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Nuclear Power Plant Risk Analysis and Management for Critical Asset Protection (RAMCAP) Trial Applications Summary Report

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Technical Report

Nuclear Power Plant Risk Analysis and Management for Critical Asset Protection (RAMCAP) Trial Applications Summary Report

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U.S. Department of Energy
Nuclear Energy Plant Optimization Program
1000 Independence Avenue
Washington, DC

American Society of Mechanical Engineers-
Innovative Technologies Institute, LLC
1828 L Street NW, Suite 906
Washington, DC 20036

EPRI Project Manager
J. Gaertner

ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1395 ▪ PO Box 10412, Palo Alto, California 94303-0813 ▪ USA
800.313.3774 ▪ 650.855.2121 ▪ askepri@epri.com ▪ www.epri.com

ORGANIZATION(S) THAT PREPARED THIS DOCUMENT

Electric Power Research Institute (EPRI)

ERIN Engineering and Research, Inc.

NOTE

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or e-mail askepri@epri.com.

CITATIONS

This report was prepared by

Electric Power Research Institute (EPRI)
3412 Hillview Avenue
Palo Alto, CA 94304

Principal Investigator
J. Gaertner

ERIN Engineering and Research, Inc.
2175 North California Boulevard, Suite 810
Walnut Creek, CA 94596-7396

Principal Investigators
R. Hill
G. Teagarden
D. True

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REPORT SUMMARY

The nuclear power plant risk analysis and management for critical asset protection (NPP RAMCAP[1]) methodology provides a common, high-level framework for evaluating NPP risk from terrorist attacks that plant owners/operators can use. Development of this method has been coordinated with other U.S. Department of Homeland Security (DHS) efforts in order to enable a consistent risk characterization among all critical infrastructure sectors. This effort culminated in a generic RAMCAP methodology potentially applicable to facilities in many infrastructures. This document continues to evolve at the time of this writing. Based on the successful application at three sites and the incorporation of lessons learned from the trial applications, implementation is continuing for all remaining NPPs.

Background

Since the events of September 11, 2001, it is essential for security officials and government agencies to make risk-informed resource allocation decisions concerning the prevention, deterrence, mitigation, and the appropriate responses to a terrorist threat. DHS and the American Society of Mechanical Engineers-Innovative Technologies Institute (ASME-ITI) recognized the need for a generic RAMCAP methodology that would be applicable to facilities in many infrastructures. NPPs, chemical plants, petrochemical refineries, and liquid natural gas facilities were chosen as lead subsectors. The Electric Power Research Institute (EPRI) was selected to develop and demonstrate the RAMCAP method for the NPP subsector. The Nuclear Sector Coordinating Council (NSCC) selected this project and its successful industry-wide implementation as critical initiatives. This NPP RAMCAP trial applications summary report is a product of EPRI's development and trial applications effort.

Objectives

- To develop and demonstrate a high-level methodology that could be used by NPP owners/ operators to characterize their risk from terrorist threats
- To require only a few person-weeks of effort and make the maximum use of existing analysis and knowledge
- To be consistent with generic RAMCAP guidance provided by ASME and DHS that could be used for all infrastructure sectors
- To provide insights and bases for security resource decisions made by individual owners/ operators
- To provide a basis for sector resource or regional decisions made by DHS and other government decision makers

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[1] RAMCAP is copyrighted by ASME-ITI.

The specific objectives of the NPP RAMCAP trial applications were:

- To test the methodology's ability to consistently develop site-specific security risk results
- To develop technical enhancements to the methodology
- To assess the capability to apply the methodology within the projected schedule and with the available resources

Approach

The first step was to identify the owners/operators and their respective sites for the trial applications. For this purpose, RAMCAP was offered as a supporting analysis for ongoing interagency comprehensive reviews (CR) of nuclear sites sponsored by DHS. The first three CR sites chosen as RAMCAP trial application sites reflect diverse design, threat susceptibility, and security postures. The NPP RAMCAP method was modified to address the needs of the CR teams. The trial applications used the NPP RAMCAP Implementation Guidelines developed by EPRI for ASME-ITI and DHS for these implementations. The method evolved with the sequential performance of these trial applications. This report details these changes and lessons learned. Preliminary analyses, data, and site information were requested of the site prior to the site assessment date, and the necessary resources and security clearances were identified. The RAMCAP assessment was performed by a facilitated process over two days at each site.

Results

The three successful trial applications were performed in May and June 2005, using the approach previously described. The method was found to meet the objectives of the project when it was implemented during an intensive, two-day, on-site visit through a facilitated process with appropriate on-site participation by plant staff. Significant preparation and documentation time were needed. Results were reported to the respective CR teams, and a final, controlled report to the owner/operator was then prepared by the facilitators. Due to the highly sensitive nature of the plant-specific assessment results, this report focuses on the assessment methodology insights, lessons learned, and on high-level results rather than detailed site-specific results.

EPRI Perspective

U.S. NPPs are unique among potential terrorist targets because they have a large security force prepared for a spectrum of design basis threats. They also have a hardened design, systems and barriers to mitigate scenarios, emergency response plans for the public, and a strong risk management culture among the staff. Nonetheless, a consistent method to characterize risk and to compare terrorism risk among infrastructure sectors is important. Therefore, EPRI worked collaboratively with DHS, ASME, and nuclear sector stakeholders to develop and trial-apply the NPP RAMCAP methodology. The three trial applications were successful in meeting the objectives of all stakeholders with the implementation being continued at numerous additional sites. Insights are being used by owners/operators and by governmental review teams. RAMCAP results from NPPs and other sectors will eventually constitute a comprehensive DHS database that will potentially be a rich resource for decision makers. Threat frequency information from DHS is important for use in RAMCAP results for risk management and cost/benefit decisions.

Keywords

Risk/safety management
Probabilistic risk assessment
Nuclear plant security

ACRONYMS AND ABBREVIATIONS

ASME-ITI	American Society of Mechanical Engineers – Innovative Technologies Institute
BWR	Boiling water reactor
CR	Comprehensive review
DBT	Design basis threat
DHS	Department of Homeland Security
EPRI	Electric Power Research Institute
EPZ	Emergency planning zone
FHA	Fire hazard assessment
NPP	Nuclear power plant
NRC	Nuclear Regulatory Commission
PA	Protected area
PCII	Protected critical infrastructure information
PRA	Probabilistic risk assessment
PWR	Pressurized water reactor
RAMCAP	Risk analysis and management for critical asset protection
SAMG	Severe accident management guidelines
SBO	Station blackout
SFP	Spent fuel pool
SGI	Safeguards information
SSCs	Systems, structures, and components
UHS	Ultimate heat sink
VBIED	Vehicle-borne improvised explosive device
WBIED	Water-borne improvised explosive device

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1
INTRODUCTION

Since the events of September 11, 2001, the perceived increase in security threats to critical infrastructure in the United States has resulted in changes to security processes within many industries and municipalities. The U.S. Department of Homeland Security (DHS) contracted with the American Society of Mechanical Engineers-Innovative Technologies Institute, LLC (ASME-ITI) to develop a risk-based approach to security assessment applicable to multiple industrial sectors. This effort culminated in a generic risk analysis and management for critical asset protection (RAMCAP) methodology that is potentially applicable to facilities in many infrastructures [1].

