RISK CHARACTERIZATION

OF THE POTENTIAL CONSEQUENCES

OF AN ARMED TERRORIST GROUND ATTACK

ON A U.S. NUCLEAR POWER PLANT

An Assessment
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RISK CHARACTERIZATION OF THE POTENTIAL CONSEQUENCES OF AN ARMED TERRORIST GROUND ATTACK ON A U.S. NUCLEAR POWER PLANT

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ABSTRACT

Following the tragic events of September 11, 2001, both the Federal Government and the owners and operators of commercial nuclear power plants have engaged in significant efforts to ensure continuing high standards of public health and safety can be maintained, in light of this new domestic threat to our nation's infrastructure. This study assesses the consequences of an armed attack on a U.S. nuclear power plant, using risk analysis techniques. This probabilistic treatment of the terrorist threat to a nuclear plant is appropriate because of the relatively low likelihood that threats will propagate to severe consequences and is consistent with NRC's policy to implement risk-informed approaches to reactor safety matters.

Therefore, this study evaluates both the likelihood and consequences of armed terrorist ground attacks against commercial nuclear facilities. Specifically, the study evaluates prompt fatalities, latent cancer fatalities, and areas of contaminated farmland as consequences. The risk results are presented as cumulative distribution functions; that is, plots of cumulative frequency versus magnitude for each consequence. The results show that the risk to the public from a core damage event caused by such an attack is small, comparable to or less than the risk from other types of radiological accidents already analyzed in the design and licensing of US commercial plants. This result is due to the unique physical security at commercial nuclear plant sites, the extra strength of the reactor and containment design, and detailed emergency response plans, which together make it very unlikely that terrorists could cause a significant radioactive release.

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EXECUTIVE SUMMARY

The purpose of this study is to respond to a request to the Nuclear Energy Institute (NEI) from the Nuclear Regulatory Commission (NRC) regarding the consequences of a hypothetical terrorist ground attack on a commercial nuclear power plant. The Department of Homeland Security (DHS) has an interest in this question, since allocation of federal resources for infrastructure protection and attack response both depend on realistic assessments of the likelihood of an attack and the likely consequences. Congress has an interest in this question as well. This report addresses the above needs, and provides insights of value to nuclear plant operators.

OVERALL APPROACH

The approach taken in this study to address the possible effects of a terrorist ground attack on a commercial nuclear plant is to consider the consequences in a risk context. While risk methods, i.e., methods involving estimates of both probability and consequences of events implemented with a probabilistic risk assessment (PRA), have been widely used in assessing commercial nuclear power plant safety, and to a lesser extent the safety of other industrial facilities, very few attempts have been made historically to apply these methods to terrorist attacks. Thus, this is one of, if not the first, industry-initiated risk analysis to address commercial nuclear plant terrorist scenarios.

Despite the fact that the data for assessing nuclear plant terrorist attack risk is not as extensive as that for other types of nuclear plant risk, data from non-nuclear plant terrorist events, information from nuclear plant security inspections by NRC, and expert input from nuclear plant design and security professionals are being used as input for the probabilistic part of this work, and are considered adequate to support the frequency estimates in the study. The consequence work uses state of the art tools and plant design input data.

A risk context is being used for several reasons:

- Risk to the public is the essential basis for decision-making by federal agencies responsible for allocating resources for public health and safety purposes.
- It is important to account for the fact that risk to the public is some combination of high probability-less severe consequence events, and low probability-higher consequence events.
- There is in fact a relatively low likelihood that terrorist threats at a nuclear plant will propagate to severe consequences. The unique physical security, extra strength of the reactor and containment design, and detailed emergency response plans for the public lead to a significant likelihood that terrorists would fail to cause a radioactive release or severe public health effects - even if they were successful at overwhelming the site. Therefore, considering only the consequences of a “worst case” scenario is not considered meaningful.

A final reason for using a risk context for the evaluation of a terrorist attack at a nuclear plant is to provide a basis for future comparisons with other elements of our national infrastructure that may have little or no comparable protection and inherent resistance to attack. Examples of infrastructure elements that offer little resistance to attack include: large, heavily populated office and commercial buildings, large public gathering areas such as shopping malls and stadiums, chemical plants, and elements of our national electric grid system and our natural gas pipeline systems. Other elements of our national infrastructure are better protected or inherently resistant to severe consequences, some approaching the level of resistance of a nuclear plant.

