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

September 30, 2014

Mr. G. Cusatis
Northwestern University
1801 Maple Avenue
Evanston, Illinois 60201

VIA Electronic Mail
g-cusatis@northwestern.edu

SUBJECT: GRANT NO: NRC-HQ-60-14-G-0003

Dear Mr. G. Cusatis:

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 Northwestern University (hereinafter referred to as the "Grantee" or "Recipient"), the sum of $877,691.00 to provide support to the "Service Lifetime Extension of Nuclear Power Plants: Prediction of Concrete Aging and Deterioration Through Accelerated Tests, Nondestructive Evlauation, and Stochastic Multiscale Computations" as described in attachment B 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 September 30, 2014 and ending August 1, 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.

Based on the pre-award compliance review conducted by NRC's Small Business and Civil Rights Office (SBCR), your institution is placed in a periodic status pending resolution of concerns raised during the review. Within 60 days, SBCR will conduct a periodic review to ensure compliance with applicable Civil Rights statutes. Your cooperation with SBCR is essential. The continued eligibility of Federal financial assistance is conditioned upon compliance with anti-discrimination regulations.

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. Sunshine Wilson by email at Sunshine.Wilson@nrc.gov.

Sincerely yours,
Erika Eam
Erika Eam
Grants Officer
Resources and Grants Team
Acquisition Management Division

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

TEMPLATE - ADM001 SUNSI REVIEW COMPLETE ADM002

Grant and Cooperative Agreement

CHOOSE ONE:
- [ ] COOPERATIVE AGREEMENT
- [X] GRANT

CHOOSE ONE: [ ] EDUCATION [ ] FACILITIES [X] RESEARCH [ ] SDCR [ ] TRAINING

1. GRANT/COOPERATIVE AGREEMENT NUMBER	2. SUPPLEMENT NUMBER	3. EFFECTIVE DATE	4. COMPLETION DATE
NRC-HQ-60-14-G-0003		09/30/2014	

5. ISSUED TO
NAME/ADDRESS OF RECIPIENT (No., Street, City/County, State, Zip)
NORTHWESTERN UNIVERSITY
Attn: Michael Green
1801 Maple Ave.
EVANSTON IL 60201

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)
36-2167817

8. COMMERCIAL & GOVERNMENT ENTITY (CAGE) NO.

9. PRINCIPAL INVESTIGATOR/ORGANIZATION'S PROJECT OR PROGRAM MGR. (*Name & Phone*)
Prof. G. Cusatis, 847-491-4027
Email: g-cusatis@northwestern.edu

10. RESEARCH, PROJECT OR PROGRAM TITLE
See Schedule

11. PURPOSE
See Schedule

12. PERIOD OF PERFORMANCE (*Approximately*)
09/30/2014 through 08/01/2017

13A.	AWARD HISTORY	13B.	FUNDING HISTORY
PREVIOUS	$0.00	PREVIOUS	$0.00
THIS ACTION	$877,691.00	THIS ACTION	$425,000.00
CASH SHARE	$0.00	TOTAL	$425,000.00
NON-CASH SHARE	$0.00		
RECIPIENT SHARE	$0.00		
TOTAL	$877,691.00		

14. ACCOUNTING AND APPROPRIATION DATA
2014-X0200-FEEBASED-60-60D002-11-6-213-1032-4110

PURCHASE REQUEST NO.	JOB ORDER NO.	AMOUNT	STATUS
RES-14-0483			

15. POINTS OF CONTACT

	NAME	MAIL STOP	TELEPHONE	E-MAIL ADDRESS
TECHNICAL OFFICER	CHON DAVIS	CSB/ C4 A8	301-251-7567	Chon.Davis@nrc.gov
NEGOTIATOR				
ADMINISTRATOR	M'LITA R. CARR		301-287-0909	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
ERIKA EAM *Erika Eam*	09/24/2014		

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)	ESTIMATED COST AMOUNT (F)
	CFDA Number: 77.009 Project Title: Service Lifetime Extension of Nuclear Power Plants: Prediction of Concrete Aging and Deterioration Through Accelerated Tests, Nondestructive Evlauation, and Stochastic Multiscale Computations Technical Analyst: Jacob Philip Mailstop: CSB/ C2 C8 Telephone: 301-251-7471 Email: Jacob.Philip@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: 09/30/2014 to 08/01/2017 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 "Service Lifetime Extension of Nuclear Power Plants: Prediction of Concrete Aging and Deterioration Through Accelerated Tests, Nondestructive Evlauation, and Stochastic Multiscale Computations" 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 August 1, 2017.

2. Funds obligated hereunder are available for program expenditures for the estimated period: September 30, 2014 – August 1, 2017.

A. GENERAL

1. Total Estimated NRC Amount:	$877,691.00
2. Total Obligated Amount:	$425,000.00
3. Cost-Sharing Amount:	$0.00
4. Activity Title:	Service Lifetime Extension of Nuclear Power Plants: Prediction of Concrete Aging and Deterioration Through Accelerated Tests, Nondestructive Evlauation, and Stochastic Multiscale Computations
5. NRC Project Officer:	Chon Davis
6. Technical Analyst:	Jacob Philip
7. DUNS No.:	160079455

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	Year 3
Total Salaries & Wages	$ 58,101.00	$ 59,844.00	$ 61,639.00
Fringe Benefit	$ 9,572.00	$ 9,926.00	$ 10,293.00
Travel	$ 5,026.00	$ 5,026.00	$ 5,026.00
Contractual	$150,263.00	$149,752.00	$150,042.00
Other (Tuition)	$ 12,924.00	$ 13,569.00	$ 14,245.00
Indirect Costs (55%)	$ 80,496.00	$ 40,764.00	$ 41,942.00
Yearly Total	**$316,382.00**	**$278,881.00**	**$283,187.00**

All travel must be in accordance with the Northwestern 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 $877,691.00 for the three year period.

