UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

September 22, 2014

Dr. Mohammad Modarres
University of Maryland
3112 Lee Building
College Park, MD 20742

VIA Electronic Mail:
modarres@umd.edu

SUBJCT: GRANT NO: NRC-HQ-60-14-G-0015

Dear Dr. Modarres:

Pursuant to the authority contained in the Federal Grant and Cooperative Grantee Act of 1977 and the Atomic Energy Act of 1954, the Nuclear Regulatory Commission (NRC) hereby awards to The University of Maryland (hereinafter referred to as the "Grantee" or "Recipient"), the sum of $207,783 to provide support for the "Study of the Implication of Multi-Unit Accidents in the Context of NRC's Quantitative Health Objectives".

This award is effective as of the date of this letter and shall apply to expenditures made by the Grantee furtherance of program objectives during the period beginning with the effective date of September 30, 2014 and ending date of September 29, 2016.

This award is made to the Recipient on condition that the funds will be administered in accordance with the terms and conditions as set forth in Attachment A (the Schedule); Attachment B (the Program Description); and Attachment C (the Standard Provisions); all of which have been agreed to by your organization.

Please ensure individuals selected as beneficiaries of support under this grant meet the legal requirements consistent with recent Supreme Court Decisions including *Fisher, Gratz, and Grutter.*

Please sign the enclosed grant to acknowledge your receipt of the award, and return as a pdf file to Mr. Daniel App by email at Daniel.App@nrc.gov.

Sincerely yours,

Sheila Bumpass

Sheila Bumpass
Grants Officer
Acquisition Management Division

Attachments:
Attachment A – Schedule
Attachment B – Program Description
Attachment C – Standard Terms and Conditions

Grant and Cooperative Agreement

CHOOSE ONE:
- ☐ COOPERATIVE AGREEMENT
- ☒ GRANT

CHOOSE ONE: ☐ EDUCATION ☐ FACILITIES ☒ RESEARCH ☐ SDCR ☐ TRAINING

1. GRANT/COOPERATIVE AGREEMENT NUMBER	2. SUPPLEMENT NUMBER	3. EFFECTIVE DATE	4. COMPLETION DATE
NRC-HQ-60-14-G-0015		09/30/2014	

5. ISSUED TO
NAME/ADDRESS OF RECIPIENT (No., Street, City/County, State, Zip)
UNIVERSITY OF MARYLAND
Attn: ANTOINETTE Lawson
OFFICE OF RESEARCH ADMINISTRATION
3112 LEE BUILDING
COLLEGE PARK MD 207425141

6. ISSUED BY U.S. NRC - HQ
Mailing Address: Acquisition Management Division
Mail Stop: 3WFN-05-C64MP
Washington DC 20555-0001

7. TAXPAYER IDENTIFICATION NO. (TIN)

8. COMMERCIAL & GOVERNMENT ENTITY (CAGE) NO.

9. PRINCIPAL INVESTIGATOR/ORGANIZATION'S PROJECT OR PROGRAM MGR. (*Name & Phone*)
Dr. Mohammad Modarres
Email: modarres@umd.edu Phone:301-314-9601

10. RESEARCH, PROJECT OR PROGRAM TITLE
Study of the Implication of Multi-Unit Accidents in the Context of NRC's Quantitative Health Objectives

11. PURPOSE
See Schedule

12. PERIOD OF PERFORMANCE (*Approximately*)
09/30/2014 through 09/29/2016

13A.	AWARD HISTORY	13B.	FUNDING HISTORY
PREVIOUS	$0.00	PREVIOUS	$0.00
THIS ACTION	$207,783.00	THIS ACTION	$207,783.00
CASH SHARE	$0.00	**TOTAL**	$207,783.00
NON-CASH SHARE	$0.00		
RECIPIENT SHARE	$0.00		
TOTAL	$207,783.00		

14. ACCOUNTING AND APPROPRIATION DATA
2014-X0200-FEEBASED-60-60D002-11-6-213-1052-4110

PURCHASE REQUEST NO.	JOB ORDER NO.	AMOUNT	STATUS
RES-14-0458			

15. POINTS OF CONTACT

	NAME	MAIL STOP	TELEPHONE	E-MAIL ADDRESS
TECHNICAL OFFICER	CHON DAVIS		301-251-7567	Chon.Davis@nrc.gov
NEGOTIATOR				
ADMINISTRATOR	DANIEL APP		301-287-0939	Daniel.App@nrc.gov
PAYMENTS				

16. THIS AWARD IS MADE UNDER THE AUTHORITY OF :
PURSUANT TO SECTION 31B AND 141B OF THE ATOMIC ENERGY ACT OF 1954, AS AMENDED

17. APPLICABLE STATEMENT(S), IF CHECKED:
- ☐ NO CHANGE IS MADE TO EXISTING PROVISIONS
- ☐ FDP TERMS AND CONDITIONS AND THE AGENCY-SPECIFIC REQUIREMENTS APPLY TO THIS GRANT

18. APPLICABLE ENCLOSURE(S), IF CHECKED:
- ☐ PROVISIONS ☐ SPECIAL CONDITIONS
- ☐ REQUIRED PUBLICATIONS AND REPORTS

UNITED STATES OF AMERICA		COOPERATIVE AGREEMENT RECIPIENT	
CONTRACTING/GRANT OFFICER	DATE	AUTHORIZED REPRESENTATIVE	DATE
SHEILA H. BUMPASS Sheila Bumpass	09/22/2014		

Grant and Cooperative Agreement

ITEM NO (A)	ITEM OR SERVICE (Include Specifications and Special Instructions) (B)	QUANTITY (C)	UNIT (D)	ESTIMATED COST	
				UNIT PRICE (E)	AMOUNT (F)
	CFDA Number: 77.009 Payment will be made through the Automated Standard Application for Payment (ASAP.gov) unless the receipient has failed to comply with the program objectives, award conditions, Federal reporting requirements or other conditions specified in 2 CFR 215 (OBM Circular A110). Delivery: 09/29/2016 Delivery Location Code: NRCHQ US NUCLEAR REGULATORY COMMISSION- MAIL PROCESSING CENTER 4930 BOILING BROOK PARKWAY ROCKVILLE MD 20852 USA Payment: ASAP GRANT FUNDS REIMBURSEMENT SYS US TREASURY Period of Performance: 09/30/2014 to 09/29/2016				

ATTACHMENT A - SCHEDULE

A.1 PURPOSE OF GRANT

The purpose of this Grant is to provide support to the "Study of the Implication of Multi-Unit Accidents in the Context of NRC's Quantitative Health Objectives" as described in Attachment B entitled "Program Description."

A.2 PERIOD OF GRANT

1. The effective date of this Grant is September 30, 2014. The estimated completion date of this Grant is September 29, 2016.

A.3 GENERAL

1. Total Estimated NRC Amount:	$207,783.00
2. Total Obligated Amount:	$207,783.00
3. Activity Title:	Study of the Implication of Multi-Unit Accidents in the Context of NRC's Quantitative Health Objectives
4. NRC Project Officer:	Chon Davis
5. NRC Technical Analyst:	Jeff Wood
6. DUNS No.:	790934285

A.4 BUDGET

Revisions to the budget shall be made in accordance with Revision of Grant Budget in accordance with 2 CFR 215.25.

	Year 1	**Year 2**
Personnel	$ 46,988.00	$ 50,694.00
Fringe	$ 11,747.00	$ 12,673.00
Travel	$ 2,500.00	$ 2,500.00
Other Direct Costs (Tuition)	$ 7,151.00	$ 7,437.00
Total Direct Cost	$ 68,386.00	$ 73,304.00
Indirect Cost	$ 31,842.00	$ 34,251.00
Total	$ 100,228.00	$ 107,555.00

All travel must be in accordance with University of Maryland's Travel Regulations or the US Government Travel Policy absent Grantee's travel regulation.

A.5 AMOUNT OF AWARD AND PAYMENT PROCEDURES

1. The total estimated amount of this Award is $207,783.00 for the two year period.

2. NRC hereby obligates the amount of $207,783.00 for program expenditures during the period set forth above and in support of the Budget above. The Grantee will be given written notice by the Grants Officer when additional funds will be added. NRC is not obligated to reimburse the Grantee for the expenditure of amounts in excess of the total obligated amount.

3. Payment shall be made to the Grantee in accordance with procedures set forth in the Automated Standard Application For Payments (ASAP) Procedures set forth below.

Attachment B – Program Description

PROGRAM DESCRIPTION

Project Title: *Study of the Implication of Multi-Unit Accidents in the Context of NRC's* Quantitative Health Objectives

1.0 Introduction

It is of much interest to formally define and assess representative risk metrics for PRA analysis and evaluation of multi-unit nuclear power plants in one site or even in multiple sites, as well as in Small Modular Reactors (SMRs). Additionally, multi-unit and multi-module SMR plants, although physically independent to a large extent, have many direct and indirect inter-connections that make them dependent. Examples of these dependencies include, certain initiating events simultaneously occurring in multiple units, a transient in one unit affecting some or all of the other units, proximity of the units to each other, shared structures, components (e.g., shared batteries and diesel generators), common operation practices, and substantial procedural and other organizational similarities. This two-year grant proposal seeks to address issues and develop a formal framework for the assessment of site risks and implications of the current quantitative safety goals in the context of multi-unit risk consideration. As such it involves investigation of the options to define and assess multi-unit / multi-module risk metrics for CDF, Large Release Frequency (LRF) and LERF, and subsequent health effects such as the prompt fatality contributing to the total site risk. The results of this research will help to determine whether it can be shown that the site risk is below the corresponding safety goals' QHOs. This proposal in particular supports the probabilistic risk assessment area of interest in this FOA, however, it is also relates to two other areas, namely: severe accident research and technical basis for issues affecting voluntary consensus standards.

