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

September 30, 2014

Mr. Amit H. Varma
Purdue University
155 South Grant Street
West Lafayette, Indiana 47907

VIA Electronic Mail
ahvarma@purdue.edu

SUBJECT: GRANT NO: NRC-HQ-60-14-G-0001

Dear Mr. Amit H. Varma:

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 Purdue University (hereinafter referred to as the "Grantee" or "Recipient"), the sum of $378,844.00 to provide support to the "Steel Plate Composites (SC) Walls: Behavior, Analysis and Design for Missile Impact" 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 September 29, 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
- ☒ GRANT

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

1. GRANT/COOPERATIVE AGREEMENT NUMBER	2. SUPPLEMENT NUMBER	3. EFFECTIVE DATE	4. COMPLETION DATE
NRC-HQ-60-14-G-0001		09/30/2014	

5. ISSUED TO
NAME/ADDRESS OF RECIPIENT (No., Street, City/County, State, Zip)
PURDUE UNIVERSITY
155 SOUTH GRANT ST
WEST LAFAYETTE IN 479072024

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

7. TAXPAYER IDENTIFICATION NO. (TIN)

8. COMMERCIAL & GOVERNMENT ENTITY (CAGE) NO.

9. PRINCIPAL INVESTIGATOR/ORGANIZATION'S PROJECT OR PROGRAM MGR. *(Name & Phone)*
Amit H. Varma, 765-496-3419
Email: ahvarma@purdue.edu

10. RESEARCH, PROJECT OR PROGRAM TITLE
Steel Plate Composite Walls: Behavior, Analysis and Design for Missle Impact

11. PURPOSE
See Schedule

12. PERIOD OF PERFORMANCE *(Approximately)*
09/30/2014 through 09/29/2017

13A.	AWARD HISTORY	13B.	FUNDING HISTORY
PREVIOUS	$0.00	PREVIOUS	$0.00
THIS ACTION	$378,844.00	THIS ACTION	$114,699.00
CASH SHARE	$0.00	TOTAL	$114,699.00
NON-CASH SHARE	$0.00		
RECIPIENT SHARE	$0.00		
TOTAL	$378,844.00		

14. ACCOUNTING AND APPROPRIATION DATA
2014-X0200-FEEBASED-60-60D001-11-6-213-1058-4110

PURCHASE REQUEST NO.	JOB ORDER NO.	AMOUNT	STATUS
RES-14-0459			

15. POINTS OF CONTACT

	NAME	MAIL STOP	TELEPHONE	E-MAIL ADDRESS
TECHNICAL OFFICER	CHON DAVIS	CSB/ C6 D2	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)	AMOUNT (F)
	CFDA Number: 77.009 Technical Analyst: Hernando Candra MS: CSB/ C5 C1 Telephone: 301-251-7635 Email: Hernando.Candra@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 09/29/2017 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 "Steel Plate Composites (SC) Walls: Behavior, Analysis and Design for Missile Impact" as described in Attachment B entitled "Program Description."

A.2 PERIOD OF GRANT

1. The effective date of this Grant is September 30, 2014. The estimated completion date of this Grant is September 29, 2017.

2. Funds obligated hereunder are available for program expenditures for the estimated period: September 30, 2014 – September 29, 2017.

A. GENERAL

1. Total Estimated NRC Amount:	$378,884.00
2. Total Obligated Amount:	$114,699.00
3. Cost-Sharing Amount:	$0.00
4. Activity Title:	Steel Plate Composites (SC) Walls: Behavior, Analysis and Design for Missile Impact
5. NRC Project Officer:	Chon Davis
6. Technical Analyst:	Hernando Candra
7. DUNS No.:	072051394

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	$ 41,608.00	$ 42,570.00	$43,554.00
Fringe Benefit	$ 8,110.00	$ 8,313.00	$ 8,521.00
Travel	$ 0.00	$ 3,000.00	$ 0.00
Supplies	$ 12,764.00	$ 1,697.00	$ 3,000.00
Contractual	$ 0.00	$ 78,000.00	$ 0.00
Other (Tuition)	$ 10,271.00	$ 10,405.00	$10,540.00
Indirect Costs (55%)	$ 34,365.00	$ 31,875.00	$30,291.00
Yearly Total	**$107,118.00**	**$175,860.00**	**$95,906.00**

All travel must be in accordance with the Purdue 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 $378,884.00 for the three year period.

2. NRC hereby obligates the amount of $114,699.00 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

Introduction:

Steel-plate reinforced concrete (SC) walls are efficient from fabrication, erection, and construction perspectives. They have been used effectively as primary and secondary shield walls in the current generation of nuclear power plants [1,2], and are being considered for the next generation of small modular reactors. It is important for engineers to have an accurate and convenient method to design SC walls for impulsive and Impactive loading. The design of SC walls for impulsive (pressure) loading is the subject of a recent project funded by the US DOE. This project focuses on the design of SC walls for Impactive loading including both local failure (perforation) and global response.

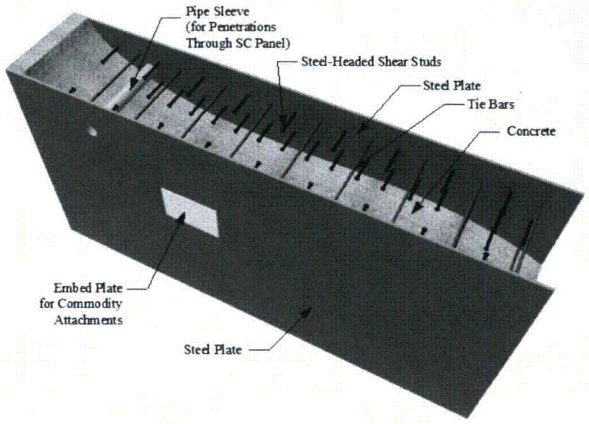


Figure 1. Schematic Layout of SC Wall [3]

There are important differences between SC walls and conventional reinforced concrete (RC) walls. As shown in Figure 1, the internal reinforcing bar curtains are replaced by external steel plates. These steel plates are connected to each other using tie bars, and anchored to the concrete infill using steel headed stud anchors (also referred as shear studs). The concrete infill is plain, i.e., there are no reinforcing bars to restrain shrinkage or influence concrete behavior. For SC walls, the term reinforcement ratio refers to the ratio of the total steel plate thickness to the total depth of the section ($\rho=2t_p/T$).