2. NRC hereby obligates the amount of $425,000.00 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

PROJECT DESCRIPTION

Scope

Lifetime extension of existing nuclear power plants (NPPs) and the design of new NPPs necessitate addressing many different issues including the accurate assessment of long-term aging and deterioration of concrete materials. Concrete in NPPs deteriorates over time due to the effect of several chemical and physical phenomena including alkali-silica reaction (ASR), carbonation, freeze-thaw damage, corrosion, shrinkage, delayed ettringite formation (DEF), and exposure to neutron or gamma radiation fields. When deterioration appears, destructive and non-destructive evaluation is typically performed to assess the *status quo* and to use such information to formulate appropriate strategies for repair and/or reconstruction.
This requires the assessment of the expected deterioration evolution in time as well as the associated structural safety and serviceability consequences. *The overarching goal of this research effort is to formulate and validate a stochastic framework for the prediction of concrete aging and deterioration with specific focus on ASR damage.*
Towards this goal, the objectives of the project are: (1) to formulate a **multiscale model** for the description of **ASR deterioration** mechanisms in concrete as well as its coupling with temperature and relative humidity variations; (2) to enrich such model with **stochastic representation** of material parameters; (3) to develop and use **accelerated tests** as well as **non-destructive evaluation** techniques specifically tailored towards the stochastic parameter identification of the formulated model; (4) to formulate a **predictive stochastic framework** that incorporates mechanics-based models; random field models; and laboratory/field data; and (5) to validate the overall framework against a **reduced scale case study**.
Successful completion of the proposed research will have a significant impact on the ability of the national technical community to assess reliability and durability of concrete constructions in Nuclear Power Plants (NPP) and to estimate the remaining service lifetime. This will contribute towards a better management of NPP maintenance resources, the possible lifetime extension of existing NPP, and better designs of new NPP.


Figure 1: Crack in a pit of Fukushima reactor 2.

Motivation, Research Needs, and Scientific Challenges

In the United States there are more than one hundred operative NPPs that provide about twenty percent (20%) of the national electric energy needs. As existing NPPs age and new NPPs are planned, it is increasingly important to ensure that the utilized structural materials perform optimally for the entire NPP's lifetime and that material degradation does not endanger the safety of NPP operations. In addition, it is important to be able to assess the level of degradation of existing plants in order to possibly consider their lifetime extension.
The importance of being able to assess the long-term deterioration of concrete in NPPs is of dramatic actuality after the relatively recent disruptive magnitude 9 earthquake and the associated tsunami that hit Japan on March 11, 2011. In this incident, the reinforced concrete structural elements of the Fukushima reactors were impacted, in a short period of time, by

various severe loading conditions: *first they were subject to the dynamic loadings due to the* earthquake; then suffered from the impact of the water from the surging tsunami; finally they were struck by the explosion caused by hydrogen accumulation and were exposed to the high temperatures of the subsequent fires. This extreme loading scenario resulted in the severe damage and failure of various structural components. Figure 1 shows the crack occurred in a pit of Fukushima reactor 2 which led to the leaking of highly radioactive water in the environment. The events unfolding around the crisis of the Fukushima reactors, have urged the American technical community to take measures preventing similar occurrences in the United States where thirty-five (35) of the reactors in use are of the same kind (Boiling Water Reactor) of the Fukushima reactors.

Obviously, the estimation of the probability of failure under these complicated circumstances requires a robust probabilistic framework with accurate probabilistic demand models for the combined loading events as well as accurate probabilistic capacity models evolving with time as function of material degradation.

Degradation phenomena span several length and time scales, which make it extremely difficult, if not impossible, to gain a fundamental understanding and to formulate remediation strategies by using classical approaches. Obviously, the experimental investigation of phenomena lasting several decades is not an option and the use of accelerated test techniques is required. In addition, analysis, interpretation, and extrapolation of accelerated test data cannot be performed with standard deterministic phenomenological models lacking real predictive capabilities but they rather need to be based on a framework that includes: (1) precise mechanistic descriptions of the deterioration phenomena of interest and their intertwined evolution; (2) accurate stochastic models for all input variables characterized by joint probability density functions (PDFs) and their changes in time; (3) rigorous statistical analysis techniques for experimental data; (4) framework for realistic small sample probabilistic simulations; and (5) methods for the continuous or time discrete updating of performance estimates and predictions on the basis of data gathered through permanent monitoring, periodic non-destructive evaluation, or data derived by inverse system identification.

The overall outcome of this research effort is a comprehensive and general stochastic framework for the prediction of aging and deterioration of concrete as well as for the calculation of evolving probability of failure of concrete structures with specific focus on ASR damage. This will enable the technical community with a fundamental tool for aging and deterioration assessment of reinforced concrete structural elements in NPP.

Proposed Research

The proposed research consists of six main tasks providing a logical path towards the accomplishment of the aforementioned technical objectives.

Task 1: Multiscale/Multiphysics Modeling of Concrete. At the macroscopic scale, concrete can be approximated as statistically homogeneous. Nevertheless, its macroscopic behavior shows quasi-brittleness, strain softening, and size-effect evidencing a strong influence of material heterogeneity. Material heterogeneity also influences dramatically the appearance and evolution of cracking due to the incompatible volume changes arising from the most typical deterioration phenomena observed in concrete structures.

A model naturally accounting for material heterogeneity is the **Lattice Discrete Particle Model (LDPM) developed by Prof. Cusatis in the recent past**. LDPM [1-3] simulates the mesostructure of concrete by a three-dimensional assemblage of particles (Figure 2a) that are generated randomly according to the given grain size distribution. An algorithm, based on Delaunay tetrahedralization and three-dimensional domain tessellation, allows the generation of a system of cells interacting through triangular facets (Figure 2b).

Discrete compatibility equations are formulated by means of displacements and rotations of adjacent particles and adopting rigid body kinematics. A mesoscale constitutive law that simulates cohesive fracture, compaction due to pose collapse, frictional slip, and rate effect, is formulated at each cell facet. The formulation is completed by the equilibrium equations of each single particle. LDPM has been extensively calibrated and validated and it has shown superior capabilities in reproducing and predicting (qualitatively and quantitatively) concrete behavior under a wide range of loading conditions ranging from uniaxial and multiaxial compression to fragmentation. Figure 2 shows a collection of typical LDPM results.

One of the most remarkable and unique feature of LDPM is that the model is able to capture very well the strain softening behavior under uniaxial unconfined compression even though the mesoscale behavior in compression is always hardening. LDPM correctly simulates macroscopic failure under compression as mainly governed by mesoscale tensile fracturing and shearing [4,5]. Another unique feature of LDPM is the ability to capture the transition from localized failure to complete fragmentation under impact depending upon the energy of the impact. **Recently, LDPM was also further extended to simulate the deterioration associated with Alkali-Silica reaction (ASR)** [3] and, as shown in Figure 2e, it can reproduce very well the resulting crack patterns and effect of applied load. LDPM is the only model available in the literature that can predict automatically strength and stiffness degradation associated with ASR damage under different stress states without formulating any phenomenological dependence of the mechanical behavior upon ASR expansion [3]. LDPM has been also employed to simulate reinforced concrete elements with excellent results. Figure 2f and 2g show the numerical simulation of an over-reinforced beam in which the rebars are simulated as elastic beams and the LDPM-rebar coupling is obtained through a simple penalty algorithm [6].

