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

May 1, 2015

Dr. Tunc Aldemir
The Ohio State University
1960 Kenny Road
Columbus, OH 43210

VIA Electronic Mail
aldemir.1@osu.edu

SUBJCT: GRANT NO: NRC-HQ-60-15-G-0002

Dear Dr. Aldemir:

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 Ohio State University (hereinafter referred to as the "Grantee" or "Recipient"), the sum of $224,922.00 to provide support for "Severe Accident Management Guideline (SAMG) Validation within the Context of Severe Accident Uncertainties" entitled "Program Description."

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 May 1, 2015 and ending April 30, 2017.

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 Ms. M'Lita Carr by email at Mlita.Carr@nrc.gov.

Sincerely yours,

M'Lita Carr
M'Lita Carr
Grant Officer
Research & Grants Team
Acquisition Management Division

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

TEMPLATE - ADM001 SUNSI REVIEW COMPLETE ADM002

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-60-15-G-0002		05/01/2015	

5. ISSUED TO
NAME/ADDRESS OF RECIPIENT (No., Street, City/County, State, Zip)
OHIO STATE UNIVERSITY OFFICE OF SPONSORED PROGRAMS THE
1960 KENNY RD
COLUMBUS OH 432101016

6. ISSUED BY: US 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*)
Prof. Tunc Aldemir
Email: aldemir.1@osu.edu; Phone: (614) 292-4627

10. RESEARCH, PROJECT OR PROGRAM TITLE
Severe Accident Management Guideline (SAMG) Validation within the Context of Severe Accident Uncertainties

11. PURPOSE
See Schedule

12. PERIOD OF PERFORMANCE (*Approximately*)
05/01/2015 through 04/30/2017

13A.	AWARD HISTORY	13B.	FUNDING HISTORY
PREVIOUS	$0.00	PREVIOUS	$0.00
THIS ACTION	$224,922.00	THIS ACTION	$224,922.00
CASH SHARE	$0.00	**TOTAL**	$224,922.00
NON-CASH SHARE	$0.00		
RECIPIENT SHARE	$0.00		
TOTAL	$224,922.00		

14. ACCOUNTING AND APPROPRIATION DATA
2015-X0200-FEEBASED-60-60D003-11-6-213-1045-4110

PURCHASE REQUEST NO.	JOB ORDER NO.	AMOUNT	STATUS
RES-15-0122			

15. POINTS OF CONTACT

	NAME	MAIL STOP	TELEPHONE	E-MAIL ADDRESS
TECHNICAL OFFICER	SARAH B. SHAFFER		(301) 251-7942	SARAH.SHAFFER@NRC.gov
NEGOTIATOR				
ADMINISTRATOR	M'LITA R. CARR		(301) 415-6869	MLITA.CARR@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
M'LITA R. CARR	04/16/2015		

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 NRC Technical Analyst: Tina Ghosh, Tina.Ghosh@nrc.gov. Payment will be made through the Automated Standard Application for Payment (ASAP.gov) unless the recipient has failed to comply with the program objectives, award conditions, Federal reporting requirements or other conditions specified in 2 CFR 215 (OMB Circular A110). Payment: ASAP GRANT FUNDS REIMBURSEMENT SYS US TREASURY Period of Performance: 05/01/2015 to 04/30/2017 NRC-HQ-60-14-FOA-0001				

ATTACHMENT A - SCHEDULE

A.1 PURPOSE OF GRANT

The purpose of this Grant is to provide support to the "Severe Accident Management Guideline (SAMG) Validation within the Context of Severe Accident Uncertainties" as described in Attachment B entitled "Program Description."

A.2 PERIOD OF GRANT

1. The effective date of this Grant is May 1, 2015. The estimated completion date of this Grant is April 30, 2017.

2. Funds obligated hereunder are available for program expenditures for the estimated period: May 1, 2015 – April 30, 2017.

GENERAL

1. Total Estimated NRC Amount:	$224,922.00
2. Total Obligated Amount:	$224,922.00
3. Cost-Sharing Amount:	$0.00
4. Activity Title:	Severe Accident Management Guideline (SAMG) Validation within the Context of Severe Accident Uncertainties
5. NRC Project Officer:	Sarah Shaffer
6. Technical Analyst:	Tina Ghosh
7. DUNS No.:	832127323

A.3 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	$ 9,102.00	$ 9,375.00
Fringe	$ 1,511.00	$ 1,556.00
Travel	$ 2,000.00	$ 2,000.00
Other	$ 67,857.00	$ 70,558.00
Total Direct Cost	$ 80,470.00	$ 83,489.00
Indirect Cost	$ 30,068.00	$ 30,895.00
Total	$110,538.00	$114,384.00

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

A.4 AMOUNT OF AWARD AND PAYMENT PROCEDURES

1. The total estimated amount of this Award is $224,922.00 for the two year period.

2. NRC hereby obligates the amount of $224,922.00 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

1. **Introduction**

One of the findings of the U.S. Nuclear Regulatory Commissions (NRC's) Fukushima near term task force involved deficiencies in the implementation of Severe Accident Management Guidelines (SAMG) and in the subsequent training of plant staff in their use. The industry has moved forward aggressively in the development of new SAMGs as well as Flex Support Guidelines (FSG), which include the incorporation of Flexible Coping Strategies (FLEX) equipment and post-accident instrumentation. The proposed effort addresses the need for uncertainty analysis in the "validation" of SAMGs and to support the subsequent training of plant personnel.

Emergency Operating Procedures (EOPs) play an analogous role within design basis space that SAMGs play for beyond design basis events. The EOPs are intended to smoothly transition into SAMGs at a point in an event in which the focus of the event changes from the avoidance of fuel damage to the mitigation of severe accident consequences. Following the development of generic EOPs by reactor vendors subsequent to the Three Mile Island Unit 2 accident, utilities undertook a process of modifying the generic EOPs to plant-specific conditions and then the "validation" of those EOPs on plant-specific simulators. Although there are significant uncertainties in the predictive capabilities of accident simulation within the design basis space, they are not nearly as great as the uncertainties associated with severe accident behavior and with the ability of plant instrumentation to inform the operators of the current state of the plant.

At the point of transition from the EOPs to the SAMGs, control of the accident switches from the control room operators to the Technical Support Center (TSC). Although the TCS staff will have received training in severe accident behavior and the implementation of SAMGs, their expertise will be limited. They will also be exposed to extreme Performance Shaping Factors (PSFs) that will affect their ability to make optimal decisions. Thus, human reliability assessment (HRA) is a key element of evaluating the impact of uncertainty on the effectiveness of SAMGs.

