U.S. NUCLEAR REGULATORY COMMISSION
NOTICE OF GRANT/ASSISTANCE AWARD

1. GRANT/AGREEMENT NO.	2. MODIFICATION NO.	3. PERIOD OF PERFORMANCE	4. AUTHORITY
NRC-HQ-11-G-04-0083	M001	FROM: 10/01/2011 TO: 09/30/2012	Pursuant to Section 31b and 141b of the Atomic Energy Act of 1954, as amended

5. TYPE OF AWARD

[X] GRANT

[ ] COOPERATIVE AGREEMENT

6. ORGANIZATION TYPE

State Controlled Institution of Higher Education

DUNS: 259999779

NAICS: 611310

7. RECIPIENT NAME, ADDRESS, and EMAIL ADDRESS

Governing Council of the University of Toronto

McMurrich Building, Third Floor
12 Queen's Park Cres.
Toronto, Ontario Canada M5S 1S8

8. PROJECT TITLE:

Load Redistribution for Steel-Concrete Composite Structures

9. PROJECT WILL BE CONDUCTED

PER GOVERNMENT'S/RECIPIENT'S PROPOSAL(S) DATED

AND APPENDIX A-PROJECT GRANT PROVISIONS

10. TECHNICAL REPORTS ARE REQUIRED

[x] PROGRESS AND FINAL

[ ] FINAL ONLY

[ ] OTHER (Conference Proceedings)

11. PRINCIPAL INVESTIGATOR(S) NAME, ADDRESS and EMAIL ADDRESS

Dr. Frank Vecchio
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12 Queen's Park Cres.
Toronto ON M5S 1S8
(416) 978-5910 fjv@civ.utoronto.ca

12. NRC PROGRAM OFFICE (NAME and ADDRESS)

NRC
ATTN: Robin Barnes, Robin.Barnes1@nrc.gov
21 Church Street MS: C6D20
Rockville, MD 20850
(301) 251-7401
Jose Pires, TA Jose.Pires@nrc.gov

13. ACCOUNTING and APPROPRIATION DATA

APPN. NO:	31X0200.160
B&R NO:	201160176161
JOB CODE:	G6021
BOC NO:	4110
OFFICE ID NO:	Administrative RFPA

14. METHOD OF PAYMENT

[ ] ADVANCE BY TREASURY CHECK

[ ] REIMBURSEMENT BY TREASURY CHECK

[ ] LETTER OF CREDIT

[x] OTHER (SPECIFY) Electronic ASAP.gov
(See Remarks in Item #20 "Payment Information")

15. NRC OBLIGATION FUNDS

THIS ACTION	$0.00
PREVIOUS OBLIGATION	$96,681.00
TOTAL	$96,681.00

16. TOTAL FUNDING AGREEMENT

NRC	$96,681.00
RECIPIENT	$0.00
TOTAL	$96,681.00

This action provides funds for Fiscal Year in the amount of $0.00

17. NRC ISSUING OFFICE (NAME, ADDRESS and EMAIL ADDRESS)

U.S. Nuclear Regulatory Commission
Div. of Contracts
Attn: M`Lita Carr
Mail Stop: TWB-01-B10M
Washington, DC 20555
MLita.Carr@nrc.gov

18.

Signature Not Required

19. NRC CONTRACTING OFFICER

Sheila Bumpass 11/18/2011
(Signature) (Date)

NAME (TYPED) Sheila Bumpass

TITLE Contracting Officer

TELEPHONE NO. (301)492-3484

20. PAYMENT INFORMATION

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).

21. Attached is a copy of the "NRC General Provisions for Grants and Cooperative Agreements Awarded to Non-Government Recipients.
Acceptance of these terms and conditions is acknowledged when Federal funds are used on this project.

22. ORDER OF PRECEDENCE
In the event of a conflict between the recipient's proposal and this award, the terms of the Award shall prevail.

23. By this award, the Recipient certifies that payment of any audit-related debt will not reduce the level of performance of any Federal Program.