In this task, it is proposed to further extend LDPM to account for (1) temperature and relative humidity changes; (2) long-term mechanical phenomena such as creep and shrinkage; (3) coupling with hygro-thermal diffusion/transfer processes; and (4) effect of damage on concrete diffusivity properties which govern the ingress of corrosive agents posing an important durability threat to concrete structures; (5) full probabilistic description and calibration of model parameters.

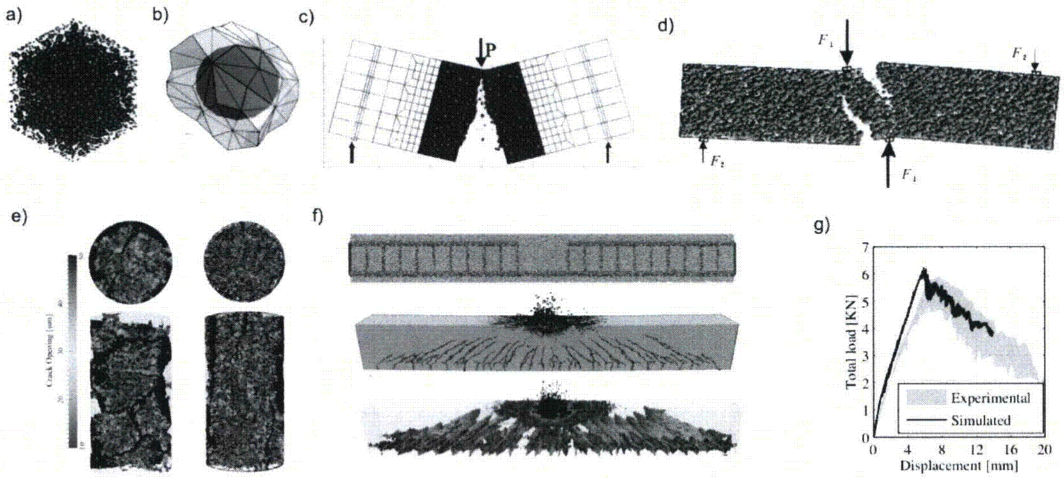

Figure 2: LDPM modeling: a) particle assemblage, b) single LDPM cell, c) fracture propagation under a three-point bending test, d) mixed-mode fracture propagation under four-point loading condition, e) complex crack patterns associated with alkali-silica reaction deterioration without (left) and with (right) applied load, f) simulation of reinforced concrete beams, and g) comparison with experimental data for the response of over-reinforced concrete beams.

Moreover, the time scale of deteriorating and aging phenomena is in the order of magnitude of decades. The time scale of meso-scale LDPM simulations is much shorter due to the fine spatial LDPM discretization and the high-frequency features of its mechanical response. Due to

this time-scale difference, the numerical simulation of long-term behavior of concrete through LDPM is extremely intensive from a computational point of view. This issue will be addressed by formulating a temporal multiscale approach based on the so-called Equation-Free Method (EFM) that has been already used successfully in other disciplines [5] but, to the best of writers' knowledge, it has been never applied to the analysis of concrete structures.
According to the EFM, the fine LDPM discretization will be superimposed by a coarse finite element (FE) mesh. If one adopts an explicit time integrator for both the fine and the coarse system one may write: $v(t_{n+1/2}) = v(t_{n-1/2}) + r(t_n)/m$ for the fine LDPM system and $V(T_{n+1/2})=V(T_{n-1/2}) + R(T_n)/M$ for the coarse FE system, where v, V are velocities, R, r are force imbalances, and M, m are masses, at the coarse and fine scales, respectively. The two discretizations are such that the fine time step Δt of the fine time integrator is much smaller than the time step ΔT of the coarse one. The main idea of EFM is to use the fine-scale time integrator only in time intervals of duration $\tau << \Delta T$ centered on the coarse integration times. Averaging the fine scale solution in the interval $T_n-\tau/2$ to $T_n+\tau/2$ allows the calculation of the force residual $R(T_n)$ at the coarse scale without the need of constitutive equations (from this the name of equation-free method). The fine scale simulations are performed by initial and boundary conditions obtained from the projection of the coarse scale solution at time $T_n-\tau/2$ into the fine scale. Since $\tau << \Delta T$ the EFM scheme leads to a dramatic reduction of the number of fine-scale steps and, consequently, a significant saving in terms of computational cost. In this task the LDPM-based EFM will be formulated, implemented, and accurately validated by comparison with full fine-scale simulations. Sensitivity analysis will be performed to assess the optimal choice for the ratio $\Delta T/\tau$ ensuring the best computational performance while retaining an acceptable accuracy.
Finally, the course scale description of LDPM will be obtained by using a multiscale approach. Multiscale modeling and simulation techniques can be broadly classified into two categories: sequential (information passing) multiscale methods and concurrent multiscale methods. In sequential multiscale methods, fine scale response is averaged and introduced into coarse scale models in the form of constitutive relations. In concurrent methods, two or more models are simultaneously resolved in different regions of a problem domain. A powerful theoretical and computational framework that can be used to formulate macroscopic constitutive equations starting from high-fidelity fine-scale models is the so-called Mathematical Homogenization Theory [7]. In general, the Mathematical Homogenization Theory employs a multiple scale asymptotic expansion to approximate the kinematic of the system as

$$\mathbf{u}(\mathbf{x},\mathbf{y}) = \mathbf{u}^0(\mathbf{x}) + \xi\mathbf{u}^1(\mathbf{x},\mathbf{y}) + \xi^2\mathbf{u}^2(\mathbf{x},\mathbf{y}) + ... \qquad (1)$$

where **x**, and **y** represent the *coarse-scale* and *fine-scale* vector position, respectively, and $\xi << 1$denotes the ratio between the fine and coarse characteristic lengths. In Equation 1 the coarse scale solution $\mathbf{u}^0(x)$ is enriched through additional terms that express the fluctuation due to the finer scales. These terms embed the response of the fine-scale problem that can be calculated by solving a unit cell problem, which is the analysis of a unit cell of material, also called representative volume element, RVE, representing the smallest amount of material which contains a complete description of the fine scale – Figures 3a and 3b.

Classical homogenization 1) retains only the first term, $\mathbf{u}^1$; 2) assumes that $\mathbf{u}^1$ is proportional to the macroscopic strain tensor; and 3) assumes that the coefficients of proportionality (influence functions) are computed by applying the macroscopic strain tensor as boundary conditions to the unit cell. For linear elastic constitutive behavior, the influence functions can be calculated in the pre-processing phase whereas, for nonlinear constitutive behavior, they need to be calculated incrementally. The classical homogenization approach has been applied successfully in a wide variety of situations and can be used to obtain the macroscopic stress versus strain curves (Figure 3c) accounting for the effect of distributed damage as for deteriorating concrete.