Empirical equations and design methodologies for preventing local failure of RC walls by perforation, scabbing, or penetration limit states have long been available. These equations were established during the 1940s for munitions projectiles and later extended and modified to include the effects of missile deformability [4] and low velocity projectiles [5]. The design limit state selected for RC walls depends on the required level of protection. Scabbing is the most commonly selected design limit state because of the risk of damage to internal equipment or personnel. Perforation may be the design limit state for structurally robust safety-related components that can withstand impact from spalled concrete. DOE-3014 [4] provides equations to determine RC wall thickness required to prevent the limit states of scabbing, penetration, or perforation as applicable. Additionally, ACI 349-06 [6] Appendix F includes recommendations for assessing the global response of RC walls subjected to Impactive loading. These include recommendations for: (i) the idealized displacement-resistance-ductility relationship, and (ii) associated permissible ductility ratios for RC walls. These recommendations are typically used with single-degree-of-freedom (SDOF) models to assess the inelastic dynamic global response of walls subjected to Impactive loading.

The local failure mode of SC walls for missile impact differs from that of RC walls because the rear (non-impact side) steel plate prevents scabbing of the concrete prior to perforation [5]. As shown in Figure 2, and demonstrated experimentally [12, 13, 16, 18, and 20], SC walls subjected to missile impact may undergo the following events sequentially: (i) missile penetration on front (impact) side, (ii) rear steel plate bulging, (iii) rear steel plate splitting, and finally (iv) perforation of the entire thickness.

The governing local failure mode for SC walls is perforation because the rear steel plate limits scabbing on the non-impact side. The global response of SC walls also differs from that of RC walls due to the biaxial state of stresses in the rear (tension) steel plate, and its influence on permissible ductility ratios.

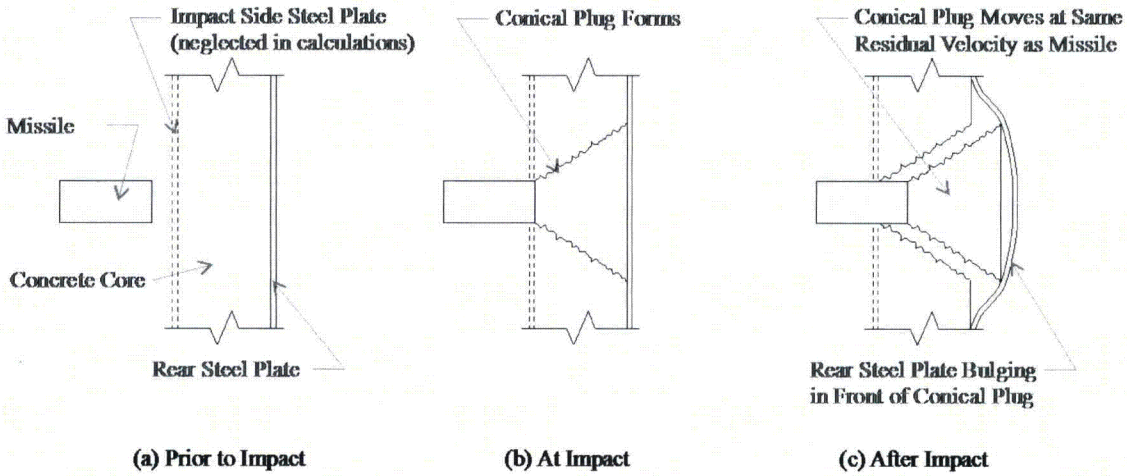


Figure 2. Local failure mode for SC walls [7]

Motivation and Relevance:

Currently, there is a lack of systematic research leading to development and implementation of design equations and methodologies in code provisions to assess failure of SC walls by perforation due to missile impact. There is also a lack of codified (standards-based) recommendations for evaluating the global response of SC walls subjected to Impactive loading. The idealized displacement-resistance-ductility relationships and associated permissible ductility ratios for SC walls have not been established by conducting systematic numerical research or experimental investigations to confirm candidate provisions in design standards.

AISC N690-12s1 [8] includes Appendix N9 for the design of SC walls. This is the first industry consensus standard for the design of SC walls in the US. It addresses the biggest challenge to the use and licensing of SC walls by the US NRC. However, it does not include specific recommendations or guidance for the design of SC walls for Impactive loading. The commentary includes references to recent research by the PI [3, 7, 9] to evaluate the local failure (perforation) and global response of SC walls to Impactive loading.

Therefore, additional confirmatory and systematic research on the design and evaluation of SC walls subjected to Impactive loading will support NRC efforts related to the development of guidance for the assessment of new and future designs of safety-related nuclear facilities subjected to Impactive loads.

Prior Research:

Published standards include experimentally verified equations to calculate the required RC wall thickness to prevent local failure due to missile impact [4, 10, 11]. To apply these methods to SC walls, some recommend converting the thickness of steel faceplates to equivalent thickness of concrete [12, 13, 14]. While the original equations in [12, 13] are based on limited experimental data and do not account for the material properties of steel faceplates or their relation to the adjacent concrete, recent work expands this method to a wider range of parameters [14]. Mizuno et al [15] published an empirical method, but it was limited to a single faceplate thickness and missile and does not account for material properties. There is a need for a general method that accounts for typical design parameters,

accounts for the independent behavior of the concrete and steel portions of the wall, and follows the sequence of missile impact on SC walls.