TEMPLATE - ADM001 SUNSI REVIEW COMPLETE ADM002

DESCRIPTION OF MODIFICATION

The purpose of this modification number 001 is to:

1. Correct the recipient name and address;
2. Correct the terms and conditions of the award document.

As a result of this modification:

1. On the Notice of Grant/Assistance Award in box 7. entitled "RECIPIENT NAME, ADDRESS and EMAIL ADDRESS" delete in its entirety and replace with the following:

   Governing Council of the University of Toronto
   McMurrich Building, Third Floor
   12 Queen's Park Cres.
   Toronto, Ontario Canada M5S 1S8

2. On page 12 of Attachment C – Standard Terms and Conditions delete the section entitled "Nondiscrimination";
3. On page 14 of Attachment C – Standard Terms and Conditions delete the section entitled "Drug-Free Workplace";
4. On page 17 of Attachment C – Standard Terms and Conditions delete the section entitled "Audit Requirements".

Base Period: October 1, 2011 – September 30, 2012 (unchanged)
Assistance Award Ceiling: $96,681.00 (unchanged)
Total Obligated Amount: $96,681.00 (unchanged)

All other terms and conditions remain the same.

ATTACHMENT A - SCHEDULE

A.1 PURPOSE OF GRANT

The purpose of this Grant is to provide support to the "Ductility and Load Redistribution in SC Safety-related Nuclear Power Plant Structures Subjected to Combined In-Plane and Out-of-Plane Shear" as described in Attachment B entitled "Program Description."

A.2 PERIOD OF GRANT

1. The effective date of this Grant is October 01, 2011. The estimated completion date of this Grant is September 30, 2012.

2. Funds obligated hereunder are available for program expenditures for the estimated period: October 01, 2011– September 30, 2012.

A. GENERAL

1. Total Estimated NRC Amount:	$96,681.00
2. Total Obligated Amount:	$96,681.00
3. Cost-Sharing Amount:	$0.00
4. Activity Title:	Ductility and Load Redistribution in SC Safety-related Nuclear Power Plant Structures Subjected to Combined In-Plane and Out-of-Plane Shear
5. NRC Project Officer:	Robin Barnes, Jose Pires (TA)
6. DUNS No.:	259999779

B. SPECIFIC

RFPA No.:	RES-11-280
FAMIS:	GR0115
Job Code:	G6021
BOC:	4110
B&R Number:	2011-60-17-6-161
Appropriation #:	31X0200.160
Amount Obligated:	$96,681.00

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
Personnel	$40,000.00
Fringe benefits	$600.00
Travel	$5,000.00
Other	$21,400.00
Total Direct Charges	$67,000.00
Indirect Cost	$29,681.00
Yearly Total	$96,681.00

A.4 AMOUNT OF AWARD AND PAYMENT PROCEDURES

1. The total estimated amount of this Award is $96,681.00 for the 12 month period.
2. NRC hereby obligates the amount of $96,681.00 program expenditures during the period set forth above and in support of the Budget above. The Grantee will be given written notice by the Contracting Officer when additional funds will be added. NRC is not obligated to reimburse the Grantee for the expenditure of amounts in excess of the total obligated amount.

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

Attachment B – Program Description

PROGRAM DESCRIPTION

Description: Steel-concrete (SC) composite wall systems are being considered for use in the construction of 'new generation' concrete nuclear containment structures. While data from experiments conducted to-date indicate that such wall systems are superior to conventionally reinforced concrete walls, their behavior under combined in-plane and out-of-plane shear conditions is not well understood, particularly in regards to structural ductility under seismic loading conditions. Moreover, currently available analytical tools have proven to be unreliable in accurately calculating expected response. The proposed project will aim to develop improved material modeling formulations, based on proven conceptual models for concrete, and implement these models into a numerically stable and robust analytical procedure. This analytical tool will then be used to investigate the behavior of a typical steel-concrete composite domed cylindrical structure, focusing on the interactions between in-plane and out-of-plane shear, and their influence on structural ductility, damage progression and failure mode under lateral push-over conditions. The design of a suitable confirmatory experimental program will also be developed. This project will enable a better understanding of the response and failure mode of SC safety-related nuclear structures, and will provide tools for improved confirmatory analyses and establishment of acceptance criteria.

