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PETITION TO THE U.S. NUCLEAR REGULATORY COMMISSION REQUESTING EMERGENCY ENFORCEMENT ACTIONS TO ADDRESS STRUCTURAL VULNERABILITY OF BOILING-WATER REACTORS WITH MARK I & II CONTAINMENTS AND THEIR IRRADIATED FUEL POOLS

Annex to the Petition

August 2004

Preface

The Nuclear Security Coalition, a consortium of independent organizations that serve the public interest, submits an accompanying Petition to the US Nuclear Regulatory Commission (NRC). This document, the Annex to the Petition, provides supporting information and is part of the Petition.

The Petition is submitted pursuant to NRC Regulations 10 CFR Part 2, Subpart B, whereby any person may request the NRC to institute a proceeding to impose requirements by order to modify, suspend or revoke the license of all GE Mark I and Mark II operators as necessary.

The NRC is obligated by the Atomic Energy Act of 1954, as amended, to take actions of the type requested in this Petition. The Act states in Title I, Chapter 1, Section 2(d):

> "The processing and utilization of source, byproduct, and special nuclear material must be regulated in the national interest and in order to provide for the common defense and security and to protect the health and safety of the public."

This Petition discusses potential destructive attacks on nuclear facilities, attacks that could cause great public harm. All information contained in this Petition was taken from publicly available documents. No information is contained in the Petition, including this Annex, which could assist the perpetrator of such an attack. Accordingly, this Petition and Annex are appropriate for general distribution.

Table of Contents

1. Introduction

The Petition that includes this Annex addresses a particular class of commercial nuclear reactors – boiling water reactors (BWRs) with Mark I and II containments. The relevant reactors are listed in the Appendix to this Annex. In the USA, 103 operational commercial reactors operate at 65 sites in 31 states.[1] Of these 104 reactors, 69 are pressurized-water reactors (PWRs), 9 with ice-condenser containments and 60 with dry containments. The remaining 34 reactors are BWRs, 22 with Mark I containments, 8 with Mark II containments and 4 with Mark III containments. In addition there are 27 previously-operating commercial reactors in various stages of storage or decommissioning. As of December 2000, all but 2 of the 103 operating reactors had been in service for at least 9 years, and 55 reactors had been in service for at least 19 years.[2] The nominal duration of a reactor operating license is 40 years.

All of the 103 operating reactors are vulnerable to accidents or acts of malice or insanity. Such an event could lead to a substantial release of radioactive material from a reactor to the environment. A similar release could occur from spent nuclear fuel stored in a pool adjacent to a reactor, or stored in an independent spent fuel storage installation (ISFSI).

The Mark I and II BWRs have a particular vulnerability that is explained in Section 6, below. This Petition calls for actions that address this class of reactors. In focusing on Mark I and II BWRs, the Petitioners do not imply that the vulnerability of other commercial reactors is less deserving of attention.

This Annex to the Petition provides important background information in Sections 2 through 5, below. Then, in Section 6, it explains the particular vulnerability of Mark I and II BWRs. Options to address structural vulnerabilities of these reactors and their irradiated fuel to terrorist attack are described in Section 7. The need to involve the public in addressing these vulnerabilities is described in Section 8. Actions sought by this Petition are set forth in Section 9, and a bibliography is provided in Section 10.

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[1] In addition, Browns Ferry Unit 1, a BWR with a Mark I containment, is nominally operational. However, the reactor is defueled and operation under Administrative Hold. The irradiated fuel pool is still operational, however.
[2] Data from the NRC website (www.nrc.gov), accessed on 24 April 2002.

2. Nuclear Power Plants are Critical National Infrastructure and Prime Targets

As the regulator of nuclear power plants and their spent fuel, the US Nuclear Regulatory Commission (NRC) bears a heavy responsibility for homeland security. The National Strategy for The Physical Protection of Critical Infrastructures and Key Assets (hereafter, the National Strategy), which was published in February 2003, identifies nuclear power plants as key assets, defined as follows: [3]

> "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".

President Bush, in his preface to the National Strategy, stated that the Strategy "establishes a foundation for building and fostering a cooperative environment in which government, industry, and private citizens can work together to protect our critical infrastructures and key assets".[4] The Petitioners share the conviction that broad cooperation is an essential ingredient of homeland security, and present this Petition in that spirit.

In a January 2004 speech, the Chairman of the National Intelligence Council, Robert Hutchings, commented on the potential for attacks on nuclear power plants and for deliberate release of radioactive material.[5] Hutchings stated:

> “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”.

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[3] White House, 2003, page 7.
[4] ibid, page iii.
[5] Hutchings, 2004.