2.0 Background

Currently, multi-unit site risk is neither formally nor adequately considered; this includes operating plant sites in either the regulatory or the commercial nuclear environment [1-3]. Fleming, Arndt, Omoto, Jung, et al. have recommended methods to deal with different facets of a multi-unit PRA analysis [3-6]; however, there is still no well-established understanding of the implications of multi-unit risks.

The U.S. Nuclear Regulatory Commission (NRC) has been discussing how to address the issue of risk metrics and risk assessment methods of sites involving multi-reactor units for many years [7] and identifies multi-unit risk metrics and assessment methods as a "Potential PSA Technology Challenge." The NRC regulations require units to be physically independent. For example, NRC's deterministic General Design Criterion 5 (GDC-5) prohibits sharing of Structures, Systems, and Components (SSCs) unless it can be shown that such sharing *will not be significant* in the event of an accident in one unit and an orderly shutdown of the remaining units. It is not clear how this GDC will be applied in a risk-informed regulatory framework and its implications on safety [8].

The NRC has dealt with multi-unit risk with certain actions following major accident events. For example, after the Chernobyl accident the NRC issued four recommendations involving noble gases and airborne volatiles being transported to the other three units onsite during the accident through a shared ventilation system[1]. As such, control room habitability, contamination outside of the control room, smoke control, and shared shutdown systems were more intensely evaluated for vulnerabilities to such events [9]. In 2005, NRC staff recommended an integrated risk analysis [10, 11] and presented the Commission with three options to deal with this so-called integrated risk: 1) take no action, 2) quantify the integrated risk at the site for new reactors being built, or 3) quantify the risk for all reactors at a site. The staff recommended Option 3 [12] however, the Advisory Committee on Reactor Safeguards (ACRS) suggested Option 2. The Commission later directed the staff to consider the ACRS's recommendations [12].

In 2005, the NRC staff recommended that modular reactor designs should account for the integrated risk posed at multi-unit sites [13]. The result of all this was NUREG-1860, which presented an approach to integrated risk that required the risk from new reactors be "limited" but with no prescriptive guidelines [14]. More recently, the NRC has been conducting an effort to create an integrated Level-3 PRA that includes the effects of multiple units, as well as the risk from all radiation sources onsite, such as the spent fuel pool [15].

The nuclear industry's integrated site risk solutions generally focus on only one facet of the PRA at a time without considering other concurrent events. For example, the station blackout (SBO) has been investigated because of its site impact and interdependencies in the electrical systems. Similarly, the industry has looked at seismic events at a site. One methodology recently looked at the seismic-induced dependencies between sister units and component fragilities across the site; however, severe accident damage that could interfere with emergency operation of other undamaged units were not addressed [1]. Although specific aspects of multi-unit risk have been looked at in an ad hoc fashion with greater detail, no integrated approach exists.

In the international arena, the International Atomic Energy Agency (IAEA) has been working on this area and its International Seismic Safety Centre has been working on developing ideas for the multi-unit PRA [16-18]. Also in 2012, IAEA sponsored a workshop that discussed the issue of multi-unit PRA, but did not offer any methodological solutions [19]. Finally, IAEA is planning another workshop on this subject that will take place in November 2014 [20]. However, the IAEA's efforts have not offered any formal integrated site-level risk assessment methodology. Finally, the ASME/ANS Joint Committee on Nuclear Risk Management (JCNRM) is discussing the development of a standard for PRA applications to SMRs, but this effort is still in its infancy with no standards available.

In summary, although recognized as an important issue by the Commission, ACRS, and IAEA, very little progress has been made in understanding and measuring the safety significance of

[1] Similar transport mechanism also occurred during the Fukushima Daiichi event, during which the fire/explosion at Unit 4 was caused by leakage of hydrogen released from Unit 3 through shared ductwork with Unit 4.

multi-unit risks and implications of NRC's QHOs in the context of multi-unit sites. Further, performing PRAs on multi-unit sites, one reactor at a time, yields misleading and optimistic risk insights and should be discontinued [8] and "site-based risk metrics should be defined and used in risk-informed decision making". This proposal's objective is to work toward addressing formal approaches to site-based risk assessment.

3.0 Multi-Unit Risk Metric and Assessment Options

The definition of the site CDF, LRF and LERF is more complex than the simple sum of the individual frequencies of a single unit because the units don't operate in a fully independent manner from each other, and there are interactions that tie them together. Dependencies between the units (albeit small) do exist because of specific design features, operating practices, safety features and culture, economic considerations, and construction layout. In order to quantify a multi-unit PRA, the CDF, LRF and LERF metrics must be clearly defined, dependencies between the units identified, accounted and modeled, the PRA model of the site developed and quantified, and the health effects estimated. This is a problem of major scope and the proposed research is to identify and recommend technical approaches that can pave the way for a full-scale study to assess and characterize safety implications of a site-level risk. It is important to start the research with a probabilistic definition of multi-unit site risk. Site risk can be viewed as an event in which one or more of the units experience the core damage (CD) event. Considering the site risk as an aleatory multivariate distribution (describing random variables $CD_1,\ldots,CD_n$ of each unit), risk of a single module CD can be expressed in two ways: marginal CD risk of each unit, or conditional CD risk of one unit given a CD event in other specific units. In each of these definitions, there are dependences within each unit (inter-unit dependencies) as well as among the units (intra-unit dependences). The intra-unit dependencies may exist among all units or among a subset of them. Intra-unit dependencies must be defined and probabilistically measured so as to make estimation of the marginal CD risk or conditional CD risk of a unit possible. Schroer [21] has identified six categories of intra-unit dependencies. Figure 1 depicts Schroer's unit-to-unit dependencies including examples [22]. In a causal-dependency situation, the root causes of these dependencies can be viewed as the *condition* that couples the units together.

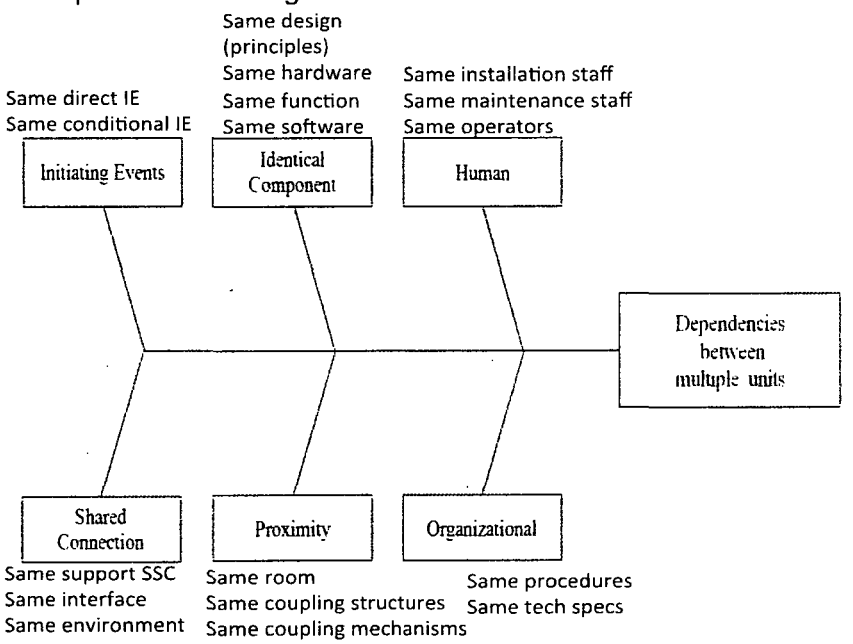

Figure 1. Classes of Intra-Unit Dependencies [22]

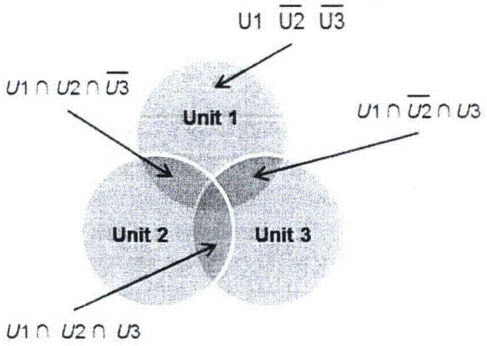

Figure 2. Multi-Unit CD as Single Event

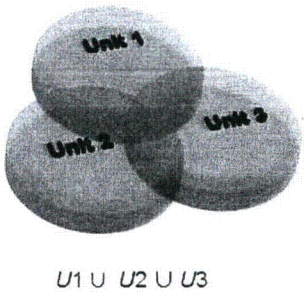

Figure 3. Multi-Unit CD as a Multiple Event

Figure 2 depicts the meaning of site CD as a set of mutually exclusive CD states for a hypothetical 3-units site, where each unit can be expressed by its marginal or conditional definitions of CD. Another view of the multi-unit risk could be expressed as a series system of two or more units. Figure 3 depicts this interpretation of the site CD that amounts to the event of *at least one CD*. The former definition makes the expression of the corresponding radiological release source term more meaningful. Regardless of the risk definition used, to estimate multi-unit risk a PRA model representing each unit and dependencies among the units must be developed and used. Two general approaches are possible: 1) treating each unit through a separate unit-specific PRA and combine the single-unit PRAs into a multi-unit one by superimposing the effects of the unit-to-unit dependencies, or 2) using a dynamic probabilistic risk assessment (DPRA) to establish a simulation approach capturing interaction of the units. To make the scope manageable and practical for limited two-year effort, we propose to use the former approach. The later approach is subject of a current Ph.D. research at the University of Maryland[2] from which the proposed research will benefit from and synergize.