1. INTRODUCTION AND NEED FOR RESEARCH

1.1 Steel-Concrete Composite Walls

Steel-concrete (SC) composite wall elements generally consist of a thick concrete core section integral with thin steel faceplates. Typically the element contains no conventional in-plane reinforcement (i.e., no horizontal or vertical rebar) and no conventional shear reinforcement (i.e., no stirrups or T-headed bars). The steel skin plates are connected to the core with regularly spaced stud anchors. In some cases, cross-tie bars connecting the two steel faceplates are used, thus also functioning as shear reinforcement.

SC elements offer several advantages relative to conventional reinforced concrete (RC) walls. In particular, they lend themselves to more efficient construction practices, allowing the steel shells to be prefabricated in manageable sized panels, which can then be assembled on site and act as formwork for the in-situ casting of the concrete core. As well, they exhibit superior behavior characteristics, particularly with respect to dynamic response and impact resistance.

The nuclear power industry was a driving force in the design, development and use of SC wall systems. Research activity in this area was extensive in the late 1980s and early- to mid-1990s. As the construction of new nuclear power plants abated worldwide at the turn of the century, research interest declined. However, a resurgence in the design and construction of nuclear plants has resulted in renewed interest in SC wall systems. Use of SC walls has also expanded to other applications such as concrete gravity based offshore structures and blast- and impact-resistance protective structures.

1.2 Example Applications

In past years, there was considerable interest in SC composite systems for application in the design of large structural components of nuclear power plants. In a 1997 NUREG report [1], it was noted that the use of SC modular construction in advanced reactor designs can be a major contributor toward improving the cost competitiveness of nuclear power. In that study, it was noted that Westinghouse was applying SC modularization in the design of the then current AP600 Plant. General Electric had proposed modularization for the Simplified Boiling Water Reactor (SBWR). Other advanced reactors which also had proposed to use SC composite systems included the Sodium Advanced Fast Reactor, the Modular High Temperature Gas-Cooled Reactor, the Prototype Reactor Inherently Safe Module, and the CANDU3 Reactor. This interest has been rekindled today.

An example of the current proposed use of SC composite systems for large-scale structural components can be found in Westinghouse's design of the AP1000 Plant [2]. This new prototypical nuclear power generating facility includes a Shield Building (SB), which is a cylindrical domed structure that encapsulates the containment vessel. The SB is a Seismic Category I structure which provides radiation shielding, missile protection and passive containment cooling functions. Where exposed on its exterior surfaces, the structure employs a 'double-skin' steel and concrete (SC) composite design comprised of a monolithic concrete section between two tied steel faceplates (see Figure 1). Typically, the concrete core of the wall contains no vertical or circumferential reinforcement. The tie-bars attached to opposite faceplates serve as shear reinforcement; they are placed at a relatively close spacing (in both directions) in high shear regions and at a wider spacing elsewhere. Anchor studs attached to the steel faceplates are also employed to ensure full realization of composite action
seismic design forces.

1.3 Performance of SC Walls in Shear

To support the design and use of the SC concept, particularly with respect to its performance under out-of-plane shear conditions, Westinghouse undertook a comprehensive program of full-scale testing. Test specimens included beams subjected to monotonic out-of-plane shear, beams subjected to cyclic out-of-plane shear, and beams subjected to combined axial tension and out-of-plane shear. To test performance under in-plane shear conditions, a 1/3-scale shear wall specimen was subjected to reversed cyclic lateral (in-plane) loads. Several other subassemblies examining anchorage and connection details were also tested. All experiments were conducted at Purdue University.

The Purdue test results indicated that the SC wall elements met or exceeded shear strength requirements for both in-plane and out-of-plane shear conditions. Consistent with the findings of other researchers, the Purdue tests showed that shear strengths obtained from SC elements were at least equivalent to those of conventionally reinforced concrete elements of comparable design.