Walter & Wolde [12] suggested that the steel faceplate thickness be considered as an equivalent concrete thickness, where the equivalence was calculated by equating perforation equations for steel plates to those for concrete slabs. This equation assumed concrete strength (f'_c) of 3800psi, neglected the missile weight and diameter, and only considered the perforation limit state. Tsubota et al. [13] presented equations to convert steel faceplate thickness to equivalent thickness of concrete perforation, splitting, and bulging limit states. The equations were developed empirically using results from a database of 50 experiments. The experiments supporting the development of these equations included panels with concrete strength of 3500 psi and thin steel sheets (0.03 – 0.08-in). The experiments used only one missile configuration. These equations are simple to use but limited in applicability.

Grisaro & Dancygier [14] expanded the work in [12] and [13] to convert steel plate to equivalent concrete across a range of concrete and steel strengths and missile weights and diameters. They developed their method using a best-fit approach by comparing different combinations of equations for the perforation velocity of concrete and steel. Their method is well-suited for assessing the perforation limit of existing structures but is not intuitive for use in design of new structures. Additionally, their approach focuses on conventional RC walls with a steel plate added for scabbing resistance rather than true SC walls shown in Figure 1.

There has been little to no research on the development of displacement-resistance-ductility relationships and permissible ductility ratios for SC walls subjected to missile impact. The PI has initiated this work recently [3], but more in-depth research is needed to investigate details of the bilinear load-deformation curves with strain hardening, and the influence of various material, geometric, and detailing parameters on the permissible ductility ratios that can be used to assess the global response of SC walls subjected to Impactive loading.

Research Goals: The overall goals of this research project are to develop and confirm: (i) design approaches to prevent local perforation failure of steel-plate composite (SC) walls subjected to missile impact, and (ii) standardized recommendations including computational models to evaluate their global response.

Research Objectives: The objectives of the research project are to:

1. Assemble the experimental database of missile impact tests conducted on SC walls, and use the compiled results to develop design approaches to prevent local perforation failure of SC walls subjected to missile impact.

2. Develop and benchmark 3D finite element models to numerically model and predict the local penetration and perforation behavior of SC wall specimens subjected to missile impact.

3. Conduct experimental investigations to confirm the local penetration and perforation behavior of SC walls subjected to missile impact and the influence of section detailing parameters such as reinforcement ratio and tie bar spacing.

4. Conduct numerical parametric studies using benchmarked models to evaluate the influence of various material (reinforcement ratio, steel yield stress, concrete strength), geometric (thickness, stud spacing, tie spacing), and missile parameters (mass, velocity, diameter, and nose type) on the local penetration and perforation failure of SC walls, and also the global behavior of SC walls.

5. Finalize and confirm the design approach for preventing local perforation failure using the experimental and numerical analysis results.

6. Finalize and recommend displacement-resisting-ductility relationships and permissible ductility ratios for single degree of freedom (SDOF) models that can be used to evaluate the global behavior of SC walls that prevent missile perforation.

Research Plan by Tasks:

The research objectives will be achieved systematically by conducting a series of five inter-related tasks over a period of three years. These Tasks are described in the following sections.

Task 1 - Experimental Database and Design Approach

A comprehensive database of missile impact tests performed on SC walls will be compiled as part of this task. The database will include more than 130 missile impact tests conducted on SC walls by researchers over three decades [12, 13, 16, 17, 18, 19, and 20]. Tests conducted by Abdel-Kader & Fouda [20], Barr et al. [18], Hashimoto et al. [16], Mizuno et al. [19], and Tsubota et al. [13] focusing on SC walls with a few companion RC or plain concrete wall tests will be included. Tests summarized by Walter and Wolde [12], and those conducted by Sugano et al. [17] focused on RC walls, but included a few samples of RC walls with rear steel plates. These will also be included.

The PI has initiated such an experimental database of SC wall impact tests [7, 9]. It has a wide range of specimen and missile parameters. Missile weights range from 1.0 to 4600 lb; missile initial velocities range from 380 to 1400 ft/s; and missile diameters range from 0.9 to 39 in. SC wall thicknesses range from 2.0 to 54 in.; steel faceplate thicknesses range from 0.02 to 0.38 in.; concrete strengths range from 3000 to 7300 psi; and steel yield strengths range from 44 to 79 ksi. The database includes results for tests where SC walls stop the missile, and also for tests where SC walls are perforated by the missile. The missile penetration depth (x_c) is the test result of interest for SC walls that stop the missile, and the missile residual velocity (V_r) is the test result of interest for SC walls perforated by the missile.

The simple (equivalent thickness) design approaches developed by previous researchers [12, 13, 14, and 15] will be evaluated using the comprehensive experimental database compiled as part of this Task. Additionally, the systematic design approach developed by the PI [7, 9] and included in the commentary of AISC N690s1 [8] will also be further evaluated using the comprehensive database. The focus will be on evaluating the mechanics, assumptions, and outcomes of the design approach. These will also be reviewed and revised based on the results of Tasks 2, 3, and 4.

The PIs design approach [7, 9] is based on the idealized failure mechanism shown in Figure 3, which was assumed based on available test results and research. The steel faceplate on the impact (front) side is assumed to have little influence on the

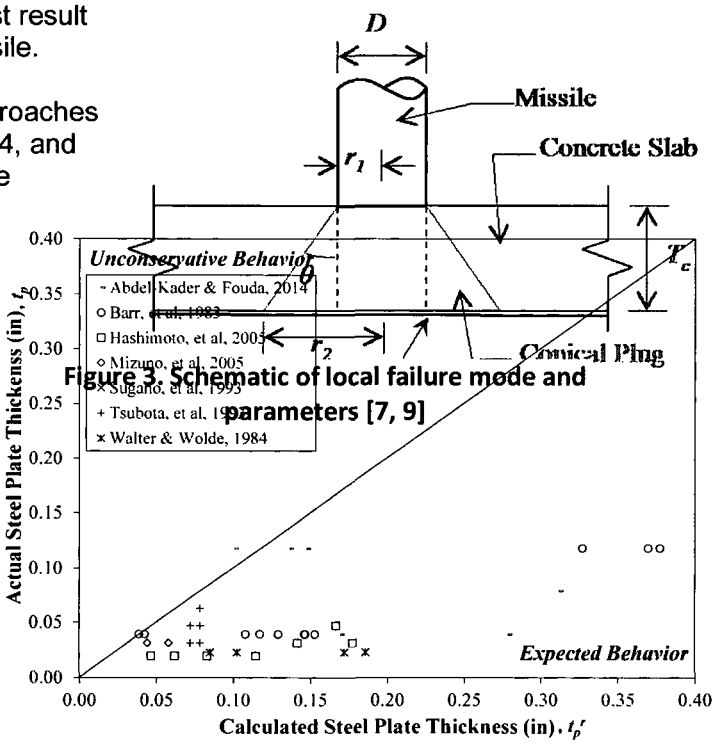


Figure 3. Schematic of local failure mode and parameters [7, 9]