Significant security threats have previously been assessed by all commercial nuclear power plants (NPPs) through the design basis threat evaluation process mandated by the U.S. Nuclear Regulatory Commission (NRC). The resulting security programs, in combination with the robust design of NPP structures, the redundancy and diversity of safety systems, and the spatial separation that is inherent in the NPP design philosophy, provide significant protection for the facility from a broad spectrum of threats. However, the level of protection afforded against security threats has typically not been characterized in a risk context. The Electric Power Research Institute (EPRI) developed and published a prototype security vulnerability assessment process that would enable the NPP industry to make risk-informed decisions related to security threats [2].

Based on its previous work and relationships in the NPP industry, EPRI was selected by ASME to develop and demonstrate the RAMCAP method for the NPP subsector. A draft NPP RAMCAP Implementation Guidelines [3] document was the basis for trial applications at three NPP sites in May and June 2005. The three sites chosen were the first three NPP sites to undergo the governmental interagency comprehensive review (CR) process sponsored by DHS. RAMCAP provided supporting analysis to the CR teams. The three sites reflect diverse design, threat susceptibility, and security postures. A revision of the implementation guidelines reflects lessons learned from the three trial applications and is currently the basis for ongoing RAMCAP assessments at other plants. A final version of the NPP RAMCAP Implementation Guideline is anticipated by the end of 2005. Additional implementation guidance for the nuclear sector is included in a companion document, the *NPP RAMCAP Facilitators' Handbook* [4]. This handbook and results of the analyses performed using the guideline include material that is highly sensitive Safeguards Information (SGI) and must be controlled per the requirements in U.S. Regulation 10 CFR 73.21.

Due to the highly sensitive nature of the plant-specific assessment results, this trial application report focuses on the assessment methodology insights, lessons learned, and high-level assessment results rather than detailed site-specific assessment results. Separate reports were developed for each of the three trial application assessments and are controlled as SGI per the requirements in 10 CFR 73.21 (that is, distributed only to personnel with appropriate clearances and a need to know).

1.1 RAMCAP Objectives

The primary objective of the RAMCAP assessment process is to provide a practical, consistent method to identify, characterize, and compare security risks resulting from terrorist-type threats. An owner/operator can use the methodology to assess potential vulnerabilities of a facility, the effectiveness of existing security countermeasures, and the potential consequences of an attack. With this information, security risks can be assessed and strategies can be formed to reduce vulnerabilities.

A principal use of the RAMCAP results is to assist DHS in enhancing the protection of our nation's critical infrastructure and key resources against terrorist acts through an understanding of the risks associated with the facilities that comprise the critical infrastructure. The results of each RAMCAP application provide a characterization of the risk of the facility relative to a common, pre-defined set of threats and a common, pre-defined set of consequences for critical assets at the facility. The risk characterization includes estimates of consequence magnitudes and likelihoods for a spectrum of scenarios, given the occurrence of the threat, using a common risk matrix. In the case of NPPs, the scenarios also include a timeline from threat initiation to realization of consequences. This common, structured approach will allow entry into a DHS database of risk information across all sectors of interest. Combined with consistent assessments from other sectors, the NPP RAMCAP information is useful for resource prioritization, allocation, and policy decisions on a regional and national level. The RAMCAP results also provide supporting analysis to the governmental interagency CR process that is being performed at all NPP sites.

1.2 Trial Application Objectives

The objectives of the NPP RAMCAP trial applications were:

- To test the methodology's ability to develop site-specific security risk results on a consistent basis
- To develop technical enhancements to the methodology
- To assess the capability to apply the methodology within the projected schedule and with the available resources

1.3 Scope of Trial Applications

The scope of the trial applications was consistent with that of the guideline and focused on the targets of the reactor plant and the spent fuel pool (SFP). Dry cask storage of spent fuel and spent fuel transportation were not addressed or assessed as part of the trial applications in the NPP

RAMCAP guidelines. Separate RAMCAP guidelines for spent fuel storage and transportation are currently under development by EPRI and will apply to dry cask storage.

1.4 Report Organization

This report is organized as follows:

- Section 1 presents an introduction to the objectives of the NPP RAMCAP methodology and trial applications.
- Section 2 provides an overview of the NPP RAMCAP concepts and methodology.
- Section 3 reviews the three trial application sites and high-level results.
- Section 4 summarizes the insights, lessons learned, and enhancements made to the assessment methodology.
- Section 5 provides summary conclusions of the trial applications.

2
NPP RAMCAP OVERVIEW

This section provides an overview of the RAMCAP risk concepts and methodology. A more thorough presentation of the risk concepts and methodology as applied to NPPs may be found in the NPP RAMCAP Implementation Guidelines [3].

2.1 RAMCAP Risk Concepts

The basic components of risk, including terrorism risk, are the estimated consequences of an event and the likelihood of that event occurring. Mathematically, this is expressed as:

Risk = (Consequence) × (Likelihood of the Event Producing the Consequence)

The nuclear industry has an embedded a strong risk management culture relative to other industries. Probabilistic risk assessment (PRA) results from accident initiators and severe natural phenomenon are commonly used for design, licensing, and operational decision making. This use of quantitative risk information and the associated set of common risk metrics and other assessment conventions are unique among infrastructure sectors. Acceptable methods for estimating the initiating event likelihood concerning security events have not been developed. Because RAMCAP is intended for use across many sectors on a voluntary basis, the approach, terminology, and assessment rules of RAMCAP are quite different from a nuclear plant PRA. The quantification of risk using the simple formula mentioned earlier is not fully employed.

Instead, RAMCAP considers the following mathematical representation of security risk:

Risk = f (Consequence, Vulnerability, and Threat)

Risk is recognized to be a function of the consequence, the vulnerability to achieve the consequence, and the threat capable of exploiting the vulnerability.