Assume events $CD_1,\ldots,CD_n$ represent random variables describing the "events of a core damage" in units 1 to n. The union of the minimal cut sets of the individual units will represent clearly multi-unit CD. Two closely related definitions of the multi-unit CDF (or site CDF) may be formal summation of individual unit CDFs either expressed as the *marginal probability* (*per year*) for *all* conditions imposed by intra-unit dependencies of $P(CD_i)$ or, the *conditional* CDF of a unit, i, given condition C_j may be expressed by $P(CD_i|C_j)$. Accordingly, the definition of the multi-unit CDF expressed as *the annual probability of one or more core damage events* based on the marginal probability of a single unit CD using the total probability theorem would be

$$P(U_{i=1}^{n} CD_i) = \Sigma_{i\leq n} P(CD_i) - \Sigma_{i1<i2} P(CD_{i1} \cap CD_{i2}) + \cdots + (-1)^{n+1} \Sigma_{i1<i2,\ldots<i(n-1)} P(CD_{i1} \cap CD_{i2} \cap \ldots \cap CD_{in}) \quad (1)$$

Using Boole's inequality, a simpler and slightly more conservative estimate of the multi-unit CD can be obtained from

$$P(U_{i=1}^{n} CD_i) \leq \Sigma_{i\leq n} P(CD_i) \quad (2)$$

If a condition C_j exists that couples a *subset* of reactor units, say 1 through k, then each term of Equation (2) may be written as:

$$\Sigma_{i\leq n} P(CD_i|C_j) = P(CD_1|C_j) + P(CD_2|C_j) + \cdots + P(CD_n|C_j)$$

For multiple reactor core damage events under condition C_j;

$$P(\cap_{i=1}^{k} CD_i|C_j) = P(CD_1|C_j) P(CD_2|CD_1 \cap C_j) P(CD_3|CD_1 \cap CD_2 \cap C_j) \ldots P(CD_k| \cap_{i=1}^{k-1} CD_i \cap C_j) \quad (3)$$

From Equation (3) the total annual probability for the k units under all conditions C_j would be:

$$P\left(\cap_{i=1}^{k} CD_i\right) = \sum_j P\left(\cap_{i=1}^{k} CD_i | C_j\right) P(C_j) \quad (4)$$

Note that there may be causal dependencies among conditions such that one condition leads to others. Accordingly the hierarchy of such multiple causal conditions is

$$P(C_j) = \sum_m P(C_j | C_{j1}, \ldots C_{jm}) P(C_{j1}, \ldots C_{jm}) \quad (5)$$

where $P(C_{j1},\ldots,C_{jm})$ is the joint probability of conditions $C_{j1},\ldots,C_{jm}$. The problem now reduces to how one can determine the marginal annual probability of a CD event for one unit, or conditional probability of CD for a unit for specific set of conditions. For this purpose, there are several possible methods which could be extended (combination, parametric, and causal-based) to conduct multi-unit risk analysis. A major task of the research proposed here is to use these methods to address Equation (5) and will be discussed further in the next sub-section. Ultimately, we seek to estimate the site risk based on the two CD interpretations offered earlier and compare and discuss the technical pros and cons and of each definition.

3.1 Probabilistic Estimation of Multi-Unit Dependencies

Schroer [21] discusses a number of dependent analysis methods and classifies them into 3 major groups called: *combination, parametric and causal-based.* A key research in this proposal would be to study and extend these methods and to make them useful and practical in the context of multi-unit PRA analysis.

3.1.1 Combination

In this case the condition, C_j, describes a common event that should be explicitly modeled in each unit's PRA model (e.g., same SSCs serving multiple units, same initiating event, such as loss of power); they simply need to be represented as an identical item in the multi-unit PRA logic, so that they are not double counted in the quantification of the site CDF, LERF, LRF, etc. This would be a simple problem to handle and the accounting is done as part of the PRA logic manipulation.

3.1.2 Parametric

Parametric methods are commonly used in traditional single-unit PRAs for common cause failure events. The Seabrook Multi-Unit PRA, one of the only multi-unit PRAs and created in 1983, used the parametric beta factor [23]; however, there is not much information on how parameters currently used in single-unit PRAs would be applicable to the multi-unit PRAs. This issue needs to be investigated as part of this research. Use of the beta factor (and similarly alpha factor) in a multi-unit PRA may be problematic, given the conservatism that occurs when the common cause failure group is higher than four [24]. The other current parametric methods may not adequately address multi-unit PRAs because they use parameter estimators that assume that when one train of a system is challenged, all similar trains are also challenged [24]. This is oftentimes not the case for multi-unit events. For example, during a single-unit reactor trip, the supporting systems for that unit will be called upon while other units' systems usually continue with normal operation. In this research the implications of using the parametric methods across multi-unit reactors will be fully investigated.

3.1.3 Causal-based

This type of modeling appears as the most important and difficult coupling mechanism and constitutes a prime topic of investigation in this research. As such in this approach one attempts to estimate the CDF conditioned on a common causal factor C_j to multiple units. There are

several techniques for causal-based probabilistic estimation in the literature, including process modeling techniques, regression-based techniques, deterministic dynamic techniques, or Bayesian Belief Networks (BBN) [25]. The most established and promising causal-based technique is the use of BBNs. The nodes of the BBN graph represent random variables, and the links represent relationships between these probabilistically determined variables [26]. BBNs also allow dissimilar information to be combined, such as qualitative information like that from expert panels, as well as quantitative data [27].
Alternatively a causal-based method may use an integrated probabilistic physics-of-failure model [28]. The physics-of-failure approach used in this method allows the underlying physical failure mechanisms induced by the root cause of the condition C_j (e.g., wear, fatigue fracture, creep, etc.) to be incorporated into the assessment of $Pr(C_j)$ and thus the entire risk model (as depicted by Figure 4 for inter-unit dependencies, but can be equally applied to intra-unit dependencies too). Causal relationships in Figure 4 can be established based on probabilistic physically based models such as those used in fracture mechanics.

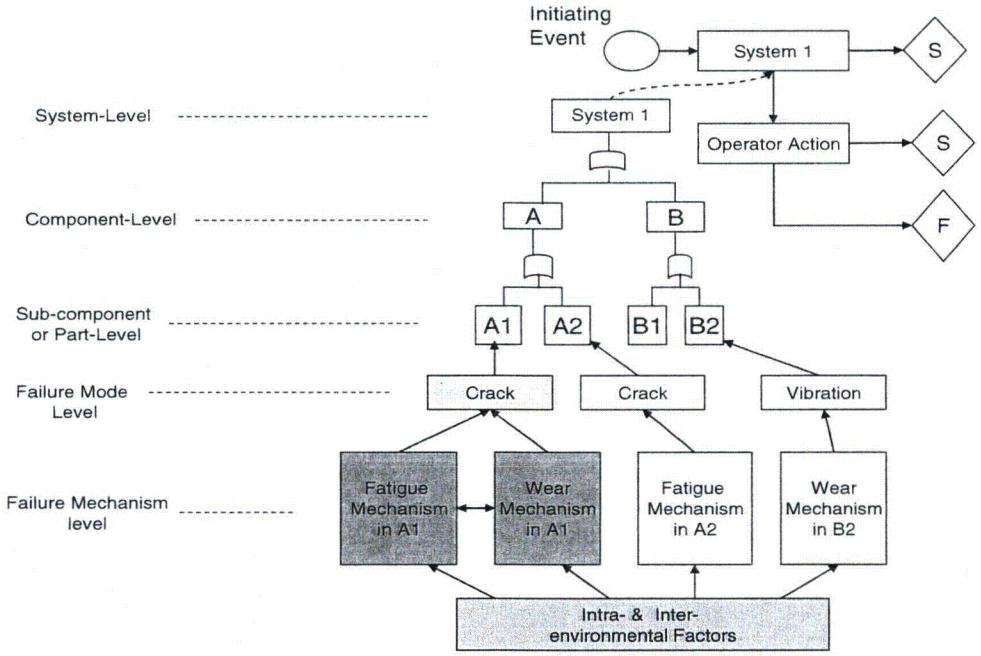

Figure 4. Physic-of-Failure approach to the Assessment of Conditional Condition Failures [29]

Considering Figure 4, one could build the BBN model of dependence too. For example, Mohaghegh [29] offers an example of a BNN using the underlying mechanistically-based damaged for two independent compressor units failing due to a common external condition (high compression state of operation) which causes a resulting synergic failure mechanism (between fatigue and wear), whereby coupling the two components (See Fig. 5).

