendix A.

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 US. 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 is the purpose 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 Diablo Canyon nuclear power plant and its 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 Pacific Gas and Electric (PG&E) that could arise from the provision of the enhanced defense.

[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.

PG&E has not included such costs in its application. Consideration of these costs affects the cost/benefit analyses related to replacement of the Diablo Canyon steam generators.

Q. Please briefly summarize your testimony.

A. This testimony has nine sections. After this introduction (Section I), Section II describes the Diablo Canyon nuclear power plant. Section III discusses the defense of nuclear power plants in the context of US national security. Section IV reviews the 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 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 the Diablo Canyon plant and its 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. Appendix B is a bibliography to support this testimony. Literature cited in the testimony appears in the bibliography.

This testimony discusses potential destructive attacks, at the Diablo Canyon plant 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. THE DIABLO CANYON NUCLEAR POWER PLANT

Q. Please describe the Diablo Canyon nuclear power plant.

A. The Diablo Canyon plant has two nuclear generation units. These units employ essentially identical pressurized-water reactors (PWRs), each rated at a nominal 1,100 MWe. The two units share an auxiliary building and some components of auxiliary systems. Each reactor has a dedicated fuel-handling system and one spent-fuel pool. The reactors were furnished by Westinghouse. Unit 1 began commercial operation in May 1985 and Unit 2 in March 1986. The operating licenses expire in September 2021 for Unit 1 and April 2025 for Unit 2.[2]

Q. Please describe the storage facilities for spent fuel.

A. The two spent-fuel pools at Diablo Canyon were originally equipped with low-density racks, so that each pool could accommodate one and one-third cores of spent fuel. Each reactor core contains 193 fuel assemblies. In the late 1980s, the low-density racks were replaced by high-density racks that are currently in use. Each pool can now accommodate 1,324 spent fuel assemblies. Each unit operates on an 18-21 month refueling cycle and discharges 76-96 spent fuel assemblies per refueling. As of December 2001, each unit had operated for 10 cycles. It follows that each spent-fuel pool contained 760-960 spent fuel assemblies in December 2001. Thus, given a pool capacity of 1,324 assemblies, while allowing space for a full-core offload of 193 assemblies, each pool could, as of December 2001, accommodate an additional 171-371 assemblies beyond the assemblies then stored in the pool. PG&E has projected

[2] PG&E, 2001, page 1.1-1.

that each pool can accommodate a full-core offload and the accumulated inventory of discharged fuel until 2006.[3]

Q. What are PG&E's plans for storage of spent fuel assemblies produced at the Diablo Canyon plant after 2006?

A. To accommodate spent fuel discharged from Units 1 and 2 after the pools are full, PG&E has applied for permits from the NRC, San Luis Obispo County, and the California Coastal Commission to establish an independent spent-fuel storage installation (ISFSI) on the Diablo Canyon plant site. This facility would hold up to 140 dry-storage casks, employing the Holtec HI-STORM 100 cask system. PG&E expects that most of the casks would be capable of holding 32 fuel assemblies per cask. Assuming 140 casks each holding 32 assemblies, the proposed ISFSI could accommodate 4,480 spent fuel assemblies. PG&E projects that this storage capacity would be sufficient to hold all the spent fuel discharged by Diablo Canyon Units 1 and 2 through the duration of their present operating license terms (2021 for Unit 1 and 2025 for Unit 2).[4]

PG&E plans to build the ISFSI in increments. The storage casks would sit on concrete pads, 20 casks per pad in a 4 by 5 array. Initially, two pads would be built.[5] Ultimately, seven pads would be built side by side, covering an area about 500 feet by 105 feet. PG&E expects that spent fuel would be transferred from the pools to the ISFSI after at least 5 years of storage in the pools. Specifically, casks would be installed as needed to accommodate the spent fuel that would be removed from the pools in order to free up space in the pools for storage of fuel discharged from the

---

[3] PG&E, 2001, page 1.1-1.
[4] PG&E, 2001, page 1.2-2.

reactors.[6] Thus, from 2006 through the present Unit 1 and 2 operating license terms, the pools would hold spent fuel at nearly their full capacity. After 2006, the average post-discharge age of the spent fuel in each pool would be about 10 years.

Each cask in the planned ISFSI would be about 11 feet in diameter and 20 feet high. The surface-to-surface distance between casks would be about 6 feet. The ISFSI's full capacity of 140 casks would be achieved by placing casks in a 5 by 28 array. A security fence would surround the area needed for this array, at a distance of about 50 ft from the outermost casks. That fence would in turn be surrounded by a second fence, at a distance of about 100 feet from the outermost casks.[7]

The HI-STORM 100 dry-cask storage system employs a multi-purpose canister (MPC) that contains the fuel, and a storage overpack that surrounds the MPC during storage. The MPC is a thin-walled stainless-steel cylinder containing a basket structure to hold the spent fuel assemblies. After the MPC receives fuel and is sealed, it is filled with helium. The overpack is a thick-walled concrete cylinder whose surfaces are clad with a thin coating of carbon steel. Cooling of the MPC occurs by natural circulation of ambient air in a space between the MPC and the overpack. This air enters the overpack through holes near its base, passes over the MPC, and leaves the overpack through holes near its top.[8]

Q. Was PG&E aware of the need for additional on-site, spent-fuel storage capacity when the NRC approved construction of the Diablo Canyon plant?

---

[5] PG&E, 2001, page 3.1-1.
[6] PG&E, 2001, page 1.2-1.
[7] PG&E, 2001, Chapter 3.
[8] PG&E, 2001, Chapter 3.

A. No. The long-term, on-site storage of spent fuel at the Diablo Canyon plant was never considered because it was assumed that the waste would be transported to an off-site facility.

Q. Please describe the inventory of radioactivity that will be present in spent fuel at the site.

A. Each fuel assembly 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 testing nuclear weapons in the atmosphere.[9] Cesium is a volatile element that would be liberally released during the meltdown of a reactor core or during a fire in a drained spent-fuel pool.

The inventory of cesium-137 in the Diablo Canyon plant pools or the proposed ISFSI can be readily estimated. Three parameters govern the estimate -- the number of spent fuel assemblies, their respective burnups, and their respective ages after discharge. I have made such estimates, assuming a representative, uniform burnup of 46 gigawatt-days per tonne.[10] As a separate exercise, I have estimated the inventory of cesium-137 in the Diablo Canyon reactors.

PG&E projections indicate that each of the Diablo Canyon plant pools will contain, from 2006 until the 2020s and potentially beyond, an inventory of spent fuel approaching the pool's capacity of 1,131 assemblies. The average post-discharge age

[9] DOE, 1987.

[10] Burnup is the cumulative fission energy released in a fuel assembly during its period of use.

of the fuel will be about 10 years. This inventory of spent fuel -- 1,131 assemblies aged for 10 years -- will contain about 56 million Curies (630 kilograms) of cesium-137. For comparison, the core of each Diablo Canyon reactor contains about 6 million Curies (67 kilograms) of cesium-137. At the proposed Diablo Canyon ISFSI, one cask containing 32 fuel assemblies with an average post-discharge age of 20 years would contain about 1.3 million Curies (14 kilograms) of cesium-137.

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.[11] Atmospheric testing of nuclear weapons led to the deposition of about 20 million Curies (220 kilograms) of cesium-137 across the land and water surfaces of the Northern Hemisphere.[12]

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: [13]

> "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:[14]

---

[11] Krass, 1991.
[12] DOE, 1987.
[13] White House, 2003, page 7.
[14] Hutchings, 2004.

> 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 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.[15] 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".[16]

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

[15] Deller, 2002; Scarry, 2002.
[16] ElBaradei, 2004, page 9.

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.

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 task force convened by the Council on Foreign Relations. In an October 2002 report, this group stated:[17]

> "*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?

[17] Hart et al, 2002, pp 14-15.

A. The NRC requires only a light defense for civilian nuclear facilities. It does not require security measures that reflect the actual security risks. The NRC is, in effect, rejecting 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:[18]

> "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 the NRC's approach to security at nuclear facilities?

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

---

[18] Meserve, 2002a, page 22.

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. The 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 the NRC. It states:[19]

> "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.[20] Nevertheless, experience has forced the NRC to increase licensees' obligations to defend nuclear facilities. A series of events,

---

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

[20] 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.

including the 1993 bombing of the World Trade Center in New York, forced the NRC to introduce a rule in 1994, requiring licensees to defend nuclear power plants against vehicle bombs.[21] The terrorist events of September 11, 2001 have forced the NRC to require additional measures, described below. Yet, as shown below, the NRC currently requires only a light defense of nuclear facilities.

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

A. After the events of September 11, the NRC concluded that its requirements for nuclear-facility security were inadequate. Accordingly, the 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".[22] The additional measures required by these orders were not publicly disclosed, but the NRC chair stated that they included:[23]

(i) increased patrols;

(ii) augmented security forces and capabilities;

(iii) additional security posts;

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

---

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

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

[23] Meserve, 2002b.

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

(vi) additional restrictions on unescorted access authorizations;

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

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

The 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 the NRC require?