The specific consequences considered by RAMCAP are somewhat different from those common in nuclear plant PRA. The specific consequences include early fatalities, early injuries, total financial impacts of physical damage and radiological cleanup costs, and certain consequences with strong psychological, economic, or national security impacts.

The likelihood element of risk is addressed in RAMCAP by the explicit consideration of vulnerability and threat. Vulnerability is the representation of effectiveness of any on-site countermeasures and the available mitigation from systems and structures to a given terrorist threat within the context of a developed scenario. In PRA, vulnerability would be represented as the conditional likelihood of a consequence, given a specific initiator or threat. In RAMCAP, vulnerability is represented by descriptive categories that can be determined by a likelihood quantification or by other, more qualitative means.

Threat, in RAMCAP, corresponds to the concept of the initiating event in PRA. Each threat is a completely defined characterization of a hypothetical attack including the strength of the force, weaponry, knowledge and capabilities, and means of deployment. RAMCAP considers 16 benchmark threats that represent a spectrum of physical threats (see Table 2-1). These threat categories are provided by DHS to represent nuclear plant risk. These benchmark threats will also be used by other critical infrastructure sectors in order to provide a consistent basis for the comparison of results across sectors.

Table 2-1
RAMCAP Benchmark Threats

Mode	Smallest Threat	Small Threat	Medium Threat	Large Threat
Aircraft (impact, explosion and fire)	√	√	√	√
Vehicle-borne improvised explosive devices (VBIEDs)	√	√	√	√
Water-borne improvised explosive devises (WBIEDs)	√	√	Under development*	Under development*
Armed attack (personnel)	√	√	√	√

* These threats were evaluated in the first NPP trial application, but have been withdrawn pending recharacterization by DHS.

The expected frequency of each threat is clearly part of the likelihood of any risk scenario. The NPP RAMCAP process does not quantify or otherwise estimate the frequency of the terrorist threat. The likelihood of the attack developing and occurring (for example, off-site planning, preparation, and initiation) will be developed by DHS at a later time to complete the total RAMCAP risk assessment. The likelihood of the attack occurring considers the expert judgment that terrorists intend to attack, are capable of it, and are prepared for it, as well as the applicability of this attack to the target in question. It also requires access to threat data that cannot be made available to the owner/operator or to NPP RAMCAP analysts.

However, the NPP RAMCAP method does solicit qualitative information from the owner/operator about several elements that relate to threat likelihood. This information includes:

- The perceived attractiveness of each site relative to other nuclear plants
- The attractiveness of a particular scenario to a terrorist based on attributes of the plant
- The deterrence posed by the plant for each scenario

This deterrence and attractiveness information can be combined with the knowledge of the terrorists capability and intent to estimate a threat likelihood.

2.2 NPP RAMCAP Method

The overall RAMCAP process is depicted in Figure 2-1. The trial applications of NPP RAMCAP and the subsequent ongoing implementation focus on Steps Three through Six. Step One is designed to screen out critical infrastructure sites of low consequences. However, all NPP sites are judged to potentially have high consequences. Step Two has been completed by DHS and provided to the owner/operator in the form of the 16 benchmark threats. Step Seven, risk management, will be performed by DHS in view of regional and national priorities, and by individual owners/operators as deemed appropriate for local decision making.

Potential scenarios are postulated and examined for each of the 16 threats, and generally, the scenario developed fully is that which presents the worst reasonable consequences for each benchmark threat. Specific NPP structures examined during the scenario development process are shown in Table 2-2. The assessment results are documented during the process using an electronic spreadsheet documentation tool called the *RAMCAP Evaluator (Beta Version)* [5]. Figure 2-2 presents a screen shot of a scenario worksheet in the tool.

Table 2-2
NPP Structures for Evaluation

BWRs	PWRs

• Control building
• Reactor building (Mark I, Mark II)
• Containment (Mark III only)
• Auxiliary building
• SFP
• Others (as needed)
  - Intake structure/ultimate heat sink (UHS)
  - Diesel generator building
	• Control building
	• Containment
	• Auxiliary building
	• SFP
	• Others (as needed)
	  - Intake structure/UHS
	  - Diesel generator building

Process Step	Essential Considerations
Step One: Asset Characterization	Asset Identification Assessment of Potential Severity of Consequences Consequence-Based Screening Target Determination
Step Two: Threat Characterization	Adversary Characterization: Capabilities, Tactics, and Weapons Threat Characterization Provided Separately by DHS Owner/Operator Can Choose Lesser Threats for Their Own Purposes
Step Three: Consequence Analysis	Potential Damage Assessment for Each Threat Worst Reasonable Case Consequences
Step Four: Vulnerability Analysis	Identify Vulnerabilities Leading to Worst Reasonable Consequences Assessment of Likelihood of Adversary Success in Achieving Worst Reasonable Consequences Evaluate Existing Countermeasures and Mitigation Capability
Step Five: Threat Assessment	Asset Attractiveness and Deterrence (asset owner) Adversary Capability and Intent Determination (DHS) Threat (relative likelihood of attack) as a Function of Attractiveness and Adversary Capability and Intent (DHS)
Step Six: Risk Assessment	Consequence from Step Three Vulnerability from Step Four Threat from Step Five Risk = Consequence x Vulnerability x Threat Documentation of Scenarios
Step Seven: Risk Management	Consider Risk Goals and Determine Need for Recommendations Determine Recommendations Evaluate Options and Decide on Enhancements

Figure 2-1
Overall RAMCAP Assessment Process

Scenario:	W1A						
Threat:	W1	Waterborne 1					
Target/Location:							
Scenario Discussion (Including Potential Damage):							
Consequences							
Fatalities		Injuries		Radiological Cleanup		Repair / Book Value	Asset Replacement
On-Site	Off-Site	On-Site	Off-Site	On-Site	Off-Site		
0	0	0	0	$0 B	$0 B	$0 B	$0 B
Fatalities Risk Index		Injuries Risk Index		Financial Risk Index			
0		0		0			
Consequences Discussion:							
Representative Fuel Damage Scenario:	No fuel damage						
Time To Fuel Damage: (Hours)	NA	Discussion:					
Time To Release: (Hours)	NA	Discussion:					
Vulnerability							
Estimation of Attack Success (0.00 - 1.00)		Discussion:					
0.00							
Likelihood of Attack Success							
Beyond Concern	0						
Mitigation Capability		Discussion:					
Not Required	0						
Overall Vulnerability:	0						
Threat Assessment							
Deterrence							
Threat Deterrence		Discussion:					
High							
Attractiveness							
Perceived Potential For Public Consequences		Discussion:					
Low							
Perceived Ability To Achieve Public Consequences		Discussion:					
Low							
Assumptions:							
Comments:							

Figure 2-2
Sample Assessment Worksheet

The NPP RAMCAP methodology assesses on-site and off-site consequences using pre-defined categories of human fatalities, injuries, and direct economic consequences in order to provide a means of comparison between facilities and other sectors. Consequences are assessed for all scenarios (that is, even those that do not result in a radiological release) in order to provide comparisons to other industries. Additionally, information is collected concerning potential societal or governmental impacts for further investigation by DHS if needed (for example, nearby military bases that could be impacted by a radiological release). The consequences assessed in the NPP RAMCAP are shown in Table 2-3.