However, the Westinghouse/Purdue tests were inconclusive in confirming the ductility or post-peak deformation capacity of the SC wall elements. For example, shown in Figure 2 is the load-deflection response for beam specimen OOPS-3.5 which was subjected to out-of-plane shear; the deflection measured at the midspan is given by the curve labeled as N75. [Note: Coordinate values have been removed to protect proprietary information] The load capacity of the beam exceeded the value calculated using ACI Code formulations. Immediately following the attainment of peak load, however, the beam sustained a brittle shear failure. There was essentially no post-peak deformation capacity (i.e., ductility) demonstrated by this beam. Ductility is extremely important in seismic engineering due to the key role it plays in allowing a structure to dissipate energy during an earthquake event. This is especially true for commercial buildings that invoke energy dissipation in the nonlinear range of response to calculate the seismic design forces.

1.4 Ductility in Shear-Critical Structures

The intent of Chapter 21 of American Concrete Institute Standard ACI-349 (Provisions for Seismic Design) is that a structure be designed to behave, at its ultimate limit state, in a ductile manner. This necessitates that the structure exhibit a failure mechanism that involves yielding of the principal reinforcement such that a high deformation capacity can be achieved, providing sufficient energy dissipation and avoiding all brittle failure mechanisms. The Code provides no specific guidance on the level of ductility required.

A generally accepted criterion for assessing adequate ductile behavior does not exist amongst jurisdictions or design code worldwide, although many are working toward criteria based on the concept of displacement or ductility demand. The criterion proposed in New Zealand, for example, states that if the structure can withstand four cycles at four times the yield displacement with no more than 20% decay in force capacity, then it is adequately designed to resist high seismic loading. It is understood that this is a highly stringent criterion, particularly when isolating the behaviour in a single member or joint. Given the size and nature of nuclear power plant structural components, a less stringent criterion may be more appropriate.

Although ACI-349 does not define specific target levels for ductility, it is worth noting that it implicitly requires that the failure mechanism be ductile regardless of the magnitudes of the actual design loads. For shear design of flexural members, Clause 21.3.4.1 states that "...the design shear force shall be determined from consideration of the statical forces on the portion of the member between the faces of the joints. It shall be assumed that moments of opposite sign corresponding to the probable flexural moment strength act at the joint faces...". In other words, the design shear force is dictated by the flexural capacity of the member, ensuring that a ductile flexural failure occur before a brittle shear failure can develop. This criterion was developed specifically for frame-type structures. In the case of the SC composite wall elements, the thick steel faceplates create a large moment capacity, and thus the shear capacity required to maintain a ductile failure mechanism is high, regardless of the actual out-of-plane shear forces acting. As with Specimen OOPS-3.5, the flexural reinforcement (i.e., the faceplates) did not yield, so clearly this criterion was not met.

With regards to the behavior of concrete elements subjected to combined in-plane and out-of-plane shear, little experimental data can be found in the literature. Thus, it is uncertain how the interactions between the two mechanisms will manifest themselves in safety-related SC structures, and how ductility, load redistribution and failure mode will be affected.

1.5 Analysis of Westinghouse Test Specimens

For analyses of the Shield Building, including in regards to the structure's ability to exhibit adequate ductility during design earthquake events, Westinghouse employed sophisticated nonlinear finite element analyses using commercial software such as ABAQUS and LS-DYNA. However, the ability of such analysis tools to adequately simulate the behavior and failure mode of shear-critical concrete structures has not been confirmed. Consider, for example, the results of analyses performed by Westinghouse for Specimen OOPS-3.5 using program ABAQUS. Four analyses were done, differing in the material model assumed for the concrete post-cracking tensile response. The results are shown in Figure 2, labeled as (i), (ii), (iii) and (iv). In all cases, the analyses predicted a highly ductile response, well beyond the displacement levels the test specimen was able to achieve; the actual brittle failure mode was not captured. Thus Westinghouse was forced to employ artificial strain limits in their analyses to avoid overestimating ductility and force redistribution in their confirmatory analyses. Clearly, however, the capabilities of currently available commercial analysis packages are deficient when considering the behavior of shear-critical concrete structures.

1.6 Need for Research

To satisfy current design and performance requirements, including ductility, a complete understanding is required of the full range of response of structural components under single and combined loads. This understanding can then be used to model the full range of behavior of the structures including the expected failure modes. The tools and results thus acquired can, in turn, be used to quantify seismic margins for review purposes (both for independent reviews and for confirmatory reviews by NRC staff) and also to formulate acceptance criteria.
Achieving these goals requires having the capability to model the response of the overall structure, accounting for nonlinear behavior and redistribution of stresses. To do this with full confidence, it is necessary to have reliable and robust modeling tools that can represent the behavior of the components under single loads and combined loads, particularly for brittle shear-critical conditions.