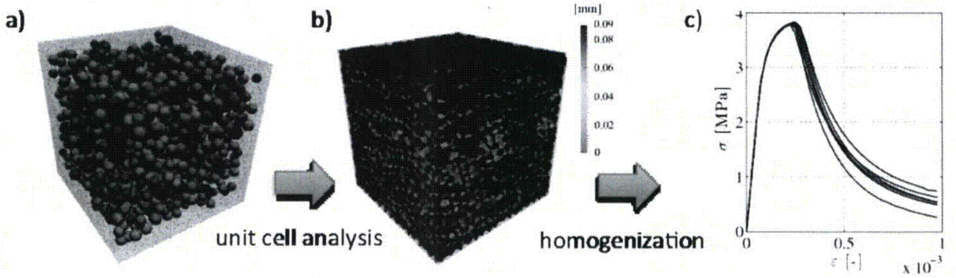

Figure 3: Mathematical Homogenization. a) Unit cell. b) Cracking analysis of unit cell. d) Homogenized macroscopic stress versus strain curves.

Research in this task will be performed by taking advantage of the NU supercomputing platform, Quest and the ES3 computational capabilities as discussed in Section VI.

Task 2: Accelerated Tests. ASR mitigation in both new and existing concrete structures requires test methods that assess the risk associated with the development of damage. Although the understanding of ASR mechanisms and proper testing methodologies have improved significantly, it is generally recognized that accelerated lab test data do not always correlate to damage observed in actual structures. Existing ASR test methods, **routinely performed by Dr. D'ambrosia at CTLGroup**, are passive, involving measurement of unrestrained expansion under various curing regimes that accelerate the reaction in order to obtain meaningful results in a reasonable time. As a result, the levels of measured expansion occur in the absence of confinement and do not necessarily reflect the mechanisms of damage propagation in ASR affected structures. The generally accepted mechanism of ASR, whereby ions from the cement pore solution react with aggregate, leading to the formation of a hydrophilic gel in and around the aggregate particles that expands as it absorbs water, does not typically rely on mechanical properties to explain the levels of damage. **This gap will be addressed in this task through the development of new accelerated testing methodologies that incorporate advanced mechanical constitutive relationships (see Task 1) and the dependence on confinement.** These new methodologies have also the potential to be useful in other degradation mechanisms such as corrosion, delayed ettringite formation, freeze-thaw deterioration, or physical salt attack. The time to develop visible distress and cracking varies significantly in field structures, but with better understanding of the damage mechanisms as they relate to various expansive aggregates, the gap between predicted behavior through accelerated testing and actual field performance can be reduced. The inherent reduction in service life of a structure due to ASR is partially caused by the mechanical damage. Further degradation occurs as cracks create avenues for moisture and corrosive ions to penetrate concrete structures. The initiation and propagation of reinforcing steel corrosion and damage from freezing and thawing are intimately connected to ASR and yet accelerated tests combining different deterioration mechanisms are not available at the moment. Toward this end the research team will also develop new accelerated test techniques aimed at studying the coupled effect of ASR and steel corrosion by means of diffusivity measurements. The focus will not be on the corrosion mechanisms *per se* but rather on the effect of ASR to produce an environment in which reinforcement is more prone to corrode. This type of tests will help assessing the durability and serviceability effects of ASR to reinforced concrete structures. The restrained-type test configuration to be developed will have the capability to quantify applied stress through the duration of the test. Important aspects of the restrained test may include the ability to control temperature distribution, exposure to alkaline solution, and inclusion of integral alkali during mixing, which are all methods of accelerating the reactivity in order to develop a response in a reasonable period of time relative to the construction process. Such timeframes are of critical importance to the industry, which will only adopt methods that are capable of providing evaluation results in short timeframes. Such acceleration of the process is likely a primary source of disagreement between laboratory test methods and field results, along with the lack of mechanical restraint in current standard tests.

Utilization of a first-principles approach for the creation of a new ASR test method will constitute a fundamental change in the industry. The current status quo relies on vague laboratory characterization, lacks theoretically justified acceptance criteria, and relies on weak correlation to field behavior. The potential impact of this research is significant in that it will enable researchers to close very obvious gaps between theory and practice currently relying on empirical correlation, which unfortunately must be relearned every other decade as materials and construction practices change. Reliance on theoretical relationships and fundamental materials constitutive properties is the only way to advance the state of knowledge and address a very serious problem in civil engineering infrastructure. Moving toward new methods that incorporate material constitutive relationships will eliminate the need for standard mixes and allow for performance-based comparison of ASR using actual project mixture proportions, which is not possible under the current testing protocols.

Facilities at the CTLGroup will be utilized to conduct both standard ASTM test methods for detection and mitigation of ASR potential, as well as to develop new methods for restrained behavior. The facilities include multiple temperature controlled lab spaces and heated chambers capable of accelerating ASR behavior in many types of test configurations, in addition one of the largest laboratories dedicated to creep and shrinkage in the world. IP1 is ISO 9001 certified, its laboratories are ISO 17025 accredited and the quality program is compliant with 10CFR50 Appendix B NQA-1 requirements, a rare qualification in the engineering testing industry. IP1 brings its vast expertise, developed since the start of the nuclear energy age, in performing research and testing services for both the nuclear energy industry and national laboratories.

Task 3: Non Destructive Evaluation. In this task, an ultrasonic nondestructive evaluation (NDE) technique will be developed to assess the degree of ASR damage in concrete. **Prof. Qu has extensive experience in this field** and his work will leverage on some other current related projects. The proposed NDE technique will be based on the mixing of nonlinear waves. As *an ultrasonic wave of monolithic frequency* ω *propagates in a concrete sample, a second* harmonic wave of frequency 2ω will be generated by the damage in the material. The amplitude of the second harmonic wave is proportional to the acoustic nonlinearity parameter (ANLP) β. It has been shown that β is an intrinsic material property and is well correlated with the degree of ASR damage in concrete [8-12]. For example, when a concrete bar is immersed in an alkaline solution at elevated temperature to accelerate the ASR damage, the bar will elongate, and the magnitude of the elongation indicates the degree of ASR damage. Figure 4a shows the elongation of a concrete bar (Samples L1) versus the number of days of alkaline solution immersion. As a comparison, Sample L2 was left in an ambient environment (~ 50%RH, and ~ 25^{0}C). The corresponding ANLP β for Samples L1 and L2 is plotted in Figure 4b. The error bars are the ranges of values measured at different locations of the same sample.