Plant operating staff currently spend a significant fraction of their time in simulator-based training and retraining in the implementation of EOPs. This extensive training on variations in the conditions to which the operators are exposed provides an excellent means for continually checking on the effectiveness of the EOPs in place at the plant. It is not anticipated that training on the implementation of SAMGs will be nearly as extensive as for EOPs and, although severe accident simulators are being developed, the analog to the plant simulator doesn't exist. Table top exercises need to be performed periodically in which variations in scenarios are presented to the TSC staff. These exercises should include consideration of severe accident uncertainties and a program of continuing improvement in SAMGs based on lessons learned from the exercises.

The objective of the proposed program is to develop a methodology for examining the impact of severe accident uncertainties and their likelihoods on the appropriateness and effectiveness of existing SAMGs. The project will lead to a software tool that would support the independent validation of SAMGs accounting for uncertainties in severe accident phenomenology, instrumentation reliability in a severe accident environment, and human performance. The software tool can be also used for TSC staff training. Section 2 of the proposal gives an overview of the overall approach. The related work to date that has been performed at The Ohio State University (OSU) is described in Section 3. Section 4 describes the scope of work. The program management, deliverables, schedule and project cost are given in Sections 5 through 8, respectively.

2. Approach

The proposed approach is based on the use of the dynamic event tree tool ADAPT (Analysis of Dynamic Accident Progression Trees) which employs the concept of dynamic event trees (DETs) and parallel processing to perform exhaustive uncertainty analyses and a cognitive model of human reliability similar to the approach used in the IDAC computer code. The NRC in their white paper on advanced modeling techniques for Level 2/3 PRA recommended development of a DET method (Approach 3 in the white paper) for advancing the Level 2/3 PRA methodology.

The proposed study represents an extension of the Level 3 PRA that is currently in progress at the NRC, which is being performed for Units 1 and 2 of the Vogtle Plant using a NUREG-1150 plant as example plant. The study will examine both aleatory and epistemic sources of uncertainties in an inner-loop (for modeling uncertainties), outer-loop (for input uncertainties) approach. The study will focus on Level 1/Level 2 uncertainties. Scenarios resulting in containment failure will be carried into MACCS2 code to obtain offsite consequences. However, it is not the intent of the study to examine the uncertainties associated with offsite emergency response actions. The EOPs and SAMGs provide natural branching points for the DETs in the generation of possible scenarios.

The MELCOR code will be used in the analysis of the Level 2 phase of scenarios, including conditions in the initial phase of the accident. In applying ADAPT to account for uncertainties, a large number of scenarios will be generated. Because of the computational expense of outer iterations, only a subset of these scenarios will be subjected to the full uncertainty study, which includes epistemic uncertainties. It is likely that the outer loop will employ Latin Hypercube Sampling (rather than full Monte Carlo) and a very small sample size for the purpose of demonstrating the methodology in sampling from uncertainty distributions in the quantification of the scenario frequencies. However, early in the study consideration will be given to alternative sampling schemes that could provide accelerated convergence on figure of merits to be used (e.g. magnitude of release, latent cancer fatalities). The output of the analyses will be clustered in order to assist in the interpretation of results.

Uncertainties in accident phenomenology, plant state monitoring, and human performance will be included in each case analyzed. Variations in SAMGs and in instrumentation performance will be included in separate cases, so that the potential benefits of alternative strategies and augmented instrumentation can be determined.

The proposed work will leverage previous and existing work at OSU and Sandia National Laboratories (SNL).

3. Previous Relevant Work at OSU

The OSU developed the ADAPT computer code with partial support from SNL. ADAPT has been used in the assessment of severe accident uncertainties in Level 2 PRA both by OSU[3] and SNL. This tool provides a basis for evaluating the impact of severe accident uncertainties on the effectiveness of SAMGs. The first applications of the ADAPT methodology by OSU involved MELCOR analyses of a pressurized water reactor (PWR) station blackout event which contributed to the dissertation of Dr. Aram Hakobyan (currently on the risk analysis staff of Grand Gulf Nuclear Power Plant). This study focused on the competitive failure of steam generator tubes, surge line and hot leg piping due to creep rupture within the scope of Level 2 PRA. The dissertation of Dr. Kyle Metzroth (currently at Knolls Atomic Power Laboratory) investigated a broad spectrum of station blackout scenarios and compared the scenarios generated in the Zion plant in NUREG-1150 with scenarios generated by ADAPT with the MELCOR code. That work looked in detail at pump seal loss of coolant accident and hydrogen combustion events. It also was limited to Level 2 outcomes. Dr. Acacia Brunett's (currently at the Argonne National Laboratory (ANL)) dissertation heavily overlapped in scope with the currently proposed program. Dr. Brunett also performed Level 2 analyses examining the potential impact of station blackout recovery measures, the sensitivity of hydrogen production to emergency cooling flow rate at different time periods after the start of core damage, and the potential for hydrogen and carbon monoxide combustion more realistically than in the previous ADAPT/MELCOR studies. It was shown that, for concretes with high limestone aggregate, the potential exists for a deflagration of sufficient magnitude to fail the containment, if power is recovered late in the accident. Under those conditions, alternative accident management strategies might be preferred involving only partial depressurization of the containment. Dr. Brunett developed an approach for the successive refinement of fragility curves in demonstrating the convergence of results. Dr. Douglas Osborn's dissertation (currently at SNL) involved a seamless Level 2/3 analysis of station blackout scenarios with ADAPT coupled with MELCOR and MACCS2. This study involved the running over 3,000 scenarios over an extended time period. In order to better interpret the results, the data were clustered using Level 2 parameters. DET analysis is computationally intensive particularly if an inner-loop/outer-loop approach is taken to examine both aleatory and epistemic uncertainties. In Dr. David Grabaskas's dissertation (also currently at the ANL), accelerated convergence sampling techniques were examined as alternatives to the standard Wilkes approach used in regulatory analyses.

In view of the large number of scenarios generated with the DET approach, analysis of the results requires additional aides for post processing. An approach that has been proposed by OSU is to use clustering based on various techniques. Clustering (as opposed to binning) does not require prespecification of the bounds of sets into which the scenarios will be grouped. Dr. Diego Mandelli's dissertation (currently at the Idaho National Laboratory) investigated the use of hierarchical, K-means, fuzzy C-means and mode seeking clustering techniques to facilitate the analysis of dynamic PRA results. Using the analysis of a Zion Plant station blackout event with ADAPT coupled to MELCOR as an example, it was shown that 2,225 scenarios requiring 844 GB of memory could be grouped in 19 clusters requiring 400 MB of memory which drastically reduces the effort and computational requirements in the analysis of the results.