Thus, there are two outstanding research needs in regards to the behavior of SC safety-related structures: a general need for improved analysis capabilities, and a specific need for a more thorough assessment of the expected ductility of the proposed structures under seismic loading conditions.

Need 1: Improved Analysis Capability
With finite element analyses, the common approach to modeling SC wall elements is to use powerful general purpose software packages and apply them in a micro-modeling of the wall details. That is, the finite element meshes are typically so finely detailed as to model individual anchor studs as well as the concrete and steel continuums in a full three-dimensional representation. Interface elements are also typically used to capture the effects of contact/bond stresses and interfacial slip. However, this approach has met with only limited success for two reasons. First, the micro-modeling approach is time consuming and expensive both in the preparation of the models and in the computational demand; large structural systems represent a significant challenge. Secondly, the general purpose commercial software typically available for these purposes have shown difficulty in accurately capturing the response of concrete, particularly in brittle shear-critical situations.

Thus, a general need exists for improved finite element analyses of steel-concrete composite elements. In particular, a smeared modeling approach, as has been developed by several research groups for the simulation of RC structures, has the potential for simplifying the modeling process and decreasing the computational demand. This will better enable analyses for varying load intensities and combinations. Moreover, the incorporation of models more sensitive to the complex nuances in concrete constitutive behavior hold the potential for improved accuracy in the calculation of SC element response.

Need 2: Assessment of Ductility in SC Safety-Related Structure
While some experimental studies have been reported examining the behavior of reinforced concrete elements subjected to combined in-plane and out-of-plane shear, no such studies have been performed on SC elements. Thus, until such experimental investigations are performed, we must rely on analytical investigations. Once a reliable finite element based analysis tool has been developed, one that can accurately simulate post-peak decay in strength without artificial strain limits and thus allow load redistributions to occur, it can be used to investigate the expected behavior of the SC safety-related structures being proposed.

Thus, for the review of safety-related SC structures in nuclear power plants, a more specific research need must be fulfilled addressing such questions as: Can the building be expected to behave in a ductile manner? What interactions exist between in-plane shear and out-plane shear? Does significant load redistribution occur and what is the nature of the expected failure mode?

2. Background Information

The applicant has been engaged in the development of advanced constitutive models for reinforced concrete, and their implementation into advanced analysis procedures, for his entire research career. The study proposed herein draws heavily on preceding work completed by the applicant.

The Modified Compression Field Theory (MCFT) was co-developed by the applicant, together with Dr. Michael Collins, about 30 years ago as a rational model for describing the behavior of reinforced concrete [3]. Cracked reinforced concrete was modeled as a composite continuum material using a smeared, rotating crack approach. Conditions of compatibility and equilibrium were formulated in terms of average stresses and average strains, but local conditions at crack locations were also taken into account. Mechanisms such as compression softening due to transverse cracking, and post-cracking tensile stresses due to tension stiffening, were identified as significant influencing factors. These behaviors were embodied in new constitutive relations based on data derived from tests performed on panel elements under general well-defined in-plane stress conditions; it was the first time such tests had been successfully completed. Today, the MCFT is commonly used worldwide. The paper written presenting the theory is the most heavily cited paper in the history of the American Concrete Institute journal.

More recently, the Disturbed Stress Field Model (DSFM) was formulated as a refinement of the MCFT, giving improved accuracy in the context of finite element analyses (FEA) [4]. Efforts were also successful in recasting the MCFT into a form more suitable for design code implementation [5, 6]; it now forms the basis for the Canadian code's design of concrete structures in shear [8]. Concurrent with the experiment and theoretical research, work was directed towards implementing the MCFT/DSFM models and constitutive relations into advanced

nonlinear analysis procedures. Over the last 20 years, the VecTor(c) suite of programs has evolved. The programs include analysis capabilities for beam sections (VecTor1), 2D membrane structures (VecTor2), 3D solid structures (VecTor3), plates and shells (VecTor4), plane frames (VecTor5), and ax symmetric solids (VecTor6). These analysis programs have been extensively calibrated against test data involving large and complex specimens tested both in-house and elsewhere, have been used in numerous consulting assignments. The types of structures examined include offshore platforms, nuclear plant structures, bridges, silos, shear walls, slabs, frame structures, and crash barriers. In many cases, the VecTor analysis programs provided a means of accurately investigating complex nonlinear behavior to a degree that was difficult or impossible by other means.