A. Present NRC requirements for the defense of nuclear facilities are focused primarily on site security, which the 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.[24]

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

A. At a nuclear power plant or an ISFSI, the NRC requires the licensee to implement a set of physical protection measures. According to the 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 the 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, the dominant sources of hazard are the reactor(s) and the spent-fuel pool(s). In theory, both of these items receive the same level of protection against attack, but in

---

[24] For information about the NRC's requirements – expressed in regulations, rules and orders -- for nuclear-facility defense, see: the NRC website (www.nrc.gov); Markey, 2002; Meserve, 2002b; Meserve,

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.

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

A. In April 2003 the DBT for a nuclear power plant was revised, but the NRC announced that the features of the revised DBT would not be published. The previously-applicable DBT had the following features:[25]

> "(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, the NRC stated:[26]

> "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. The NRC's April 2003 announcement of a revised DBT did not mention ISFSIs. Thus, it can be presumed that the previous DBT continues to apply to these facilities. For an ISFSI, the previous DBT was the same as for a nuclear power plant except that

---

2003; and NRC, 2002.

[25] 10 CFR 73.1, Purpose and Scope, from the NRC web site (www.nrc.gov).

[26] NRC Press Release No. 03-053, 29 April 2003.

it did not include the use of a 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.[27] Thus, an ISFSI at a reactor site would be less protected than the reactor(s) and spent-fuel pool(s) at that site. At a reactor site or a new site, an ISFSI would be vulnerable to attack by a vehicle bomb.

Q. If the new DBT is not published, how do we 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 will 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 a reluctance by the NRC to contest that resistance.[28] Fourth, available information shows no marked change in prevailing practices of site security.[29]

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 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

[27] 10 CFR 73.1, Purpose and Scope, from the NRC web site (www.nrc.gov).
[28] Hirsch et al, 2003.

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 new DBT. Please summarize your conclusions regarding these requirements.

A. At present, the 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 securing a nuclear facility against the threat of an attack?

A. Before deciding upon the level and type of defense for securing 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.

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

---

[29] POGO, 2002; Brian, 2003.

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?

---

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

[31] Hannerz, 1983.

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 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 the Diablo Canyon nuclear power plant unusual in its robustness or vulnerability?

A. The Diablo Canyon plant is a typical representative of the PWR nuclear power plants that are common in the US. Its two reactor containments are comparatively thick-walled concrete structures, and its two spent-fuel pools are partially sunk below grade level. These design features provide some protection against attack. Nevertheless, the Diablo Canyon plant has several points of vulnerability that will be evident to informed readers of PRA literature.

Q. Do you have a particular area of concern regarding the Diablo Canyon nuclear plant?

A. Yes. The vulnerability of the spent-fuel pools deserves special consideration for two reasons. First, each pool at the Diablo Canyon plant now contains an amount of long-lived radioactive material that is substantially larger than the amount in a reactor core. Second, the potential for a spent-fuel-pool fire exists because the Diablo Canyon pools have been equipped with high-density racks. Loss of water from a pool could cause

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

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]

Because high-density racks have a closed structure, to suppress criticality, each fuel assembly is surrounded by solid, neutron-absorbing panels, and there is little or no gap between the panels of adjacent cells.[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 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. 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,

---

[33] The 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, 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.

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 the 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 V-1, below, 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 V-1 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."

A form of explosive that might be used in an attack on a nuclear power plant or an ISFSI is a shaped charge. These have many civilian and military applications, and have

[34] Criticality is a situation in which a nuclear fission reaction becomes self-sustaining.
[35] Dillingham, 2003, page 14.

been used for decades.[36] They are used, for example, as human-carried demolition charges or as warheads for anti-tank missiles. In illustration of their availability, a quick search of the Web identified a commercial supplier of military-surplus, shaped-charged warheads to licensed civilian users. A surplus warhead with a diameter of 14 cm and length of 21 cm was advertised as being capable of penetrating more than 65 cm of rolled homogeneous armor. Much larger shaped charges are available. For example, the US government has developed, and described in a published report, a shaped charge that can create a hole of 10 inches diameter to a depth of 20 feet in rock.[37]

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 the probability of an attack on a US nuclear power plant, with a substantial 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 probability of success is a realistic possibility, 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.

---

[36] Walters, 2003.

[37] This device has a diameter of 28 inches and a length of 29 inches, and weighs 900 pounds.

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 assessment of the potential release of cesium-137 from the Diablo Canyon plant in the event of an attack?

A. As discussed above, each of the two spent-fuel pools at the Diablo Canyon plant will contain, from 2006 forward, about 56 million Curies (630 kilograms) of cesium-137. Each of the two reactor cores contains about 6 million Curies (67 kilograms) of cesium-137. A typical dry-storage cask at the planned ISFSI will contain about 1.3 million Curies (14 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.[38] A similar range of release fractions can be assumed for attack-induced atmospheric releases from reactor cores or dry casks. An attack on the Diablo Canyon plant could lead to an atmospheric release of radioactive materials from one or both of the reactors, and/or one or both of the spent-fuel pools, and/or the planned ISFSI. Thus, the atmospheric release of cesium-137 following an attack on the Diablo Canyon plant 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 such a 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.[39] They assumed a release of 3.5 or 35 million Curies of cesium-137 at each of five nuclear-power-plant sites (not including the Diablo Canyon site), and estimated the offsite

[38] Alvarez et al, 2003.
[39] Beyea et al, 2004.

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 made by my colleagues.

My colleagues' paper 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.

My colleagues considered a set of direct costs arising from contamination of the environment with cesium-137. There would be many additional, indirect costs of a successful attack on a US nuclear power plant, including the following five examples. First, the attack would probably lead to temporary or permanent shutdown of other nuclear 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 US, 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.

Q. How is the above analysis relevant to this proceeding regarding the Diablo Canyon plant?

A. Analysis could be performed to estimate the direct costs of an atmospheric release of cesium-137 from the Diablo Canyon plant. Also, the accompanying indirect costs could be analyzed. In the absence of such analyses, it is prudent to assume that the direct and indirect economic consequences of a successful attack on the Diablo Canyon nuclear power plant would be not less than $1,000 billion.

///

///

///

///

///

Table V-1
Potential Modes and Instruments of Attack on a Nuclear Power Plant[40]

Mode of Attack	Characteristics	Present Defense
Commando-style attack	• Could involve heavy weapons and sophisticated tactics • Successful attack would require substantial planning and resources	Alarms, fences and lightly-armed guards, with offsite backup
Land-vehicle bomb	• Readily obtainable • Highly destructive if detonated at target	Vehicle barriers at entry points to Protected Area
Anti-tank missile	• Readily obtainable • Highly destructive at point of impact	None if missile launched from offsite
Commercial aircraft	• More difficult to obtain than pre-9/11 • Can destroy larger, softer targets	None
Explosive-laden smaller aircraft	• Readily obtainable • Can destroy smaller, harder targets	None
10-kilotonne nuclear weapon	• Difficult to obtain • Assured destruction if detonated at target	None

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, the 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.[41]

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.[42]

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

---

[40] Adapted from Table 1 of: Thompson, 2003.
[41] Barami, 2004.

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.[43]

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

A. Increasingly, citizens and public officials across the US 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.[44] 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. 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 Mothers for Peace, have joined in litigation seeking a full evidentiary hearing to examine the threat posed by potential acts of malice or insanity at the planned ISFSI at Diablo Canyon.

Q. In addition, publications by other authors and me helped to influence Congress to request from the National Academy of Sciences (NAS) an independent, classified

---

[42] Solomon, 2004.

[43] Glanz, 2004.

[44] 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 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.

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.[45] The study began in January 2004, and it is said that a classified report was provided to Congress in late June or early July 2004. 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".[46] 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. 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.[47] 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

[45] Inside NRC staff, 2003.
[46] Weil, 2004.
[47] A Postulated Threat is a hypothetical threat that can be used for planning purposes and is, in effect, a suggested DBT.

DBT is significantly smaller than the Postulated Threat.[48] 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.

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

A. Within the nuclear-power industry, there is growing recognition that the industry will be obliged to respond to public demands for an 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 deployment could occur within one year.[49] As another example, in April 2004 the Holtec company asked the 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 at the planned ISFSI at the Diablo Canyon 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

[48] Schwartz, 2004.
[49] Reuters, 2004.

attacks".[50] There is no indication that PG&E intends to employ this system at the Diablo Canyon plant.

VII. A POTENTIAL PLAN FOR ENHANCED DEFENSE OF THE DIABLO CANYON PLANT

Q. What are the implications for the Diablo Canyon plant of the trends that you have described above?

A. It is reasonable and prudent to assume that the Diablo Canyon nuclear power plant and its spent fuel will receive an enhanced defense during the coming years. In order to estimate the additional costs to PG&E 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 the NRC and/or other arms of the federal government.

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.

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

[50] Conley, 2004.

would be implemented at or near a nuclear site. Implementing agencies would include the licensee, the NRC and other entities such as the National Guard. The physical protection measures now required by the 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 the Diablo Canyon plant. I believe that the following set of additional site-security measures is representative of what would be required for the Diablo Canyon site under an enhanced-protection plan:

(i) Establishment of a mandatory aircraft-exclusion boundary around the site.

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

I assume that the Sentinel system – a portable, phased-array radar system -- would be used to detect approaching aircraft. Two units of Sentinel should suffice. The units would be owned and operated by the military, probably the National Guard, but PG&E 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 the Diablo Canyon plant by 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. 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 the Diablo Canyon plant, two Phalanx units could provide reliable coverage. Again, the units would be owned and operated by the military, probably the National Guard, but PG&E would bear the costs of their deployment and operation.