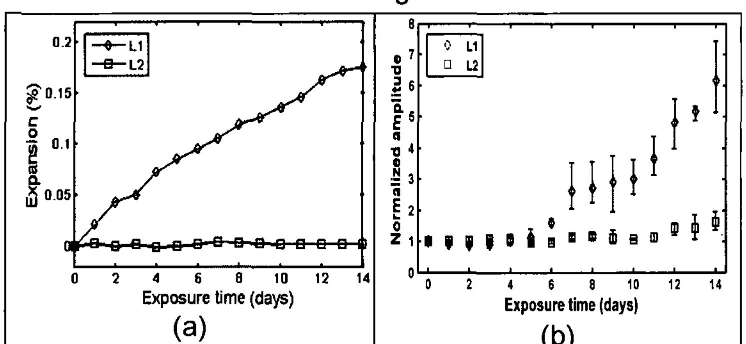

Figure 4 (a) Expansion versus exposure time, and (b) β *versus exposure time (Samples were kept at ~ 50%RH and ~ 25^{0}C).*

In this work, it is proposed to develop measurement methods based on nonlinear wave mixing. Nonlinear wave mixing occurs when two incident waves pass by each other in a nonlinear medium. Under certain conditions, such mixing produces a third propagating wave whose amplitude is proportional to the size of the region where the two incident waves mix, as well as to the acoustic nonlinearity parameter β at this region. This third wave is called the resonant wave. Once generated, the resonant wave propagates as a regular wave. Its frequency ω_3 and the wave vector $\mathbf{k}_3$ are, depending on the types and the directions of propagation of the two incident waves, either the sum or the difference of those of the two incident waves.

One of the major advantages of using wave mixing techniques is the ability to choose the frequency of the resonant wave by selecting the frequencies of the two incident waves. This avoids the use of second order harmonic, which may also be generated by the measurement system. More important to our interest here is the desire to use low frequency waves in order to minimize attenuation. By using two very similar frequencies for the two incident waves, the resulting resonant wave may have very low frequency that can travel longer distance. Another advantage is the ability to control the location where the two incident waves mix. Since the resonant wave is generated only within the region where the two incident waves mix, its amplitude is proportional to the ANLP within this region. Therefore, it is potentially possible to map the distribution of β by steering the incident waves so their intersecting zone scans through the entire sample. Various potential configurations for the wave mixing measurements will be explored to allow changing location and size of the mixing zone by varying either the timing, pulse duration, and/or the directions of the incident waves. This will allow scanning through the thickness of the sample.

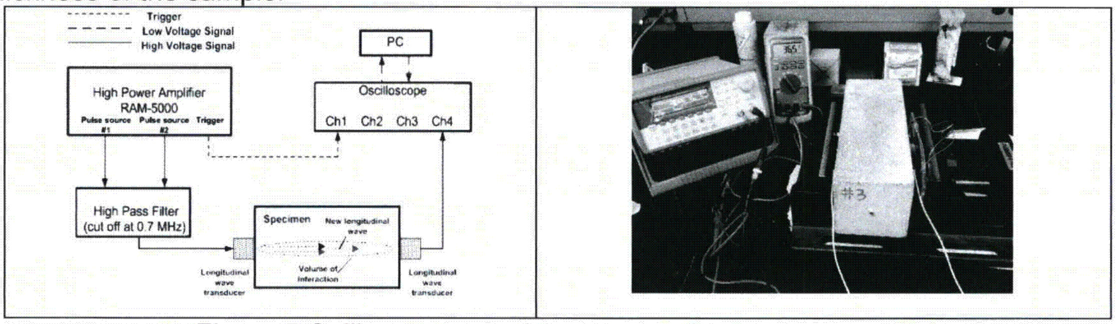

Figure 5 Collinear wave mixing ultrasonic measurement setup.

To demonstrate the feasibility of using nonlinear wave mixing (NWM) methods for detecting ASR damage, Prof. Qu has carried out some preliminary measurements. Using the collinear mixing configuration shown in Figure 5a, he measured the ANLP **β** versus the immersion time in the alkaline solution. A schematic of the ultrasonic measurements setup is shown in Figure 5a, and a photo of the actual measurement system is shown in Figure 5b. The measurement results are shown in Figure 4b. These preliminary results clearly demonstrated the feasibility of using NLUT techniques to track the progress of ASR damage in concrete.

In order for NDE measurements to be used for model updating and prediction of future damage evolution, a direct relationship between the increase of nonlinearity parameter and degradation of material properties need to be established. This is not a trivial task due to the fact that all NDE techniques measure the occurrence and evolution of nonlinear phenomena but cannot distinguish between various nonlinear phenomena that might occur in the material internal structure. Recent work of the PIs on ASR deterioration has shown that a precise interpretation of NDE measurements in concrete can be obtained by performing accurate LDPM simulations of the wave propagation phenomena through the affected concrete. Figure 6 show how metrics of LDPM-calculated ASR-induced cracking (for example max or mean crack opening) correlates very well with the nonlinearity parameter β (both experimental and numerical) for the case of a classical accelerated ASR mortar bar test. In this task the NWM techniques will be used to monitor nonlinearity

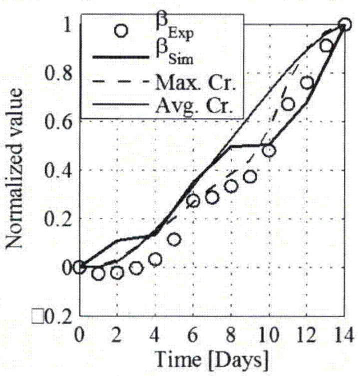

Figure 6: Correlation between nonlinearity parameter and LDPM simulated cracking metrics.

parameter evolution in the samples tested at CTLGroup. These measurements, interpreted and analyzed through the LDPM framework will allow correlating the nonlinearity parameter and the actual failure mechanisms. This in turn will allow extrapolating such correlation to measurements in the field in which only NDE measurements are available.