It is expected that the causal dependencies represented in Figure 5 are useful and possible to model as part of this research. Further, the limited causal dependencies that may tie multiple units are not expected to make this approach impractical. It is indeed possible to model in many cases the external events that can impose mechanical or thermal loads, which create a causal chain of dependencies in the PRAs as was experienced in the Fukushima Daiichi accident.

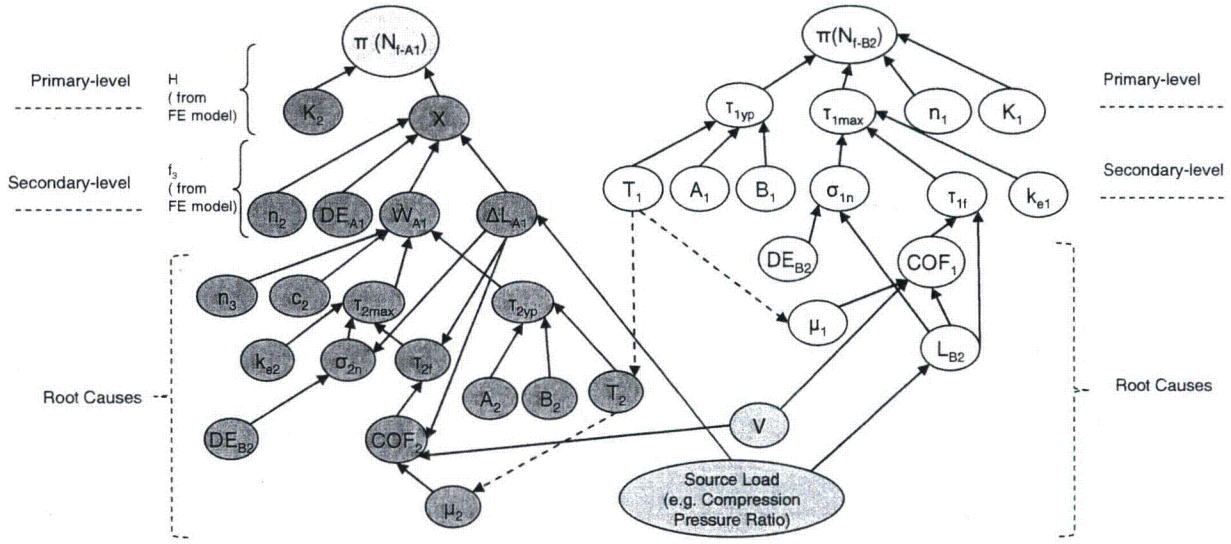

Figure 5. A BBN Model of Causal Dependencies Based on Known Physics Models [29]

The efficient application of BBNs to model a causal chain of dependencies in the PRAs requires the use of hybrid models formed with discrete and continuous variables. The evaluation of hybrid networks offers a challenge, as inference algorithms have limitations, such as dealing with state space explosion and finding an appropriate discretization. Furthermore, the strength of the relationships is measured in terms of conditional distributions, which require the computation of marginal estimates related to the variables of interest. To circumvent these limitations, we proposed the development of a new and efficient approach to deal with hybrid BBNs [30] based on stochastic simulation techniques. This method presents no constraint about the nature of the variables into BBN, and allows for BBNs that are capable of dealing with any probability distribution function.

Indeed, the proposed approach involves an extension of the Griddy-Gibbs Sampling (GGS) algorithm. One of the advantages of GGS over alternatives such as Metropolis-Hastings (MH) sampling algorithms arises from the possibility of using approximate functions when computing marginal distributions. The flexibility of GGS is paramount for its applicability to complex BBN models. Thus, the proposed procedure to deal with hybrid BBNs is based on an extended GGS sampling algorithm to effectively and efficiently (i) determine the target distribution, (ii) to promote a more adequate exploration of the support of the probability model under study, and (iii) to perform a better inference about the marginal distribution of interest, π as depicted by the distribution for the output node corresponding to component A1 in Figure 5.

The ultimate result of this part of the research would be the establishment of efficient techniques to assess Equation (5) for various classes of root causes that makes SSCs and initiating events in multi-unit sites dependent. This will ultimately allow estimation of the conditional and marginal annual probability of site risk determination.

4.0 Case Study: Simplified Multi-Unit PRA Assessment and Explicit Accounting of Unit-to-Unit Dependencies

4.1 Simplified Multi-Unit CDF

To make a more manageable and practical approach to quantify the multi-unit risk, we seek extension of accident scenarios from a single-unit "static" PRA into multi-unit "static" PRA by identifying and accounting the unit-to-unit dependencies. The CD scenarios of a single unit PRA may be used to branch off to the other units. Four possible types of dependencies that extend a single-unit static PRA into multi-unit static PRA model may be identified based on Schroer's dependency classes [21] as depicted by Figure 6. It is envisioned that the dependency quantification research discussed in Section 3.1 of this proposal will form the basis for estimation of the likelihood of probabilistically important dependencies (illustrated by the dashed lines in Figure 6). In this concept the initiating events and SSC-based dependencies will be identified for the single-unit PRA models at a multi-unit site. That is, it will be shown what initiating events affect multi-units and what SSC failures, human errors or external events can affect or be affected by an SSC modeled in each static PRA unit. Then, a simple logic or Boolean manipulation of the minimal cut sets of each unit along with the dependencies identified, a priori, will tie the individual unit cut sets into a single set of multi-unit cut sets.

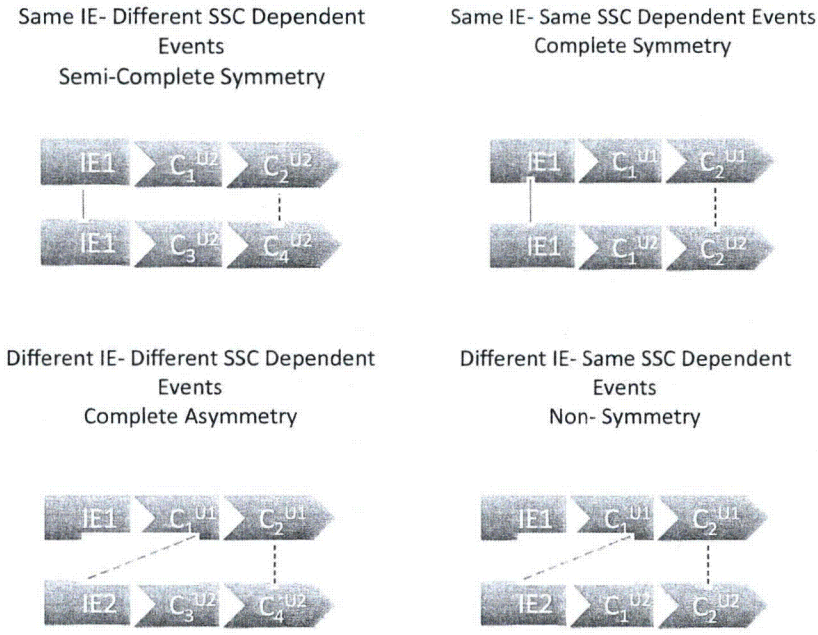

Figure 6. Depiction of Four Multi-Unit Types of Scenarios Developed Based on Schror's [21] Classes Dependencies (Dashed lines are causal dependencies and solid lines are hard, physical dependencies such as the same SSC or same IE).

4.2 Simplified Multi-Unit LRF and LERF

To estimate consequences of a multi-unit accident, the simplified approach to multi-unit scenario development discussed in Section 4, it is necessary to estimate large releases of radioactivity that lead to prompt fatalities. Modarres et al. [31] summarized three options for estimation of large release frequency. In the first option the magnitude of release may be measured on the basis of associating a "large" release with an expectation that it would result in at least one early fatality. For example, the ASME/ANS Standard for PRA (RA-Sa-2009) [32] defines a "large early release" as a "rapid, unmitigated release of airborne fission products … such that there is a potential for early health effects." Incorporating the effectiveness of temporal consequences, such as public evacuation and other protective actions, however,

complicates the definition of a large release in this context. NUREG/CR-6094 [33] removes this complication by defining a release as large when it leads to an early fatality (with high probability) for a stationary individual standing one-mile from the site. This is a simple and convincing measure. However, it nevertheless requires some assumptions when applied to a particular site. To determine this measure of LRF, a hypothetical site should be assumed along with subjective meteorological data and an assumption of what constitutes a "high probability." While identifying a representative site is possible, major conservatisms may be necessary to make it justifiable.

The second option measures the large release (i.e., on the basis of magnitude of the source term associated with each multi-unit core damage scenarios) in the form of either absolute or relative quantities of radionuclides released. The absolute measure is often expressed in terms of activity released to the environment as a surrogate for a quantitative calculation of dose. This is typically done for a few isotopes that tend to dominate estimates of offsite health effects, such as I-131 or Cs-137. For relative release, the traditional form expressed is fractional release of core inventory of various radionuclide groups to the environment and the timing of the release may be specified. NUREG/CR-6595 [34] (Appendix A) suggests specific release fractions that may considered as large (e.g., 2-3% of the iodine inventory). This option is simple to describe, but selecting the total amount of release or release fractions considered large is subjective and contentious.