(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 planned ISFSI on the site 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 planned ISFSI, might require strengthening of vehicle barriers to resist more than one vehicle bomb, and would require a larger and more capable guard force. A 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:[51]

> "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."

[51] Nazzaro, 2004, page 4.

This set of measures 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 the Diablo Canyon plant 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 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 the Diablo Canyon plant are 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 an onsite ISFSI.

The following discussion illustrates how this might be done. First, each of the two Diablo Canyon reactors would operate on a 20-month refueling cycle and discharge 90 spent-fuel assemblies per refueling. Second, each pool would contain 1,100 fuel assemblies at the point when operations begin to re-equip the pools with low-density racks. Third, each pool would, after re-equipment with low-density racks, have a capacity of 470 fuel assemblies.[52] This capacity would support a full-core offload of 193 fuel assemblies plus three refueling discharges of 90 assemblies per discharge, thereby allowing fuel to age over three refueling cycles -- 60 months, or 5 years -- before it is transferred to an onsite ISFSI. Thus, while the core is in the reactor, each pool would contain up to 270 fuel assemblies. Fourth, reduction of the spent-fuel inventory in each pool, from 1,100 assemblies to 270 assemblies, would occur over a period of 2 years. It follows that the onsite ISFSI would receive 830 fuel assemblies per year during an initial 2-year period, and an average of 108 fuel assemblies per year thereafter.

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

There is, at present, no indication that PG&E intends to change the design of the planned ISFSI at the Diablo Canyon plant, so as to employ hardened, dispersed, dry storage of spent fuel. As I have noted above, the Holtec company has asked the NRC to provide expedited generic approval of partial-underground placement of HI-STORM 100 dry-storage casks, the type of cask that is to be used at Diablo Canyon.

[52] Each Diablo Canyon spent-fuel pool has a floor area, excluding the cask pit, of 1,282 square feet (see: PG&E, 1985, Figures 2.1a and 2.1b). Racks with a capacity of 470 fuel assemblies would occupy, on average, 2.73 square feet per fuel assembly. This density would allow a center-to-center spacing of fuel assemblies of up to 20 inches, which would allow the use of open-frame racks.

This arrangement might satisfy requirements for hardened, dispersed, dry storage, although concerns have been expressed about the quality and durability of Holtec casks. I have written at length about the need for hardened, dispersed, dry storage of spent fuel, and the options for providing such storage.[53]

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 the NRC has required licensees of nuclear power plants to undertake some planning for damage control following explosions or fires.[54] The following are additional measures that could be taken at Diablo Canyon:

(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

---

[53] Thompson, 2003.
[54] Meserve, 2002b.

(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" releases arising from human error, equipment failure or natural forces (e.g., earthquake). However, 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.[55] 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 the Diablo Canyon plant to significantly enhance emergency-response capability.[56] 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

[55] 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.
[56] Golding et al, 1992.

accommodate both accidental releases and malice- or insanity-induced releases. Major features of the model plan include:[57]

(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[58];

(iv) criteria for long-term protective actions;

(v) three planning zones, with the outer zone extending to any distance necessary[59];

(vi) improved structure for accident classification;

(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

///

---

[57] Golding et al, 1992, pp 8-13.

[58] A security alert could be a condition calling for a precautionary response.

[59] 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 and made generally accessible nationwide. This zonal arrangement would require adaptation to the specific circumstances of the Diablo Canyon site.

(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 THE DIABLO CANYON PLANT

Q. How have you estimated the additional costs to PG&E that would arise from introduction of the enhanced-defense measures that you have described above?

A. As a first step, I have reviewed data on the overall operating and maintenance (O&M) expenses and capital expenses at the Diablo Canyon plant. These data provide a baseline for considering the costs that arise from defending the plant. Second, I have reviewed PG&E historical data and projections on the portions of the O&M expenses and capital expenses for the Diablo Canyon plant 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 the Diablo Canyon plant with its present level of defense?

A. Table VIII-1 below, which is taken from PG&E's 2003 General Rate Case filing, shows the overall O&M and nuclear fuel expenses for the Diablo Canyon plant, as projected by PG&E in 2003 for the period 2002-2005. I recognize that PG&E has updated these projections in the context of these proceedings. However, the projections shown in Table VIII-1 remain useful for two reasons. First, this table shows the number of personnel for each expense category. Second, this table shows "loss prevention" as an expense category. That category covers site security, industrial safety and health, emergency preparedness, and fire protection. There is no equivalent category in the PG&E projections that have been submitted in these proceedings.[60] Those projections show average O&M expenses of $280 million per year for the period 2002-2005, a value 9 percent higher than the $257 million shown in Table VIII-1.

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

A. PG&E states that capital expenses for the period 2000-2002 averaged $14.3 million per year. PG&E projects, assuming that the plant's steam generators are replaced, that capital expenses will average $141 million per year for the period 2003-2011 and $42.2 million per year for the period 2012-2024.[61]

Q. What portion of the overall O&M expenses for the Diablo Canyon plant is attributable to measures for defending the plant at the present level of defense?

A. Some relevant historical data have become available in data responses from PG&E in these proceedings.[62] These data show that O&M costs for site security at the Diablo Canyon plant averaged $13.3 million annually over the period 1997-2003, with a maximum annual value of $17.8 million in 2003, while O&M costs for emergency-response planning averaged $1.3 million annually over the period 1998-2003.

PG&E has estimated the additional O&M costs for site security that will arise from security enhancements attributable to the attacks of September 11, 2001. The annual value of these additional costs is $2 million in 2003, $5 million in 2004, $4 million in 2005, and $5 million during the period 2006-2010.[63]

---

[60] PG&E, Chapter 5A, Detailed Testimony on Operation and Maintenance Expenses and Capital Expenditures, revised 05/27/04, Table 5A-1.

[61] PG&E, Chapter 5A, Detailed Testimony on Operations and Maintenance and Capital Expenditures, Workpapers – Application, pages 5A-17 and 5A-18.

[62] PG&E Data Responses MFP002-12 and 002-13, June 30, 2004.

[63] PG&E, Chapter 5A, Detailed Testimony on Operation and Maintenance Expenses and Capital Expenditures, revised 05/27/04, Table 5A-14.

Q. What portion of the overall capital expenses for the Diablo Canyon plant is attributable to measures for defending the plant at the present level of defense?

A. A data response from PG&E in these proceedings shows that capital expenses for site security over the period 1997-2003 averaged $1.6 million annually, while capital expenses for emergency-response planning averaged $0.2 million annually over the same period.[64]

PG&E has estimated the additional capital costs for site security that will arise from compliance with NRC orders. The annual value of these additional costs is $1 million in 2003, $5 million in 2004, and zero during the period 2005-2006.[65]

Q. What are your estimates of the additional costs to PG&E that would arise from deployment of the Sentinel and Phalanx systems?

A. For Sentinel, I estimate a capital expense of $15 million over an initial 2-year period in providing 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.[66] I assume here that: (i) the Sentinel units at Diablo Canyon would be owned and operated by the US military, but PG&E would bear the costs of their deployment and operation; (ii) the capital cost to the military of deploying two Sentinel units at Diablo Canyon would be $10 million; (iii) the capital cost would be recovered from PG&E over 4 years without interest; and (iv) continuous operation

[64] PG&E Data Response, MFP002-14.

[65] PG&E, Chapter 5A, Detailed Testimony on Operation and Maintenance Expenses and Capital Expenditures, revised 05/27/04, Table 5A-25.

[66] DSCA, 2002.

would require a 30-FTE crew costing, with overheads and supplies, $0.2 million per annum per person.[67]

For Phalanx, I estimate a capital expense of $20 million over an initial 2-year period in providing 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.[68]

Q. What is your estimate of the additional costs to PG&E of meeting an expanded DBT and providing the planned ISFSI with the same level of protection as is provided for the nuclear generating units?

A. I estimate an additional annual O&M expense of $15 million to meet these requirements, assuming that PG&E 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 an additional annual capital cost of $5 million.

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.[69] Also, I assume that R&D costs for these new systems would be borne by the NRC or another arm of the federal government, potentially with cost recovery from all licensees of US nuclear power plants.

---

[67] From Table VIII-1, it will be noted that the O&M cost per FTE staff member at Diablo Canyon is $194,000.

[68] An amateur website (Doehring, 2004) gives a unit cost of $5.6 million for Phalanx.

[69] This estimate reflects a range of $50-60 million.

Q. What is your estimate of the additional costs of reducing inventory in the spent-fuel pools and providing hardened, dispersed, dry storage of the excess fuel in an onsite ISFSI?

A. I estimate an additional capital expense of $91 million per year for an initial 2-year period and $6 million per year thereafter. In Section VII, above, I describe a reduction of the spent-fuel inventory in each Diablo Canyon pool from 1,100 assemblies to 270 assemblies over a period of 2 years. Thus, the onsite ISFSI would receive 830 fuel assemblies per year during an initial 2-year period, and an average of 108 fuel assemblies per year thereafter. Note that the onsite ISFSI would receive an average of 108 fuel assemblies per year in the absence of a plan for providing an enhanced defense of the Diablo Canyon plant. Additional costs would arise in three respects. First, during an initial 2-year period, the onsite ISFSI would receive an additional 830 minus 108 = 722 fuel assemblies per year. Second, additional costs would arise in providing hardened, dispersed storage at the onsite ISFSI. Third, costs would arise in replacing the existing racks in the Diablo Canyon pools with low-density, open-frame racks.