Table 2-3
Consequences Assessed

Consequence Category	Specific Consequence Metric
Human health and safety impact	• Acute fatalities (on-site and off-site) • Early injuries (on-site and off-site)
Economic impact	• Environmental impact cost (on-site and off-site) • Repair cost • Book value (for loss of plant) • Facility replacement cost (for loss of plant)
National security and government functionality impact	• Impact on military mission capability* • Impact on delivery of public health services*
Psychological impact	• Impact on multiple economic sectors* • Impact on icons* • High profile/symbolic casualties*

* Facilities within 10 miles identified for assessment by DHS.

2.3 RAMCAP Results

Figure 2-3 illustrates several important aspects of the RAMCAP results. First, consequences are represented by categories on a logarithmic scale. The example shown is for economic consequences. The lowest category includes consequences of $100M and below, a range more appropriate to regional and national interests. The vulnerability is represented by categories that are also intended to increase logarithmically, although the actual category determination may not be quantitative. The plotted point represents the result from one scenario for the consequence of interest. The complete RAMCAP assessment result would consist of plots of each scenario for each of the three consequences considered (that is, fatalities, injuries, and economic impact).

Compared to the PRAs familiar to NPP personnel, the RAMCAP assessment is a much coarser, qualitative assessment of security risks. The RAMCAP process has been designed to allow assessment in two days at the site using a facilitation process. Significant use of engineering judgment is used and is sufficient for the purposes of the RAMCAP assessment.

Level	Range	Representative Likelihood of Adversary Success	Level	CONSEQUENCE LEVELS*										
				0	1	2	3	4	5	6	7	8	9	10
Likely	0.5 - 1	> 50/50	5	5	6	7	8	9	10	11	12	13	14	15
Somewhat Likely	0.25 - 0.5	~1 in 3	4	4	5	6	7	8	9	10	11	12	13	14
Possible	0.125 - 0.25	~1 in 5	3	3	4	5	6	AA4A	8	9	10	11	12	13
Unlikely	0.0625 - 0.125	~1 in 10	2	2	3	4	5	6	7	8	9	10	11	12
Very Unlikely	0.0312 - 0.0625	~1 in 20	1	1	2	3	4	5	6	7	8	9	10	11
Beyond Concern	<0.0312	< 1 in 50	0	0	1	2	3	4	5	6	7	8	9	10
				<$0.1B	$0.1B - $0.2B	$0.2B - $0.4B	$0.4B - $0.8B	$0.8B - $1.6B	$1.6B - $3.2B	$3.2B - $6.4B	$6.4B - $12.8B	$12.8B - $25.6B	$25.6B - $51.2B	$51.2B - $102.4B

*Only includes scenarios with consequence and vulnerability levels greater than zero

Figure 2-3
Conditional Risk Results – Economics

2.4 RAMCAP Guiding Principles

A number of guiding principles and assumptions are used in the assessment process. Application of the guiding principles and assumptions are discussed in relevant portions of the guidance, but the more important ones are summarized here:

- The primary objective of the threat in the NPP subsector is to inflict sufficient damage to cause a radiological release to the surrounding communities. Therefore, scenarios are developed with a focus on causing fuel damage and radiological release.
- An intelligent, adaptive adversary is assumed to plan an attack in order to maximize the consequences. Therefore, the scenario assumptions that develop the worst reasonable consequences for a given benchmark threat are those that are used in the assessment.
- Although adversaries do not have insider assistance, they do have a level of insider information that is equivalent to what was publicly available prior to September 11, 2001 (for example, safety analysis reports).

3
TRIAL APPLICATIONS

As part of the NPP RAMCAP development and demonstration, the methodology was applied at three trial sites. This section summarizes the characteristics of the trial sites and the high-level results.

3.1 Application Sites

The three sites selected for trial application reflect diverse design, threat susceptibility, and security postures. Two sites were pressurized water reactor sites (PWRs) and one site was a boiling water reactor (BWR) site. Table 3-1 summarizes specific characteristics of the trial sites.

Table 3-1
Trial Site Characteristics

Characteristic	Trial Site 1	Trial Site 2	Trial Site 3
Reactor type	PWR	PWR	BWR
Waterway	Ocean	None	River
Number of units	Multiple units	Multiple units	Multiple units
Unit configuration	Adjacent units	Non-adjacent units	Adjacent units
Regional population	Above median for NPPs	Approximately median for NPPs	Below median for NPPs

3.2 Trial Assessment Process

Two RAMCAP facilitators (non-site personnel with detailed knowledge and experience with the NPP RAMCAP assessment method) with appropriate security clearances led the two-day, on-site assessment process. The RAMCAP assessments were conducted at the SGI level. The assessment results were documented during the assessment process using the *NPP RAMCAP Evaluator* [5]. The lead RAMCAP facilitator solicited plant information in advance of the site visit for preparation purposes. The detailed information request sent to the site was incrementally modified as a part of the trial application and was very similar to the applications shown in Appendix A. The information request included site plot plans and photographs, site equipment layout drawings, architectural drawings for key structures, plant PRA success criteria and thermal hydraulic results, the net MWe rating of the individual reactor plants, and the book value of the individual reactor plants and/or site.

Site personnel required for the two-day period included:

- A security manager or associate to assist in scenario development and to provide estimates on the site's ability to counter the benchmark threats
- An operations manager or trainer to provide insights on reactor operational configurations, system capabilities, and operating practices that would impact the potential for accident progression

Other personnel required for shorter periods of time or to answer specific questions included:

- A risk/safety engineer to provide PRA core damage accident progression insights and functional system success criteria
- An SFP manager to summarize the spent fuel management approaches used at the site
- Structural engineering personnel to summarize site engineering studies that were conducted as a part of recent security upgrades

An informal site walkdown outside the protected area was performed at the beginning of the assessment process to orient the RAMCAP facilitators to the site. A confirmatory site walkdown was sometimes necessary on the second day to confirm specific details or assumptions made as part of the scenario development process.