Panels in which the projectile perforated the panel

Figure 4. Comparison of design approach with test results [7, 9]

behavior except that it constrains concrete spalling on its side. The missile is assumed to penetrate into concrete thickness and dislodge (fracture) a conical plug of concrete that starts moving with the same residual velocity (V_r) as the impacting missile. The rear steel plate has to stop the mass of the concrete plug and the original missile to prevent perforation failure.

It is important to note that the failure mode assumed in Figure 3 (the punching 'cone') is an idealization. Usually, the failure surface is more complex and may be less cone-like at higher speeds. There is some spalling (or scabbing in the back face) that is shallow and the failure surface may have a small theta angle and the 'cone' may be almost a cylinder, depending on the speed, thickness of the slab, and diameter of the missile. This is based on observations of impact tests on RC walls [5, 16].

The steel plate thickness required (t_p^r) to stop the missile and concrete plug is calculated using Equation 1, wherein m is the total mass of the missile and concrete plug, d is the equivalent diameter of the missile, σ_s is the quasi-static radial stress calculated using Equation 2, V_r is the residual velocity of missile and concrete plug calculated using Equation 3. In Equation 3, V_o is the initial missile velocity, V_p is the velocity required to dislodge the concrete plug, and W_{cp}/W is the ratio of the weight of the concrete plug-to-original missile. Equations for V_p are given in the articles [7, 9] and not repeated here for brevity. Figure 4 shows comparisons of the steel plate thickness required (t_p^r) calculated by the design approach with the actual steel plate thickness (t_p) of specimens that were perforated during testing. As expected, the missiles perforated wall specimens with steel plate thickness t_p less than t_p^r.

$$t_p^r = 0.72\left(\frac{(12V_r)^2 m}{\frac{\pi}{2}d^2\sigma_s}\right) \tag{1}$$

$$\sigma_s = \frac{f_y}{\sqrt{3}}\left(1+\left(\frac{E}{\sqrt{3}f_y}\right)^n \int_0^{(1-\frac{\sqrt{3}f_y}{E})} \frac{(-\ln(x))^n}{1-x}dx\right) \tag{2}$$

$$V_r = \sqrt{\left\{\frac{1}{1+W_{CP}/W}\right\}\left(V_o^2 - V_p^2\right)} \tag{3}$$

This design approach will be further evaluated, reviewed, and revised using the comprehensive database developed as part of this Task.

Task 2 - Development of Numerical Models

Task 2 will focus on the development and benchmarking of numerical models for predicting the behavior and local failure (penetration and perforation) of SC walls subjected to missile impact. The numerical models will be developed using the finite element method (FEM), and benchmarked initially using test results in the experimental database, and finally using test results from Task 3 of this project. The 3D FEM models will be developed using both LS-DYNA [21] and ABAQUS [22], which have been used extensively by the PI for previous research.

The PI has recently [7] started developing and benchmarking these 3D FEM models for the fifty tests conducted by Tsubota et al. [13]. These tests were conducted to study systematically examine the influence of steel plates on the front and rear of reinforced concrete (RC) walls to improve impact protection of nuclear facilities from external missiles. The models were developed using LS-DYNA [21] as follows. Reduced integration solid elements were used to model the concrete and steel plate(s). Beam elements were used to model the rebar and shear studs. Zero-length discrete beam (connector)

elements were used to model the interfacial force-slip displacement behavior of the shear studs welded to the steel plate.

The Winfrith concrete model (MAT_084/085) was used for the concrete material properties. It is a smeared crack model that accounts for tension softening due to crack opening. It was developed in response to the nuclear industry's need to model accidental impact and blast loads on reinforced concrete structures and has been validated for a variety of impact and blast tests [23]. The measured concrete compressive strength was used in the model. The rest of the input parameters (elastic modulus, tensile strength, and fracture energy) were estimated using equations from accepted standards [6, 24]. A bilinear curve was used to model tension softening (post-crack) concrete behavior as shown in Figure 5 [25]. Crack widths (w_1 and w_2) associated with the points on the bilinear curve are computed using Equation (4), in which G_f and f_t (UTS) are the fracture energy and tensile strength and c_i is the crack width constant from Figure 5.