The common approach to developing advanced analysis procedures has been to accentuate the formulation of sophisticated nonlinear algorithms, and then rely on rudimentary constitutive models for concrete usually based on classical solid mechanics concepts. These models typically fail to capture the nuances and influences of various second-order mechanisms unique to reinforced concrete. Consequently, conventional approaches to performance modeling of concrete structures have met with only limited success, particularly in large general-purpose software packages. The approach the applicant has favored is one which places greater emphasis on accurately describing the constitutive behavior of concrete, done through the development of rational theoretical models based on comprehensive experimental investigation. These models are then implemented into simple and numerically robust nonlinear analysis algorithms specifically formulated for reinforced concrete.

3. RECENT RELATED WORK

4.

The applicant recently concluded a study for the U.S. Nuclear Regulatory Commission, on Contract NRC-DR-04-10-139, resulting in a report entitled "Towards Improved Modeling of Steel-Concrete Composite Wall Elements", dated February 2011 [8].
In that study, theory and formulations were developed and added to the DSFM to enable the analysis of steel concrete (SC) composite panel elements. The enhanced formulation was then implemented into an existing nonlinear finite element analysis algorithm for the analysis of two-dimensional planar structures (VecTor2). Verification studies were undertaken, modeling the response of various SC test specimens including panels subjected to uniaxial compression, panels subjected to in-plane shear, and shear walls subjected to reversed cyclic lateral displacements. As well, a number of large-scale specimens tested in a proprietary experimental program undertaken by Westinghouse Corporation, including beams subjected to out-of-plane shear, beams subjected to combined tension and out-of-plane shear, beams subjected to cyclic shear, and a flanged shear wall subjected to reversed cyclic lateral displacements, were modeled. From a numerical modeling perspective, the study confirmed that the DSFM is a suitable platform for modeling SC structures. The resulting FEA program was numerically stable and robust, even so for post-peak response and for reversed cyclic loading conditions. The smeared element approach represented advancement over current FEA methods for analysis of SC structures, which typically rely on three-dimensional micro-modeling of wall details and thus entail significantly more modeling and computational effort.

More importantly, the analysis tool developed resulted in significantly improved accuracy in the modeling of SC elements subjected to in-plane or out-of-plane shear. In modeling the behavior of test specimens subjected to various in-plane loading conditions, the SC formulation developed was able to provide highly accurate predictions of ultimate strength; the ratio of the calculated to

measured strength for the 19 specimens examined had a mean of 0.99 and a coefficient of variation of 7.1%. For in-plane loading conditions, the formulation developed also gave accurate simulations of pre- and post-peak load-deformation response, chronology of damage, and failure mode. In particular, it correctly captured the lack of post-peak ductility in shear-critical structures without the use of artificial limits placed on strains or other parameters.

The strength, behavior and failure mode of SC specimens subjected to out-of-plane loading, particularly those shear-critical in nature, were also accurately simulated by the analysis method. For the 7 beams examined, subjected to various conditions of out-of-plane shear, the ratio of the calculated to measured strength had a mean of 1.02 and a coefficient of variation of 3.0%. For the beams tested by Westinghouse, the results obtained from the procedure developed were typically much more consistent in their predictions of response than were the results obtained by Westinghouse using their ABAQUS analyses.