The OSU has a strong background in testing, revising and validating HRA models for use in dynamic PRA. This expertise will be leveraged in integrating HRA into the SAMG PRA and in developing mature models for severe accident analysis.

Ranjit Sundaramurthi (MS 2011) developed the human reliability model requirements for dynamic PRA models used to determine risk-informed safety margins for nuclear power plants. Sundaramurthi's model integrates fine-grain and coarse-grain analysis to provide the desired resolution for each subsection of the PRA model. This is achieved by employing a variety of HRA models to address the desired level of detail. Simple models are used when they are sufficient, and more complex models are employed when necessary. This flexible approach will be extended beyond EOPs to SAMGs and severe accident condition analysis.

This work also analyzed the existing IDA/IDAC HRA model to incorporate functionalities demanded by advanced/dynamic PRA. This approach will be employed to update existing HRA models for use with SAMGs. The study developed a Bayesian Belief Network of PSFs based on the IDAC model and data collected from aviation and nuclear accidents. The impact of PSFs on the strategy-selection process of the operator is addressed, and a foundation is laid for developing mental models related to NPP operation.

This work has continued in the OSU Nuclear Power Plant Simulator Facility, which was established in 2011 to study the dynamic relationship between a commercial nuclear power plant and the plant operators. Atul Gupta (MS 2012) oversaw the installation of a digital boiling water reactor simulator program, setting up the facility for HRA validation studies, and development of an HRA course.

Work related to development of NPP Operator mental models continues in the simulator facility in conjunction with collaboration with University of Maryland to validate the IDAC model. Rachel Benish Shirley and Nan Wang (MS 2014) are refining their method for measuring PSF impact on operator performance and eliciting operator mental models. To support this work, undergraduate students are trained to operate the simulator program in the extensive laboratory sessions incorporated in a NPP Systems and Operations course. Student performances in the simulator are being compared with results from the IDAC model. This comparison (currently underway) is expected to provide direction for significant improvements to the IDAC model. Student operator mental models—obtained through extensive interviews, video observations, and student coursework—will provide the foundation for a student operator mental model module in IDAC. The same approach can be used with experienced operators to develop mental models for professionals rather than students. Similar methods will be used for incorporating SAMGs into IDAC and other HRA methods.

The OSU's expertise in HRA is not limited to IDAC; classical models are considered as well. For example, Rachel Benish Shirley analyzed THERP to determine the statistical requirements for a full-scope validation of the method in a simulator study. The approach employed joins abstract theoretical analysis of the method with lessons learned from a small pilot study conducted in the simulator facility. The proposed validation uses Bayesian analysis to reduce the otherwise prohibitively large sample size necessary to validate the model. This tactic lends itself well to the uncertainty and large scope inherent in SAMG analysis.

4. Scope of Work

The scope of work is divided into two phases corresponding approximately to the two year duration of the project. Phase I addresses the model and software tool development work and testing required in undertaking an application study. A preliminary analysis will be performed in Phase II for a selected plant damage state.

4.1 Phase I: Methodology and Software Tool Development

The methodology will utilize the ADAPT/MELCOR tool developed by OSU and SNL[9] interfaced with HRA and MACCS2 consequence code.

ADAPT will be used dynamically generate DETs during an accident simulation in response to variations or uncertainties in important parameters including phenomenological events, the behavior of active and passive components, and the operators' cognitive activities and actions. ADAPT relies on branching rules (i.e., determine when a branch point is needed); handles system code initiation, termination, and file processing; and determine scenario probabilities. More detailed descriptions of ADAPT is provided in Reference 4.

In the current ADAPT/MELCOR logic, control functions located within the MELCOR model stop the calculation at specified branching parameters. The reason for the stoppage is determined by ADAPT by parsing the text file listing of the pre-determined MELCOR variables of interest which then initiates a new MELCOR run to reflect the phenomenological event or component failure associated with the branching parameter that caused MELCOR to stop. Consideration is being given in this project to change the ADAPT/MELCOR interface to be able to access all MELCOR data during the execution to allow easier modifications of branching rules.

Similar to IDAC, HRA model developed for SAMG analysis will be a rule-based methodology that simulates the cognition, decision, and action processes of an a TSC team; accounts for performance influencing factors and memory; and probabilistically simulates the crew's responses, which generally include cognitive responses (e.g. information retrieval, strategy selection) and actions (e.g. communications or physical interactions with the system). However, because SAMGs (and related Level 2 procedures) are significantly different in levels of specificity from EOPs, and the process involving the TSC directing the post-core damage actions are different, the HRA model will take account of the potential for actions to be delayed or trade-offs of alternative actions to be analyzed. Rules-of-behavior encode the dynamics of information processing, problem solving, strategy selection and execution of actions. The level of effort required to develop a routine as complex as IDAC is not warranted, however, at this time. Phase I tasks are described below.

Task 1.1 HRA Development and Coupling

The suggested approach for near-term coupling of ADAPT, the HRA model, MELCOR and MACCS2 is illustrated in Fig. 1. To efficiently implement this scheme, work will be performed by OSU in collaboration with SNL. As indicated in Fig. 1, it is currently suggested that the HRA model will interface directly with MELCOR. Information from MELCOR is required by the HRA model for making branching decisions and for changing control parameters (i.e., non-branching decisions). The information consists of nodal information that simulates the parameters monitored by operators and the TSC

during an accident. Additional information on whether a component is failed will also be required as it will potentially affect operator actions:

1. Interactive input variables (via file or socket).
2. User–specified output files (EDF package) from MELCOR to drive the control room signals.
3. Interactive executive control arguments (STOP, START, PAUSE).