The capital cost of placing spent fuel in dry casks at ISFSIs at US nuclear power plants ranges from $90 to $210 per kg of uranium.[70] Here, I assume that the capital cost for the currently-planned ISFSI at Diablo Canyon would be $120 per kg of uranium, while the capital cost for a hardened, dispersed ISFSI would be $240 per kg of uranium. A fresh Diablo Canyon fuel assembly contains 460 kg of uranium. Thus, placing 722 fuel assemblies in a hardened, dispersed ISFSI at Diablo Canyon would involve a capital expense of $80 million. The incremental capital expense of placing

108 fuel assemblies in a hardened, dispersed ISFSI at Diablo Canyon, instead of in the currently-planned ISFSI, would be $6 million. I assume that replacement of the high-density racks in the Diablo Canyon spent-fuel pools with low-density racks would involve a capital expense of $10 million over a 2-year period.

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 an additional annual O&M expense of $10 million and an additional annual capital cost of $2 million. Providing the enhanced capability for onsite damage control would require an increase in the size of the Diablo Canyon 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 PG&E's annual O&M expense by $10 million. I assume that the same increase in personnel and annual O&M expense 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.

Q. What is the overall additional cost of providing the enhanced defense of the Diablo Canyon plant?

A. Table VIII-2 summarizes the cost estimates developed above. Note that these costs are additional to the O&M expenses and capital expenses that PG&E is currently incurring.

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

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

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.

///

Table VII-1
Diablo Canyon O&M and Nuclear Fuel Expenses:
Annual Average for 2002-2005 as Projected by PG&E in 2003[71]

Expense Category	2002-2005 Annual Average Expense ($ million)	Approximate Number of Personnel
Manage production	37.2	284
Manage DCPP plant assets	112	499
People performance	19.5	67
Manage business and information management	23.8	100
Manage supply chain	5.59	51
Manage engineering assets and maintain license and strategic projects	36.7	156
Loss prevention	22.5	168
Subtotal	257	1,325
Nuclear fuel	86.9	
Total	343.9	

///

///

///

///

///

[71] **Notes:**
(i) Expenses are in mixed, unadjusted, current-year dollars.
(ii) O&M expenses are actual 2001 values adjusted to account for projected changes.
(iii) Personnel numbers "are approximate since employees often work in more than one process and split their time accordingly".
(iv) A 1987 study (EIA, 1995, page 3) found that about two-thirds of reported O&M expenses at US nuclear power plants are for labor, the remaining one-third being for materials and supplies.

Source: PG&E, 2003, Chapter 4.

Table VIII-2
Estimated Additional Costs of Potential Measures to Provide Enhanced Defense of the Diablo Canyon Nuclear Power Plant and its Spent Fuel

Defensive Measure	**Capital Expense ($ million)**	**Annual O&M Expense ($ million)**
Sentinel (2 units)	7.5/yr for 2 yrs	8.5
Phalanx (2 units)	10/yr for 2 yrs	11
Expanded DBT and stronger defense of the onsite ISFSI	5/yr	15
Automated shutdown system	37.5/yr for 2 yrs	N/A
Emergency cooling system	37.5/yr for 2 yrs	N/A
Re-equipment of spent-fuel pools with low-density racks and transfer of excess fuel to a hardened, dispersed, onsite ISFSI	91/yr for 2 yrs; 6/yr thereafter	N/A
Enhanced capability for onsite damage control	2/yr	10
Enhanced capability for offsite emergency response	2/yr	10
Total	192.5/yr for 2 yrs; 15/yr thereafter	54.5

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.

The 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 US to call for enhanced defense of US nuclear power plants and spent fuel. It is therefore prudent to assume that the Diablo Canyon plant and its spent fuel will receive an enhanced defense during the coming years.

This testimony describes measures that would be included in a potential plan for enhanced defense of the Diablo Canyon plant and its spent fuel. These measures could be required by the 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 PG&E if the measures were implemented. PG&E 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 the Diablo Canyon plant and its spent fuel storage. Such an assumption is not appropriate, and the costs that I have estimated should be considered in evaluating PG&E's application.

Appendix A: Curriculum Vitae for Gordon Thompson (August 2003)

Professional expertise

Technical and policy analyst in the fields of energy, environment, sustainable development, and international security.

Current appointments

- Executive director, Institute for Resource & Security Studies (IRSS), Cambridge, Massachusetts.
- Research Professor, George Perkins Marsh Institute, Clark University, Worcester, Massachusetts.

Education

- D.Phil. in applied mathematics, Oxford University (Balliol College), 1973.
- B.E. in mechanical engineering, University of New South Wales, Sydney, Australia, 1967.
- B.Sc. in mathematics & physics, University of New South Wales, 1966.

Project sponsors and tasks (selected)

- STAR Foundation, New York, 2002-2003: reviewed planning and actions for decommissioning of research reactors at Brookhaven National Laboratory.
- Attorney General of Utah, 2003: conducted technical analysis on a proposed storage facility for spent nuclear fuel.
- Mothers for Peace, California, 2002-2003: analyzed risk issues associated with the Diablo Canyon nuclear power plant; prepared a Call for Action to protect US nuclear power plants and spent fuel.
- Citizens Awareness Network, Massachusetts, 2002-2003: conducted analysis on robust storage of spent nuclear fuel.
- Tides Center, California, 2002-2003: conducted analysis for the Santa Susana Field Laboratory (SSFL) Advisory Panel regarding the history of releases of radioactive material from the SSFL.
- Orange County, North Carolina, 1999-2002: assessed risk issues associated with the Harris nuclear power plant; identified risk-reduction options.
- William and Flora Hewlett Foundation and other sponsors, 1999-2003: performed research and project development for conflict-management projects, through IRSS's International Conflict Management Program.
- STAR Foundation, New York, 2000-2001: assessed risk issues associated with the Millstone nuclear power plant; identified risk-reduction options.
- Massachusetts Water Resources Authority, 2000: evaluated risks associated with water supply and wastewater systems that serve greater Boston.
- Canadian Senate, Energy & Environment Committee, 2000: reviewed risk issues associated with the Pickering Nuclear Generating Station.

• Greenpeace International, Amsterdam, 2000: reviewed impacts associated with the La Hague nuclear complex in France.
• Government of Ireland, 1998-2001: developed framework for assessment of impacts and alternative options associated with the Sellafield nuclear complex in the UK.
• Clark University, Worcester, Massachusetts, 1998-1999: participated in review of a major foundation's grant-making related to climate change.
• UN High Commissioner for Refugees, 1998: developed a strategy for conflict management in the CIS region.
• General Council of County Councils (Ireland), W. Alton Jones Foundation (USA), and Nuclear Free Local Authorities (UK), 1996-2000: assessed safety and economic issues of nuclear fuel reprocessing in the UK; assessed alternative options.
• Environmental School, Clark University, Worcester, Massachusetts, 1996: session leader at the Summer Institute, "Local Perspectives on a Global Environment".
• Greenpeace Germany, Hamburg, 1995-1996: a study on war, terrorism and nuclear power plants.
• HKH Foundation, New York, and Winston Foundation for World Peace, Washington, DC, 1994-1996: studies and workshops on preventive action and its role in US national security planning.
• Carnegie Corporation of New York, Winston Foundation for World Peace, Washington, DC, and others, 1995: collaboration with the Organization for Security and Cooperation in Europe to facilitate improved coordination of activities and exchange of knowledge in the field of conflict management.
• World Bank, 1993-1994: a study on management of data describing the performance of projects funded by the Global Environment Facility (joint project of IRSS and Clark University).
• International Physicians for the Prevention of Nuclear War, 1993-1994: a study on the international control of weapons-usable fissile material.
• Government of Lower Saxony, Hannover, Germany, 1993: analysis of standards for radioactive waste disposal.
• University of Vienna (using funds supplied by the Austrian government), 1992: review of radioactive waste management at the Dukovany nuclear plant, Czech Republic.
• Sandia National Laboratories, 1992-1993: advice to the US Department of Energy's Office of Foreign Intelligence.
• US Department of Energy and Battelle Pacific Northwest Laboratories, 1991-1992: advice for the Intergovernmental Panel on Climate Change regarding the design of an information system on technologies that can limit greenhouse gas emissions (joint project of IRSS, Clark University and the Center for Strategic and International Studies).
• Winston Foundation for World Peace, Boston, Massachusetts, and other funding sources, 1992-1993: development and publication of recommendations for strengthening the International Atomic Energy Agency.
• MacArthur Foundation, Chicago, Illinois, W. Alton Jones Foundation, Charlottesville, Virginia, and other funding sources, 1984-1993: policy analysis and public education on a "global approach" to arms control and disarmament.
• Energy Research Foundation, Columbia, South Carolina, and Peace Development Fund, Amherst, Massachusetts, 1988-1992: review of the US government's tritium production (for nuclear weapons) and its implications.