The assessment process consisted of the systematic development of worst-case consequence scenarios for each of the 16 benchmark threats in a group meeting environment. Considering the elements of each threat, site experts identified the targets that could lead to important damage sets. Considering countermeasures, barriers, and mitigation capabilities, various scenarios were postulated, and the worst-case consequence scenario was determined. For the worst-case consequence scenario defined, vulnerability estimation was performed by considering the effectiveness of countermeasures, barriers, and mitigation capabilities. The attractiveness and deterrence of the scenario were then qualitatively judged as high, medium, or low, based on site attributes. Scenarios involving releases from both the SPFs and the reactors were considered. Timelines for fuel damage and release were estimated. At least one scenario was fully developed for each applicable benchmark threat. Sometimes, multiple scenarios were developed for a threat if they represented equivalent but different risks. Early fatalities, early injuries, and economic impacts were explicitly identified for each scenario. Also, potential impacts of selected scenarios on the remaining consequences of interest to DHS were identified. Finally, the site attractiveness was estimated based on the population within 50 miles of the site.

The NPP RAMCAP process includes extensive rules, algorithms, and pre-analyzed damage and consequence conditions as aids in performing the analysis quickly. The RAMCAP facilitators guided the application of these elements. Estimates of likelihood used in the vulnerability determination were approximate and based on the professional judgment and consensus of the assessment team. The basis was documented in all cases.

RAMCAP results were summarized in a presentation format at the close of the assessment. The RAMCAP facilitators developed a Safeguards summary report in the weeks following each site visit. The report was delivered to the owner/operator for comment and finalization. Upon finalization, the report became the property of the owner/operator. The owner/operator will submit the results to DHS under the protections afforded by the Protected Critical Infrastructure Information (PCII) designation.

3.3 Assessment Results

Site-specific results were produced due to the methodology that was successfully applied at all three sites. The methodology was judged to develop site-specific security risk results on a consistent basis across the three trial sites. A total of 60 scenarios were formally developed over the course of the three trial applications. These scenarios considered a wide spectrum of plant targets including multi-unit impacts, attacks on a reactor plant and SFP simultaneously, and the total loss of site control to the adversaries. The detailed site-specific results are sensitive information and are not presented in this report. High-level results are presented in Tables 3-2 and 3-3.

Table 3-2
Scenarios Evaluated

Characteristic	Trial Site 1	Trial Site 2	Trial Site 3
Total number of scenarios evaluated	26	19*	15*
Number of reactor plant scenarios evaluated	52 (all 3 sites combined)		
Number of SFP scenarios evaluated	8 (All 3 sites combined)		
Number of scenarios with potential for off-site consequences	16 (All 3 sites combined)		

* All 16 threat types were not applicable at this site.

Table 3-3
Scenarios with Potential for Off-Site Consequences

Threat Mode	Number of Scenarios Evaluated with the Potential for Off-Site Consequences (All three sites combined)			
	Smallest Capability	Small Capability	Medium Capability	Large Capability
WBIED	0	0	0	0
VBIED	0	0	0	1
Airborne	0	0	0	6
Armed attack	0	1	3	5

3.4 Assessment Results Insights

The following insights related to the assessment results were identified through the trial applications. Insights and enhancements associated with the NPP RAMCAP methodology and general assessment process are detailed in Section 4.

3.4.1 Plant-Specific Results

The worst-case consequence scenarios associated with each benchmark threat were determined to be very site specific. Site geographical features (for example, waterway accessibility and topography) were found to be critical due to their impact on scenario development for a given threat mode. Spatial aspects of plant design and layout were also found to have a strong influence (for example, cooling towers that serve as intervening structures for aircraft threats). Finally, physical security strategies and features were important in assessing the likelihood of attack success. All three of these influences confirmed the need for site-specific assessment, rather than more generic-type assessments.

3.4.2 Worst-Case Consequences

As shown in Table 3-3, only the largest threat capabilities were found to potentially result in severe consequences (that is, off-site radiological releases). Lesser threat capabilities were generally not able to produce off-site consequences for the scenario likelihoods of interest. The worst-case consequences were dominated by radiological cleanup costs and facility replacement costs rather than human health impacts (that is, fatalities or injuries). For scenarios involving radiological release, the economic impacts were in the billions of dollars, while human health impacts associated with radiation release impacts were always less than 100 persons. The three trial applications demonstrated that the NPP industry consequences of concern, as captured in the methodology, are financial rather than human impacts. This finding is generally expected to be true for the entire industry.

3.4.3 Contributors to Low Risk

The trial applications identified several attributes of NPPs that contribute to a low-risk designation for many of the scenarios evaluated. First, the rugged design of structures affords significant protection to plant equipment for many threats. Secondly, the existing security posture at NPP sites generally provides rapid and effective response to many initiated threats. Finally, substantial accident mitigation capabilities at NPPs, through the presence of redundant systems and spatial separation, provide a significant ability to operationally respond to site events. These three attributes result in a low-risk designation for the benchmark threats as compared to other industries.

3.4.4 Potential Enhancements Identified

The trial applications identified potential site-specific changes in procedures, plant practices, or minor security fortifications that could reduce the risk associated with some benchmark threats evaluated by RAMCAP. These identified items were viewed by owners/operators to be a beneficial result of the RAMCAP assessment.

4
NPP RAMCAP INSIGHTS

This section identifies insights and lessons learned from the trial applications associated with the NPP RAMCAP methodology and its implementation.

4.1 Methodology Insights

The NPP RAMCAP methodology was successfully applied at all three trial sites and provided site-specific security risk results on a consistent basis. Enhancements to the methodology were identified, particularly after the first trial application. The following changes were made to the NPP RAMCAP methodology based on the trial applications.

4.1.1 Attack Success Estimation

At the first trial application, the estimation of likelihood of attack success was generally performed (documented) by identifying the likelihood category (for example, likely), rather than generating and documenting a numerical likelihood estimate (for example, 0.7). The likelihood categories and associated probability ranges are presented in Table 4-1. It was subsequently judged preferable to solicit and document the numerical estimate in order to allow subsequent modifications of the binning schemes by DHS.[2] This practice of documenting the numerical estimate was successfully applied at the subsequent two trial applications.

[2] DHS is currently planning to develop more resolution in the binning scheme for the likelihood of attack success highest bin and the economic consequences lowest bin. Per reference 3, the highest likelihood of attack success bin will be subdivided into three bins of: 0.5–0.75, 0.75–0.9, and 0.9–1.0. The lowest economic bin will be subdivided into four bins of: $0–$25M, $26–$50M, $51–$75M, and $76–$100M.