Risk to the public is an important consideration by owners and operators of infrastructure facilities, who are responsible for protecting their assets and the surrounding public. This is the only balanced, objective way to characterize and compare potential health and safety concerns for a spectrum of potential targets to affected stakeholders.

ANALYSIS APPROACH

The approach used here employs three sequential risk analysis steps, the result of which is a simplified analog to the three levels of a PRA for nuclear plants: Level 1 (probabilistic analysis of specific accident scenarios), Level 2 (analysis of radionuclide release from containment), and Level 3 (analysis of health consequences to the public).

For the probabilistic analysis, a two-phase event tree approach was used. The first phase is an event tree that characterizes the key attributes and estimates the likelihoods for a spectrum of potential ground-based armed terrorist threats ranging from the threats that are within the existing design basis up to a very large organized attack. (Note that airplane impacts are not considered in this work.) The second phase is an event tree, which, for each of the threats from the first event tree, characterizes the plant damage scenarios, including emergency core cooling system and containment damage, the radionuclide release path, timing of the initial release, and the likelihood of each scenario.

For each of the resulting scenarios, a radionuclide release to the environment (i.e., a source term) was calculated. A combination of the latest research on fission product phenomena and best estimate analysis of core damage and containment severe accident response was used in order to provide realistic estimates of radionuclide release to the environment—its magnitude, radioisotope makeup, and duration and distribution over time.

Each source term was then input to an offsite consequence analysis simulation code, which calculates three effects on the public – prompt fatalities, latent cancer fatalities, and land contamination. The offsite consequence code simulates releases representing a full year of observed, hourly meteorological conditions for the site. The frequency of each scenario is then used in combination with the consequence analyses to provide a cumulative complementary distribution function (CCDF) for each effect. The CCDF presents the expected frequency of any severity level of the consequence of interest.

The analysis was performed for a representative U.S. nuclear plant. The analysis plant was a nominally 1000 MWe PWR with a large dry containment. The plant site analyzed was a composite site, with conservative meteorology from one site and conservative demography (e.g., population density) from another site, which is expected to yield a more conservative estimate of

public health risks than for an average plant site. Emergency response of the public was modeled from publicly available information for an actual plant for which a Level 3 analysis already has been performed.

In summary, the risk analysis produces a probabilistic consequence assessment for armed terrorist ground attack scenarios. There are limitations in the analysis because the data for assessing the likelihood of nuclear plant ground terrorist attack success is not as extensive as that for other types of nuclear plant risk, because of the simplified event tree approach that selected representative scenarios for analysis (as opposed to exhaustive quantification of all scenarios that could be hypothesized), and because it examines only ground attack scenarios. Nonetheless, the analysis is considered complete enough to provide meaningful risk results to support comparison with risks presented by other elements of our national infrastructure, when available.

RESULTS OF THE ANALYSIS

The health effects from exposure to an accidental radioactive release are grouped in two broad categories: acute exposure effects, which include prompt fatalities that occur within approximately one month of the exposure; and chronic exposure effects, which include latent cancer fatalities projected by computer models out to thirty years from the time of the exposure. The effect on land contamination is also considered.

The risks to the public from terrorist-induced accidental radioactive release are small. There are two reasons for this:

- The probabilities of terrorist scenarios leading to core damage at a given plant are low. This is attributable to several factors: 1) low likelihood of a threat to a specific plant, 2) high likelihood that the threat will be thwarted before an attack can be launched that could be successful in taking over the plant, and 3) low likelihood that a successful attack could ultimately lead to core damage and release. The first factor, assessed at a frequency of one in 2500 years, is considered to be not under the plant owner/operator control. The relative likelihood of such a threat is determined in large part by the effectiveness of Federal and other government agencies in detecting and preventing the attack. The second factor is assessed as about 35% of attempted attacks not being thwarted prior to plant damage. The third factor is –assessed at about 5% of attempted attacks result in core damage, and about 1% result in a release. Figure ES-1 illustrates the recurrence intervals associated with these factors.

- Even if a core damage accident occurs from terrorist attack, the consequences to the public are not likely to be severe. This is attributable to three factors:
  - even for extreme types of scenarios, the containment is able to remove a significant fraction of the radioactive release before it escapes to the environment,
  - core damage tends to occur over several hours or a longer period, thus allowing time for emergency response measures to be taken, and
  - longer-term recovery from the accident is likely.