• Coalition of Environmental Groups, Toronto, Ontario (using funds supplied by Ontario Hydro under the direction of the Ontario government), 1990-1993: coordination and conduct of analysis and preparation of testimony on accident risk of nuclear power plants.
• Greenpeace International, Amsterdam, Netherlands, 1988-1990: review of probabilistic risk assessment for nuclear power plants.
• Bellerive Foundation, Geneva, Switzerland, 1989-1990: planning for a June 1990 colloquium on disarmament and editing of proceedings.
• Iler Research Institute, Harrow, Ontario, 1989-1990: analysis of regulatory response to boiling-water reactor accident potential.
• Winston Foundation for World Peace, Boston, Massachusetts, and other funding sources, 1988-1989: analysis of future options for NATO (joint project of IRSS and the Institute for Peace and International Security).
• Nevada Nuclear Waste Project Office, Carson City, Nevada (via Clark University), 1989-1990: analyses of risk aspects of radioactive waste management and disposal.
• Ontario Nuclear Safety Review (conducted by the Ontario government), Toronto, Ontario, 1987: review of safety aspects of CANDU reactors.
• Washington Department of Ecology, Olympia, Washington, 1987: analysis of risk aspects of a proposed radioactive waste repository at Hanford.
• Natural Resources Defense Council, Washington, DC, 1986-1987: preparation of testimony on hazards of the Savannah River Plant.
• Lakes Environmental Association, Bridgton, Maine, 1986: analysis of federal regulations for disposal of radioactive waste.
• Greenpeace Germany, Hamburg, 1986: participation in an international study on the hazards of nuclear power plants.
• Three Mile Island Public Health Fund, Philadelphia, Pennsylvania, 1983-1989: studies related to the Three Mile Island nuclear power plant.
• Attorney General, Commonwealth of Massachusetts, 1984-1989: analyses of the safety of the Seabrook nuclear plant.
• Union of Concerned Scientists, Cambridge, Massachusetts, 1980-1985: studies on energy demand and supply, nuclear arms control, and the safety of nuclear installations.
• Conservation Law Foundation of New England, Boston, Massachusetts, 1985: preparation of testimony on cogeneration potential at a Maine papermill.
• Town & Country Planning Association, London, UK, 1982-1984: coordination and conduct of a study on safety and radioactive waste implications of the proposed Sizewell nuclear plant.
• US Environmental Protection Agency, Washington, DC, 1980-1981: assessment of the cleanup of Three Mile Island Unit 2 nuclear plant.
• Center for Energy & Environmental Studies, Princeton University, Princeton, New Jersey, and Solar Energy Research Institute, Golden, Colorado, 1979-1980: studies on the potentials of renewable energy sources.
• Government of Lower Saxony, Hannover, Federal Republic of Germany, 1978-1979: coordination and conduct of studies on safety aspects of the proposed Gorleben nuclear fuel cycle center.

Other experience (selected)

• Principal investigator, project on "Exploring the Role of 'Sustainable Cities' in Preventing Climate Disruption", involving IRSS and three other organizations, 1990-1991.
• Visiting fellow, Peace Research Centre, Australian National University, 1989.
• Principal investigator, Three Mile Island emergency planning study, involving IRSS and Clark University, 1987-1989.
• Co-leadership (with Paul Walker) of a study group on nuclear weapons proliferation, Institute of Politics, Harvard University, 1981.
• Foundation (with others) of an ecological political movement in Oxford, UK, which contested the 1979 Parliamentary election.
• Conduct of cross-examination and presentation of evidence, on behalf of the Political Ecology Research Group, at the 1977 Public Inquiry into proposed expansion of the reprocessing plant at Windscale, UK.
• Conduct of research on plasma theory (while a D.Phil candidate), as an associate staff member, Culham Laboratory, UK Atomic Energy Authority, 1969-1973.
• Service as a design engineer on coal-fired plants, New South Wales Electricity Commission, Sydney, Australia, 1968.

Publications (selected)

• "Reducing the Hazards from Stored Spent Power-Reactor Fuel in the United States" (with Robert Alvarez, Jan Beyea, Klaus Janberg, Jungmin Kang, Ed Lyman, Allison Macfarlane and Frank N. von Hippel), *Science and Global Security*, Volume 11, 2003, pp 1-51.
• "Health, Human Security and Social Reconstruction in Afghanistan" (with Paula Gutlove and Jacob Hale Russell), in John D. Montgomery and Dennis A. Rondinelli (eds), *Beyond Reconstruction in Afghanistan*, Palgrave Macmillan, in press.
• *Psychosocial Healing: A Guide for Practitioners, based on programs of the Medical Network for Social Reconstruction in the Former Yugoslavia* (with Paula Gutlove), IRSS, Cambridge, Massachusetts and OMEGA Health Care Center, Graz, Austria, May 2003.
• *A Call for Action to Protect the Nation Against Enemy Attack on Nuclear Power Plants and Spent Fuel*, and a Supporting Document, Mothers for Peace, San Luis Obispo, California, April 2003 and May 2003.
• "Human Security: Expanding the Scope of Public Health" (with Paula Gutlove), *Medicine, Conflict and Survival*, Volume 19, 2003, pp 17-34.
• *Social Reconstruction in Afghanistan through the Lens of Health and Human Security* (with Paula Gutlove and Jacob Hale Russell), IRSS, Cambridge, Massachusetts, May 2003.
• *Robust Storage of Spent Nuclear Fuel: A Neglected Issue of Homeland Security*, a report commissioned by Citizens Awareness Network, Shelburne Falls, Massachusetts, January 2003.
• *Medical Network for Social Reconstruction in the Former Yugoslavia: A Survey of Participants' Views on the Network's Goals and Achievements*, IRSS, Cambridge, Massachusetts, September 2001.
• *The Potential for a Large, Atmospheric Release of Radioactive Material from Spent Fuel Pools at the Harris Nuclear Power Plant: The Case of a Pool Release Initiated by a*

Severe Reactor Accident, a report for Orange County, North Carolina, 20 November 2000.
• *A Review of the Accident Risk Posed by the Pickering 'A' Nuclear Generating Station,* a report for the Standing Committee on Energy, Environment and Natural Resources, Canadian Senate, August 2000.
• *High-Level Radioactive Liquid Waste at Sellafield: An Updated Review*, a report for the UK Nuclear Free Local Authorities, June 2000.
• *Hazard Potential of the La Hague Site: An Initial Review*, a report for Greenpeace International, May 2000.
• *A Strategy for Conflict Management: Integrated Action in Theory and Practice* (with Paula Gutlove), Working Paper No. 7, IRSS, Cambridge, Massachusetts, March 1999.
• *Risks and Alternative Options Associated with Spent Fuel Storage at the Shearon Harris Nuclear Power Plant*, a report for Orange County, North Carolina, February 1999.
• *High Level Radioactive Liquid Waste at Sellafield: Risks, Alternative Options and Lessons for Policy*, IRSS, Cambridge, Massachusetts, June 1998.
• "Science, democracy and safety: why public accountability matters", in F. Barker (ed), *Management of Radioactive Wastes: Issues for local authorities*, Thomas Telford, London, 1998.
• "Conflict Management and the OSCE" (with Paula Gutlove), *OSCE/ODIHR Bulletin*, Volume 5, Number 3, Fall 1997.
• *Safety of the Storage of Liquid High-Level Waste at Sellafield* (with Peter Taylor), Nuclear Free Local Authorities, UK, November 1996.
• *Assembling Evidence on the Effectiveness of Preventive Actions, their Benefits, and their Costs: A Guide for Preparation of Evidence*, IRSS, Cambridge, Massachusetts, August 1996.
• *War, Terrorism and Nuclear Power Plants,* Working Paper No. 165, Peace Research Centre, Australian National University, Canberra, October 1996.
• "The Potential for Cooperation by the OSCE and Non-Governmental Actors on Conflict Management" (with Paula Gutlove), *Helsinki Monitor*, Volume 6 (1995), Number 3.
• "Potential Characteristics of Severe Reactor Accidents at Nuclear Plants", "Monitoring and Modelling Atmospheric Dispersion of Radioactivity Following a Reactor Accident" (with Richard Sclove, Ulrike Fink and Peter Taylor), "Safety Status of Nuclear Reactors and Classification of Emergency Action Levels", and "The Use of Probabilistic Risk Assessment in Emergency Response Planning for Nuclear Power Plant Accidents" (with Robert Goble), in D. Golding, J. X. Kasperson and R. E. Kasperson (eds), *Preparing for Nuclear Power Plant Accidents*, Westview Press, Boulder, Colorado, 1995.
• *A Data Manager for the Global Environment Facility* (with Robert Goble), Environment Department, The World Bank, June 1994.
• *Preventive Diplomacy and National Security* (with Paula Gutlove), Winston Foundation for World Peace, Washington, DC, May 1994.
• *Opportunities for International Control of Weapons-Usable Fissile Material*, ENWE Paper #1, International Physicians for the Prevention of Nuclear War, Cambridge, Massachusetts, January 1994.
• "Article III and IAEA Safeguards", in F. Barnaby and P. Ingram (eds), *Strengthening the Non-Proliferation Regime*, Oxford Research Group, Oxford, UK, December 1993.