The subtasks associated with Task 1.1 are the following:

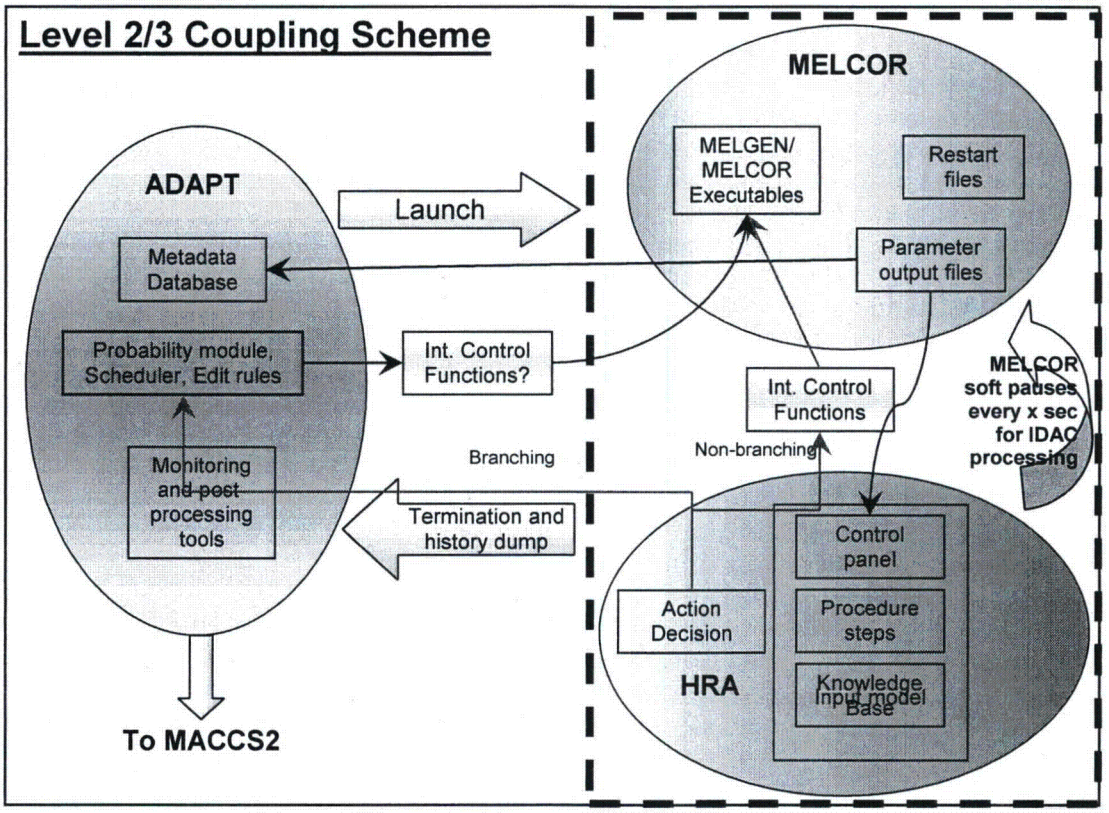

Figure 1. Proposed scheme for coupling ADAPT, HRA, MELCOR and MACCS2.

Subtask 1.1.1: Add any additional interface capability as necessary to the MELCOR code. For example, the user-specified output file may need a buffer flush to support simultaneous access. Additional flexibility may require new results to be appended to an existing file from the previous calculation.

Subtask 1.1.2: Develop the required MELCOR output variables to drive the HRA model for the selected demonstration transient The output variables are those parameters which would be monitored by the operators in the control room and by personnel in the TSC as part of their efforts to respond to a transient, both in trying to prevent core damage and in maintaining containment integrity. The interface list will need to be enhanced to include EOPs during early stages of the accident transitioning into SAMGs.

Subtask 1.1.3: Develop HRA model to provide human control actions (i.e., non-branching actions) to the MELCOR model through interactive control functions.

Subtask 1.1.4: Develop the required interactive control variables for the MELCOR model. The plant model control system will need to be enhanced to accept interactive control directives from the HRA model. Also, any built-in operator action controllers in the plant model will be removed.

Subtask 1.1.5: An HRA model will be developed, which will interface with MELCOR and ADAPT. Replace the branching functions with directives to stop MELCOR and specify an informational message on why the calculation was stopped (i.e., identify the branch point decision to which it is related).

The IDAC HRA method will be modified to interface with MELCOR. This work will build on the modifications already incorporated into IDAC for the *Discrete Dynamic Probabilistic Risk Assessment Model Development and Application* at SNL. In addition to providing a technical basis for integrating IDAC and MELCOR, this project incorporated three significant improvements to IDAC: new procedures (SAMGs) were coded for the IDAC model, calculational aids provided to operators for severe accident conditions were coded into the IDAC model, and new elements were added to the operator knowledge base.

These additions represent a base level of adaptation of the IDAC model. Other elements of the model that should be addressed for a full-scope update include problem solving strategies, PSFs, operator mental state, information module, and crew dynamics. Additional improvements to the knowledge base will also be considered.

Goal and strategy selection processes will be reviewed and revised to reflect the uncertainty of the situation, relative unfamiliarity with SAMGs, and extreme working conditions. While the set of strategies incorporated in IDAC is probably sufficient, the relative frequency with which an operator will use these strategies is likely to change in severe accident conditions. Similarly, PSFs included in the model and the operator mental state module will be assessed and updated if necessary to reflect the uncertain, unfamiliar operating conditions.

Information available to the crew will be impacted by the severe accident conditions. During the Fukushima accident, total loss of on-site power meant indicators failed in the control room, and debris and damage on the plant site prevented operators from accessing local controls. The information module will be modified to reflect various possible conditions during the accident duration.

IDAC also needs to be modified to better match the crew structure in severe accident conditions. In the initial SNL work[23] discussed above, the modified crew structure (decision making transferred to the TSC) was accounted for by using the Decision Making Operator (ODM) role for TSC activities and allocating all plant activities to the Action Taking Operator (OAT). The initial study was also limited by IDAC's structure, which precludes following multiple written procedures simultaneously. As a workaround, procedures executed in parallel are coded into IDAC as mental procedures rather than written procedures. To fully capture severe accident response activities, additional operator roles and the capability of following multiple procedures in parallel must be added to the model.

The most significant difference between Level 1 and Level 2 analysis (in terms of human performance) is the uncertainty around the operator response. Resilience studies highlight the extraordinary contribution operators can make in difficult situations. On the other hand, the unprecedented demands and seemingly unsolvable challenges can lead to a paralyzing response, shutting down cognitive processes and making latent knowledge inaccessible. With this in mind, we propose developing several operator profiles that reflect various stages of enhanced or degraded performance.

As these changes cannot be implemented all at once, a staged development plan is proposed below:

- *Stage 1*: Integrate the modified IDAC model developed at Sandia into the ADAPT/MELCOR platform. Continue to use the ODM for TSC activities and OAT for plant activities.
- *Stage 2*: Review the goal and strategy algorithms, PSFs and mental state modules to assess their applicability to Level 2 accidents. Update these elements as necessary.
- *Stage 3*: Further modify the Level 2 knowledge base to reflect several characteristic operators (high performing, moderate performing, and low performing).
- *Stage 4*: Develop new crew roles for TSC personnel and other crew variations not captured by the current model.
- *Stage 5*: Modify the IDAC model to allow for multiple written procedures executed in parallel.