Nuclear power plants and their irradiated fuel are especially likely to be targeted in a future attack on the US homeland, for symbolic and practical reasons. These facilities have a symbolic connection with nuclear weapons. The US government flaunts its superiority in nuclear weapons and rejects any constraint on these weapons through international law.[6] Yet, the government justified its invasion of Iraq in large part by the possibility that the Iraqi government might acquire a nuclear weapon. It would be prudent to assume that this situation will motivate terrorist groups to search for ways to attack US nuclear facilities. Also, nuclear power plants and Independent Spent Fuel Storage Installations (ISFSI) are large, fixed targets that are, at present, 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.

3. Addressing the Structural Vulnerability of Nuclear Power Plants is a National-Security Imperative

An attack on a US nuclear facility would be either an act of insanity or an act of malice. If malicious, the attack would support 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, in opposing them, the nation must balance the costs and benefits of offensive and defensive actions.

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:[7]

> "*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".

By requiring only a light defense for civilian nuclear facilities, the NRC is, in effect, rejecting the advice of the Council on Foreign Relations' task force. An explicit rejection of this type of advice was articulated by the former NRC chairman, Richard Meserve, in late 2002:[8]

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[6] Deller, 2002; Scarry, 2002.
[7] Hart et al, 2002, pp 14-15.
[8] Meserve, 2002a, page 22.

> "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."

In this statement, Meserve offers a false choice. To deter attack, the nation need not scrap every modern technology or infrastructure asset. Instead, the more attractive and vulnerable targets could receive a level of defense that substantially reduces the likelihood of a successful attack and the consequences of an attack. Replacement of the target with a more robust alternative would be an option if the cost of a stronger defense were prohibitive. However, the petitioners also regard reactor closure and dismantlement of these potential nuclear targets as a viable option to reduce, remove or harden its collaterally destructive profile and public safety threat.

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 civilian nuclear facilities.

4. The NRC Requires Only a Light Defense of Nuclear Power Plants

The NRC's basic policy on the protection of nuclear facilities from attack is laid down in the regulation 10 CFR 50.13. This regulation was promulgated in September 1967 by the US Atomic Energy Commission (AEC) -- which preceded the NRC -- and was upheld by the US Court of Appeals in August 1968. It states:[9]

> "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."

The AEC was motivated to introduce this regulation by the intervention of a citizen -- Paul Siegel -- in the construction-license proceeding for the Turkey Point nuclear power plants in Florida. Mr. Siegel argued that these plants might be attacked from Cuba. The AEC pre-empted any consideration of this issue during the license proceeding by initiating the rulemaking process that led to 10 CFR 50.13.

Although 10 CFR 50.13 limits a licensee's responsibility for defending a nuclear facility, this regulation does not prevent the US government from providing a stronger,

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

supplementary defense. This point was discussed by Richard Meserve, then chairman of the NRC, in an essay published in late 2002.[10] Meserve stated:[11]

> "Although NRC licensees must defend nuclear power plants against the DBT [design basis threat], September 11 revealed a type of attack that neither the NRC nor other agencies anticipated. Thus, the attacks demanded that the NRC and its licensees reevaluate the scope of potential assaults. There are limits, however, to what should be expected from a private guard force. For example, if it were determined that nuclear plants should be defended against aircraft attack, society would not expect licensees to acquire and operate anti-aircraft weaponry. Rather, this type of defense is better suited to the military."

Experience has forced the NRC to increase licensees' obligations to defend nuclear facilities. A series of events, including the 1993 bombing of the World Trade Center in New York, forced the NRC to introduce, in 1994, regulations requiring licensees to defend nuclear power plants against vehicle bombs. The terrorist events of 11 September 2001 forced the NRC to require additional measures. Nevertheless, present NRC regulations require only a light defense of nuclear facilities.

NRC Regulations for Site Security

Present NRC regulations 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 7, below, site security is one of four types of measure that, taken together, could provide a defense in depth against acts of malice or insanity. The other three types of measure are, with some limited exceptions, ignored in present NRC requirements for facility defense.[12]

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.

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[10] Meserve, 2002a.
[11] ibid, page 22.
[12] For information about the NRC's present regulations and requirements for nuclear-facility defense, see: the NRC website (www.nrc.gov), accessed on 23 May 2003; Markey, 2002; Meserve, 2002b; Meserve, 2003; and NRC, 2002.

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 Basis Threat

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. At a nuclear power plant, the dominant sources of hazard are the reactor and the spent-fuel pool(s). In theory, both of these items receive the same level of protection, but in practice the reactor has been the main focus of attention. The DBT for an ISFSI is less demanding than that for a nuclear power plant.

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:[13]

> "(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."

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[13] 10 CFR 73.1, Purpose and Scope, from the NRC web site (www.nrc.gov), accessed on 2 September 2002.

For an ISFSI, the DBT was the same as for a nuclear power plant except that 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 an old reactor site. Thus, an ISFSI at a reactor site would be less protected than the reactor(s) and irradiated 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.