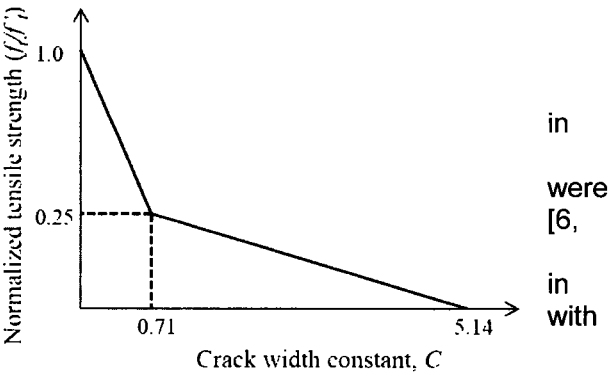


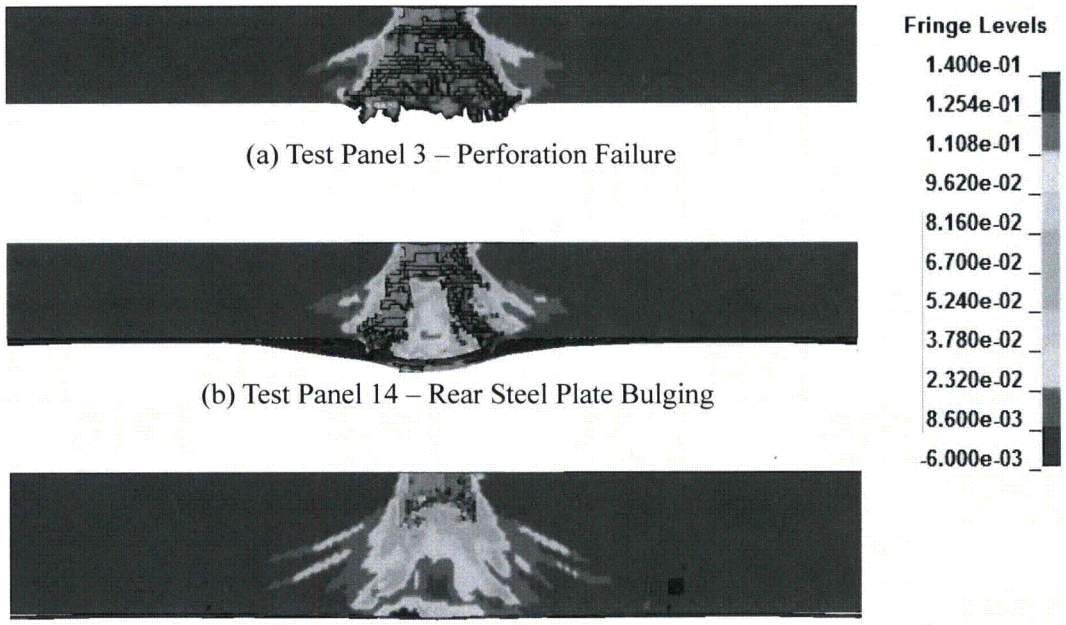
Figure 5. Tension Softening (post-crack) Concrete Behavior [7, 25]

$$w_i = c_i \frac{G_f}{f_t}$$

Careful consideration of the element erosion (deletion) criteria is important for conducting impact analysis. The maximum strain corresponding to the crack width (w_2) at zero residual tensile stress (identified in Figure 5) was used initially to set the element erosion criteria. This failure strain depends on the characteristic length (mesh size) of the concrete elements. Additional erosion criteria will also be considered as part of this project.

A piecewise linear kinematic hardening material model was used for the steel components of the model. Rate effects were accounted by using dynamic increase factors prescribed in NEI 07-13. As part of this Task, we will systematically explore including Cowper-Symonds rate effects coefficients, steel damage models, and element erosion with damage. The missiles in the tests were designed to be non-deformable, and were therefore modeled as rigid cylinders in LS-DYNA. The density was computed based on the known missile weight and the volume of the solid cylinder to ensure accuracy of the missile mass.

The concrete was modeled using two different mesh densities. The central region in which the conical plug is expected to form consisted of a much finer mesh of 0.125 in. solid elements using constant stress reduced integration elements (SOLID ELFORM 1). The outer region was composed of a slightly coarser mesh of 0.5 in. solid elements with the same element formulation. The steel plate was modeled with the same mesh sizes as for concrete. The element formulation requires hourglass control, so Flanagan-Belytschko viscous form with exact volume integration for solid elements (IHQ3) was used with an hourglass coefficient of 0.10 as recommended by Erhart [26] for high velocity analyses. Rebar (if present in the specimens) was modeled with 0.5-in beam segments of Hughes-Liu with cross-section integration elements (BEAM ELFORM 1). Penalty based contact definition was used to define contact between the rigid missile and the SC walls and also to define contact between the steel plates and the concrete infill. Rebar and studs were mathematically embedded in the concrete using a penalty coupling mechanism.



(a) Test Panel 3 – Perforation Failure

(b) Test Panel 14 – Rear Steel Plate Bulging

(c) Test Panel 28 – Penetration

Figure 6. Typical results from numerical analysis with different failure modes [7]

Figure 6 shows three representative failure modes (perforation, bulging, and penetration) modeled for Tsubota's tests by the PI recently [7]. These results compare favorably with experimental results, and were obtained using the modeling approach described above. As part of this Task, we will comprehensively develop and benchmark numerical models for predicting the impact behavior of all specimens in the experimental database, and those tested as part of this project in Task 3. We will extend the numerical models to explore other concrete models in LS-DYNA and also using ABAQUS. The numerical models will be used to investigate the mechanics of local failure, and compare them with the assumptions made in the design approach (Task 1). The models will also be used to finalize the design of the experimental investigations to be conducted in Task 3. Additionally, the experimental results from Task 3 will be used to confirm and finalize the benchmarking of these numerical models.

Task 3 - Experimental Investigation

In this task, a total of six SC wall specimens will be designed and tested to evaluate the local penetration and perforation behavior of SC walls subjected to missile impact and the influence of section detailing parameters such as reinforcement ratio and tie bar spacing. This Section presents the preliminary design of these SC wall specimens using: (i) the design approach developed by the PI [7, 9] and discussed earlier in Task 1, and (ii) the experimental constraints of the missile impact testing facility for the project. This design will be further verified and finalized during the project using the numerical models developed in Task 2.

The SC wall specimens will be tested at the Projectile Penetration Research Facility (PPRF) located at the United States Corps of Engineers (USACE) Engineering Research and Development Center (ERDC) in Vicksburg, MS. Figure 7 shows the test equipment at the facility. As shown, the test panels will be bolted to a test frame, which will provide support on all four edges. Projectiles will be launched from a powder-powered gun with 3.25 in. bore and maximum projectile weight of 45 lbs.