• *Risk Implications of Potential New Nuclear Plants in Ontario* (prepared with the help of eight consultants), a report for the Coalition of Environmental Groups, Toronto, submitted to the Ontario Environmental Assessment Board, November 1992 (3 volumes).
• *Strengthening the International Atomic Energy Agency*, Working Paper No. 6, IRSS, Cambridge, Massachusetts, September 1992.
• *Design of an Information System on Technologies that can Limit Greenhouse Gas Emissions* (with Robert Goble and F. Scott Bush), Center for Strategic and International Studies, Washington, DC, May 1992.
• *Managing Nuclear Accidents: A Model Emergency Response Plan for Power Plants and Communities* (with six other authors), Westview Press, Boulder, CO, 1992.
• "Let's X-out the K" (with Steven C. Sholly), *Bulletin of the Atomic Scientists*, March 1992, pp 14-15.
• "A Worldwide Programme for Controlling Fissile Material", and "A Global Strategy for Nuclear Arms Control", in F. Barnaby (ed), *Plutonium and Security*, Macmillan Press, UK, 1992.
• *No Restart for K Reactor* (with Steven C. Sholly), Working Paper No. 4, IRSS, Cambridge, Massachusetts, October 1991.
• *Regulatory Response to the Potential for Reactor Accidents: The Example of Boiling-Water Reactors,* Working Paper No. 3, IRSS, Cambridge, Massachusetts, February 1991.
• *Peace by Piece: New Options for International Arms Control and Disarmament*, Working Paper No. 1, IRSS, Cambridge, Massachusetts, January 1991.
• *Developing Practical Measures to Prevent Climate Disruption* (with Robert Goble), CENTED Research Report No. 6, Clark University, Worcester, Massachusetts, August 1990.
• "Treaty a Useful Relic", *Bulletin of the Atomic Scientists*, July/August 1990, pp 32-33.
• "Practical Steps for the 1990s", in Sadruddin Aga Khan (ed), *Non-Proliferation in a Disarming World*, Proceedings of the Groupe de Bellerive's 6th International Colloquium, Bellerive Foundation, Geneva, Switzerland, 1990.
• *A Global Approach to Controlling Nuclear Weapons*, Occasional Paper published by IRSS, Cambridge, Massachusetts, October 1989.
• *IAEA Safety Targets and Probabilistic Risk Assessment* (with three other authors), Greenpeace International, Amsterdam, August 1989.
• *New Directions for NATO* (with Paul Walker and Pam Solo), published jointly by IRSS and the Institute for Peace and International Security (both of Cambridge, Massachusetts), December 1988.
• "Verifying a Halt to the Nuclear Arms Race", in F. Barnaby (ed), *A Handbook of Verification Procedures*, Macmillan Press, UK, 1990.
• "Verification of a Cutoff in the Production of Fissile Material", in F.Barnaby (ed), *A Handbook of Verification Procedures*, Macmillan Press, UK, 1990.
• "Severe Accident Potential of CANDU Reactors," Consultant's Report in *The Safety of Ontario's Nuclear Power Reactors*, Ontario Nuclear Safety Review, Toronto, February 1988.
• *Nuclear-Free Zones* (edited with David Pitt), Croom Helm Ltd, Beckenham, UK, 1987.
• *Risk Assessment Review For the Socioeconomic Impact Assessment of the Proposed High-Level Nuclear Waste Repository at Hanford Site, Washington* (edited; written with five other authors), prepared for the Washington Department of Ecology, December 1987.

• *The Nuclear Freeze Revisited* (with Andrew Haines), Nuclear Freeze and Arms Control Research Project, Bristol, UK, November 1986. Variants of the same paper have appeared as Working Paper No. 18, Peace Research Centre, Australian National University, Canberra, February 1987, and in *ADIU Report*, University of Sussex, Brighton, UK, Jan/Feb 1987, pp 6-9.
• *International Nuclear Reactor Hazard Study* (with fifteen other authors), Greenpeace, Hamburg, Federal Republic of Germany (2 volumes), September 1986.
• "What happened at Reactor Four" (the Chernobyl reactor accident), *Bulletin of the Atomic Scientists*, August/September 1986, pp 26-31.
• *The Source Term Debate: A Report by the Union of Concerned Scientists* (with Steven C. Sholly), Union of Concerned Scientists, Cambridge, Massachusetts, January 1986.
• "Checks on the spread" (a review of three books on nuclear proliferation), *Nature*, 14 November 1985, pp 127-128.
• Editing of *Perspectives on Proliferation*, Volume I, August 1985, published by the Proliferation Reform Project, IRSS.
• "A Turning Point for the NPT ?", *ADIU Report*, University of Sussex, Brighton, UK, Nov/Dec 1984, pp 1-4.
• "Energy Economics", in J. Dennis (ed), *The Nuclear Almanac*, Addison-Wesley, Reading, Massachusetts, 1984.
• "The Genesis of Nuclear Power", in J. Tirman (ed), *The Militarization of High Technology*, Ballinger, Cambridge, Massachusetts, 1984.
• *A Second Chance: New Hampshire's Electricity Future as a Model forthe Nation* (with Linzee Weld), Union of Concerned Scientists, Cambridge, Massachusetts, 1983.
• *Safety and Waste Management Implications of the Sizewell PWR* (prepared with the help of six consultants), a report to the Town & Country Planning Association, London, UK, 1983.
• *Utility-Scale Electrical Storage in the USA: The Prospects of Pumped Hydro, Compressed Air, and Batteries*, Princeton University report PU/CEES #120, 1981.
• *The Prospects for Wind and Wave Power in North America*, Princeton University report PU/CEES # 117, 1981.
• *Hydroelectric Power in the USA: Evolving to Meet New Needs*, Princeton University report PU/CEES # 115, 1981.
• Editing and part authorship of "Potential Accidents & Their Effects", Chapter III of *Report of the Gorleben International Review*, published in German by the Government of Lower Saxony, FRG, 1979--Chapter III available in English from the Political Ecology Research Group, Oxford, UK.
• *A Study of the Consequences to the Public of a Severe Accident at a Commercial FBR located at Kalkar, West Germany*, Political Ecology Research Group report RR-1, 1978.

Expert presentations and testimony (selected)

• European Parliament, 2003: gave an invited presentation to members regarding safety and security issues at the Sellafield nuclear site; discussed broader implications.
• US Congress, 2002 and 2003: gave member-sponsored staff briefings on vulnerabilities of nuclear-power facilities and options for improved defenses.

• Numerous public forums in the USA, 2001-2003: gave invited presentations to public officials and general audiences regarding vulnerabilities of nuclear-power facilities and options for improved defenses.
• UK Consensus Conference on Radioactive Waste Management, 1999: provided invited testimony on information and decision-making.
• Joint Committee on Public Enterprise and Transport, Irish Parliament, 1999: provided invited testimony on nuclear fuel reprocessing and international security.
• UK and Irish Parliaments, 1998: gave members' briefings on risks and alternative options associated with nuclear fuel reprocessing in the UK.
• Center for Russian Environmental Policy, Moscow, 1996: presentation at a forum in parallel with the G-7 Nuclear Safety Summit.
• Lacey Township Zoning Board, New Jersey, 1995: testimony regarding radioactive waste management.
• Ontario Court of Justice, Toronto, Ontario, 1993: testimony regarding Canada's Nuclear Liability Act.
• Oxford Research Group, seminar on "The Plutonium Legacy", Rhodes House, Oxford, UK, 1993: presentation on nuclear safeguards.
• Defense Nuclear Facilities Safety Board, Washington, DC, 1991: testimony regarding the proposed restart of K-reactor, Savannah River Site.
• Conference to consider amending the Partial Test Ban Treaty, United Nations, New York, 1991: presentation on a global approach to arms control and disarmament.
• US Department of Energy, hearing on draft EIS for new production reactor capacity, Columbia, South Carolina, 1991: presentation on tritium need and implications of tritium production options.
• Society for Risk Analysis, 1990 annual meeting, New Orleans, special session on nuclear emergency planning: presentation on real-time techniques for anticipating emergencies.
• Parliamentarians' Global Action, 11th Annual Parliamentary Forum, United Nations, Geneva, 1990: presentation on the potential for multilateral nuclear arms control.
• Advisory Committee on Nuclear Facility Safety, public meeting, Washington, DC, 1989: submission on public access to information and on government accountability.
• Peace Research Centre, Australian National University, seminar on "Australia and the Fourth NPT Review Conference", Canberra, 1989: proposal of a universal nuclear weapons non-proliferation regime.
• Carnegie Endowment for International Peace, Conference on "Nuclear Non-Proliferation and the Role of Private Organizations", Washington, DC, 1989: options for reform of the non-proliferation regime.
• US Department of Energy, EIS scoping hearing, Columbia, South Carolina, 1988: appropriate scope of an EIS for new production reactor capacity.
• International Physicians for the Prevention of Nuclear War, 6th and 7th Annual Congresses, Koln, FRG, 1986 and Moscow, USSR, 1987: relationships between nuclear power and the threat of nuclear war.
• County Council, Richland County, South Carolina, 1987: implications of severe reactor accidents at the Savannah River Plant.
• Maine Land Use Regulation Commission, 1985: cogeneration potential at facilities of Great Northern Paper Company.
• Interfaith Hearings on Nuclear Issues, Toronto, Ontario, 1984: options for Canada's nuclear trade and Canada's involvement in nuclear arms control.