Evolution of the DBT

After the events of 11 September 2001, 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".[14] The additional measures required by these orders were not publicly disclosed, but the NRC Chairman stated that they included:[15]

(i) increased patrols;
(ii) augmented security forces and capabilities;
(iii) additional security posts;
(iv) vehicle checks at greater stand-off distances;
(v) enhanced coordination with law enforcement and military authorities;
(vi) additional restrictions on unescorted access authorizations;
(vii) plans to respond to plant damage from explosions or fires; and
(viii) assured presence of Emergency Plan staff and resources.

In addition to requiring these additional security measures, the NRC 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.

The NRC has described its new, revised DBT for nuclear power plants as follows:[16]

> "The Order that imposes revisions to the Design Basis Threat requires power plants to implement additional protective actions to protect against sabotage by

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[14] The quoted language is from page 2 of the NRC's order of 25 February 2002 to all operating power reactor licensees. Almost-identical language appears in the NRC's orders of 23 May 2002 to all decommissioning power reactor licensees and 16 October 2002 to all ISFSI licensees who also hold 10 CFR 50 licenses.
[15] Meserve, 2002b.
[16] NRC Press Release No. 03-053, 29 April 2003.

> terrorists and other adversaries. The details of the design basis threat are safeguards information pursuant to Section 147 of the Atomic Energy Act and will not be released to the public. This Order builds on the changes made by the Commission's February 25, 2002 Order. 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. It was arrived at after extensive deliberation and interaction with cleared stakeholders from other Federal agencies, State governments and industry."

Inferred Characteristics of the New DBT

Although the new DBT for nuclear power plants was not published, 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 reluctance by the NRC to contest that resistance.[17] Fourth, available information shows no marked change in prevailing practices of site security.[18]

Thus, it can be inferred that 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 an attack by water or submerged charge targeting the cooling water intake. It probably does not allow for antitank 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 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, 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.

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[17] Hirsch et al, 2003.
[18] POGO, 2002; Brian, 2003.

5. Nuclear Power Plants and Irradiated Fuel are Vulnerable to Attack

It is not appropriate to publish a detailed discussion of scenarios whereby a nuclear power plant or an ISFSI might be successfully attacked. However, it must be assumed 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 USA. This material is archived at many locations around the world. Thus, a public discussion, in general terms, of potential modes and instruments of attack will not assist attackers. Indeed, such a discussion is needed to ensure that appropriate measures are taken to address structural vulnerabilities of reactor containments and irradiated fuel storage.[19]

Safety Systems and their Vulnerability

The safe operation of a US commercial reactor and its associated irradiated 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. A variety of 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. Irradiated fuel pools have thick concrete walls but are typically covered by lightweight structures.

Attack through Brute Force or Indirectly?

A group of attackers equipped with highly-destructive instruments could take a brute-force approach to attacking a reactor or an irradiated fuel pool. Such an approach would aim to directly breach the reactor containment and primary cooling circuit, or to breach the wall or floor of an irradiated fuel pool. Alternatively, the attacking group could take an indirect approach, and many such approaches will readily suggest themselves to technically-informed attackers. Insiders, or outsiders who have taken over the plant, could obtain a release of radioactive material without necessarily employing destructive instruments. Some attack scenarios will involve the disabling of plant personnel, which could be accomplished by armed attack, use of lethal chemical weapons, or radioactive contamination of the site by an initial release of radioactive material.

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

Vulnerability of ISFSIs

Dry-storage ISFSIs differ from reactors and irradiated fuel pools in that their operation is entirely passive. Thus, each dry-storage container in an ISFSI must be attacked directly. To obtain a release of radioactive material, the wall of the fuel container must be penetrated from the outside, or the container must be heated by an external fire to such an extent that the containment envelope fails. The attack could also exploit stored chemical energy in the zirconium cladding of the spent fuel. Combustion of this cladding in air, if initiated, would generate heat that could liberate radioactive material from the fuel to the outside environment. A knowledgeable attacker could combine penetration of the fuel container with the initiation of combustion.

Requirements for a Vulnerability Study

Every US commercial reactor has been subjected to a probabilistic risk assessment (PRA) or equivalent study.[20] This analysis examined the reactor's potential to experience accidents due to human error, equipment failure or natural forces (e.g., earthquake), but did not consider acts of malice or insanity. Few irradiated fuel pools or ISFSIs have been subjected to a PRA-type study or a study of its vulnerability to acts of malice or insanity. Indeed, there has never been a comprehensive study of the vulnerability of any US nuclear facility to acts of malice or insanity. Spurred by the attacks on the World Trade Center and Pentagon in September 2001, the NRC has sponsored some secret studies on nuclear-facility vulnerability. However, available information shows that these studies are narrow in scope and will provide limited guidance regarding the overall vulnerability of nuclear facilities.[21]

A comprehensive study of a facility's vulnerability would begin by identifying a range of potential attacks on the facility. The probability of each potential attack would be qualitatively estimated, with consideration of the factors (e.g., international events, changing availability of instruments of attack) that could alter the probability over time. Site-specific factors affecting the feasibility and probability of attack scenarios include local terrain and the proximity of coastlines, airports, population centers and national symbols. A variety of modes and instruments of attack would be considered.