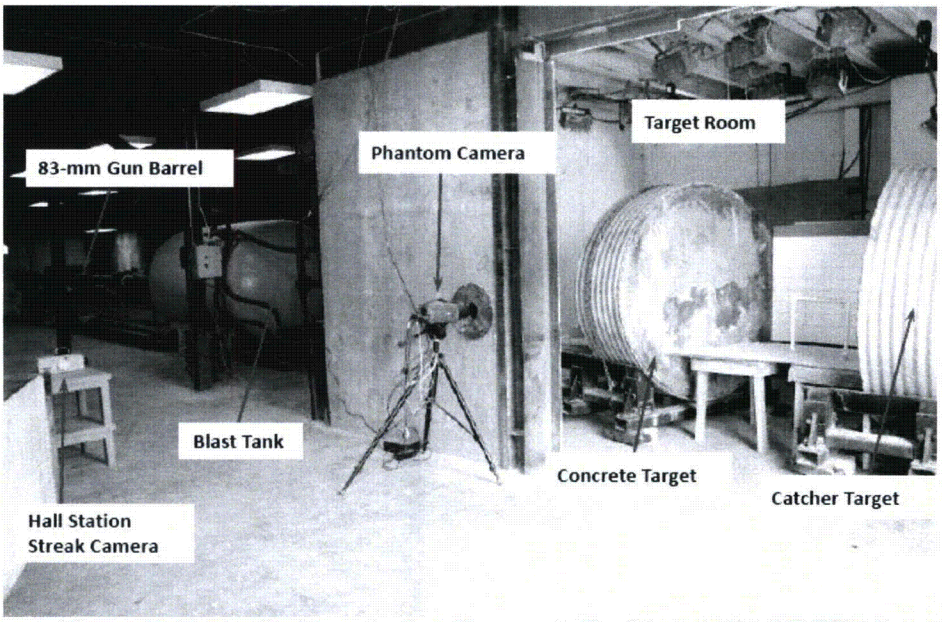


Figure 7. Projectile Penetration Research Facility in USACE ERDC

Preliminary specimen design is governed by the maximum capabilities of the PPRF facility and the perforation resistance of SC walls, which was estimated using the design approach developed by the PI [7, 9]. The constraints associated with specimen design are as follows:

- Since the missile diameter and weight are limited to 3 in. and 45 lb respectively, the wall thicknesses were limited to 6 in. and 12 in. to achieve wall thickness-to-missile diameter (T/D) ratios of two and four.
- Missile velocities greater than approximately 725 ft/s are not practical because they are beyond the range of typical nuclear plant design considerations. Additionally, 3 in. diameter missiles moving faster than 725 ft/s can have tunneling effects.
- Missile velocities in the range of 250 – 550 ft/s are desired because of the range of missile velocities considered for nuclear plant designs.
- Tests resulting in missile perforation of the walls are preferred because this data will be more useful in evaluating and confirming the mechanics assumed by design approaches. Additionally, these tests will provide valuable data that include fracture of the rear steel plate, residual velocity of the missile (after perforation) and the concrete plug dimensions for benchmarking of numerical models.
- Fewer tests resulting in the missile being stopped by the walls are also proposed to confirm the conservatism of the design approach, and to provide valuable data that include penetration depth and steel plate bulging for benchmarking of numerical models.

Table 1 summarizes the preliminary test matrix. As shown, the geometric dimensions of the SC wall specimens will be equal to at least five times the wall thickness (5T x 5T). Four SC wall specimens will have wall thickness (T) of 6 in. and plate thickness (t_p) of 0.1 in. resulting in reinforcement ratio of 3.3%, which is typical of nuclear construction and comparable to RC wall reinforcement ratio of 1.7%. Two SC wall specimens will have thickness (T) of 12 in. and plate thickness (t_p) of 0.25 in., resulting in reinforcement ratio of 4.2%.

The nominal compressive strength for the concrete infill will be the same (5000 psi) for all six specimens, and steel plates will have nominal yield strength of 50 ksi. All tests will be conducted using flat-nose solid steel (rigid) projectiles having 3 in. diameter and 45 lb weight. Figure 8 shows the transition curves obtained for both the SC wall designs (6 in. and 12 in. thick) using the design approach developed by the PI. These curves correspond to the transition from 'missile perforating the wall' to 'missile stopped by the wall'. Missiles with mass and velocity exceeding the curve perforate the

corresponding wall, and missiles with mass and velocity less than the curve are stopped by the corresponding wall.

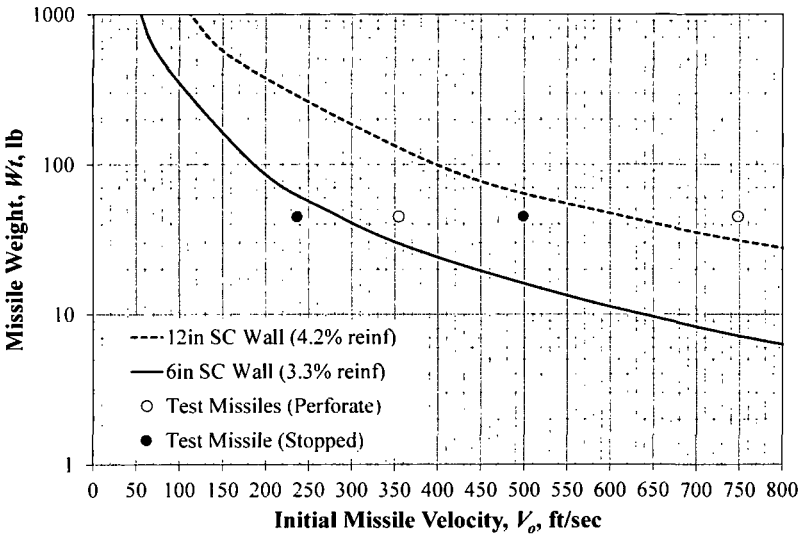


Figure 8. Transition curves for SC wall designs developed using approach in [9]

The missile weight of 45 lb (the maximum possible for the PPRF) was used along with these transition curves to select the impact velocities for the experimental investigations. As shown in Figure 8, two impact velocities were selected for each SC wall design to result in either perforation or stopping. These velocities were selected to be ±20% from the transition velocity to ensure the expected outcome. Table 1 includes the missile velocity for each test and the expected outcome.