• Sizewell Public Inquiry, UK, 1984: safety and radioactive waste implications of the proposed Sizewell nuclear plant.
• New Hampshire Public Utilities Commission, 1983: electricity demand and supply options for New Hampshire.
• Atomic Safety & Licensing Board, US Nuclear Regulatory Commission, 1983: use of filtered venting at the Indian Point nuclear plants.
• US National Advisory Committee on Oceans and Atmosphere, 1982: implications of ocean disposal of radioactive waste.
• Environmental & Energy Study Conference, US Congress, 1982: implications of radioactive waste management.

Miscellaneous

• Married, two children.
• Extensive experience in public speaking and interviews by mass media.
• Author of numerous essays and letters in newspapers and magazines.

Contact information

Institute for Resource and Security Studies
27 Ellsworth Avenue, Cambridge, Massachusetts 02139, USA
Phone: 617-491-5177   Fax: 617-491-6904   E-mail: gthompson@irss-usa.org

Appendix B: Bibliography

(Alvarez et al, 2003)
Robert Alvarez and seven other authors, "Reducing the Hazards from Stored Spent Power-Reactor Fuel in the United States", Science and Global Security, 11:1-51, 2003.

(AT, 2004)
Army Technology, Avenger Low Level Air Defense System, USA, Army Technology website (www.army-technology.com/projects/avenger/), accessed on 16 June 2004.

(Baker, Cutler et al, 2001)
Howard Baker and Lloyd Cutler (co-chairs, Russia Task Force) et al, A Report Card on the Department of Energy's Nonproliferation Programs with Russia (Washington, DC: Secretary of Energy Advisory Board, US Department of Energy, 10 January 2001).

(Barami, 2004)
Bahar Barami (senior economist, Volpe Center), "Market Trends in Homeland Security Technologies", paper presented at the IEEE Conference on Technologies for Homeland Security, Volpe Center, Cambridge, Massachusetts, 21-24 April 2004.

(Beyea et al, 2004)
Jan Beyea, Ed Lyman and Frank von Hippel, "Damages from a Major Release of 137Cs into the Atmosphere of the United States", Science and Global Security, 12:125-136, 2004.

(Beyea et al, 1979)
Jan Beyea, Yves Lenoir, Gene Rochlin and Gordon Thompson (subgroup chair), Report of the Gorleben International Review, Chapter 3: Potential Accidents and their Effects, submitted (in German) to the Government of Lower Saxony, March 1979.

(Brian, 2003)
Danielle Brian (executive director, Project on Government Oversight), speech to the NRC's Regulatory Information Conference, 16 April 2003, available at <http://www.pogo.org/p/environment/et-030401-nuclear.html>, accessed on 24 May 2003.

(Chapin et al, 2002)
Douglas M. Chapin et al, "Nuclear Power Plants and Their Fuel as Terrorist Targets", Science, Volume 297, 20 September 2002, pp 1997-1999.

(Clover, 2004)
Charles Clover, "Natural-born killers will not win hearts and minds", Financial Times, 25 June 2004.

(Collins et al, 2000)

Timothy Collins et al, Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants (Washington, DC: US Nuclear Regulatory Commission, October 2000).

(Conley, 2004)
Maureen Conley, "Holtec to ask NRC to approve underground design for dry storage facility", Nuclear Fuel, 26 April 2004, pages 1 and 11.

(Deller, 2002)
Nicole Deller, "Rule of Power or Rule of Law?", Science for Democratic Action, Volume 10, Number 4, August 2002.

(Diaz, 2003)
Nils J. Diaz (chairman, US Nuclear Regulatory Commission), letter of 23 October 2003 to US Representative Edward J. Markey.

(Dillingham, 2003)
Gerald L. Dillingham (US General Accounting Office), Testimony before the Committee on Commerce, Science and Transportation, US Senate, Aviation Security: Progress Since September 11, 2001, and the Challenges Ahead, 9 September 2003.

(DOE, 2002)
US Department of Energy, Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada, DOE/EIS-0250F (Washington, DC: DOE, February 2002).

(DOE, 1987)
US Department of Energy, Health and Environmental Consequences of the Chernobyl Nuclear Power Plant Accident, DOE/ER-0332 (Washington, DC: DOE, June 1987).

(Doehring, 2004)
Thoralf Doehring, Mk-15 Phalanx Close-In Weapons System, Doehring personal website (navysite.de/weapons/phalanx.htm), accessed on 16 June 2004.

(DSCA, 2002)
Defense Security Cooperation Agency, News Release, Egypt – AN/MPQ-64 SENTINEL Radar Systems, 4 September 2002.

(EIA, 1995)
Energy Information Administration, US Department of Energy, An Analysis of Nuclear Power Plant Operating Costs: A 1995 Update (Washington, DC: EIA, April 1995).

(ElBaradei, 2004)
Mohamed ElBaradei (director general, International Atomic Energy Agency), "Nuclear Non-Proliferation: Global Security in a Rapidly Changing World", keynote address, Carnegie International Non-Proliferation Conference, Washington, DC, 21 June 2004.

(Ewing and Macfarlane, 2002)
Rodney C. Ewing and Allison Macfarlane, "Yucca Mountain", Science, Volume 296, 26 April 2002, pp 659-660.

(FAS, 2003)
FAS Military Analysis Network, MK 15 Phalanx Close-In Weapons System (CIWS), Federation of American Scientists website (www.fas.org/man/dod-101), updated on 9 January 2003.

(FAS, 2000a)
FAS Military Analysis Network, AN/MPQ-64 Sentinel, Forward Area Air-Defense Ground Based Sensor (FAAD-GBS), Federation of American Scientists website (www.fas.org/man/dod-101), updated on 29 May 2000.

(FAS, 2000b)
FAS Military Analysis Network, Avenger (Pedestal Mounted Stinger), Federation of American Scientists website (www.fas.org/man/dod-101), updated on 5 May 2000.

(FAS, 2000c)
FAS Military Analysis Network, FIM-92A Stinger Weapons System: RMP & Basic, Federation of American Scientists website (www.fas.org/man/dod-101), updated on 9 August 2000.

(Ford, 1982)
Daniel Ford, Cult of the Atom (New York, New York: Simon and Schuster, 1982).

(Friedman, 1991)
Norman Friedman, The Naval Institute Guide to World Naval Weapons Systems 1991/92 (Annapolis, Maryland: Naval Institute Press, 1991).

(Gale and Husick, 2003)
Stephen Gale and Lawrence Husick, "From MAD (Mutual Assured Destruction) to MUD (Mutual Unconstrained Disruption): Dealing with the New Terrorism", Foreign Policy Research Institute Wire, Volume 11, Number 1, February 2003.

(Glanz, 2004)
James Glanz, "15 Miles Offshore, Safeguarding Iraq's Oil Lifeline", New York Times, 6 July 2004.

(Goff, 2003)
Stanley A Goff, Predeployed Radiological Weapon: Reducing the targetability of Shearon Harris Nuclear Plant and the risk to the North Carolina public (Durham, North Carolina: NC-WARN, 1 May 2003).

(Golding et al, 1995)

Dominic Golding et al, Preparing for Nuclear Power Plant Accidents (Boulder, Colorado: Westview Press, 1995).

(Golding et al, 1992)
Dominic Golding et al, Managing Nuclear Accidents: A Model Emergency Response Plan for Power Plants and Communities (Boulder, Colorado: Westview Press, 1992).

(Hannerz, 1983)
K. Hannerz, Towards Intrinsically Safe Light Water Reactors (Oak Ridge, Tennessee: Institute for Energy Analysis, February 1983).

(Hart et al, 2002)
Gary Hart and Warren B. Rudman (co-chairs), Stephen E. Flynn (project director) and Task Force members, America Still Unprepared -- America Still in Danger: Report of an Independent Task Force Sponsored by the Council on Foreign Relations (New York, NY: Council on Foreign Relations, 25 October 2002).

(HCDC, 2002)
UK House of Commons Defence Committee, Defence and Security in the UK: Sixth Report of Session 2001-02 (London: The Stationery Office Limited, 24 July 2002).

(Hirsch et al, 2003)
Daniel Hirsch, David Lochbaum and Edwin Lyman, "The NRC's Dirty Little Secret", Bulletin of the Atomic Scientists, May/June 2003, pp 45-51.

(Hirsch et al, 1989)
H. Hirsch et al, IAEA Safety Targets and Probabilistic Risk Assessment (Hannover, Germany: Gesellschaft fur Okologische Forschung und Beratung mbH, August 1989).

(Hutchings, 2004)
Robert L. Hutchings (chairman, National Intelligence Council), speech to the International Security Management Association, 14 January 2004.

(Inside NRC staff, 2003)
Washington staff of Inside NRC, "NRC instructed to hire NAS for spent fuel pool hazards study", Inside NRC, 17 November 2003, pp 1, 12-13.

(Jones, 2002a)
David Jones, "Sandia says its study not proof of nuke plant durability" Inside Energy, 30 September 2002, page 14.

(Jones, 2002b)
Gary Jones (director, Natural Resources and Environment, US General Accounting Office), "Nuclear Waste: Uncertainties about the Yucca Mountain Repository Project", testimony before the Subcommittee on Energy and Air Quality, House Committee on Energy and Commerce, 21 March 2002.

(Krass, 1991)
Allan S. Krass, Consequences of the Chernobyl Accident (Cambridge, Massachusetts: Institute for Resource and Security Studies, December 1991).

(Macfarlane, 2001a)
Allison Macfarlane, "Interim Storage of Spent Fuel in the United States", Annual Review of Energy & Environment, Volume 26 (2001), pp 201-235.