Table 4-1
Likelihood of Attack Success Scale

Bin	Category	Probability Range	Representative Likelihood
5	Likely	0.5–1	> 50/50
4	Somewhat likely	0.25–0.5	~1 in 3
3	Possible	0.125–0.25	~1 in 5
2	Unlikely	0.0625–0.125	~1 in 10
1	Very unlikely	0.0312–0.0625	~1 in 20
0	Beyond concern	< 0.0312	< 1 in 50

4.1.2 Mitigation Capability Credit

The NPP RAMCAP methodology considers the potential for mitigation capability to prevent fuel damage. The mitigation capability is credited as a reduction in the overall vulnerability likelihood. At the first trial, credit for mitigation was applied as indicated in Figure 4-1, where credit was provided based on the number of mitigation pathways available in the scenario.

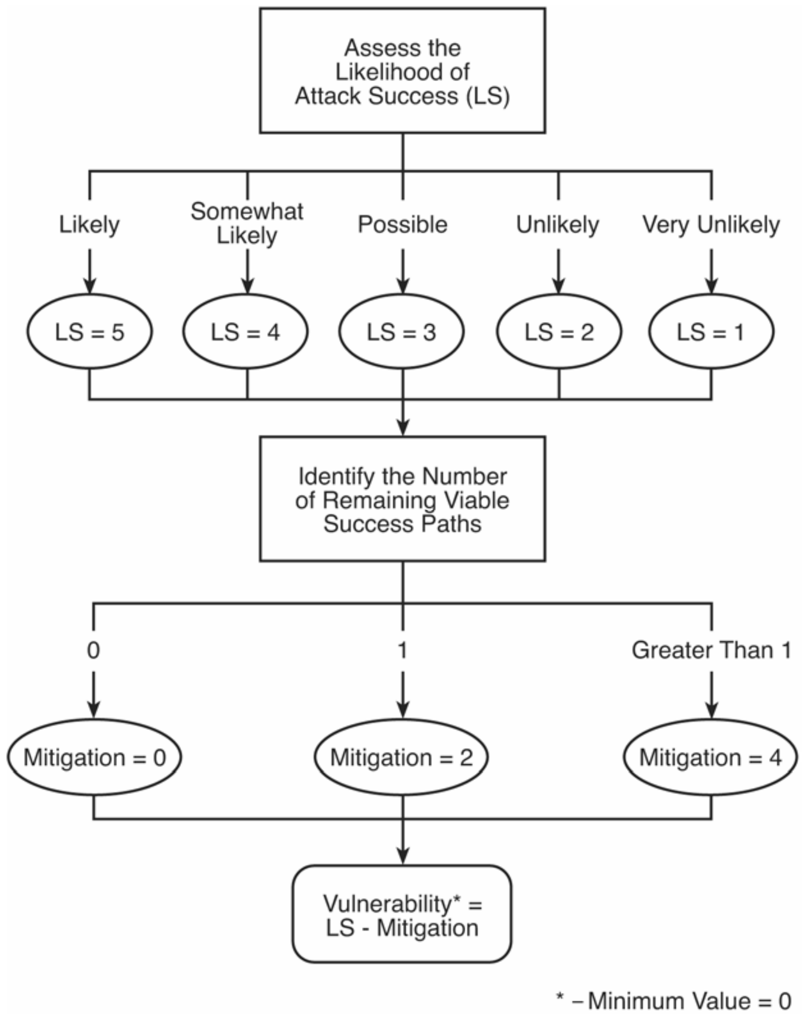

Figure 4-1
First Trial Application Mitigation Credit Approach

Additional granularity was deemed necessary to consider that some mitigation pathways might be expected to be successful with high confidence, while other mitigation pathways might have low confidence due to potential damage, limited accessibility, or minimal time available for implementation. As part of the trial applications, the process for crediting mitigation capability was refined (see Figure 4-2) in order to add consideration of the confidence of the mitigation pathways. The revised methodology was successfully applied at subsequent trial applications.