Tie spacing is an important parameter considered in the experimental investigations. Specimens 1, 2, and 3 have tie spacing of 1.5T, T, and 0.5T, respectively. The specimens have shear studs with diameter (*d*), length, and spacing equal to 0.125 in., 6d, and 1.5 in. (T/4), respectively. Specimens 1 - 3 will be tested with missile velocity equal to 360 ft/s to get wall perforation. Specimen 4 will be identical to Specimen 1, but tested with reduced missile velocity of 240 ft/s to get penetration but no perforation, i.e., stopped by the wall. Specimens 5 and 6 have wall thickness equal to 12 in. and tie spacing equal to T and 0.5T, respectively. These specimens have shear studs with diameter, length, and spacing equal to 0.25 in., 6d, and 3 in. (T/4), respectively. Specimen 5 will be tested with missile velocity at the high-end equal to 760 ft/sec to get wall perforation. Specimen 6 will be tested with missile velocity equal to 507 ft/s to get penetration but no perforation, i.e., stopped by the wall.

Table 1 Experimental test matrix

Spec.	T (in.)	Size	t_p (in.)	Stud s/T	Tie S_t/T	ρ □□□□ (%)	M (lb)	V_o (ft/s)	Expected Outcome
1	6	5T x 5T	0.10	0.25	1.5	3.3	45	360	Perforation
2	6	5T x 5T	0.10	0.25	1.0	3.3	45	360	Perforation
3	6	5T x 5T	0.10	-NA-	0.5	3.3	45	360	Perforation
4	6	5T x 5T	0.10	0.25	1.5	3.3	45	240	Stopped
5	12	5T x 5T	0.25	0.25	0.5	4.2	45	760	Perforation
6	12	5T x 5T	0.25	0.25	0.5	4.2	45	507	Stopped

The displacements and accelerations of the SC wall specimens will be measured using laser-displacement sensors and accelerometers. The accelerometer results will be filtered and adjusted using baseline correction. Mid-span deflection will also be measured using high-speed cameras. Additional behavior data will be obtained using strain gages on the rear steel plates (non-impact side) of the SC walls, and strain gages on the tie bars within the panels.

Impact velocity, V_o, and residual velocity, V_r, will be measured during the test. The mass of the projectile and its deformed shape after the test will be measured and photographed. Damage to each specimen (diameter of hole, edge crack patterns, impact and rear steel plate fracture), will be measured and photographed after each test. The weight and dimensions of the concrete plug will be measured if it remains intact after being ejected from the specimens. After the tests, both steel plates will be removed and concrete crack patterns marked, measured, and photographed. All of this data will be used to verify numerical models developed in Task 2 and used for parametric studies of Task 4.

The proposed experimental investigations utilize the maximum capabilities of the PPRF in ERDC. The test results will provide valuable data to review and confirm or revise the mechanics and assumptions of local perforation failure of SC wall to missile impact. The test results will also provide valuable data to further benchmark and confirm the numerical models developed in Task 2. The test results will add to the existing experimental database compiled in Task 1, and confirm design approaches that can be specified in design codes or standards that are reviewed by the NRC to establish regulatory guides and positions.

Task 4 – Analytical Parametric Studies of Local Failure and Global Response

In this task, the finalized benchmarked models of Task 2 will be used to conduct analytical parametric studies to investigate the influence of various material (reinforcement ratio, steel yield stress, concrete strength), geometric (thickness, stud spacing, tie spacing), and projectile parameters (diameter, mass, velocity) on the local penetration and perforation failure of SC walls, and the global response of SC walls.

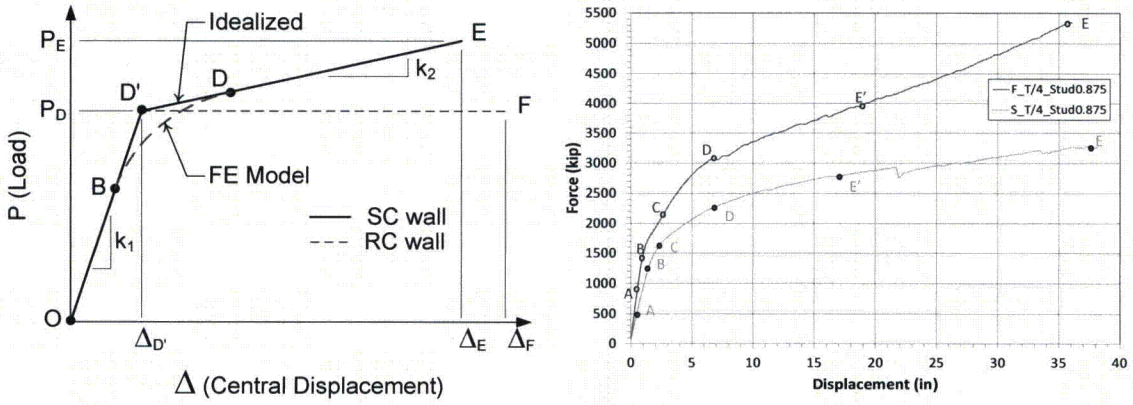
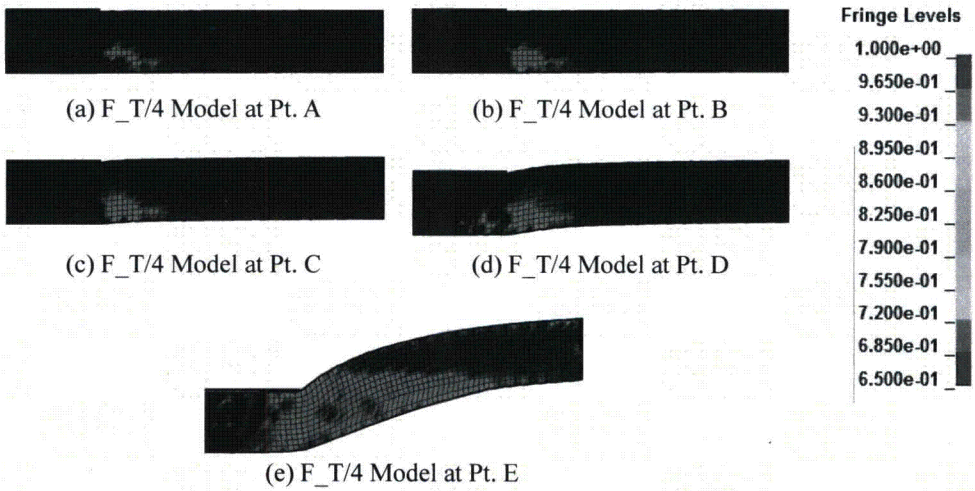