The third option for large release de-emphasizes the amount of radioactivity released, by defining it in terms of the physical condition of systems, pressure boundaries and radionuclide barriers at the time release begins. For example a large release might be considered as one involving failure of multiple reactor pressure vessels and containment pressure boundaries due to isolation failure(s), bypass, or structural damage within a few hours of core melting and fission product release from fuel, during which opportunities for attenuation of the airborne concentration are minimal. Conditions associated with multiple modules may also be defined, if necessary.

Large early release frequency (LERF) is defined by the NRC as "the frequency of those accidents leading to significant, unmitigated releases from containment in a time frame prior to effective evacuation of the close-in population such that there is a potential for early health effects." The use of system states to define large release has been discussed in NUREG/CR-6596 for calculating LERF. The simplest idea, held by many, has been that large early release is a subset of large release. With this understanding, one concludes that LERF < LRF. In April 2009, the Advisory Committee on Reactor Safeguards (ACRS) discussed this notion and considered an NEI paper which referenced LERF values calculated from five NUREG-1150 PRAs [35]. The corresponding LRF values for the same PRAs were calculated using the frequency of one or more deaths definition (i.e., option 1). Under this formulation, the NEI paper [36] concluded that actually LERF>>LRF. This is because not all LERF contributors cause deaths, as weather and population may not properly align to cause any death, but all scenarios of LRF involve deaths. The ACRS and members of the staff who participated largely agreed with the NEI formulation and conclusions.

A contribution from the proposed research will be a detailed evaluation of the pros and cons of the LRF and LERF options discussed above. For example in option 3 discussed above, multi-unit reactor-system states and other conditions can be selected by pursuing to perform a level-3 PRA based on a surrogate site, from which one can roll back to the level-2 release categories to see which ones contribute to one or more deaths. Having identified those release categories, the contributing unit (system states) with characteristics that may be designated as large releases can be defined. While this method is certainly conservative for a single unit, its extension as part of the proposed research can justify events considered as appropriate release frequency measures for simultaneous release events from multiple units.

4.3 Simplified Estimation of Prompt Fatality and Comparison to QHOs

There are no safety goals or QHOs that apply to total site risk, so as pointed out in the report [37] it stands to reason that the risk from a multi-unit would need to be shown to be below the QHO for prompt fatality. For Level 3 consequence analysis, the important factors, which influence the prompt fatality risk, come from the source term parameters. This includes radionuclide activity, rate and timing of release, chemical and physical form of radionuclides, thermal energy, and release fractions. Much as was done in NUREG-1150 and WASH-1400, this proposal will make some assumptions about the source term, or do sensitivity analysis of the MACCS parameters to see what combination yields the most conservative result. Alternatively the proposed study could use source terms from either NUREG-1150 or WASH-1400; or in the best case it will take the approach and results from the State of the Art Reactor Consequence Analysis (SOARCA) study to develop best estimates of the offsite radiological health consequences for potential severe reactor accidents of multi-unit site. SOARCA analyzed the potential consequences of severe accidents at the Surry and Peach Bottom nuclear power plants[3]. This study concluded that plant resources and procedures could stop or significantly mitigate the accident. This could lead to a situation of essentially zero immediate fatalities and small increase in long-term cancer deaths.

In order to do a limited scope Level 3 consequence analysis this research would assume a "generic" site, possibly using SOARCA study's Surry and Peach Bottom model. The results of the consequence analysis for multi-unit PRA scenarios will essentially focus on quantifying and discussing the adequacy of the NRC's QHOs.

5.0 Project Schedule, Milestones and Deliverables

A two-year research program is proposed to achieve the objectives of the described in the previous sections of this proposal. Year-1 will focus on methodology development and characterization of the technical issues involved, and year-2 will perform the case study. The proposed research tasks will be described next.
Program deliverables include:

1. Development of practical probabilistic-based computational techniques to account for parametric and causal-based dependencies across reactor units.
2. Definition, meaning and measures of multi-unit risk indices.
3. Development of an approach to develop multi-unit core damage accident scenarios from static single-unit PRAs.
4. Investigation and discussion of appropriate methods to assess multi-unit CDF, LRF and LERF.
5. Assessment of multi-unit quantitative health risks, comparison and assessment of the adequacy of QHOs for multi-unit sites.

The proposed schedule and major tasks description has been depicted in the chart below:

Task Description	Year 1	Year 2
Multi-Unit Modeling and PRA Assessments		
➢ Literature review on multi-unit research		
➢ Development of causal dependency probabilities		
➢ Adaptation of parametric dependency methods		
➢ Generation of multi-unit Level-1 sequences		
➢ Quantification and generation of leading multi-unit scenarios		
➢ First conference paper preparation		
➢ Annual progress report		
Case Study: Assessment of Multi-Unit Risks and QHO Comparison		
➢ Development and discussion of appropriate LRF and LERF values for multi-unit releases		
➢ Refinement of the multi-unit level-1 PRA model		
➢ Estimation of the multi-unit source term		
➢ Level 3 analysis and assessment of multi-unit risks and comparison to QHOs		
➢ Second conference paper preparation		
➢ First journal paper preparation		
➢ Final Report		

Attachment C – Standard Terms and Conditions

The Nuclear Regulatory Commission's
Standard Terms and Conditions for U.S. Nongovernmental Grantees

Preface

This award is based on the application submitted to, and as approved by, the Nuclear Regulatory Commission (NRC) under the authorization 42 USC 2051(b) pursuant to section 31b and 141b of the Atomic Energy Act of 1954, as amended, and is subject to the terms and conditions incorporated either directly or by reference in the following:

- Grant program legislation and program regulation cited in this Notice of Grant Award.
- Restrictions on the expenditure of Federal funds in appropriation acts, to the extent those restrictions are pertinent to the award.
- Code of Federal Regulations/Regulatory Requirements - 2 CFR 215 Uniform Administrative Requirements For Grants And Agreements With Institutions Of Higher Education, Hospitals, And Other Non-Profit Organizations (OMB Circulars), as applicable.

To assist with finding additional guidance for selected items of cost as required in 2 CRF 220, 2 CFR 225, and 2 CFR 230 this URL to the Office of Management and Budget Cost Circulars is included for reference: http://www.whitehouse.gov/omb/circulars_index-ffm.

Any inconsistency or conflict in terms and conditions specified in the award will be resolved according to the following order of precedence: public laws, regulations, applicable notices published in the Federal Register, Executive Orders (EOs), Office of Management and Budget (OMB) Circulars, the Nuclear Regulatory Commission's (NRC) Mandatory Standard Provisions, special award conditions, and standard award conditions.

Certifications and Representations: These terms incorporate the certifications and representations required by statute, executive order, or regulation that were submitted with the SF424B application through Grants.gov.

I. Mandatory General Requirements

The order of these requirements does not make one requirement more important than any other requirement.

1. Applicability of 2 CFR Part 215

All provisions of 2 CFR Part 215 and all Standard Provisions attached to this grant/cooperative agreement are applicable to the Grantee and to sub-recipients which meet the definition of "Grantee" in Part 215, unless a section specifically excludes a sub-recipient from coverage. The Grantee and any sub-recipients must, in addition to the assurances made as part of the application, comply and require each of its sub-awardees employed in the completion of the project to comply with Subpart C of 2 CFR 215 and include this term in lower-tier (subaward) covered transactions.

Grantees must comply with monitoring procedures and audit requirements in accordance with OMB Circular A-133.

2. Award Package

§ 215.41 Grantee responsibilities.

The Grantee is obligated to conduct project oversight as may be appropriate, to manage the funds with prudence, and to comply with the provisions outlined in 2 CFR 215.41. Within this framework, the Principal Investigator (PI) named on the award face page, Block 11, is responsible for the scientific or technical direction of the project and for preparation of the project performance reports. This award is funded on a cost reimbursement basis not to exceed the amount awarded as indicated on the face page, Block 16, and is subject to a refund of unexpended funds to NRC.

The standards contained in this section do not relieve the Grantee of the contractual responsibilities arising under its contract(s). The Grantee is the responsible authority, without recourse to the NRC, regarding the settlement and satisfaction of all contractual and administrative issues arising out of procurements entered into in support of an award or other agreement. This includes disputes, claims, protests of award, source evaluation or other matters of a contractual nature. Matters concerning violation of statute are to be referred to such Federal, State or local authority as may have proper jurisdiction.

Subgrants
Appendix A to Part 215—Contract Provisions

Sub-recipients, sub-awardees, and contractors have no relationship with NRC under the terms of this grant/cooperative agreement. All required NRC approvals must be directed through the Grantee to NRC. See 2 CFR 215 and 215.41.

Nondiscrimination
This provision is applicable when work under the grant/cooperative agreement is performed in the U.S. or when employees are recruited in the U.S.