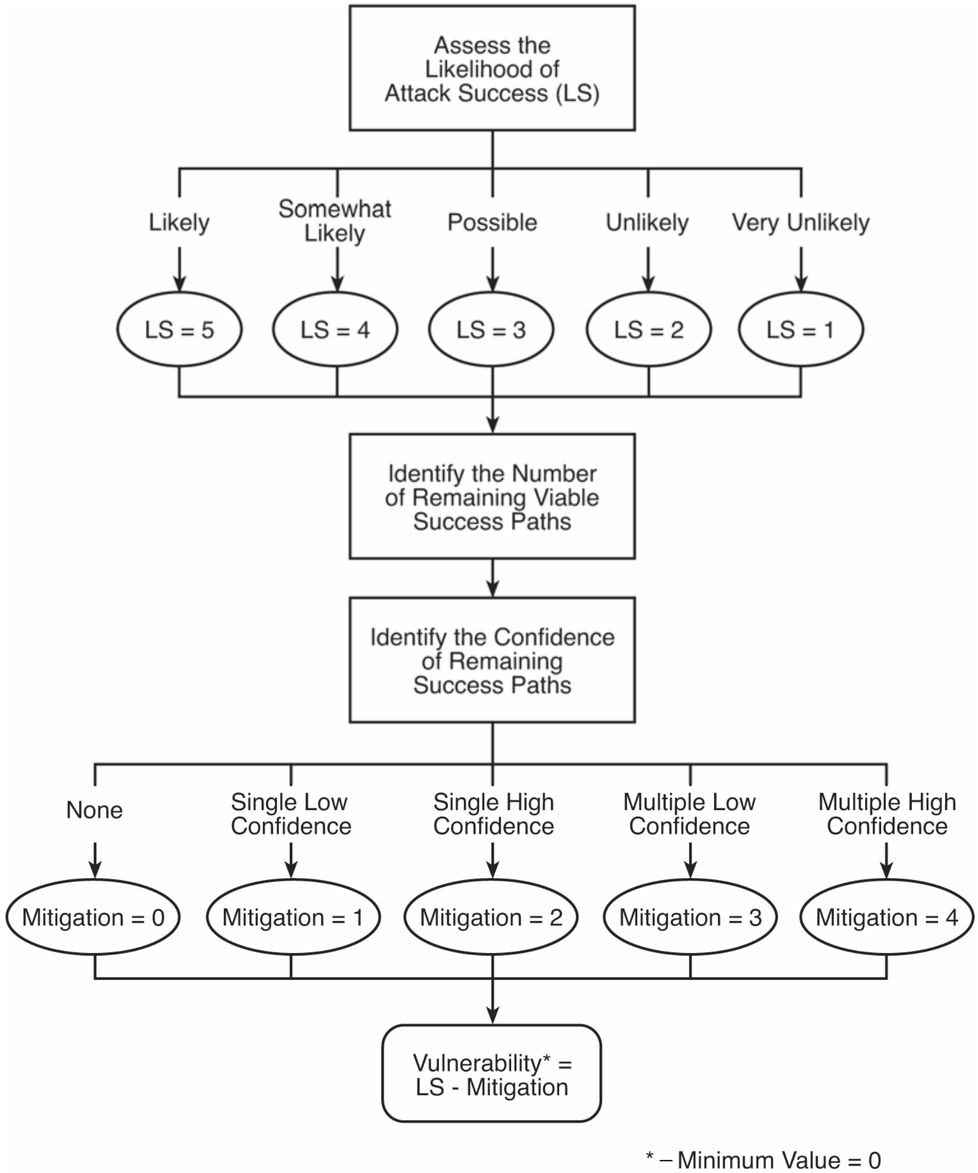

Figure 4-2
Revised Mitigation Credit Approach

4.1.3 Scenario Attractiveness

At the first trial application, attractiveness was assessed only at the site level (that is, attractiveness was the same for all scenarios). Following this first application, DHS requested that the methodology attempt to assess attractiveness at the scenario level. A qualitative rating scheme (that is, high, medium, and low) was developed (see Table 4-2) and applied to the scenarios developed in the first trial application and to subsequent trial applications. The scheme provides a measure of consistency and was successfully applied at subsequent trial applications, but it is noted that assessing the adversary's perception of potential consequences is inherently challenging. This scheme has been successfully applied at additional RAMCAP assessments.

Table 4-2
Scenario Attractiveness Assessment

Attractiveness Attribute	Attractiveness Rating		
	High	Medium	Low
Perceived potential for public consequences	Large early release would occur, thereby impacting the public during the evacuation.	Significant radiological release would occur, but after evacuation is completed.	No significant radiological release to the environment would occur.
Perceived ability to achieve those public consequences	Likely that damage necessary to cause a radiological release will result.	Uncertain if damage necessary to cause a radiological release will result.	Doubtful that damage necessary to cause a radiological release will result.

4.1.4 Water-Borne Threat Characterization

Following the review of RAMCAP results from the first trial application, DHS decided to withdraw the two largest water-borne threat characterizations for potential recharacterization. The methodology was modified for these two threat characterizations to require only a stand-off distance assessment for critical plant structures based on watercraft accessibility to the site. This simplified assessment was successfully applied at the third trial application.

4.1.5 Quantity of Scenarios

For the first trial application, a significant number of scenarios were formally developed (that is, more than one per benchmark threat) as shown in Table 3-2. This was partly due to inexperience associated with projecting which scenarios would result in the worst reasonable consequences and also due to the desire to capture potentially significant scenarios for both the reactor plant and the SFP. Fewer scenarios were developed for the subsequent trial applications. Based on the trial applications, new guidance was added to the assessment process to note that a second scenario for a given benchmark threat need be formally developed only if the assessment team judges that the conditional risk of that scenario will be greater than the conditional risk associated with the first scenario developed for that threat. This is consistent with the assessment objective of characterizing the worst reasonable consequence for each benchmark threat.

4.2 Implementation Insights

Implementation of the NPP RAMCAP methodology at the three trial applications was performed within the projected schedule (that is, two-day site assessment). Individual sites generally applied more personnel to the assessment process than requested (that is, two site individuals). The following subsections are insights associated with NPP RAMCAP implementation.

4.2.1 Schedule

The desired two-day on-site assessment schedule was achieved for all three trial applications. This is primarily attributed to considerable preparation by the RAMCAP facilitators (for example, a preliminary site assessment was performed using plant-specific information prior to the actual site assessment), the use of previously developed site-specific consequence metrics (for example, core damage timing and radiological dispersion impacts), and facilitation by individuals who were intimately knowledgeable with the RAMCAP process and rule sets (for example, damage estimation approaches). It was noted at all three trial applications that the two-day assessment schedule (which, on average, provides 30 minutes for assessment of each benchmark threat) would not have been achieved without active facilitation by knowledgeable individuals.

4.2.2 Assessment Team Size

Based on experiences at the three trial applications, it was determined that two RAMCAP facilitators and two to four site participants (at any one time) was the ideal assessment team size. The use of two RAMCAP facilitators allowed one to focus on group discussion while the other served as the primary assessment documenter (inputting information into the *NPP RAMCAP Evaluator* [5]). At least two site individuals were required to provide expert judgment on site security and operations. It was generally useful for these two individuals to have another colleague present for brainstorming and discussion. The inclusion of more than four site personnel, however, was found to slow the assessment process due to the increased time required to achieve consensus.

4.2.3 Documentation Tool

The *NPP RAMCAP Evaluator* [5] documentation tool was found to be an effective means of structuring the assessment process and developing consensus. After general assessment introductions, the assessment process was performed by filling in the scenario worksheet documentation tool from top to bottom (projected onto a screen for the assessment team). Lessons learned from the first trial application included a slight reordering of data on the spreadsheet tool and the importance of filling in the worksheet completely (for example, not leaving any fields blank) during the assessment process in order to appropriately capture details, assumptions, and decisions.

4.2.4 Threat Scenario Order

For the first trial application, the benchmark threats for each threat mode (that is, WBIED, VBIED, aircraft, and armed attack) were evaluated from lowest threat capability to highest threat capability. As part of the second trial application, the assessment order was reversed for the aircraft and armed attack threats. This sequence reversal for these two threat modes was found to increase the efficiency of assessing the less capable threats of these modes. The evaluation of WBIED and VBIED threats (which was conducted prior to the other attack modes) from lowest to highest threat capability allowed the assessment team to become proficient in the overall scenario development and assessment process before encountering the generally more challenging threats.

4.2.5 Information Security

The NPP RAMCAP assessment is conducted at the SGI level; therefore, special precautions must be taken during the assessment process. The initiation of one of the on-site trial applications was somewhat delayed (that is, an hour) due to the need to confirm proper SGI clearance of some of the participants. The lesson learned was that information security administration matters must be finalized for all planned participants prior to the on-site assessment.

5 CONCLUSIONS

The nuclear power industry has taken a leadership role in developing and implementing a risk assessment process for characterizing the conditional physical security risks at nuclear plants. Three trial applications of the NPP RAMCAP methodology were successfully completed providing useful risk characterization for a broad range of threats and beneficial insights for the owners/operators and for DHS.