Task 1.2 ADAPT/MELCOR Interface

In the proposed integration of ADAPT, HRA, MELCOR and MACCS2 coupling, scheduling, process control, and sequence tracking for the developed software tool will remain in ADAPT. In order to accomplish this, ADAPT must be modified to incorporate the capability to execute branching decisions coming from HRA in addition to branching decisions from ADAPT (e.g., phenomenological and component failure decisions) as a single simulator (referred to as a meta-simulator).

ADAPT will continue to interface with MELCOR using one of two methods. The first method, which is the current ADAPT/MELCOR interface, relies upon control functions within the MELCOR model to stop the MELCOR simulation at desired event tree branch points at conditions specified through the control function limits. ADAPT then retrieves the calculational output, evaluates why the calculation stopped, and submits new simulations that exercises desired pathways from the stop point. The developed software tool can continue to use ADAPT/MELCOR in this fashion. The following modifications are also considered to improve the capability of ADAPT to act as a meta-simulator for the first method:

1. ADAPT needs to handle proper copying of two code executables (both MELCOR and HRA module) to each computer node that is simulating a DET branch.
2. Currently ADAPT only parses a single output file (MELCOR) to extract information on what caused the MELCOR calculation to stop. In the presence of meta-simulator, it also may be needed to process the HRA information in order to extract this information.
3. Currently, the rules that govern how the MELCOR input files will be changed by ADAPT (referred to as edit-rule files) are static, only the values change at branch points. It is believed that implementation of the HRA model may require more dynamic changes due to the dynamic nature of the human response model. As long

as control functions and variables that could change are marked in the input file, ADAPT can be modified such that it accepts "edit-rule modifications" from the HRA model so that more dynamic changes can be handled.

4. HRA will require having its state information be stored and transferred to the node that will execute the new branch. The simplest approach is to dump all the state variables utilized by the HRA model into a text/binary file that will be transferred by ADAP.
5. Some further improvements can be made to enable more user-friendly execution on batch systems. Currently ADAPT assumes the nodes of the computer cluster are dedicated to ADAPT and can be directly accessible through LINUX commands (via *rsh* or *ssh)*, and data generated on a computer node will be permanently stored on the node where it is executed. ADAPT can be improved to enable use of a job submission system (PBS) for executing branches, and also transfer output files to dedicated storage systems. This will also require updating the ADAPT server's metadata database for correctly pointing the right location for final output files.

For the second method, the calculation server and the DET branching algorithms must be isolated to permit ADAPT or some other tool to perform that function. This requires development of a user-friendly interface of entering branching rules for phenomenological branches. It may be possible to use similar conformal interface to control human models. The calculation server with the DET branching model performs the following functions:

1. The probabilistic model will specify the scenario description (i.e., specific transient initiators and system failures).

2. The probabilistic model will interpret the stopping criterion for a calculation that stops at a branch point, develop the input for new pathways by writing new interactive control functions, and request the calculation server to launch new calculations.

3. The calculation server will launch and monitor all calculations and retrieve the results.

Task 1.3 ADAPT-MACCS2 Interface

The MACCS2 interface with ADAPT must be through a Linux based OS in order for ADAPT to properly document the branches. However, MACCS2 currently does not have any real dynamic analysis capability in which the code could potentially be stopped and changes made to the input variables. Thus ADAPT will not be used in the Level 3 portion of the analysis. The following approach is recommended for the ADAPT-MACCS2/WinMACCS Interfacing:

1. Upon completion of ADAPT-MELCOR-HRA runs, transfer the final MELCOR output files from each branch to a single storage location.
2. Within in this storage location, convert all MELCOR output files from UNIX to DOS via a UNIX2DOS command.
3. After this conversion, use the Windows based MELMACCS to convert the MELCOR output files into inputs for MACCS2 using the MELMACCS batch command. Because it is not planned to examine the effectiveness offsite emergency response actions in this project, it will not be necessary to explore uncertainties in the Level 3 aspect of the analysis. Use these MELMACCS outputs and combine them with a

'standard template' MACCS2 input file with the use of some kind of automated WinMACCS function.

For this type of analysis, predetermined inputs will be assigned an uncertainty distribution which will be sampled at specified intervals (5%, 25%, 50%, 75%, and 95% uncertainty for example). These specified inputs must currently be provided by the user. Once all these inputs are determined, a 1-to-N mapping of the MELCOR output-to-MACCS2 input is created for each ADAPT-MELCOR-HRA file. MACCS2 can then run in batch mode for each of the 1-to-N mapping scenarios. This will require a lot of manual manipulation of the data which is normally done using ADAPT. Also, the user will have to properly track and document each set of 1-to-N mapping probabilities and assign final conditional probabilities for all MACCS2 outputs.

Such an interface will require a tedious amount of documentation to ensure proper analysis. In that respect, linking MELMACCS and MACCS2 with ADAPT on a Linux based OS would be considered.

Task 1.4 Model Testing

All model development and testing will be performed on a computer cluster that is for the sole use of the OSU Nuclear Engineering Program (see Capabilities document). The associated subtasks are the following:

Subtask 1.4.1: Formulation of simple test case selected from either Peach Bottom or Surry Plant SOARCA studies. The test case will have limited branching rules and will perform only a few outer loop iterations. The purpose is to test the process.
Subtask 1.4.2: Input preparation for test case. The basic MELCOR input will be provided by SNL from input used in SOARCA studies. Simple uncertainty distributions will be developed relying largely on Electric Power Institute (EPRI) documentation and a very limited consideration of human reliability.
Subtask 1.4.3: *Test case execution.* These cases will be performed on a computer cluster managed by the Department of Mechanical and Aerospace Engineering.
Subtask 1.4.4: Assessment and modification to model. Based on the types of issues identified in executing the test case, changes will be made to the software.

4.2 Phase II: Demonstration

In Phase I of the proposed project, the set of tools to be used in the demonstration calculation will be developed and tested. In Phase II a preliminary analysis will be performed for a selected plant damage state. It is anticipated that in the execution of this preliminary study, unanticipated problems will be encountered, which will lead to some changes in methodology and inconsistencies in the large set of calculations performed.

Task 2.1: *Selection of computer host.* It is expected that Phase II will use the same computer cluster as Phase I. A potential option is provided by OSU's supercomputer facility (described in Capabilities document).
Task 2.2: Familiarization with EOPs, SAMGs and FSGs. EPRI[28,29] and Nuclear Energy Institute (NEI)[2,3] have made considerable information available related to modified SAMG and new FSG strategies. A survey of this information will be made to decide for the selection/modeling of plant damage state/SOARCA scenarios for analysis (Task 2.3).