The Grantee agrees to comply with the non-discrimination requirements below:

- Title VI of the Civil Rights Act of 1964 (42 USC §§ 2000d et seq)
- Title IX of the Education Amendments of 1972 (20 USC §§ 1681 et seq)
- Section 504 of the Rehabilitation Act of 1973, as amended (29 USC § 794)
- The Age Discrimination Act of 1975, as amended (42 USC §§ 6101 et seq)
- The Americans with Disabilities Act of 1990 (42 USC §§ 12101 et seq)
- Parts II and III of EO 11246 as amended by EO 11375 and 12086.
- EO 13166, "Improving Access to Services for Persons with Limited English Proficiency."
- Any other applicable non-discrimination law(s).

Generally, Title VI of the Civil Rights Act of 1964, 42 USC § 2000e et seq, provides that it shall be an unlawful employment practice for an employer to discharge any individual or otherwise to discriminate against an individual with respect to compensation, terms, conditions, or privileges of employment because of such individual's race, color, religion, sex, or national origin. However, Title VI, 42 USC § 2000e-1(a), expressly exempts from the prohibition against discrimination on the basis of religion, a religious corporation, association, educational institution, or society with respect to the employment of individuals of a particular religion to perform work connected with the carrying on by such corporation, association, educational institution, or society of its activities.

Modifications/Prior Approval
NRC's prior written approval may be required before a Grantee makes certain budget modifications or undertakes particular activities. If NRC approval is required for changes in the grant or cooperative agreement, it must be requested and obtained from the NRC Grants Officer in advance of the change or obligation of funds. All requests for NRC prior approval, including requests for extensions to the period of performance, should be made, in writing (which includes submission by e-mail), to the designated Grants Specialist and Program Office 30 days before the proposed change. The request should be signed by the authorized organizational official. Failure to obtain prior approval, when required, from the NRC Grants Officer, may result in the disallowance of costs, or other enforcement action within NRC's authority.

Lobbying Restrictions
The Grantee will comply, as applicable, with provisions of the Hatch Act (5 U.S.C. §§1501-1508 and 7324-7328) which limit the political activities of employees whose principal employment activities are funded in whole or in part with Federal funds.

The Grantee will comply with provisions of 31 USC § 1352. This provision generally prohibits the use of Federal funds for lobbying in the Executive or Legislative Branches of the Federal

Government in connection with the award, and requires disclosure of the use of non-Federal funds for lobbying.

The Grantee receiving in excess of $100,000.00 in Federal funding shall submit a completed Standard Form (SF) LLL, "Disclosure of Lobbying Activities," regarding the use of non-Federal funds for lobbying within 30 days following the end of the calendar quarter in which there occurs any event that requires disclosure or that materially affects the accuracy of the information contained in any disclosure form previously filed. The Grantee must submit the SF-LLL, including those received from sub-recipients, contractors, and subcontractors, to the Grants Officer.

§ 215.13 Debarment And Suspension.

The Grantee agrees to notify the Grants Officer immediately upon learning that it or any of its principals:

(1) Are presently excluded or disqualified from covered transactions by any Federal department or agency;

(2) Have been convicted within the preceding three-year period preceding this proposal been convicted of or had a civil judgment rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State, or local) transaction or contract under a public transaction; violation of Federal or State antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, tax evasion, receiving stolen property, making false claims, or obstruction of justice; commission of any other offense indicating a lack of business integrity or business honesty that seriously and directly affects your present responsibility;

(3) Are presently indicted for or otherwise criminally or civilly charged by a governmental entity (Federal, State, or local) with commission of any of the offenses enumerated in paragraph (1)(b); and

(4) Have had one or more public transactions (Federal, State, or local) terminated for cause or default within the preceding three years.

b. The Grantee agrees that, unless authorized by the Grants Officer, it will not knowingly enter into any subgrant or contracts under this grant/cooperative agreement with a person or entity that is listed as Exclusion on SAM (http://sam.gov).

The Grantee further agrees to include the following provision in any subgrant or contracts entered into under this award:

'Debarment, Suspension, Ineligibility, and Voluntary Exclusion'

The Grantee certifies that neither it nor its principals is presently excluded or disqualified from participation in this transaction by any Federal department or agency. The policies and procedures applicable to debarment, suspension, and ineligibility under NRC-financed transactions are set forth in 2 CFR Part 180.'

Drug-Free Workplace
The Grantee must be in compliance with The Federal Drug Free Workplace Act of 1988. The policies and procedures applicable to violations of these requirements are set forth in 41 USC 702.

Implementation of E.O. 13224 -- Executive Order On Terrorist Financing
The Grantee is reminded that U.S. Executive Orders and U.S. law prohibits transactions with, and the provision of resources and support to, individuals and organizations associated with terrorism. It is the legal responsibility of the Grantee to ensure compliance with these Executive Orders and laws. This provision must be included in all contracts/sub-awards issued under this grant/cooperative agreement.

The Grantee must comply with Executive Order 13224, Blocking Property and Prohibiting Transactions with Persons who Commit, Threaten to Commit, or Support Terrorism. Information about this Executive Order can be found at: www.fas.org/irp/offdocs/eo/eo-13224.htm.

Procurement Standards § 215.40-48
Sections 215.41 through 215.48 set forth standards for use by Grantees in establishing procedures for the procurement of supplies and other expendable property, equipment, real property and other services with Federal funds. These standards are furnished to ensure that such materials and services are obtained in an effective manner and in compliance with the provisions of applicable Federal statutes and executive orders. No additional procurement standards or requirements will be imposed by the Federal awarding agencies upon Grantees, unless specifically required by Federal statute or executive order or approved by OMB.

Travel
Travel must be in accordance with the Grantee's Travel Regulations or the US Government Travel Policy and Regulations at: www.gsa.gov/federaltravelregulation and the per diem rates set forth at: www.gsa.gov/perdiem, absent Grantee's travel regulations. Travel costs for the grant must be consistent with provisions as established in Appendix A to 2 CFR 220 (J.53). All other travel, domestic or international, must not increase the total estimated award amount.

Domestic Travel:
Domestic travel is an appropriate charge to this award and prior authorization for specific trips are not required, if the trip is identified in the Grantee's approved program description and approved budget. Domestic trips not stated in the approved budget require the written prior approval of the Grants Officer, and must not increase the total estimated award amount.

All common carrier travel reimbursable hereunder shall be via the least expensive class rates consistent with achieving the objective of the travel and in accordance with the Grantee's policies and practices. Travel by first-class travel is not authorized unless prior approval is obtained from the Grants Officer.

International Travel:
International travel requires **PRIOR** written approval by the Project Officer and the Grants Officer, even if the international travel is stated in the approved program description and the approved budget.

The Grantee will comply with the provisions of the Fly American Act (49 USC 40118) as implemented through 41 CFR 301-10.131 through 301-10.143.

Property and Equipment Management Standards
Property and equipment standards of this award shall follow provisions as established in 2 CFR 215.30-37.

Intangible and Intellectual Property
Intangible and intellectual property of this award shall generally follow provisions established in 2 CFR 215.36.

Inventions Report - The Bayh-Dole Act (P.L. 96-517) affords Grantees the right to elect and retain title to inventions they develop with funding under an NRC grant award ("subject inventions"). In accepting an award, the Grantee agrees to comply with applicable NRC policies, the Bayh-Dole Act, and its Government-wide implementing regulations found at Title 37, Code of Federal Regulations (CFR) Part 401. A significant part of the regulations require that the Grantee report all subject inventions to the awarding agency (NRC) as well as include an acknowledgement of federal support in any patents.

Patent Notification Procedures - If the NRC or its Grantees, without making a patent search, knows (or has demonstrable reasonable grounds to know) that technology covered by a valid United States patent has been or will be used without a license from the owner, EO 12889 requires NRC to notify the owner. If the Grantee uses or has used patented technology under this award without license or permission from the owner, the Grantee must notify the Grants Officer. This notice does not mean that the Government authorizes and consents to any copyright or patent infringement occurring under the financial assistance.

Data, Databases, and Software - The rights to any work produced or purchased under a NRC federal financial assistance award, such as data, databases or software are determined by 2 CFR 215.36. The Grantee owns any work produced or purchased under a NRC federal financial assistance award subject to NRC's right to obtain, reproduce, publish or otherwise use the work or authorize others to receive, reproduce, publish or otherwise use the data for Government purposes.

Copyright - The Grantee may copyright any work produced under a NRC federal financial assistance award subject to NRC's royalty-free nonexclusive and irrevocable right to reproduce, publish or otherwise use the work or authorize others to do so for Government purposes. Works jointly authored by NRC and Grantee employees may be copyrighted but only the part authored by the Grantee is protected because, under 17 USC § 105, works produced by Government employees are not copyrightable in the United States. On occasion, NRC may ask the Grantee to transfer to NRC its copyright in a particular work when NRC is undertaking the primary dissemination of the work. Ownership of copyright by the Government through assignment is permitted under 17 USC § 105.

Records Retention and Access Requirements
Grantee shall follow established provisions in 2 CFR 215.53.

Conflict Of Interest Standards
Conflict of Interest Standards for this award will follow OCOI requirements set forth in Section 170A of the Atomic Energy Act of 1954, as amended, and provisions set forth at 2 CFR 215.42 Codes of Conduct.