The trial assessment process demonstrated that results are very plant specific and that the security posture, rugged design, and accident mitigation capabilities of nuclear plants limit both the magnitude and likelihood of consequences for threats considerably larger and more challenging than those specifically considered in the design and licensing basis. Although plant-specific in nature, these NPP attributes are judged to result as relatively low risk for the benchmark threats as compared to expected results for other industries. The worst reasonable consequences were found to be dominated by radiological cleanup costs and facility replacement costs rather than human health impacts. This finding is generally expected to be true for the entire NPP industry.

The trial assessments demonstrated that the facilitation process was a key component in conducting the on-site portion of the RAMCAP assessment in the targeted two-day schedule while ensuring site-to-site consistency.

A number of methodology and assessment implementation improvements were identified, incorporated, and tested during the three trial applications. Based on the successful trial applications, NPP RAMCAP assessments are continuing to be performed across the industry. The RAMCAP results are also providing supporting analysis to the governmental interagency CR process that is being performed at all NPP sites.

6
REFERENCES

1. RAMCAP Risk Analysis and Management for Critical Asset Protection (RAMCAP) for Terrorist Threats and Homeland Security (Draft). American Society of Mechanical Engineers-Innovative Technologies Institute, LLC*,* April 2005.

2. *Probabilistic Consequence Analysis of Security Threats – A Prototype Vulnerability Assessment Process for Nuclear Power Plants.* EPRI, Palo Alto, CA: 2004. 1007975.

3. NPP RAMCAP Implementation Guidelines: Revision C (Draft). American Society of Mechanical Engineers-Innovative Technologies Institute, LLC*,* October 2005.

4. *Nuclear Power Plant RAMCAP Facilitators' Handbook (Revision C).* EPRI, Palo Alto, CA: 2005. [This document is a controlled Nuclear Safeguards (SGI) document that is available to SGI qualified individuals through John Gaertner, EPRI Project Manager].

5. *NPP RAMCAP Evaluator (Beta Version).* EPRI, Palo Alto, CA: 2005. 1012842.

A

NPP RAMCAP INFORMATION REQUEST EXAMPLE

OBJECTIVE: To provide the RAMCAP facilitators with information that will assist in site familiarization and preparations in support of the upcoming RAMCAP assessment at your site

Please provide the requested information to the lead RAMCAP facilitator <u>two</u> <u>weeks</u> prior to the week of the site RAMCAP assessment.

Facilitator contact:
Facilitator contact e-mail:
Facilitator contact phone:

Up-to-date electronic versions of all documents and drawings are requested.

<u>SITE LAYOUT AND FAMILIARIZATION</u>:

- Photographs of site from different perspectives:
  - Photographs of major buildings from each side of the site (for example, north, south, and so on)
  - Aerial photographs (if available)
- Final safety analysis report (FSAR)-type site layout drawings that show site entry roads, vehicle barriers, PA barriers, building layouts, switchyards, ultimate heat sink, and so on (drawings needs to be scaled)
- Waterway navigational accessibility data/drawings, as applicable (for example, channel depth)
- Outage books or general training material that provide a brief summary description of the site and plant systems (if available)

<u>BUILDING ARRANGEMENT</u>:
Arrangement drawings are needed to identify nominal wall thicknesses, the location of internal concrete walls, and the relative locations of important pieces of equipment. This information is generally captured in the following types of drawings:

- Equipment layout drawings for all elevations of the main buildings containing SSCs that can prevent or mitigate fuel damage. Examples of buildings of interest:
  - Containment/reactor building
  - Control building
  - Auxiliary building/safety equipment building
  - Turbine building
  - Intake structure (if applicable)
  - Fuel handling building (if applicable)
  - Diesel generator building (if applicable)

- Elevation drawings and sectional drawings (of the same structures)
- Fire hazard assessment (FHA) drawings showing the layout of 10CRF50 Appendix R fire areas (of the same structures)

PROBABILISTIC RISK ASSESSMENT (PRA) INFORMATION:

- Thermal hydraulic (for example, MAAP) results for the accident classes outlined in Attachment 1 *(Note: Complete Attachment 1 is not included in this Appendix due to the sensitive nature of the information.)*
- PRA success criteria
- PRA dependency matrices (or equivalent)
- PRA importance values for initiating events, summary pie chart results, and so on

OTHER

- Severe accident management guidelines (SAMGs) or similar guidelines (for example, station blackout coping strategies)
- Site emergency plan evacuation timing study (that is, 10 mile emergency planning zone [EPZ])
- Plant operational procedures (non-SGI only) related to imminent threat actions, losses of large portions of the plant, manual operation of mitigation equipment (for example, auxiliary FW, reactor core isolation cooling), and so on
- Monetary book value of the individual reactor plants and/or site (to estimate financial loss)
- Net MWe rating of the individual reactor plants

A three-dimensional site/plant model available can be a very useful tool to have available during the on-site portion of the assessment.

ATTACHMENT 1

BWR Version

The following pages (not included in Appendix A due to the sensitive nature of the information) present the accident scenario progression classes that are expected to be used as part of the RAMCAP assessment to assess approximate timelines. These timelines are used to estimate the potential for off-site resources to provide assistance. As part of the RAMCAP assessment, individual scenarios involving potential core damage will be binned into one of the accident scenario classes.

The site is requested to fill in these tables based on existing thermal hydraulic plant assessments (for example, MAAP results). Not all classes may be judged applicable at all sites. No new thermal hydraulic calculations need to be performed in support of the RAMCAP assessment. Sites are requested to use existing results and engineering judgment to estimate the timelines outlined on the following pages, as judged applicable to the plant. For time estimates, the following precision is suggested:

Event Time	Estimate Precision
0–2 hours	nearest 10 minutes
2–8 hours	nearest 30 minutes
8+ hours	nearest 1 hour

Supporting information (for example, applicable summary pages from existing plant MAAP results) can also be submitted if it is judged helpful.

ATTACHMENT 1

PWR Version

The following pages (not included in Appendix A due to the sensitive nature of the information) present the accident scenario progression classes that are expected to be used as part of the RAMCAP assessment to assess approximate timelines. These timelines are used to estimate the potential for off-site resources to provide assistance. As part of the RAMCAP assessment, individual scenarios involving potential core damage will be binned into one of the accident scenario classes.

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Event Time	Estimate Precision
0–2 hours	nearest 10 minutes
2–8 hours	nearest 30 minutes
8+ hours	nearest 1 hour

Supporting information (for example, applicable summary pages from existing plant MAAP results) can also be submitted if it is judged helpful.

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