Figure 9. Typical SC Wall Load-Deformation Plot [3]



(a) F_T/4 Model at Pt. A (b) F_T/4 Model at Pt. B

(c) F_T/4 Model at Pt. C (d) F_T/4 Model at Pt. D

(e) F_T/4 Model at Pt. E

Figure 10. Sequential Concrete Damage Contour Plots for Typical SC Wall [3]

The global geometric similarity of SC and RC panels suggests a natural extension of the SDOF approach for RC structures to SC structures. For conventional RC walls, the resistance function is elastic, perfectly plastic. Recent work by the PI [3] suggests that the resistance function for SC walls is bilinear with strain hardening as shown in Figure 9, and with damage states shown in Figure 10. For SC walls, global mass considerations are essentially the same for RC and SC plates since the SDOF inelastic method for plate structures assumes a response with a shape function defined by the collapse mechanism, which is dependent only on the plate global geometry. Quasi-static analyses will be conducted to characterize the resistance function, *R*, for SC panels and the effect of system parameters on its behavior.

The local damage study is directly linked to the global behavior study. For those cases in which the projectiles are stopped, the analysis results will provide global dynamic behavior to compare against results of SDOF models as described above. The cases in which the projectile perforates the wall will be used to understand the influence of system parameters on the perforation resistance of SC walls and the accuracy / conservatism of the design method to prevent perforation. The span of all local failure models will be at least 5T x 5T. The following parameters and ranges will be used for both the local failure and global behavior studies.

Wall Thickness	T	12 to 48 in.
Reinforcement ratio	ρ	2.0 to 5.0%
Stud spacing-to-plate thickness ratio	s/t_p	10 to 20
Tie spacing-to-wall thickness ratio	S_t/T	0.5 to 1.5
Steel plate yield strength	f_y	50 to 65 ksi
Concrete compressive strength	f'_c	4000 to 6000 psi
Missile impact velocity	V_o	267 to 800 ft/s
Missile mass	M	per wall design
Missile diameter-to-wall thickness ratio	D/T	0.25 to 1.0

In addition to the above, the following parameters and ranges will be included in the global behavior studies.

Span-to-wall thickness ratio	L/T	3 to 10
Boundary conditions		Pinned and Fixed

It is evident that the analytical parametric studies will involve a large number of simulations to investigate the various practical combinations of these parameters. A python-based script will be developed to conduct these simulations semi-automatically. The script will be designed to generate the large number of models necessary to thoroughly evaluate these parameters, run the analyses, and post-process the results.

The results from the parametric analyses will be post-processed to reexamine and revise (if needed) the mechanics and assumptions of the simpler design approaches developed earlier in the project. The effects of various material, geometric, and missile parameters on the local perforation failure and global response of SC walls will be evaluated and reported. These evaluations will inform the activities of Task 5.

Task 5: Development of Design Guidelines and Recommendations

The results from the experimental investigations of Task 3, the analytical parametric studies of Task 4, and the comprehensive experimental database of Task 1 will be used in this Task to review, confirm and revise the design approach developed by the PI and referenced in the commentary of AISC N690s1 [8] for local perforation failure of SC walls subjected to Impactive loading. The design approach will be refined and improved to account for the effects of material, geometric, and missile parameters as established by Tasks 1 and 4. Statistical reliability analysis will be conducted following [27] to establish a resistance factor for the design approach using the comprehensive experimental database and the analytical parametric studies.

The revised design approach will be presented to the appropriate committees for future versions of the code, and published in refereed journals. This will support NRC efforts related to the development of guidance for the assessment of new and future designs of safety-related nuclear facilities subjected to Impactive loads.

The results from the analytical parametric studies of Task 4 and the existing research on the out-of-plane shear and flexure behavior of SC walls [27] will be used to review, confirm and revise the displacement-resistance-ductility relationships and permissible ductility ratios developed by the PI [3] and referenced in the commentary of AISC N690s1 [8] for assessing the global response of SC walls subjected to Impactive loading. The revisions will be presented to the appropriate code committees to develop standardized recommendations for evaluating the global response of SC walls subjected to Impactive loading. This will further support NRC efforts related to the development of regulatory guidance for SC walls.

Schedule / Timeline for Executing Tasks:

The schedule for the proposed project is as follows:

	Year 1				Year 2				Year 3			
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Task 1: Database and Design	■	■										
Task 2: Numerical Models and Benchmarking		■	■	■				■				
Task 3: Experimental Investigations at ERDC				■	■	■	■	■	■			
Task 4: Analytical parametric							■	■	■	■		

Studies												
Task 5: Design Guidelines and Code Recommendations												

Outcomes and Relevance:

The proposed project will result in the confirmation and code implementation of research-based design guidelines and standardized recommendations for assessing the local failure and global response of SC walls subjected to Impactive loading. These guidelines and recommendations will be confirmed during the project using the comprehensive experimental database of SC wall impact tests done in the world, careful testing done as part of this project, and analytical evaluations conducted using numerical models benchmarked as part of this project.

Thus, the project will directly support NRC efforts related to the development of regulatory guidance for the assessment of new and future designs of safety-related nuclear facilities subjected to Impactive loads.

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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.