(Macfarlane, 2001b)
Allison Macfarlane, "The problem of used nuclear fuel: lessons for interim solutions from a comparative cost analysis", Energy Policy, Volume 29 (2001), pp 1379-1389.

(Markey, 2002)
Staff of US Representative Edward Markey, "Security Gap: A Hard Look At the Soft Spots in Our Civilian Nuclear Reactor Security", 25 March 2002.

(Meserve, 2003)
NRC Chairman Richard Meserve, letter to Tom Ridge, Secretary of Homeland Security, 31 March 2003. Note: This letter, when downloaded from the NRC website (www.nrc.gov, accessed on 23 May 2003), was packaged with a letter of 5 September 2002 from Meserve to Ridge.

(Meserve, 2002a)
Richard A. Meserve, "Nuclear Security in a New World", The Industrial Physicist, October/November 2002, pp 20-23.

(Meserve, 2002b)
Richard Meserve (chairman, US Nuclear Regulatory Commission), "Statement Submitted by the United States Nuclear Regulatory Commission to the Committee on Environment and Public Works, United States Senate, Concerning Nuclear Power Plant Security", 5 June 2002.

(MFP/UCS, 2003)
Mothers for Peace and Union of Concerned Scientists, Petition [to the NRC] for Rulemaking, 28 April 2003.

(NAC, 2001)
NAC Worldwide Consulting, US Spent Fuel Update: Year 2000 in Review (Atlanta, Georgia: NAC Worldwide Consulting, 2001).

(Nazzaro, 2004)
Robin M. Nazzaro (US General Accounting Office), Testimony before the Subcommittee on National Security, Emerging Threats, and International Relations, Committee on Government Reform, US House of Representatives, Nuclear Security: Several Issues Could Impede the Ability of DOE's Office of Energy, Science and Environment to Meet the May 2003 Design Basis Threat, 22 June 2004.

(NII, 2001)
UK Nuclear Installations Inspectorate, "Specification Issued under Licence Condition 32(4) for the Limitation of the Accumulation or Storage of Liquid High Level Radioactive Waste in B215. Licence Instrument 343. January 2001."

(NRC, 2003)
US Nuclear Regulatory Commission, "Briefing on the Status of Office of Research (RES) Programs, Performance, and Plans", transcript of an open session of the Commission, Rockville, Maryland, 27 March 2003.

(NRC, 2002)
US Nuclear Regulatory Commission, Fact Sheet: Nuclear Security Enhancements Since Sept. 11, 2001 (Washington, DC: US Nuclear Regulatory Commission, undated, apparently September 2002).

(NRC, 1990)
US Nuclear Regulatory Commission, Severe Accident Risks: An Assessment for Five US Nuclear Power Plants, NUREG-1150 (Washington, DC: US Nuclear Regulatory Commission, December 1990).

(Office of Homeland Security, 2002)
Office of Homeland Security, National Strategy for Homeland Security (Washington, DC: The White House, July 2002).

(Okrent, 1981)
David Okrent, Nuclear Reactor Safety (Madison, Wisconsin: University of Wisconsin Press, 1981).

(Pew, 2004)
Pew Research Center for the People and the Press, A Year After Iraq War: Mistrust of America in Europe Ever Higher, Muslim Anger Persists (Washington, DC: Pew Research Center, 16 March 2004).

(Pew, 2003)
Pew Research Center for the People and the Press, Views of a Changing World 2003 (Washington, DC: Pew Research Center, 3 June 2003).

(PG&E, 2003)
Pacific Gas and Electric Company, "General Rate Case Application to the California Public Utilities Commission (A 02-11-017)", 2003.

(PG&E, 2001)
Pacific Gas and Electric Company, Diablo Canyon Independent Spent Fuel Storage Installation: Environmental Report (Avila Beach, California: PG&E, 21 December 2001).

(PG&E, 1985)

Pacific Gas and Electric Company, Reracking of Spent Fuel Pools, Diablo Canyon Units 1 and 2 (San Francisco, California: PG&E, September 1985).

(POGO, 2002)
Project on Government Oversight, Nuclear Power Plant Security: Voices from Inside the Fences (Washington, DC: Project on Government Oversight, 12 September 2002).

(Purdue, 2002)
Purdue University, "Purdue News: New simulation shows 9/11 plane crash with scientific detail", 10 September 2002.

(Raytheon, 2003)
Raytheon, Phalanx Close-In Weapon System (Tucson, Arizona: Raytheon Missile Systems, 2003).

(Raytheon, 2001)
Raytheon, News Release, Sentinel radar number 100 rolls-off Raytheon's Forest, Miss., production line, 13 March 2001.

(Reuters, 2004)
Reuters (Frankfurt), "Smokescreens to defend German nuke plants", 17 June 2004.

(Scarry, 2002)
Elaine Scarry, "A nuclear double standard", Boston Sunday Globe, 3 November 2002, page D11.

(Schwartz. 2004)
Stephen I. Schwartz, "A slow sort of security", Bulletin of the Atomic Scientists, July/August 2004, pp 18-19, 71.

(Sholly and Thompson, 1986)
Steven Sholly and Gordon Thompson, The Source Term Debate (Cambridge, Massachusetts: Union of Concerned Scientists, January 1986).

(Solomon, 2004)
John Solomon, "Bush officials to testify today on Capitol plane scare", The Boston Globe, 8 July 2004, page A6.

(Sozen et al, 2002)
Mete A. Sozen et al, "September 11 Pentagon Attack Simulations Using LS-Dyna: Phase I, Completed September 11, 2002", available at <http://www.cs.purdue.edu/homes/cmh/simulation/>.

(Sprung et al, 2000)
J. L. Sprung et al, Reexamination of Spent Fuel Shipment Risk Estimates, NUREG/CR-6672 (Washington, DC: US Nuclear Regulatory Commission, March 2000).

(Stern, 2004)
Jessica E. Stern, "Caliphate of Terror", Harvard Magazine, July-August 2004, pp 26-27, 87.

(Thompson, 2003)
Gordon Thompson, Robust Storage of Spent Nuclear Fuel: A Neglected Issue of Homeland Security (Cambridge, Massachusetts: Institute for Resource and Security Studies, January 2003).

(Thompson, 2002a)
Gordon Thompson, Declaration of 7 September 2002 in support of a petition to the US Nuclear Regulatory Commission by Avila Valley Advisory Council et al, regarding nuclear-facility operations at the Diablo Canyon site.

(Thompson, 2002b)
Gordon Thompson, Civilian Nuclear Facilities as Weapons for an Enemy: A submission to the House of Commons Defence Committee (Cambridge, Massachusetts: Institute for Resource and Security Studies, 3 January 2002).

(Thompson, 2000)
Gordon Thompson, Hazard Potential of the La Hague Site: An Initial Review (Cambridge, Massachusetts: Institute for Resource and Security Studies, May 2000).

(Thompson, 1999)
Gordon Thompson, Risks and Alternative Options Associated with Spent Fuel Storage at the Shearon Harris Nuclear Power Plant (Cambridge, Massachusetts: Institute for Resource and Security Studies, February 1999).

(Thompson, 1998)
Gordon Thompson, High Level Radioactive Liquid Waste at Sellafield: Risks, Alternative Options and Lessons for Policy (Cambridge, Massachusetts: Institute for Resource and Security Studies, June 1998).

(Thompson, 1996)
Gordon Thompson, War, Terrorism and Nuclear Power Plants (Canberra: Peace Research Centre, Australian National University, October 1996).

(Thompson and Sholly, 1991)
Gordon Thompson and Steven C. Sholly, No Restart for K Reactor (Cambridge, Massachusetts: Institute for Resource and Security Studies, October 1991).

(USN, 1999)
US Navy, Fact File, Phalanx Close-In Weapons System, US Navy website (www.chinfo.navy.mil/navpalib), updated 13 September 1999.

(Walters, 2003)

William Walters, "An Overview of the Shaped Charge Concept", paper presented at the 11th Annual ARL/USMA Technical Symposium, 5 and 7 November 2003. This symposium was sponsored by the Mathematical Sciences Center of Excellence at the US Military Academy (USMA) and hosted by the US Army Research Laboratory (ARL) and USMA.

(Weil, 2004)
Jenny Weil, "NAS study to urge NRC to step up spent fuel pool protections", Inside NRC, 28 June 2004.

(White House, 2003)
The White House, The National Strategy for The Physical Protection of Critical Infrastructures and Key Assets (Washington, DC: The White House. February 2003).

(White House, 2002)
The White House, The National Security Strategy of the United States of America (Washington, DC: The White House, September 2002).

CERTIFICATE OF SERVICE

I, Jack McGowan, certify that I have, on this date, caused the foregoing TESTIMONY OF GORDON THOMPSON ON BEHALF OF THE SAN LUIS OBISPO MOTHERS FOR PEACE, SIERRA CLUB, PUBLIC CITIZEN, GREENPEACE AND ENVIRONMENT CALIFORNIA to be served by electronic mail on the parties listed on the Service List, and by U.S. Mail for those who have not provided an electronic address, for the proceeding in California Public Utilities Commission Docket No. A.04-01-009.

I declare under penalty of perjury, pursuant to the laws of the State of California, that the foregoing is true and correct.

Executed on August 3, 2004, 2004 in San Francisco, California.

____

Jack McGowan