After identifying a range of potential attacks, a comprehensive study would examine the vulnerability of the subject facility to those attacks. This could be done by adapting and extending known techniques of PRA, with an emphasis on the logical structure of PRA

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

[21] The NRC's Office of Research Programs has stated (NRC, 2003, page 11): "During 2003 Research will complete the realistic engineering assessments of the vulnerability of nuclear power reactors to aircraft attack and the vulnerability of spent fuel pools to explosive attacks. Two pilot plant assessments are underway to assess the threats and identify any additional potential mitigation options." Although potentially useful, these assessments could yield only a fraction of the information that would be contained in a comprehensive assessment of vulnerability.

rather than the numerical probabilities of events. The analysis would consider the potential for interactions among facilities at a site. For example, a potentially important interaction could be the prevention of personnel access at one facility (e.g., an irradiated fuel pool) due to a release of radioactive material at another facility (e.g., a reactor). Attention would be given to the potential for "cascading" scenarios in which attacks at some parts of a nuclear-power-plant site (e.g., control room, switchyard, diesel generators) lead to releases from reactors and/or irradiated fuel pools that were not directly attacked.

Vulnerability of Irradiated Fuel Pools

The vulnerability of irradiated fuel pools deserves special mention for two reasons. First, each pool now contains an amount of long-lived radioactive material that is substantially larger than the amount in a reactor core. Second, loss of water from a pool will cause some or all of the fuel in the pool to self-ignite and burn, releasing a large amount of radioactive material to the atmosphere.[22] The potential for a fire exists because the pools have been equipped with high-density racks. In the 1970s, the irradiated fuel pools of US nuclear power plants were typically equipped with low-density, open-frame racks. If water were partially or totally lost from such a pool, air or steam could circulate freely throughout the racks, providing convective cooling to the irradiated fuel. By contrast, the high-density racks that are used today 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. 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.

If water is totally lost from a high-density pool, air will pass downward through available gaps such as the gap between the pool wall and the outer faces of the racks, will travel horizontally across the base of the pool, will enter each rack cell through a hole in its base, and will rise upward within the cell, providing cooling to the irradiated fuel assembly in that cell. If the fuel has been discharged from the reactor comparatively recently, the flow of air may be insufficient to remove all of the fuel's decay heat. In that case, the temperature of the fuel cladding may rise to the point where a self-sustaining, exothermic oxidation reaction with air will begin. In simple terms, the fuel cladding -- which is made of zirconium alloy -- will begin to burn. The zirconium-alloy cladding can also enter into a self-sustaining, exothermic oxidation reaction with steam. 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.

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[22] The NRC has published a variety of technical documents that address irradiated fuel-pool fires. The most recent of these documents is: Collins et al, 2000. For more recent analyses of irradiated fuel-pool fires, see: Alvarez et al, 2003; Thompson, 2003; and Thompson, 2002. 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.

In many scenarios for loss of water from a pool, the flow of air that is described in the preceding paragraph will be blocked. For example, a falling object (e.g., a fuel-transfer cask) might distort rack structures, thereby blocking air flow. An attack might cause debris (e.g., from the roof of the fuel handling building) to fall into the pool and block air flow. The presence of residual water in the bottom of the pool would also block air flow. In most scenarios for loss of water, residual water will be present for significant periods of time. Falling debris from burning fuel assemblies could block air flow to nearby fuel assemblies that have not yet ignited. Blockage of air flow, for whatever reason, will lead to ignition of fuel that has been discharged from a reactor for long periods -- potentially 10 years or longer.

Modes and Instruments of Attack

A nuclear power plant or an ISFSI could be attacked using one or more of a variety of modes and instruments. Table 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 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.[23] The testimony stated:[24]

> "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."

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[23] Dillingham, 2003.
[24] ibid, page 14.

Table 1
Potential Modes and Instruments of Attack on a Nuclear Power Plant[25]

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
Commando-style by water	• Could involve heavy weapons/sophisticated tactics • Could target intake canal • Attack may be planned to coordinate with a land attack	• 500 yard no entry zone – marked by buoys – simply, "no trespassing" signs • Periodic Coast Guard surveillance by boat or plane
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

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 been used for decades. 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

[25] Adapted from Table 1 of: Thompson, 2003.

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.