Dispute Review Procedures
a. Any request for review of a notice of termination or other adverse decision should be addressed to the Grants Officer. It must be postmarked or transmitted electronically no later than 30 days after the postmarked date of such termination or adverse decision from the Grants Officer.

b. The request for review must contain a full statement of the Grantee's position and the pertinent facts and reasons in support of such position.

c. The Grants Officer will promptly acknowledge receipt of the request for review and shall forward it to the Director, Office of Administration, who shall appoint an intra-agency Appeal Board to review a grantee appeal of an agency action, if required, which will consist of the program office director, the Deputy Director of Office of Administration, and the Office of General Counsel.

d. Pending resolution of the request for review, the NRC may withhold or defer payments under the award during the review proceedings.

e. The review committee will request the Grants Officer who issued the notice of termination or adverse action to provide copies of all relevant background materials and documents. The committee may, at its discretion, invite representatives of the Grantee and the NRC program office to discuss pertinent issues and to submit such additional information as it deems appropriate. The chairman of the review committee will insure that all review activities or proceedings are adequately documented.

f. Based on its review, the committee will prepare its recommendation to the Director, Office of Administration, who will advise the parties concerned of his/her decision.

Termination and Enforcement
Termination of this award will follow provisions as established in 2 CFR 215.60-62,

Monitoring and Reporting § 215.50-53
Grantee Financial Management systems must comply with the provisions in 2 CFR 215.21

- Payment – 2 CFR 215.22
- Cost Share – 2 CFR 215.23
- Program Income – 2 CFR 215.24
    - Earned program income, if any, will be added to funds committed to the project by the NRC and Grantee and used to further eligible project or program objectives or deducted from the total project cost allowable cost as directed by the Grants Officer or the terms and conditions of award.
- Budget Revision – 2 CFR 215.25
    - The Grantee is required to report deviations from the approved budget and program descriptions in accordance with 2 CFR 215.25 and request prior written approval from the Program Officer and the Grants Officer.

- The Grantee is not authorized to rebudget between direct costs and indirect costs without written approval of the Grants Officer.
- The Grantee is authorized to transfer funds among direct cost categories up to a cumulative 10 percent of the total approved budget. The Grantee is not allowed to transfer funds if the transfer would cause any Federal appropriation to be used for purposes other than those consistent with the original intent of the appropriation.
- Allowable Costs – 2 CFR 215.27

Federal Financial Reports -
The Grantee shall submit a "Federal Financial Report" (SF-425) on a quarterly basis for the periods ending March 31, June 30, September 30, and December 31, or any portion thereof, unless otherwise specified in a special award condition. Reports are due no later than 30 days following the end of each reporting period. A final SF-425 is due within 90 days after expiration of the award. The report should be submitted electronically to the following:

1. Grants_FFR.Resource@NRC.gov (NOTE: There is an underscore between Grants and FFR);
2. RESGrants.Resource@NRC.gov;
3. Technical Analyst; and
4. Grants Officer.

Period of Availability of Funds 2 CFR § 215.28
If a funding period is specified, a Grantee may charge to the grant only allowable costs resulting from obligations incurred during the funding period and any pre-award costs authorized by the NRC.

Unless otherwise authorized in 2 CFR 215.25(e)(2) or a special award condition, any extension of the award period can only be authorized by the Grants Officer in writing. Verbal or written assurances of funding from other than the Grants Officer shall not constitute authority to obligate funds for programmatic activities beyond the expiration date.

The NRC has no obligation to provide any additional prospective or incremental funding. Any modification of the award to increase funding and to extend the period of performance is at the sole discretion of the NRC.

Automated Standard Application For Payments (ASAP) Procedures
Unless otherwise stated, grantee payments are made using the Department of Treasury's Automated Standard Application for Payment (ASAP) system http://www.fms.treas.gov/asap/index.html, through preauthorized electronic funds transfers. To receive payments, Grantees are required to enroll with the Department of Treasury, Financial Management Service, and Regional Financial Centers, which allows them to use the on-line method of withdrawing funds from their ASAP established accounts. The following information is required to make ASAP withdrawals: (1) ASAP account number – the award number found on the cover sheet of the award; (2) Agency Location Code (ALC) – 31000001; and Region Code. Grantees enrolled in the ASAP system do not need to submit a "Request for Advance or Reimbursement" (SF-270).

II. Audit Requirements

Audits
Organization-wide or program-specific audits are performed in accordance with the Single Audit Act Amendments of 1996, as implemented by OMB Circular A-133, "Audits of States, Local Governments, and Non-Profit Organizations." Grantees are subject to the provisions of OMB Circular A-133 if they expend $500,000.00 or more in a year in Federal awards.

The Form SF-SAC and the Single Audit Reporting packages for fiscal periods ending on or after January 1, 2008 are submitted online.

1. Create your online report ID at http://harvester.census.gov/fac/collect/ddeindex.html;
2. Complete the Form SF-SAC;
3. Upload the Single Audit;
4. Certify the Submission;
5. Click "Submit."

Organizations expending less than $500,000.00 a year are not required to have an annual audit for that year but must make their grant-related records available to NRC or other designated officials for review or audit.

III. Programmatic Requirements

Performance Progress (Technical) Reports
The Grantee shall submit performance (technical) reports electronically to the NRC Project Officer and Grants Officer on a quarterly for the periods ending March 31, June 30, September 30, and December 31, or any portion thereof, unless otherwise specified in a special award condition. Reports are due no later than 30 days following the end of each reporting period. The report should be submitted electronically to the following:

1. Grants_PPR.Resource@NRC.gov (NOTE: There is an underscore between Grants and PPR);
2. RESGrants.Resource@NRC.gov;
3. Technical Analyst; and
4. Grants Officer.

Unless otherwise specified in the award provisions, performance progress (technical) reports shall contain brief information as prescribed in the applicable uniform administrative requirements 2 CFR §215.51 which are incorporated in the award.

Unsatisfactory Performance
Failure to perform the work in accordance with the terms of the award and maintain at least a satisfactory performance rating, may result in designation of the Grantee as high risk and the assignment of special award conditions. Further action may be required as specified in the standard term and condition entitled "Termination."

Failure to comply with the award provisions may result in a negative impact on future NRC funding. In addition, the Grants Officer may withhold payments; change the method of payment from advance to reimbursement; impose special award conditions; suspend or terminate the grant.

Other Federal Awards With Similar Programmatic Activities
The Grantee will immediately notify the Project Officer and the Grants Officer in writing if after award, other financial assistance is received to support or fund any portion of the program description stated in the NRC award. NRC will not pay for costs that are funded by other sources.

Prohibition Against Assignment By The Grantee
The Grantee will not transfer, pledge, mortgage, or otherwise assign the award, or any interest to the award, or any claim arising under the award, to any party, banks, trust companies, or other financing or financial institutions without the written approval of the Grants Officer.

Site Visits
The NRC, through authorized representatives, has the right to make site visits to review project accomplishments and management control systems and to provide technical assistance as required. If any site visit is made by the NRC on the premises of the Grantee or contractor under an award, the Grantee shall provide and shall require his/her contractors to provide all reasonable facilities and assistance for the safety and convenience of the Government representative in the performance of their duties.

IV. Miscellaneous Requirements

Criminal and Prohibited Activities
The Program Fraud Civil Remedies Act (31 USC §§ 3801-3812), provides for the imposition of civil penalties against persons who make false, fictitious, or fraudulent claims to the Federal government for money (including money representing grant/cooperative agreements, loans, or other benefits.)

False statements (18 USC § 287), provides that whoever makes or presents any false, fictitious, or fraudulent statements, representations, or claims against the United States shall be subject to imprisonment of not more than five years and shall be subject to a fine in the amount provided by 18 USC § 287.

False Claims Act (31 USC 3729 et seq), provides that suits under this Act can be brought by the government, or a person on behalf of the government, for false claims under federal assistance programs.

Copeland "Anti-Kickback" Act (18 USC § 874), prohibits a person or organization engaged in a federally supported project from enticing an employee working on the project from giving up a part of his compensation under an employment contract.

American-Made Equipment And Products
Grantees are encouraged to purchase American-made equipment and products with funding provided under this award.

Increasing Seat Belt Use in the United States
EO 13043 requires Grantees to encourage employees and contractors to enforce on-the-job seat belt policies and programs when operating company-owned, rented or personally-owned vehicle.

Federal Leadership of Reducing Text Messaging While Driving
EO 13513 requires Grantees to encourage employees, sub-awardees, and contractors to adopt and enforce policies that ban text messaging while driving company-owned, rented vehicles or privately owned vehicles when on official Government business or when performing any work for or on behalf of the Federal Government.

Federal Employee Expenses
Federal agencies are barred from accepting funds from a Grantee to pay transportation, travel, or other expenses for any Federal employee unless specifically approved in the terms of the award. Use of award funds (Federal or non-Federal) or the Grantee's provision of in-kind goods or services, for the purposes of transportation, travel, or any other expenses for any Federal employee may raise appropriation augmentation issues. In addition, NRC policy prohibits the acceptance of gifts, including travel payments for Federal employees, from Grantees or applicants regardless of the source.