Task 4: Stochastic Parameter Identification. The goal of lifetime extension implies the ability to accurately predict structural safety in course of time and, thus, uncertainty in structural response. Within task 4 LDPM's inherent ability to account for material heterogeneity will be also extended to fully capture the randomness in model parameters by means of marginal distributions with characteristic auto-correlation length and statistical interdependence [13-17]. The developed stochastic LDPM will require the formulation of suitable stochastic parameter identification techniques that yield stochastic models for all required input parameters including their spatial and temporal correlation. The proposed identification framework will be able to (1) extract a comprehensive set of model parameters from incomplete and uncertain test data (such those collected from accelerated tests and NDE, see Task 2 and Task 3); (2) combine all available information from destructive testing, periodic non-destructive testing, permanent monitoring and inverse structural analyses; (3) remove statistical bias due to sampling frequency, experimental layout or monitoring concept; (4) quantify the confidence level of all parameters; and (5) provide the basis for efficient updating strategies as developed in task 5 to exploit new information as it becomes available. ***The NU team has profound experience in deterministic and stochastic parameter identification****, most recently demonstrated in related work on the calibration of multi-decade prediction models for creep and shrinkage utilizing heterogeneous and biased data.* In this work, an iterative adaptive multi-objective optimization strategy was developed. Bias towards short-term data, certain composition, testing conditions and sampling rate was removed through a hyperbox weighting scheme. Since the only true source of multi-decade test data is not laboratory tests but structural evidence the experimental test data had to be combined with the results of inverse statistical analyses.
The complexity of the proposed research in Task 4 will be addressed by the subsequently listed and logically structured subtasks that ensure an efficient workflow.

1. Definition of relevant *input parameters*, structured into (a) Mechanical model (material properties, geometry, boundary conditions); (b) Moisture transport and heat transfer model for relative humidity and temperature calculations (parameters, initial conditions, boundary conditions); (c) ASR model (parameters controlling kinetics, temperature influence).
2. Formulation of *stochastic models* for all input parameters based on literature review and experimental investigations (where possible), giving (a) Distribution type; (b) Statistical moments; (c) Correlation measures (pairwise linear correlation, covariance matrix, copulas).
3. Characterization of *available data (observations)* as: (a) Time-discrete or continuous data; (b) Local (point-wise) or distributed information (fields); (c) Deterministic (single curves) or statistical information (repeated measurements); (d) Absolute or relative data; (e) Data obtained through destructive or non-destructive means; (f) Direct or indirect information.
4. Identification strategies require the formulation of *indicators* that can be derived from the observations; describe uniquely the given data; and can be specified by a single stochastic quantity. Investigated approaches will include (a) Time series analyses; (b) Analyses of spatial trends and variability; (c) Normalization techniques (e.g. finding the displacement for 100%, and 10% load levels)
5. Using the stochastic models of the input parameters (step 2), *sensitivity fields* between model parameters (step 1) and available monitoring information (step 4) are derived, depending on the type of information (step 3). This step yields (a) Ranking of parameters according to relevance for a given type of observation; (b) Mapping of dependence structures using a threshold sensitivity factor.
6. Derivation of *weighting concepts* to remove statistical bias in the input data, impose importance weight on more reliable data sources and combine heterogeneous data in a single optimization.

7. The results of step 5 allow the transformation of a complex and probably ill-conditioned identification problem into a *logical sequence of well-defined optimization steps* that can be solved using one of the following optimization techniques (a) Artificial neural networks (ANN) for complex functional dependencies; (b) Genetic algorithm or particle swarm models (to overcome local minima); (c) Traditional gradient based optimization algorithms.
8. Quantification of confidence bounds for the identified parameters, determination of prediction bounds, and formulation of stochastic models for the identified parameters. Depending on the complexity of the problem one of the following approaches is chosen: (a) Direct calculation utilizing Jacobian of the objective function; (b) approximation through sampling schemes
9. The stochastic models that were obtained in Step 8 represent the basis for sub-sequent optimization steps and updating schemes that are investigated in Task 5.

Task 5: Predictive Stochastic Framework. Recent studies have shown that the probability of failure of infrastructure systems increases with time either with continuous and discrete increments (Figure 7). Continuous increments can be due to a gradual deterioration of the system properties due to phenomena such as ASR, corrosion of steel, delayed-ettringite formation (DEF), creep, and in case of NPPs also exposure to neutron or gamma radiation fields [18-19]. Discrete increments can be due to shocks that cause sudden changes in the system properties. Loads and deterioration mechanisms that are active for a short duration of time (e.g., impact loads, seismic loads, explosions, fire events, and small accidents) are examples of such shocks. The change in the probability of failure over time directly affects the expected remaining life of infrastructure systems. Therefore, models are needed to capture these continuous and discrete incremental changes and predict their evolution with time.

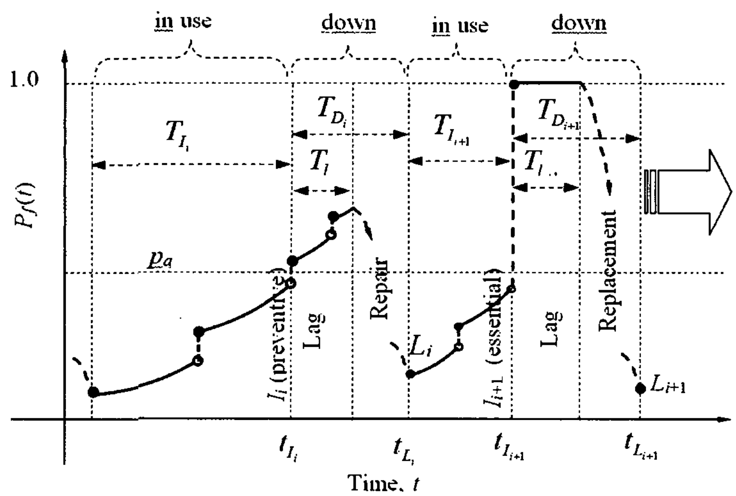

Figure 7: Probability of failure vs. life cycle of an infrastructure system

As part of the proposed work, a predictive stochastic framework will be developed to accurately estimate the actual remaining life of NPPs accounting for material degradation over time. **Prof. Gardoni at UIUC has extensive experience in developing this type of predictive frameworks.** The framework will include probabilistic models based on the mechanics-based LDPM formulated in Task 1 and calibrated in Task 4 using the data from the accelerated tests in Task 2. In addition, the input variables for the models will be obtained using data from the NDE described in Task 3. The prediction models will account for all relevant sources of information including the test data and, when available, additional data already available in the literature. Following established good practice when developing prediction models based on experimental and NDE data, the research team will account for measurement errors derived from the inexact nature of the measurement systems (in particular for the NDE data.) This will provide state-of-the-art models to predict the actual performance of NPPs subject to ASR. The developed models will provide the required information to predict the remaining life of NPPs in a fully probabilistic approach (i.e., including the expected life and confidence bounds). The confidence bounds will reflect the uncertainty present when predicting future events.