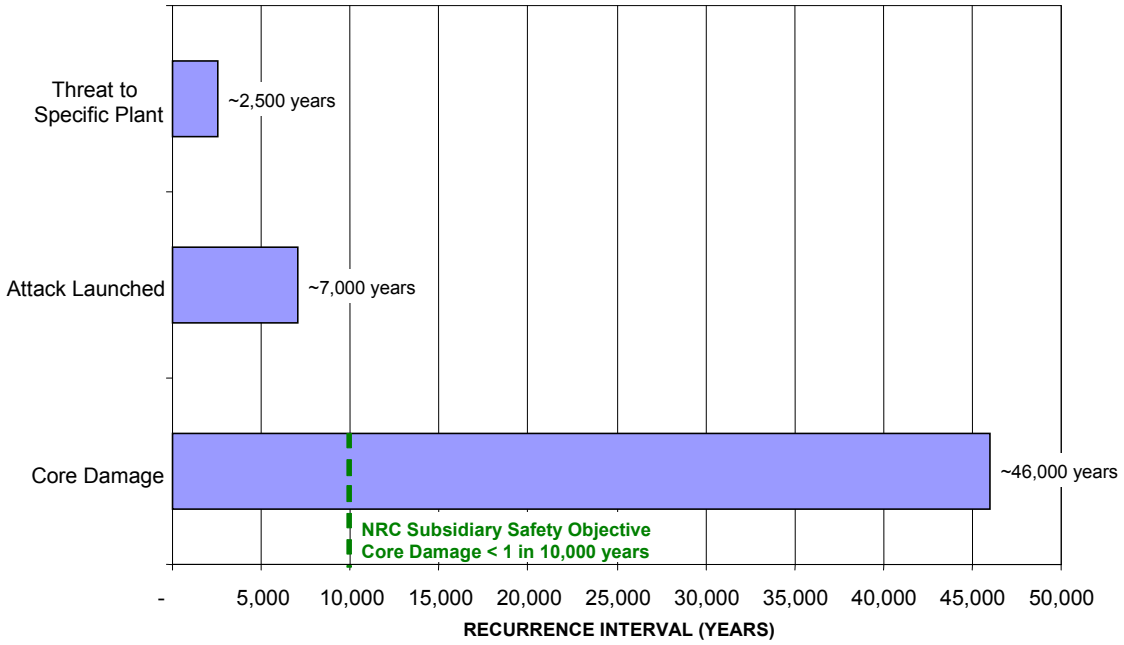

Figure ES-1 Recurrence Interval for Extent of Terrorist Threat

Prompt Fatalities

The risk of prompt fatalities to any member of the public from all potential scenarios considered from terrorist ground attack is small. The chance of one prompt fatality is less than one per 600,000 reactor years. Less than seven percent of the releases result in any prompt fatalities. Should core damage and radiological release occur, the mean number of prompt fatalities is estimated to be about 2. For more severe releases (i.e., those in which at least one prompt fatality occurs), the mean number of prompt fatalities is estimated to be about 20. The frequency of scenarios resulting in 20 or more prompt fatalities is less than one per million reactor years. Figure ES-2 illustrates the recurrence interval for one prompt fatality.

Latent Cancer Fatalities

The public risk of latent cancer fatalities from all potential scenarios considered from terrorist ground attack is also small. The chance of one latent cancer fatality is less than one in 300,000 reactor years. Should core damage and radiological release occur, the mean number of latent cancer fatalities is estimated to be less than 100, which is indistinguishable compared to cancer fatality risks without the event. For more severe releases (i.e., those in which at least one latent cancer fatality occurs), the mean number of latent cancers is estimated to be about 600. The frequency of scenarios resulting in as many as 200 latent cancer fatalities is less than one per million reactor years. Results show that the latent cancer fatality risk to the population resulting from a terrorist attack on the plant would occur over 30 years and would be indistinguishable when compared to cancer fatality risks without the event. Figure ES-2 illustrates the recurrence interval for one latent cancer fatality.

Land Contamination

The likelihood of any land contamination affecting the public is less than one in 170,000 reactor years. If a scenario causing a radioactivity release occurs, the amount of farmland that could require interdiction (conditions that render the land unusable for farming for one to 30 years) is likely to be limited to less than 80 mi^2, and the amount of farmland that could require condemnation (conditions that render the land unusable for farming for more than 30 years) is likely to be limited to less than 0.75 mi^2, based on mean results. Any other affected land could be decontaminated without significant loss of use. The frequency of scenarios resulting in land condemnation of an area of 4 mi^2 is less than one per million reactor years. Figure ES-2 illustrates the recurrence interval for offsite land contamination and interdiction.