Task 2.3: Selection of plant damage state/scenarios for analysis. These will be based on consideration of SOARCA scenarios for which SAMG actions are required to prevent severe core damage or significantly mitigate offsite consequences.
Task 2.4: Development of branching rules. Branching rules will be developed to account for events in SAMG strategies and their associated phenomenological and human response uncertainties.
Task 2.5: Case execution. The performance of the case study will require considerable computational time. The execution will be tracked on a daily basis to determine whether some scenarios are encountering computer code issues, such as aborting of scenarios and the reduction of time step size to unacceptably small levels. Any of these issues that arise will be resolved with support from the MELCOR team. A consecutive refinement process will be used to examine the truncation error associated with the degree of refinement of fragility curves.
Task 2.6: Interpretation of results. The results will be clustered to aid in their interpretation. As an example, Fig. 2 shows how 2,657 MELCOR scenarios resulting from uncertainties in: a) creep rupture of the stainless steel in the surge line, the stainless steel in the hot leg, the carbon steel weld joint between the reactor pressure vessel hot leg nozzle and the hot leg, and the Inconel in the steam generator U-tubes, b)power recovery, c) hydrogen and carbon monoxide burn, d) failure of the turbine driven auxiliary feedwater pump, e)failure of the DC station batteries, f) failure of the pressurizer and steam generator safety relief values due to high temperature cycling and total number of cycles, and, g) containment failure following a PWR station blackout can be aggregated into 16 clusters. Similarly, Fig.3 shows the impact of these uncertainties on the noble gas release from containment can be grouped in clusters. The clustering was based on 21 MELCOR input variables.

The effectiveness of SAMGs will be examined by consideration of the relative risks associated with alternative strategies. Measures of the outcomes, (e.g. CDF and LERF), will have associated uncertainty distributions. Based on the results of the Task 2.5, consideration will be given to extending the initial case study or performing a case study for a different plant damage state

The use of NUREG-115 (SOARCA) plants in the demonstration phase will also allow comparison of the proposed dynamic PRA approach to the traditional PRA approach.

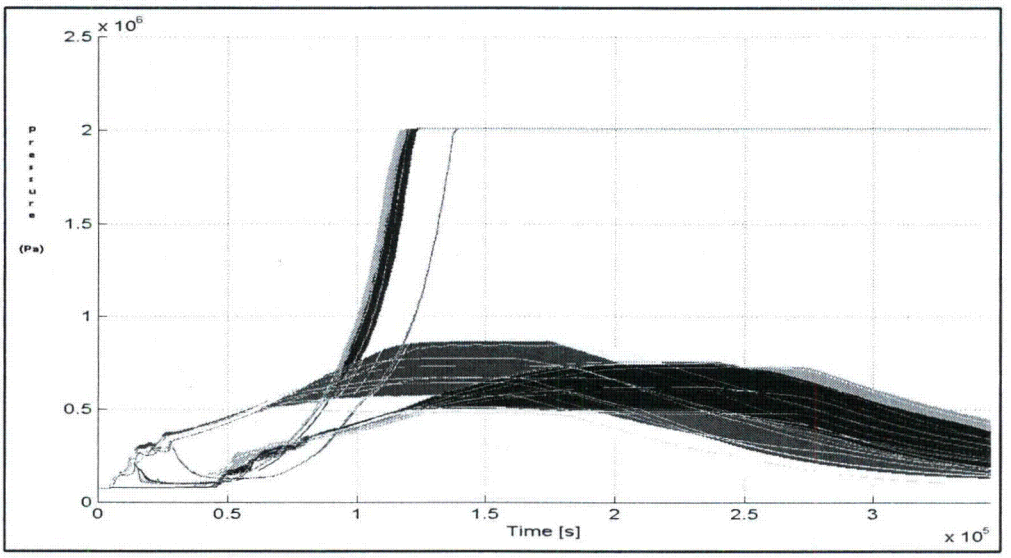

Figure 2. MELCOR predicted distribution of containment pressure following a PWR station blackout in the presence of uncertainties. Each color represents a cluster[16]

5. Program Management

The Principal Investigator (PI) for this program is Prof. Tunc Aldemir. Prof. Carol Smidts will act as co-PI with responsibility for the HRA related tasks of the program. A senior advisory committee has also been established to provide consulting and periodic oversight of the project. This committee is composed of Dr. Richard Denning and Mr. John Wreathall, who are recognized experts in the areas of severe accident behavior and human reliability analysis, respectively. Dr. Douglas Osborne (SNL) will also provide input in the selection of the scenarios and interpretation of the results.

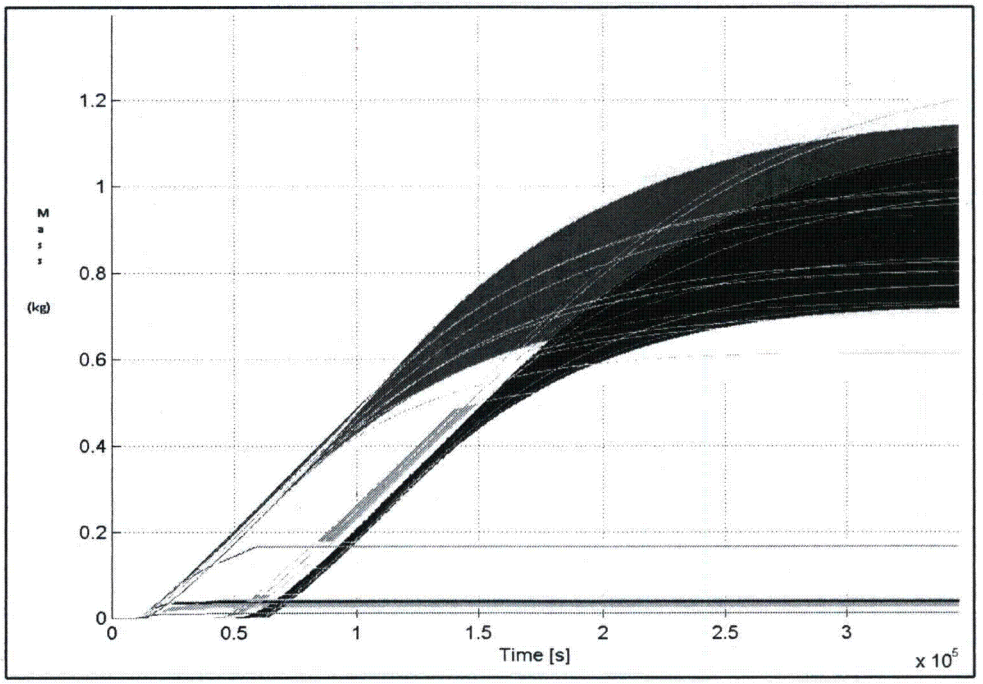

Figure 3. MACCS2 predicted distribution of noble gas release from containment following a PWR station blackout in the presence of uncertainties. Each color represents a cluster[16]

6. Schedule

The estimated duration of the proposed project is 24 months. Distribution of the tasks is shown in the Gantt chart below in months.