In particular, the research team will carry out the following activities under this task:

1. Analyze the NDE data collected in the laboratory experimentation and from the field.
2. Assess the accuracy of the NDE technique under different environmental conditions and overtime to estimate the measurement error, which is due to the imperfect measuring devices and technique.
3. Develop predictive models designed to relate the NDE measurements and the actual performance of the laboratory specimens obtained from destructive testing, accounting for the measurement errors.
4. Validate the developed predictive model and assess its accuracy. A few sets of collected data will not be used in the model assessment process and will be kept aside as test data. After the model is assessed, the model will be validated and its accuracy assessed by comparing the model predictions with the test data that will be kept aside. Since the test data will not be used in the estimation of the model parameters, a close match with the test data will be an indication of the quality of the model.
5. Estimate the quantities of interest in locations where measurements are not taken by developing *random field models*. This will require the research team to (a) Analyze the data to define homogeneous blocks in an NPP that display a similar characteristics and levels of deterioration that are topologically consistent. For this purpose, the research team will leverage the available models for the spatial characterization of deterioration processes. This task will also allow the identification of the minimum number and optimal location of the measurement points needed to have an accurate monitoring. (b) Develop random field models for each block using the NDE data collected at the selected locations. In particular, building on the general work on random fields and on the work on discretization of random fields into random variables, random fields will be develop incorporating the measurement errors due to the imperfect measuring devices and statistical uncertainty due to the limited number of measuring locations. (c) Test the random field models using data collected in other locations not used to construct the random field and kept aside for comparing the prediction of the model with the measurement from the sensors.
6. Estimate the future degradation and remaining life an NPP based on the NDE field data.
7. Update the estimates as new data/measurements become available using a Bayesian approach.

Task 6: Validation Study. The research team will validate the overall deterioration assessment framework by performing a case study in which loaded reduced-scale structural elements (columns and/or beams) will be subjected to semi-accelerated tests with ASR under various relative humidity and temperature conditions. The tests will be carried out over the last two years of the project and will be complemented by initial accelerated tests and periodic NDE, based on which medium and longterm performance estimates will be derived through the developed stochastic framework. For validation purposes, the predictions will be compared with the actual performance of the tested elements as assessed by destructive testing. In real structures, structural elements are subject to different environmental conditions spanning various length scales that, however, are much longer than the performance period of this project. For this reason, we will develop semi-accelerated tests in which, alkali ions are added to the mixing water to raise its alkali content. Typically, Ordinary Portland Cement (OPC) used in existing NPP has an alkali content that is in the range of 0.80% to 0.95% by mass of cement. For the standard concrete prism test (ASTM-129301 AC), potassium hydroxide or sodium hydroxide is to be dissolved in the mixing water in order to increase the Na_2O_{eq} content up to 1.25% of the mass of cement. In this work, we intend to use a larger alkali content (around 2% Na_2E_{eq}) in order to be able to observe ASR also at lower temperatures and under drying conditions under which ASR processes are significantly slower. While NPP walls might be in low humidity environment above ground, in many cases, its bottom part can exist in high humidity conditions, which may remain constant or vary periodically with different periods (yearly due to seasonal differences, or over the NPP lifetime due to surrounding environmental changes). Different humidity conditions will be tested and these will include the following. (1) Full saturation (under water), for which an important mechanism of ASR to be investigated is the leaching of ASR products to the surrounding water. This will be quantified by both pH level measurements and mass variation changes. (2) Sealed conditions, in which the effect of imbibed water by ASR on the amount of available evaporable water in concrete will be investigated. This is important for its possible coupling with hydration processes of cement and aging. (3) Cycles of saturation and drying. In this case, the effect of gel age on its ability to imbibe water will be studied. By precisely reporting the amount of leaching, it can be shown either that the typically reported reduction of expansion is due to gel aging or due to gel loss. The other important environmental effect is temperature, which is known to have a crucial effect on ASR. Four different thermal conditions will be considered: (1) Room temperature (25 °C). This can be considered as a reference case for the other cases. (2) Winter temperature (from -5 to 7 °C). (3) Summer temperature (from 30 or 40 °C). (4) Temperature cycles between the temperatures in case (2) and (3). Finally, the different environmental conditions will be coupled with various mechanical conditions to assess the effect of confinement and loading on expansion, cracking and gel formation. These mechanical conditions include (1) free expansion, which will serve as a reference case; and (2) sustained loading. For each case, nonreactive companion tests will be also performed to explicitly quantify the conditions effect on the reactive case. The following data will be gathered on appropriate time intervals for all tests performed using appropriate data acquisition tools reporting both averages and experimental scatters. (1) Temperature and humidity conditions on surface and inside the elements. (2) Strain measurements and deformations in relevant directions. (3) Periodic strength evaluation for both reactive and reference (nonreactive) elements and including both destructive (coring) and nondestructive evaluations. (4) pH measurements for water immersed elements to quantify the amount of leaching of ASR products. (5) Permeability measurements for the cored specimens to quantify the effect of ASR-induced cracking on water permeability.

Milestones, Deliverables, and Schedule

Milestones	Deliverables	Months from Kick-Off								
		4	8	12	16	20	24	28	32	36
Task 1: Probabilistic ASR/LDPM accounting for variable temperature and relative humidity	Technical article, source code, and user manual									
Task 2: Accelerated tests with stress effect	Technical article, test protocol and description									
Task 3: NDE techniques	Technical article									
Task 4: Stochastic parameter identification procedure	Technical article, source code, and user manual									
Task 5: Stochastic framework for lifetime assessment	Technical article									
Task 6: Case Study	Database of collected data									
Reports										

Management Plan

Within 30 days after contract award, the NU PI, Prof. Cusatis, and his team will establish a Program Master Plan, a Milestone Schedule, and a Budget Baseline on the basis of the research work proposed in this proposal. Prof. Cusatis will lead Research in Task 1 and will co-lead with Dr. D'ambrosia the research in Task 2. He will also perform, in collaboration with Dr.

Pelessone, research relevant to Task 4. Prof. Qu will be in charge of Task 3. Prof. Gardoni will lead the research in Task 5. All the PIs will be involved in the case study in Task 6.
These plans will be discussed and reviewed in details during a kick-off meeting held at NU with all the sub-contractors and NRC officials. It is from these plans and baselines that NU will monitor all progress and elements of cost for the program. The NU cost accounting system enables the PI to track the actual costs of our staff, subcontractors, travel, and material expenditures at the lowest WBS element. It is proposed here to provide NRC with Quarterly status material to include meeting reviews, technical progress reports, and cost reports.
NU's program management effort will include coordination with our subcontractors, CTLGroup, UIUC, and ES3. NU will support publication of papers, presentation of these papers, and attendance at conferences to ensure the outcomes of this program are properly disseminated to the technical community.
Progress review meetings that will be held periodically with the program sponsor and these meetings will also enable team members to familiarize themselves with everybody else's activities and promote collaboration. However, it is anticipated that most of the interaction and coordination between team members will take advantage of the virtual meeting software available over the Internet. In past and current efforts, the PIs have used software, like GoToMeetings and Skype, which have proved very beneficial in exchanging information in a quick and effective manner for large team projects.