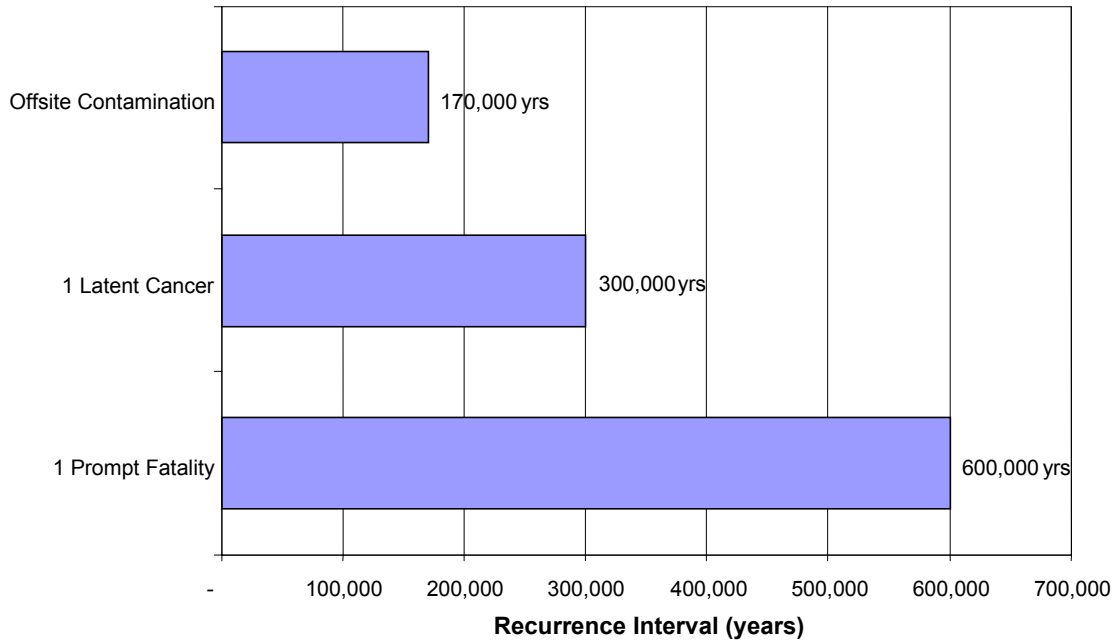

Figure ES-2 Recurrence Interval for Various Consequence Measures

Comparison of Results with NRC Safety Goals

Figure ES-3 illustrates the health risks to the public due to armed terrorist ground attack of a commercial nuclear plant compared with NRC safety goals.

The NRC safety goal for prompt fatalities is that the risk to an average individual in the vicinity of a nuclear power plant that might result from reactor accidents should not exceed 0.1% of the sum of prompt fatality risks resulting from other accidents to which members of the U.S. population are generally exposed. Since the accident risk in the U.S. is about $5x10^{-4}$ per year, this translates to $5x10^{-7}$ per year. The results of this study indicate that the individual fatality risk

from terrorist-induced accidents at nuclear plants is less than $1x10^{-8}$ per year. Thus, the NRC safety goal for prompt fatalities is met by a factor of about eighty.

The NRC safety goal for latent cancer fatalities is that the risk to the population in the area near a nuclear power plant that might result from plant operation should not exceed 0.1% of the sum of latent cancer fatality risks resulting from all other causes. Since the cancer fatality risk in the U.S. is about $2x10^{-3}$ per year, this translates to $2x10^{-6}$ per year. The results of this study indicate that the latent cancer fatality risk from terrorist-induced accidents at nuclear plants is less than $1x10^{-9}$ per year. Thus, the NRC safety goal for latent cancer fatalities is met by more than three orders of magnitude.

From this comparison, it is evident that the prompt and latent cancer fatality risks to the public resulting from a core damage accident caused by an armed terrorist ground attack on a U.S. commercial nuclear power plant are well below the NRC safety goal, which in turn is three orders of magnitude lower than the risks posed to the public by other causes of accidents and latent cancer deaths from all sources (see Figure ES-3). These risks from armed terrorist ground attack are also comparable to or less than the risk from other types of radiological accidents already analyzed in the design and licensing of U.S. commercial nuclear plants to date. While a safety goal does not exist for land contamination, comparison of the land contamination results with related results from existing nuclear plant PRAs indicates that the risk of land contamination from a core damage accident caused by terrorist ground attack is also comparable to or less than the land contamination risk from other types of radiological accidents already analyzed in the design and licensing of U.S. commercial nuclear plants to date.