The largest known shaped charge was the German MISTEL, developed late in World War II. This warhead was 2 meters in diameter, weighed 3,500 kg and contained 1,700 kg of explosive. It was carried in the nose of an unmanned bomber aircraft. The Japanese used a smaller version of this device, the SAKURA bomb, for kamikaze attacks against US warships.[26]

A US government laboratory has developed, and described in a published report, a shaped-charge warhead specifically intended to penetrate large thicknesses of rock or concrete. This warhead would be mounted in the nose of a cruise missile. The warhead has a diameter of 28 inches and a length of 28.5 inches. It weighs 900 pounds and contains 600 pounds of Octol explosive. When tested in November 2002, this device created a hole of 10 inches diameter in tuff rock to a depth of 19.5 feet.[27]

6. Mark I & II BWRs Have a Particular Vulnerability to Attack

A Mark I or II BWR has its irradiated fuel pool mounted high above the ground. The outer wall of the pool is a few feet inside one of the outer faces of the reactor building. The surface of the pool and the remainder of the refueling floor of the reactor are covered by a lightweight roof and wall structure. This arrangement makes the pool vulnerable to attack from above, below or the side. If a pool is breached, there is no surrounding structure or backfill to inhibit the drainage of water. The reactor vessel, like the pool, is above ground. Its cooling systems and containment are vulnerable to attack at several points. The exterior configuration of the reactor building facilitates accurate aiming (e.g., of an explosive-laden aircraft) by a knowledgeable attacker. Taken together, these factors could make a Mark I or II BWR a comparatively attractive target of attack.

7. Options are Available for Stronger Defense of Mark I & II BWRs

Four categories of defensive measures, taken together, could provide a stronger defense of Mark I and II BWRs. The four categories are: (i) site security; (ii) facility robustness; (iii) damage control; and (iv) emergency response planning. The degree of protection provided by these measures would be greatest if they were integrated into the design of a nuclear plant before its construction. However, a comprehensive set of measures could provide significant protection at the existing Mark I and II BWRs.

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[26] Walters, 2003.

[27] This citation is voluntarily withheld by the Petitioners.

Site Security

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 measure fall into this category. Measures of the first type would be implemented at offsite locations, and the implementing agencies might have no direct connection with the site. Airline or airport security measures are examples of measures in this category. Measures of the second type would be implemented at or near the site. Implementing agencies would include the licensee, the NRC and other entities (e.g., National Guard).

The physical protection measures now required by the NRC, as discussed in Section 4, above, are examples of site-security measures of the second type. More stringent measures of this type could be introduced for consideration in the public debate and development of compensatory security measures, such as:

(i) establishment of a mandatory aircraft-exclusion boundary around the site;
(ii) deployment of an aircraft-detection system (e.g., Sentinel) that triggers a succession of security alerts as the exclusion boundary is approached and crossed;
(iii) deployment of an automated system (e.g., Phalanx) to destroy aircraft at short range if they are closing on the plant;
(iv) expansion of the DBT, beyond that now applicable to a nuclear power plant, to include additional intruders, heavy weapons, aircraft attack, lethal chemical weapons and more than one vehicle bomb; and
(v) any ISFSI on the site to receive protection equivalent to that provided for a nuclear power plant.

Facility Robustness

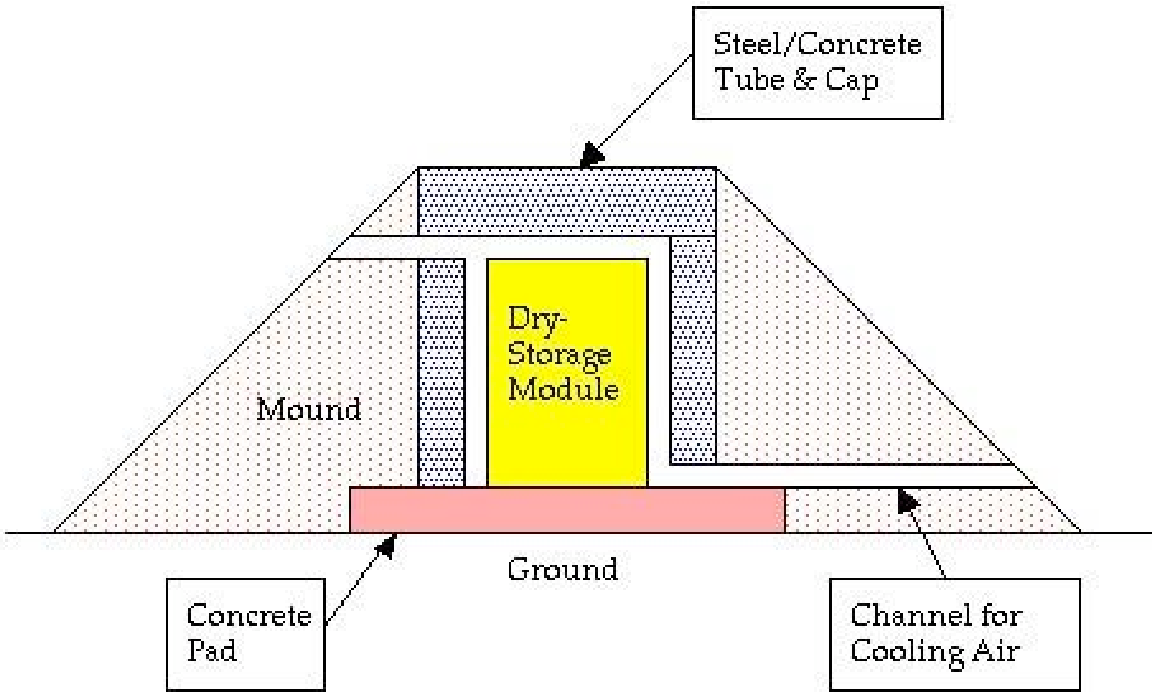
Facility-robustness measures are those that improve the ability of a nuclear facility to experience destructive acts of malice or insanity without a significant release of radioactive material to the environment. In illustration, the PIUS reactor design, developed by the reactor vendor ASEA-Atom but never built, was intended to withstand aerial bombardment by 1,000-pound bombs without suffering core damage or releasing a significant amount of radioactive material to the environment.[28] A new reactor or ISFSI could be constructed with a similar degree of robustness.