Facilities and Capabilities

The research team will take advantage of state-of-the-art experimental and computational facilities available at Northwestern University (NU), University of Illinois at Urbana Champaign (UIUC), CTL Group (CTL), and ES3.
NU Supercomputing System. The NU Supercomputing System is ranked among the TOP500 list of the fastest computers worldwide. The computational power of the Quest configuration is rated at 37,288 GFLOPS peak and is expected to provide upwards of 34,274 GFLOPS sustained performance. The original computational portion of Quest consists of 504 diskless IBM iDataplex nodes, with 2.4 GHz Intel Nehalem Quad Core Xeon processors (2 per node) for a total of 4,032 cores, with 48 GB of DDR3 memory per blade. In 2010 the Quest expansion added 252 nodes with 2.66 GHz Intel Westmere Hexacore Xeon processors (2 per node) for a total of 3,024 new cores with 48 GB of DDR3 memory. The LU Supercomputing System is directly connected to 160 TB of data intensive computing storage. Additional storage, not directly connected, allows University researchers to upload, store, and share large research related.
NU Structural Engineering and Infrastructure Materials (SEIM) Laboratory. The SEIM Laboratory has a more than three decade long record of exemplary research in concrete and is equipped to handle all challenges associated with testing rheological and mechanical properties. Specimens can be cured in a 100% humidity curing room, two Hotpack walk-in environmental chambers are available for investigations which require accurately controlled temperature and humidity conditions. A precisely controllable Polyscience water bath for small scale investigations and a GS Blue M Electric Batch Oven with a capacity of 8 ft^3 temperatures of up to 750 °F complement the equipment. Testing and sensor equipment encompasses all standard instruments and setups that are necessary to investigate concrete rheology such as a HAAKE Rheostress150 rheometer with concentric cylinder geometry. Three state of the art MTS closed-loop servo-hydraulic load frames with capacities between 20 kips (89 kN) and a 1 million pound (4.5 MN) provide optimized testing conditions for a wide range of experiments. A multitude of additional load cells of various capacities as well as extensometers and LVDTs of various travel complement an effective testing facility. Additional data acquisition systems, such as the state of the art 24 bit HBM system quantumX, are available for specialized investigations. Full field data acquisition is added by a CorrelatedSolutions VIC-2D digital image correlation system that can also serve as video extensometer.

UIUC Facilities. UIUC provides an extensive array of computing resources to support research and teaching. The facilities, equipment, and other resources available at the UIUC provide an excellent infrastructure for pursuing the proposed research. Personal computers have the necessary data, word and graphics processing software to assist in performing data analysis and report preparation. A Buffalo's TeraStation network attached storage (NAS) physically located the UP campus will be available for storing data. This solution offers a secure and reliable centralized storage and automatic backup.

CTL Experimental Facilities. The CTLGroup is an engineering, testing, and consulting firm that began in 1916 as the Research and Development Laboratory for the Portland Cement Association (PCA). With over 95 years of experience in concrete technology including standard and specialized testing of aggregates, cement, mineral admixtures, chemical admixtures, concrete, and concrete products, CTL brings expertise and experience to the project. CTL currently employs approximately 130 engineers, architects, scientists, and technicians, 25% of whom hold Ph.D.'s. With 60,000 square feet of laboratory facilities CTL is a world leader in testing, research and development, and consulting on cementitious materials, concrete masonry, construction products and structural systems used in the construction industry. The firm has industry-leading cement, mortar, concrete, chemical analysis and petrographic laboratories. The petrographic laboratory includes stereographic, petrographic and electronic microscopes, allowing materials to be examined at magnifications ranging from 10x to 10,000x. Routine and complex analyses performed in the analytical chemistry laboratories range from compliance tests to detection of trace materials, such as chemical admixtures in hardened concrete. The concrete and masonry laboratories permit mixes and test specimens to be made, cast, and cured at temperatures ranging from -25°F to 135°F. The firm's durability and physical testing labs include a variety of programmable environmental rooms. CTL participates in a variety of laboratory certification, inspection and monitoring programs. It is inspected by CCRL and participates in the Cement and Concrete Proficiency Sample Program. The Quality Management System meets the requirements of the U.S. Army Corps of Engineers and received a satisfactory assessment (no findings) by the Nuclear Industry Assessment Committee (NIAC). Additionally, all CTL physical testing technician personnel are ACI (American Concrete Institute) certified at various levels. Facilities at the CTL Group will be utilized to conduct both standard ASTM test methods, as well as to develop new methods for restrained behavior as discussed in Task 2.2. The facilities include multiple temperature controlled lab spaces and heated chambers in many types of test configurations as well as one of the largest laboratories dedicated to creep and shrinkage in the world. CTL Group is ISO 9001 certified, its laboratories are ISO 17025 accredited and the quality program is compliant with 10CFR50 Appendix B NQA-1 requirements, a rare qualification in the engneering testing industry. CTL Group brings its vast expertise in performing research in the field of bridge engineering.

ES3 Capabilities. The ES3 structural mechanics division has a long tradition and extensive experience in developing advanced numerical capabilities for modeling the structural behavior of reinforced concrete structures under various loading conditions, including blast and fragment impact response. For the last thirteen years the ES3 Co-PI, Mr. Pelessone, has been collaborating with the NU PI, Prof. Cusatis, in the development and implementation of LDPM into the MARS software. MARS (Modeling and Analysis of the Response of Structures), is an innovative computational tool for simulating the mechanical response of structural systems under static and dynamic loading conditions and for evaluating their performance. MARS is based on dynamic explicit algorithms and implements all the capabilities and versatility of a general finite element code. In addition, MARS features some unique techniques, such as adaptive remeshing algorithms for shell and solid meshes, which facilitate the solution of problems involving structural break-ups, fragmentation and post-failure response under extreme loading conditions. Additionally, MARS has an object-oriented architecture, which makes it possible to add new capabilities in an efficient and systematic fashion. All entities in MARS are organized in a hierarchical framework. Classes of simple entities, such as edges and faces, are used to derive more complex entities, such as beams and shells. The MARS software is being used to solve extremely large analytical models, which require extensive use of computer resources. The large demand on computer memory and CPU time can only be satisfied by using distributed-memory massively parallel computer systems. For this purpose, MARS incorporates domain decomposition schemes and uses the Message Passing Interface (MPI) protocol. This is an on-going area of research, which puts MARS at the leading edge of simulation software. MARS is currently installed in the ES3 Cloud, the NU supercomputing facilities, and the ERDC supercomputing system to which the ES3 PI had access for the last 20 years.

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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.