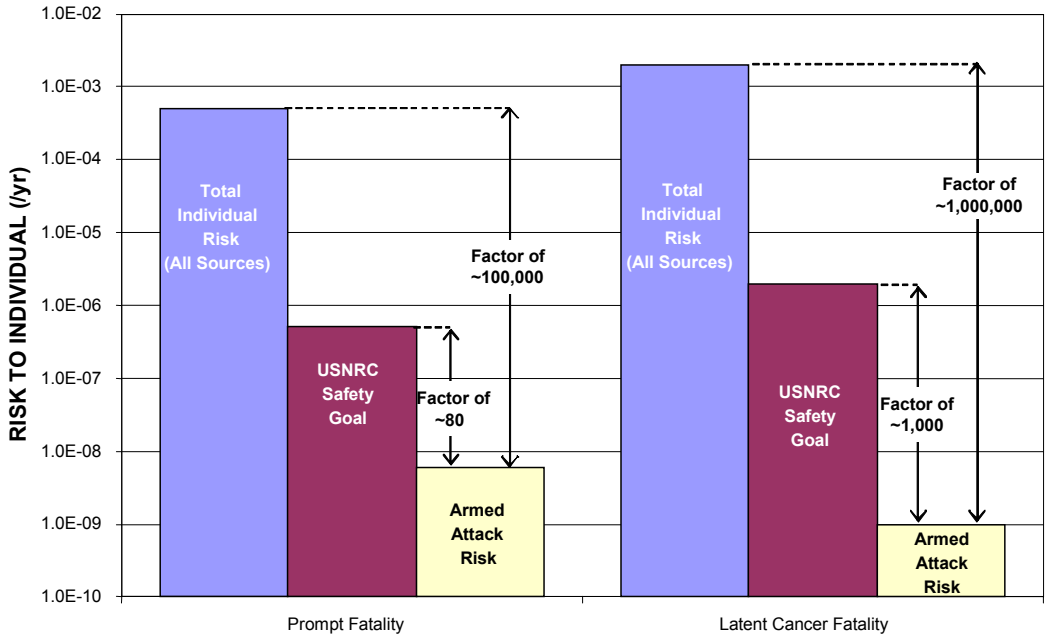

Figure ES-3 Comparison of Risks

CONCLUSIONS

The main conclusions from this study are as follows:

1. The risk to the public resulting from a core damage accident caused by an armed terrorist ground attack on a U.S. commercial nuclear power plant is small. It is comparable to, or less than the risk from other types of accidents postulated for U.S. commercial nuclear plants.

2. Given an attack, the likelihood of core damage (such as the 1979 Three Mile Island 2 Event) is unlikely because of nuclear plant owner capabilities to detect insider activities, physically deter the attackers, and mitigate accident propagation with operator actions and safety systems. The likelihood of severe release is even less because of the inherent strength of containment and radioactivity removal capabilities of containment and systems design.

3. Should core damage and radiological release occur, the public health consequences are not catastrophic. The mean number of prompt fatalities is estimated to be about 2, and the mean number of latent cancer fatalities is estimated to be less than 100, which is indistinguishable compared to cancer fatality risks without the event. For more severe releases (i.e., those in which at least one prompt fatality occurs), the mean number of prompt fatalities is estimated to be about 20 and the mean number of latent cancers is about 600.

4. Because of the very strong nature of their security systems and safety systems, and the low risk of health consequences, commercial nuclear plants are considered an unattractive target for terrorist groups intent on causing loss of life.

5. This study confirms that capability of Federal and other government agencies to detect, interdict, or otherwise disrupt an armed terrorist attack force, which is preparing to attack a commercial nuclear plant, is important to reducing the likelihood of a successful attack.

6. PRA is a practical and feasible approach to evaluating the risk to the public resulting from a core damage accident caused by an armed terrorist attack on a U.S. commercial nuclear power plant. While this study was limited in scope, it provides a useful perspective on this terrorist threat that can be used for comparison with the risks presented by attacks on other U.S. infrastructure elements.

7. Emergency response evacuation within a few miles of the site is an important contributor to minimizing prompt fatality consequences. Prompt fatality consequences could increase significantly without it, depending on the actual meteorological conditions.