At the existing Mark I and II BWRs, a variety of opportunities are available for enhancing robustness. As a high-priority example, spent-fuel pools could be re-equipped with low-density racks, so that irradiated fuel would not ignite if water were lost from a pool. As a second example, the reactor could be permanently shut down or could operate at reduced power, either permanently or at times of alert. If the reactor were shut down, its irradiated fuel could be transferred to an onsite ISFSI that employs hardened, dispersed, dry storage. Figure 1, below, shows a possible design for hardening of the storage

[28] Hannerz, 1983.

modules used in such an ISFSI. To reduce the inventory in the pool, irradiated fuel could be transferred to an onsite ISFSI that employs hardened, dispersed, dry storage.

Figure 1
Schematic View of a Possible Design for Hardened, Dry Storage of Irradiated Fuel[29]



Notes

(i) An ISFSI could employ a number of hardened storage modules in a dispersed configuration.
(ii) Cooling channels would be inclined, to prevent pooling of jet fuel, and would be configured to preclude line-of-sight access to the dry-storage module.
(iii) The tube, cap and pad surrounding the dry-storage module would be tied together with steel rods, and spacer blocks would prevent the module from moving inside the tube.
(iv) The steel/concrete tube could be buttressed by several triangular panels connecting the tube and the base pad.

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29 Adapted from Figure 2 of: Thompson, 2003.

If the reactor were not shut down, robustness of the plant could be enhanced by an integrated set of measures such as:

> (i) automated shutdown of the reactor upon initiation of a specified alert status at the plant, with provision for completion of the automated shutdown sequence if the control room is disabled;
> (ii) permanent deployment of diesel-driven pumps and pre-engineered piping to be available to provide emergency water supply to the reactor and the irradiated fuel pool;
> (iii) re-equipment of the irradiated fuel pool with low-density racks, excess fuel being stored in an onsite ISFSI; and
> (iv) construction of the ISFSI to employ hardened, dispersed, dry storage.

Damage Control

<u>Damage-control measures</u> 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. One illustration of a damage-control measure would be a set of arrangements for patching and restoring water to an irradiated fuel pool that has been breached. Other illustrations can be provided. It appears that the NRC has required licensees to undertake some planning for damage control following explosions or fires.[30] Additional measures could be appropriate, including:

> (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 any ISFSI on the site, and provision of cooling to a reactor whose support systems and control room are disabled -- with accompanying detailed plans; and
> (iv) provision of equipment and training to allow damage control to proceed on a radioactively-contaminated site.

[30] Meserve, 2002b.

Offsite Emergency Response

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.[31] 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.

Overall, an appropriate way to improve emergency-response capability at a nuclear-power-plant site could be to implement a model emergency response plan that was developed by a team based at Clark University in Massachusetts.[32] This model plan was specifically designed to accommodate radioactive releases from spent-fuel-storage facilities, as well as from reactors. That provision, and other features of the plan, would provide a capability to accommodate both accidental releases and malice- or insanity-induced releases. Major features of the model plan include:[33]

(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[34];
(iv) criteria for long-term protective actions;
(v) three planning zones, with the outer zone extending to any distance necessary[35];
(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;

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[31] 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.
[32] Golding et al, 1992.
[33] ibid, pp 8-13.
[34] A security alert could be a condition calling for a precautionary response.
[35] 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 predistributed within the 25-mile zone and made generally accessible nationwide.

(x) improved medical response;
(xi) enhanced capability for information exchange;
(xii) more emphasis on drills, exercises and training;
(xiii) improved public education and involvement; and
(xiv) requirement that emergency preparedness be regarded as a safety system equivalent to in-plant systems.

8. The Public Should be Involved in Addressing the Structural Vulnerabilities of Reactor Containments and Irradiated Fuel

Determining the general type and level of defense to be provided at a commercial nuclear facility should be a matter for open, democratic debate. This matter is, albeit at a smaller scale, analogous to determining the type and level of defense for the nation. Experience shows clearly that an open, democratic debate on national defense is necessary to preserve the Republic and provide an effective, cost-efficient defense.