Minority Serving Institutions (MSIs) Initiative
Pursuant to EOs 13256, 13230, and 13270, NRC is strongly committed to broadening the participation of MSIs in its financial assistance program. NRC's goals include achieving full participation of MSIs in order to advance the development of human potential, strengthen the Nation's capacity to provide high-quality education, and increase opportunities for MSIs to participate in and benefit from Federal financial assistance programs. NRC encourages all applicants and Grantees to include meaningful participations of MSIs. Institutions eligible to be considered MSIs are listed on the Department of Education website:
http://www.ed.gov/about/offices/list/ocr/edlite-minorityinst.html

Research Misconduct
Scientific or research misconduct refers to the fabrication, falsification, or plagiarism in proposing, performing, or reviewing research, or in reporting research results. It does not include honest errors or differences of opinions. The Grantee organization has the primary responsibility to investigate allegations and provide reports to the Federal Government. Funds expended on an activity that is determined to be invalid or unreliable because of scientific misconduct may result in a disallowance of costs for which the institution may be liable for repayment to the awarding agency. The Office of Science and Technology Policy at the White House published in the Federal Register on December 6, 2000, a final policy that addressed research misconduct. The policy was developed by the National Science and Technology Council (65 FR 76260). The NRC requires that any allegation be submitted to the Grants Officer, who will also notify the OIG of such allegation. Generally, the Grantee organization shall investigate the allegation and submit its findings to the Grants Officer. The NRC may accept the Grantee's findings or proceed with its own investigation. The Grants Officer shall inform the Grantee of the NRC's final determination.

Publications, Videos, and Acknowledgment of Sponsorship
Publication of the results or findings of a research project in appropriate professional journals and production of video or other media is encouraged as an important method of recording and reporting scientific information. It is also a constructive means to expand access to federally funded research. The Grantee is required to submit a copy to the NRC and when releasing information related to a funded project include a statement that the project or effort undertaken was or is sponsored by the NRC. The Grantee is also responsible for assuring that every publication of material (including Internet sites and videos) based on or developed under an award, except scientific articles or papers appearing in scientific, technical or professional journals, contains the following disclaimer:

"This [report/video] was prepared by [Grantee name] under award [number] from [name of operating unit], Nuclear Regulatory Commission. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the view of the [name of operating unit] or the US Nuclear Regulatory Commission."

Trafficking In Victims Protection Act Of 2000 (as amended by the Trafficking Victims Protection Reauthorization Act of 2003)

Section 106(g) of the Trafficking In Victims Protection Act Of 2000 (as amended as amended, directs on a government-wide basis that:

> "any grant, contract, or cooperative agreement provided or entered into by a Federal department or agency under which funds are to be provided to a private entity, in whole or in part, shall include a condition that authorizes the department or agency to terminate the grant, contract, or cooperative agreement, without penalty, if the grantee or any subgrantee, or the contractor or any subcontractor (i) engages in severe forms of trafficking in persons or has procured a commercial sex act during the period of time that the grant, contract, or cooperative agreement is in effect, or (ii) uses forced labor in the performance of the grant, contract, or cooperative agreement." (22 U.S.C. § 7104(g)).

EXECUTIVE COMPENSATION REPORTING

2 CFR 170.220 directs agencies to include the following text to each grant award to a non-federal entity if the total funding is $25,000 or more in Federal funding.

Reporting Subawards and Executive Compensation.

a. *Reporting of first-tier subawards.*

1. *Applicability.* Unless you are exempt as provided in paragraph d. of this award term, you must report each action that obligates $25,000.00 or more in Federal funds that does not include Recovery funds (as defined in section 1512(a)(2) of the American Recovery and Reinvestment Act of 2009, Pub. L. 111–5) for a subaward to an entity (see definitions in paragraph e. of this award term).

2. *Where and when to report.*

i. You must report each obligating action described in paragraph a.1. of this award term to *http://www.fsrs.gov*.

ii. For subaward information, report no later than the end of the month following the month in which the obligation was made. (For example, if the obligation was made on November 7, 2010, the obligation must be reported by no later than December 31, 2010.)

3. *What to report.* You must report the information about each obligating action that the submission instructions posted at *http://www.fsrs.gov* specify.

b. *Reporting Total Compensation of Recipient Executives.*

1. *Applicability and what to report.* You must report total compensation for each of your five most highly compensated executives for the preceding completed fiscal year, if—

i. the total Federal funding authorized to date under this award is $25,000.00 or more;

ii. in the preceding fiscal year, you received—

(A) 80 percent or more of your annual gross revenues from Federal procurement contracts (and subcontracts) and Federal financial assistance subject to the Transparency Act, as defined at 2 CFR 170.320 (and subawards); and

(B) $25,000,000 or more in annual gross revenues from Federal procurement contracts (and subcontracts) and Federal financial assistance subject to the Transparency Act, as defined at 2 CFR 170.320 (and subawards); and

iii. The public does not have access to information about the compensation of the executives through periodic reports filed under section 13(a) or 15(d) of the Securities Exchange Act of 1934 (15 U.S.C. 78m(a), 78o(d)) or section 6104 of the Internal Revenue Code of 1986. (To determine if the public has access to the compensation information, see the U.S. Security and Exchange Commission total compensation filings at *http://www.sec.gov/answers/execomp.htm*.)

2. *Where and when to report.* You must report executive total compensation described in paragraph b.1. of this award term:

i. As part of your registration profile at *http://www.sam.gov* .

ii. By the end of the month following the month in which this award is made, and annually thereafter.

c. *Reporting of Total Compensation of Subrecipient Executives.*

1. *Applicability and what to report.* Unless you are exempt as provided in paragraph d. of this award term, for each first-tier subrecipient under this award, you shall report the names and total compensation of each of the subrecipient's five most highly compensated executives for the subrecipient's preceding completed fiscal year, if—

i. in the subrecipient's preceding fiscal year, the subrecipient received—

(A) 80 percent or more of its annual gross revenues from Federal procurement contracts (and subcontracts) and Federal financial assistance subject to the Transparency Act, as defined at 2 CFR 170.320 (and subawards); and

(B) $25,000,000 or more in annual gross revenues from Federal procurement contracts (and subcontracts), and Federal financial assistance subject to the Transparency Act (and subawards); and

ii. The public does not have access to information about the compensation of the executives through periodic reports filed under section 13(a) or 15(d) of the Securities Exchange Act of 1934 (15 U.S.C. 78m(a), 78o(d)) or section 6104 of the Internal Revenue Code of 1986. (To determine if the public has access to the compensation information, see the U.S. Security and Exchange Commission total compensation filings at *http://www.sec.gov/answers/execomp.htm*.)

2. *Where and when to report.* You must report subrecipient executive total compensation described in paragraph c.1. of this award term:

i. To the recipient.

ii. By the end of the month following the month during which you make the subaward. For example, if a subaward is obligated on any date during the month of October of a given year (*i.e.,* between October 1 and 31), you must report any required compensation information of the subrecipient by November 30 of that year.

d. *Exemptions*

If, in the previous tax year, you had gross income, from all sources, under $300,000.00, you are exempt from the requirements to report:

i. Subawards,

and

ii. The total compensation of the five most highly compensated executives of any subrecipient.

e. *Definitions.* For purposes of this award term:

1. *Entity* means all of the following, as defined in 2 CFR part 25:

i. A Governmental organization, which is a State, local government, or Indian tribe;

ii. A foreign public entity;

iii. A domestic or foreign nonprofit organization;

iv. A domestic or foreign for-profit organization;

v. A Federal agency, but only as a subrecipient under an award or subaward to a non-Federal entity.

2. *Executive* means officers, managing partners, or any other employees in management positions.

3. *Subaward:*

i. This term means a legal instrument to provide support for the performance of any portion of the substantive project or program for which you received this award and that you as the recipient award to an eligible subrecipient.

ii. The term does not include your procurement of property and services needed to carry out the project or program (for further explanation, see Sec. __ .210 of the attachment to OMB Circular A–133, "Audits of States, Local Governments, and Non-Profit Organizations").

iii. A subaward may be provided through any legal agreement, including an agreement that you or a subrecipient considers a contract.

4. *Subrecipient* means an entity that:

i. Receives a subaward from you (the recipient) under this award; and

ii. Is accountable to you for the use of the Federal funds provided by the subaward.

5. *Total compensation* means the cash and noncash dollar value earned by the executive during the recipient's or subrecipient's preceding fiscal year and includes the following (for more information see 17 CFR 229.402(c)(2)):

i. *Salary and bonus.*

ii. *Awards of stock, stock options, and stock appreciation rights.* Use the dollar amount recognized for financial statement reporting purposes with respect to the fiscal year in accordance with the Statement of Financial Accounting Standards No. 123 (Revised 2004) (FAS 123R), Shared Based Payments.

iii. *Earnings for services under non-equity incentive plans.* This does not include group life, health, hospitalization or medical reimbursement plans that do not discriminate in favor of executives, and are available generally to all salaried employees.

iv. *Change in pension value.* This is the change in present value of defined benefit and actuarial pension plans.

v. *Above-market earnings on deferred compensation which is not tax-qualified.*

vi. Other compensation, if the aggregate value of all such other compensation (e.g. severance, termination payments, value of life insurance paid on behalf of the employee, perquisites or property) for the executive exceeds $10,000.00.