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

Preface

This award is based on the application submitted to, and as approved by, the Nuclear Regulatory Commission (NRC) under the authorization 42 U.S.C. § 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 Grant and Cooperative Agreement.
- 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 Part 200, Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards.

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 (E.O.), Office of Management and Budget (OMB) Circulars, the NRC's 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 200
All provisions of 2 CFR Part 200 and all Standard Provisions attached to this grant/cooperative agreement are applicable to the Recipient and to sub-recipients which meet the definition of "Recipient" in 2 Part §200.86, unless a section specifically excludes a sub-recipient from coverage. The Recipient 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 D of 2 CFR Part 200 and include this term in lower-tier (sub-award) covered transactions.

Recipients must comply with monitoring procedures and audit requirements in accordance with 2 CFR Part 200, Subpart F—AUDIT REQUIREMENTS.

2. Award Package
The Recipient 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 Part 200. Within this framework, the Principal Investigator (PI) named on the award face page, 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, and is subject to a refund of unexpended grant funds to the NRC.

The non-Federal entity alone must be responsible, in accordance with good administrative practice and sound business judgment, for the settlement of all contractual and administrative issues arising out of procurements related to its grant award. These issues include, but are not limited to, source evaluation, protests, disputes, and claims. These standards do not relieve the non-Federal entity of any financial or fiduciary responsibilities or obligations arising under its grant, including sub-contracts and sub-awards, or any other contractual or financial obligation. The Federal awarding agency will not substitute its judgment for that of the non-Federal entity unless the matter is primarily a Federal concern. Violations of law will be referred to the local, State, or Federal authority having proper jurisdiction. See 2 CFR § 200.318(k), General Procurement Standards.

Subawards

Appendix II to Part 200 Contract Provisions for Non-Federal Entity Contracts Under Federal Awards

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 Recipient to NRC. See 2 CFR § 200.318.

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 Recipient agrees to comply with the non-discrimination requirements below:

- Title VI of the Civil Rights Act of 1964 (42 U.S.C. §§ 2000d et seq.), which prohibits discrimination on the grounds of race, color, or national origin in any program or activity receiving federal financial assistance.
- Title IX of the Education Amendments of 1972 (20 U.S.C. §§ 1681 et seq.), which prohibits discrimination on the basis of sex in any education program or activity receiving federal financial assistance.
- Section 504 of the Rehabilitation Act of 1973, as amended (29 U.S.C. § 794), which prohibits discrimination on the basis of disability in any program or activity receiving federal financial assistance.
- The Age Discrimination Act of 1975, as amended (42 U.S.C. §§ 6101 et seq.), which prohibits discrimination on the basis of age in any program receiving federal financial assistance.
- The Americans with Disabilities Act of 1990 (42 U.S.C. §§ 12101 et seq.), which prohibits recipients from discriminating on the basis of disability in employment (Title I); State and local government services (Title II); and places of public accommodation and commercial facilities (Title III).
- Parts II and III of E.O. 11246, as amended by E.O.11375, 11478, 12086, 12107, 13279, 13665, and 13672, which prohibits federal contractors and federally assisted construction contractors and subcontractors, who do over $10,000 in Government business in one year, from discriminating in employment decisions on the basis of race, color, religion, sex, or national origin and requires that government contractors take affirmative action to ensure that equal opportunity is provided in all aspects of their employment.
- E.O.13166, "Improving Access to Services for Persons with Limited English Proficiency," which clarifies that national origin discrimination under Title VI includes discrimination on the basis of limited English proficiency (LEP) and

requires that the recipient take reasonable steps to ensure that LEP persons have meaningful access to programs and activities.
- Any other applicable non-discrimination law(s).

Generally, Title VII of the Civil Rights Act of 1964, 42 U.S.C. § 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 VII, 42 U.S.C. § 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 Recipient 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, must be made, in writing (which includes submission by e-mail), to the designated Grants Officer at least 30 days before the proposed change. The request must 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 Recipient will comply, as applicable, with provisions of the Hatch Act (5 U.S.C. §§ 1501-1508 and 7324-7328) which limits the political activities of employees whose principal employment activities are funded in whole or in part with Federal funds.

The Recipient will comply with provisions of 31 U.S.C § 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 Recipient receiving in excess of $100,000.00 in Federal funding shall submit a completed Standard Form (SF-LLL), "Disclosure of Lobbying Activities." The form concerns 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 Recipient must submit the SF-LLL, including those received from sub-recipients, contractors, and subcontractors, to the Grants Officer.

Debarment And Suspension – (See 2 CFR Part 180; 2 CFR § 200.205; 2 CFR § 200.113; and 2 CFR Part 200, Appendix II.)

The Recipient 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); or

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

(5) The Recipient agrees that, unless authorized by the Grants Officer, it will not knowingly enter into any subaward or contracts under this grant/cooperative agreement with a person or entity that is not included on the System for Award Management (SAM) (https://www.sam.gov).

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

'Debarment, Suspension, Ineligibility, and Voluntary Exclusion

The Recipient 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 2 CFR Part 180 and 2 CFR Part 200.

Drug-Free Workplace

The Recipient 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 U.S.C. §§ 8101-8106.

Implementation of E.O.13224 – Executive Order on Terrorist Financing

The Recipient 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 Recipient 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 Recipient must comply with E.O. 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:

Implementation of Executive Order 13224 Blocking Property and Prohibiting Transactions With Persons Who Commit, Threaten To Commit, or Support Terrorism , amended by E.O. 13268, 13284, and 13372.

Procurement Standards - 2 CFR §§ 200.318-200.326
Sections 200.318 - 200.326 set forth standards for use by Recipients 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 Recipients, unless specifically required by Federal statute, executive order, or approved by OMB.

Travel and Transportation
Travel must be in accordance with the Recipient's Travel Regulations or the U.S. Government Travel Policy and Regulations at: www.gsa.gov/federaltravelregulation and the per diem rates set forth at: www.gsa.gov/perdiem, absent Recipient's travel regulations. Travel and transportation costs for the grant must be consistent with provisions as established in 2 CFR § 200.473-474.