When defenses are being developed for a particular nuclear facility, some details of the defenses will not be appropriate for general distribution. However, designated representatives of local and state governments and citizen groups should be allowed access to these details, to ensure that defenses are deployed according to the general plan that has been approved through open, democratic debate. NRC regulations already contain provisions whereby, in the context of nuclear-licensing proceedings, intervenors' designated representatives can have access to safeguards information.

9. Actions Sought by this Petition

The Petitioners request that the NRC takes the following actions:

(i) issue a Demand For Information to the licensees for all Mark I and II BWRs and conduct a 6-month study of options for addressing structural vulnerabilites;

(ii) present the findings of the study at a national conference attended by all interested stakeholders, providing for transcribed comments and questions;

(iii) develop a comprehensive plan that accounts for stakeholder concerns and addresses structural vulnerabilities of all Mark I and II BWRs within a 12-month period;

(iv) issue Orders to the licensees for all Mark I and II BWRs compelling incorporation of a comprehensive set of protective measures; and

(v) make future operation of each Mark I and II BWR contingent on addressing their structural vulnerability with participation and oversight by a panel of local stakeholders.

The Demand For Information will require the licensees to provide answers to the following questions:

1. What is the current licensed capacity and inventory for spent fuel assembly storage in the spent fuel pool?
2. What is the projected number of spent fuel assemblies to be discharged from the reactor core in the next five and ten years?
3. What is the calculated decay heat load on the spent fuel pool from the current inventory and licensed capacity of spent fuel assemblies?
4. What is the calculated decay heat load on the spent fuel pool from the inventory of spent fuel assemblies projected to be discharged from the reactor core in the next five and ten years?
5. What is the radionuclide inventory of the spent fuel pool at its design basis loading?
6. What is the water volume of the spent fuel pool?
7. What is the design heat removal capacity of the spent fuel pool cooling system?
8. Is the facility licensed for onsite dry storage of spent fuel? If so, how many spent fuel assemblies are currently in dry storage?
9. What are the spent fuel pool water makeup capabilities (sources and flow rates)?
10. What are the results from studies, evaluations, and/or analyses conducted on the vulnerability of the spent fuel pool to (a) aircraft, (b) tornado-generated missiles, and (c) fires?

11.

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U.S. Commercial Reactors with Elevated Irradiated Fuel Storage Ponds

General Electric Boiling Water Reactor MARK I Containments (24 units)

Browns Ferry 1, 2 and 3	Decatur, AL
Brunswick 1 & 2	Southport, NC
Cooper	Brownville, NB
Dresden 2 & 3	Morris, IL
Duane Arnold	Palo, IA
Edwin Hatch 1 & 2	Baxley, GA
Fermi 2	Monroe, MI
Hope Creek	Artificial Island, NJ
Fitzpatrick	Scriba, NY
Millstone 1	Waterford, CT
Monticello	Monticello, MN
Nine Mile Point Unit 1	Scriba, NY
Oyster Creek	Lacey Township, NJ
Peach Bottom 2 & 3	Delta, PA
Pilgrim 1	Plymouth, MA
Quad Cities 1 & 2	Cordova, IL
Vermont Yankee	Vernon, VT

General Electric Boiling Water Reactor MARK II Containments (8 units)

LaSalle 1 & 2	Seneca, IL
Limerick 1 & 2	Pottstown, PA
Nine Mile Point Unit 2	Scriba, NY
Susquehanna 1 & 2	Berwick, PA
WNP-2 (Columbia)	Richland, WA

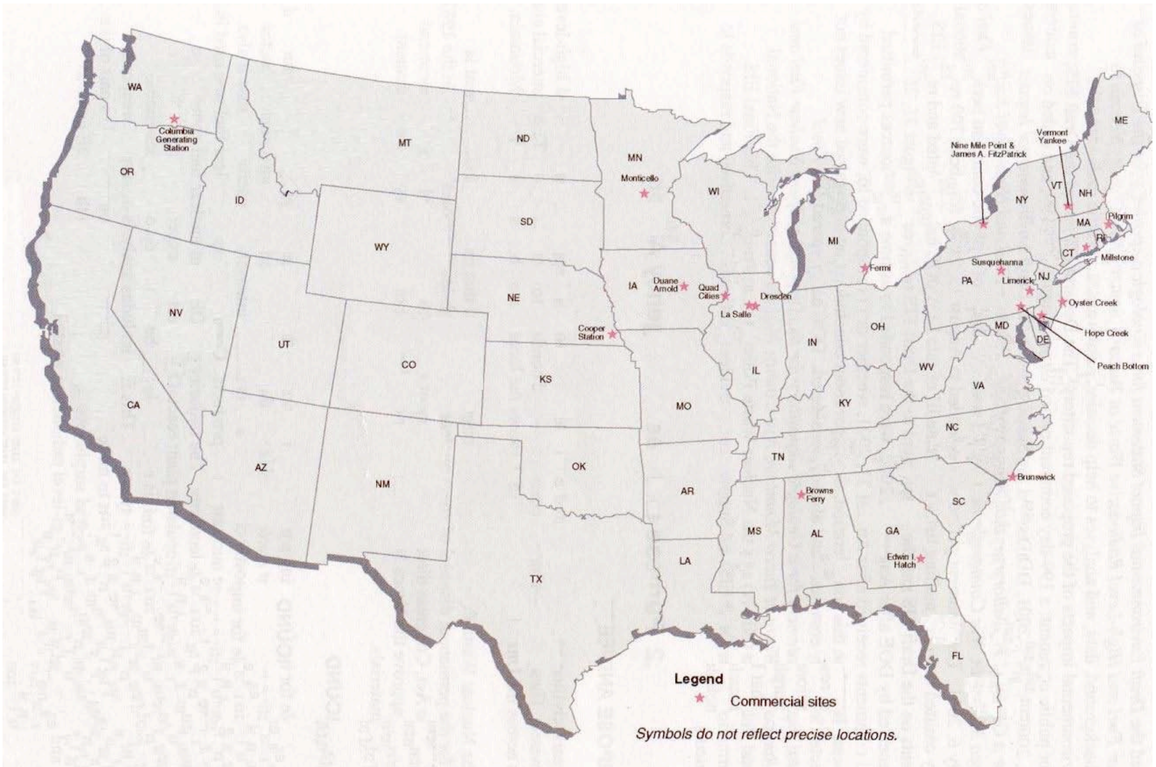
Petition Sign-On Groups To Date July 22, 2004

National Groups	Greenpeace Institute for Resource and Security Studies Nuclear Information & Resource Service Public Citizen Union of Concerned Scientists

LOCAL/ REGIONAL GROUPS	REACTORS
Alliance for Nuclear Accountability	Columbia Generating Station
Cape Downwinders	Pilgrim
Citizens Awareness Network Central New York chapter Connecticut chapter Vermont chapter Massachusetts chapter	 FitzPatrick Nine Mile Point 1 & 2 Millstone 1 Vermont Yankee Pilgrim Vermont Yankee
Citizens Campaign for the Environment	FitzPatrick Millstone 1 Nine Mile Point 1 & 2
Citizens' Environmental Coalition	FitzPatrick Nine Mile Point 1 & 2
Citizens' Regulatory Commission	Millstone 1
Citizens Resistance Against Fermi 2	Fermi 2
Clean Water Action	Pilgrim
Coalition for a Nuclear Free Great Lakes	Fermi 2
Coalition for Peace and Justice	Hope Creek
Don't Waste Michigan	Fermi 2
Earth Care	Duane Arnold
EFMR Monitoring Group	Peach Bottom 2 & 3
Environmental Coalition on Nuclear Power	Limerick 1 & 2 Peach Bottom 2 & 3 Susquehanna 1 & 2
Finger Lakes Citizens for the Environment	FitzPatrick Nine Mile Point 1 & 2
Georgians Against Nuclear Energy	Hatch 1 & 2
Heart of America Northwest	Columbia Generating Station
Independent Environmental Conservation & Activism Network	Duane Arnold Quad Cities 1 & 2
Justice Through Peace Initiative	FitzPatrick Nine Mile Point 1 & 2

Kids Against Pollution	FitzPatrick Nine Mile Point 1 & 2
Lakeshore Environmental Action	FitzPatrick Nine Mile Point 1 & 2
Massachusetts-Public Interest Research Group	Pilgrim
Nebraskans for Peace	Cooper
New England Coalition	Vermont Yankee
New Jersey-Public Interest Research Group	Hope Creek Oyster Creek
New York-Public Interest Research Group	FitzPatrick Nine Mile Point 1 & 2
North American Water Office	Monticello
North Carolina-Waste Awareness and Reduction Network	Brunswick 1 & 2
Nuclear Energy Information Service	Dresden 2 & 3 LaSalle 1 & 2 Quad Cities 1 & 2
Nuclear Free Vermont	Vermont Yankee
People's Environmental Network of New York	FitzPatrick Nine Mile Point 1 & 2
Pilgrim Watch	Pilgrim
Plymouth County Nuclear Information Committee	Pilgrim
Southern Alliance for Clean Energy	Browns Ferry 1, 2, & 3 Hatch 1 & 2
Syracuse Peace Council	FitzPatrick Nine Mile Point 1 & 2
TMI Alert	Peach Bottom 2 & 3 Susquehanna 1 & 2
UNPLUG Salem Campaign	Hope Creek

Map of U.S. Commercial Reactor Sites with Mark I and/or Mark II Boiling Water Reactors



<u>Diagram of GE Mark I Reactor Building and Elevated Irradiated Fuel Storage Pond</u>

"Mark I and Mark II secondary containments generally do not appear to have any significant structures that might reduce the likelihood of aircraft penetration, although a crash into 1 of 4 sides of a BWR secondary containment may be less likely to penetrate because other structures are in the way of the aircraft."

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