All other travel, domestic or international, must not increase the total estimated award amount for the grant.

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 Recipient'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 for the grant.

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 Recipient's policies and practices. Travel by first-class travel is not authorized unless prior approval is obtained, in writing, 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 Recipient will comply with the provisions of the Fly America Act (49 U.S.C 40118), as implemented at 41 CFR §§ 301-10.131 through 301-10.143.

Property Standards
Property standards of this award shall follow provisions as established 2 CFR §§ 200.310-200.316.

Intangible Property
Intangible and intellectual property of this award shall generally follow provisions established in 2 CFR § 200.315.

Inventions Report - The Bayh-Dole Act (P.L. 96-517) affords Recipients 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 Recipient 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 Recipient 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 Recipients, 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, E.O.12889 requires NRC to notify the owner. If the Recipient uses or has used patented technology under this award without license or permission from the owner, the Recipient must notify the Grants Officer. This notice does not imply 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 Subpart D of 2 CFR Part 200. The Recipient 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 Recipient 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 Recipient employees may be copyrighted, but only the part authored by the Recipient is protected because, under 17 U.S.C. § 105, works produced by Government employees are not copyrightable in the United States. On occasion, NRC may ask the Recipient 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 U.S.C. § 105.

Record Retention and Access

Recipient shall follow established provisions in 2 CFR §§ 200.333-337.

Conflict Of Interest

Conflict of Interest standards for this award will follow the Organizational Conflict of Interest (OCOI) requirements set forth in Section 170A of the Atomic Energy Act of 1954, as amended, and provisions set forth at 2 CFR § 200.112, Conflict of Interest.

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 Recipient'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 Acquisition Management Division, unless otherwise delegated, who shall appoint an intra-agency Appeal Board to review a recipient 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 Recipient 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.

Remedies for Noncompliance
Termination of this award will follow provisions as established and described above in "Dispute Review Process" in 2 CFR §§ 200.338-342.

Performance and Financial Monitoring and Reporting - 2 CFR §§ 200.327-329

Recipient Financial Management systems must comply with the provisions in 2 CFR § 200.302.

- Payment – 2 CFR § 200.305
- Cost Share or Matching – 2 CFR § 200.306
  - Recipients are to be careful with providing excessive cost share or match since at the end of the grant, if the identified match has not been provided, then a portion of the federal share may be required to be returned to the Government.
- Program Income – 2 CFR § 200.307
  - Earned program income, if any, will be added to funds committed to the project by the NRC and Recipient and used to further eligible project or program objectives or be deducted from the total project cost for the grant, as directed by the Grants Officer or indicated in the terms and conditions of the award.

- Revision of Budget and Program Plans – 2 CFR § 200.308
  - The Recipient is required to report deviations from the approved budget and program descriptions in accordance with – 2 CFR § 200.308(b) and request prior written approval from the Project Officer and the Grants Officer.

- The Recipient is not authorized to re-budget between direct costs and indirect costs without written prior approval of the Grants Officer.
- The Recipient is authorized to transfer funds among direct cost categories up to a cumulative 10 percent of the total approved budget. The Recipient 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 §§ 200.401-403

- See section 2 CFR §§ 200.330-332 for Subrecipient Monitoring and Management.

Federal Financial Reports - In accordance with 2 CFR § 200.327, the Recipient will 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 authorized by the Grants Officer. 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:

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.

Performance Progress Reports - In accordance with 2 CFR § 200.328, the Recipient will submit Performance Progress Reports (SF-PPR, SF-PPR-B, and the SF-PPR-E) on a quarterly basis for the periods ending March 31, June 30, September 30, and December 31, or any portion thereof, unless otherwise authorized by the Grants Officer. Reports are due no later than 30 days following the end of the reporting period. The report should be submitted electronically to:

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.

Final Reports - The Recipient is required to submit final reports, both Financial (SF-425) and Performance (SF-PPR, SF-PPR-B, SF-PPR-E) within 90 days of the grant expiration. In addition to these reports, a final SF-428, Tangible property report, is also required, if applicable.

Period of Performance – 2 CFR § 200.309

The recipient may charge to the Federal award only allowable costs incurred during the period of performance and any costs incurred before the NRC or pass-through entity made the Federal award that was authorized by the NRC or pass through entity.

Unless otherwise authorized in 2 CFR Part 200 or by special award condition, any extension of the award period can only be authorized by the Grants Officer in writing.

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 Grant Officer may authorize a no cost extension of the period of performance. However, 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, Recipient payments are made using the Department of Treasury's Automated Standard Application for Payment (ASAP) system, ASAP.gov, through preauthorized electronic funds transfers. To receive payments, Recipients 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. Recipients 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 of 1996, as amended, and as implemented by 2 CFR Part 200, Subpart F—AUDIT REQUIREMENTS. Recipients are subject to the provisions of this subpart if they expend $750,000 or more in a year in Federal awards. See 2 CFR 2 CFR § 200.501.

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

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; and
5. Click "Submit."

Organizations expending less than $750,000 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

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 Recipient as high risk and the assignment of special award conditions. Further action may be required as specified in the standard term and condition entitled "Remedies for Noncompliance."

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 Recipient 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 Recipient
The Recipient 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 Recipient or contractor under an award, the Recipient shall provide and shall require his/her contractors to provide reasonable access to all facilities and provide necessary assistance for the safety and convenience of the Government representative in the performance of his/her official duties.

IV. Miscellaneous Requirements

Criminal and Prohibited Activities
The Program Fraud Civil Remedies Act (31 U.S.C. §§ 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 U.S.C. § 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 U.S.C. § 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 U.S.C. § 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
Recipients are encouraged to purchase American-made equipment and products with funding provided under this award.

Increasing Seat Belt Use in the United States
E.O. 13043, amended by E.O. 13652, requires Recipients 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
E.O. 13513 requires Recipients 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 Recipient 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 Recipient'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 Recipients or applicants regardless of the source.

Minority Serving Institutions (MSIs) Initiative
Pursuant to E.O.s 13230 and 13270, amended by E.O. 13316 and 13385, 13532, 13592, 13555, 13515, and 13621, 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 Recipients 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 Recipient 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 Recipient organization shall investigate the allegation and submit its findings to the Grants Officer. The NRC may accept the Recipient's findings or proceed with its own investigation. The Grants Officer shall inform the Recipient 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 Recipient 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 Recipient 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 **[Recipient 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 recipient or any subrecipient, 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." (See 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.