Consider, for example, the predictions of response obtained for Specimen OOPS-3.5, shown in Figure 3. [Note: Coordinate values have been removed to protect proprietary information.] VecTor2 provided an accurate prediction of the beam's load capacity, stiffness, displacement at peak load, brittle non-ductile response after peak, and ultimate shear-dominated failure mode. ABAQUS, while also providing a reasonably accurate estimate of the load capacity given the most favorable of the four concrete tension stiffening models considered, completely miscalculated the specimen's ductility and failure mode. It is also worth noting that the strong correlations between calculated and experimental results obtained using the procedure developed were done so employing basic finite element modeling techniques, using the program's default options for all analysis parameters and material models, and without the use of complex elements such as link or bond elements. No fine-tuning of analysis parameters or structure modeling was required.
An overarching conclusion of the study was that the analyses undertaken basically concurred with experimental observations that shear-critical SC elements generally behave as well or better than comparable RC elements. However, the study also determined that post-peak ductility may be limited in some cases even though element strength may be governed by yielding of the faceplates in tension. This may occur because, as the faceplates yield in the principal tension direction, they simultaneously lose strength in the principal compression direction (according to most yield criteria), shedding load to the concrete. If the concrete is extensively cracked, compression softening effects may result in a shear-compression failure of the concrete struts at stresses well below the nominal compressive strength of the concrete. This was particularly evident in the analysis of shear panels tested by Ozaki et al. [9].

Thus the study concluded with, among others, the following recommendations:
1.
Building on the strong results obtained from the formulation developed for two-dimensional SC elements, it is proposed that the DSFM-based analysis model be further developed to extend to three-dimensional structures. In particular, it is recommended that expanded formulations be developed and implemented into VecTor3 (for three-dimensional solid structures) and VecTor4 (three-dimensional shell structures), with the latter of the two being of more practical benefit in the analysis of SC nuclear safety-related structures.

2.
Little is known about the interaction between in-plane shear and out-of-plane shear in shear-critical SC structures, particularly with regards to load redistribution and failure mode in cylindrical shell-type structures subjected to lateral shear forces. It is recommended that an

analytical investigation be undertaken in this regard using VecTor4, once that program has been modified to include SC modeling as per Item #1.

3.
Further to Item #2, it is recommended that the analytical studies be supported by experimental investigations that can provide data for verification of both the analysis program and the SC design concept. Shell element specimens, subjected to combinations of in-plane shear and out-of-plane shear and bending, can be tested using the Shell Element Tester facility currently available at the University of Toronto. Alternatively, a cylindrical shell specimen subjected to lateral loading, may serve the purpose.

The study proposed below is consistent with these findings and recommendations.

4. Proposed Research

4.1 Sub-Project 1: Implementation of SC Formulation into VecTor4

VecTor4 is a nonlinear finite element analysis package for reinforced concrete shell structures. This program was developed at the University of Toronto, based principally on the doctoral work of Professor M. A. Polak, later refined by Professor R. Seracino, and continuously improved and maintained since then by the VecTor Analysis Group. Modeling of reinforced concrete behaviour is done according to the formulations of the Modified Compression Field Theory (MCFT) and Disturbed Stress Field Model (DSFM). Essential details of the program formulation are provided by Polak and Vecchio [10]. Most notable is that the program utilizes a layered-shell formulation. Program VecTor4 provides the capability to analyze reinforced concrete shell structures while accounting for geometric and material nonlinearities. Relevant to this application is the ability to accurately represent the redistribution of internal forces that can occur due to local changes in stiffness arising from cracking or crushing of concrete, yielding of reinforcement, or other second-order mechanisms. Also relevant is the program's thick shell formulation which enables it to rigorously consider out-of-plane shear stresses, compression softening influences, and tension stiffening effects, mechanisms that bear significantly on the analysis of SC structures subjected to lateral loads.

While VecTor4 has not previously been used to model cylindrical-type concrete nuclear safety-related structures, it has been used to analyze concrete offshore structure and storage silos, both of which employ cylindrical-type designs. Many of the silos examined were constructed without transverse reinforcement, and thus were deficient in their out-of-plane shear strength according to modern design standards. For example, shown in Figure 4 is a VecTor4 model of a silo in Ecuador. Under eccentric lateral load, this silo was found by VecTor4 to be governed by an out-of-plane shear failure in the walls. Thus, work will be undertaken to implement a DSFM-based SC element formulation into VecTor4, patterned after the approach that was successful in the VecTor2 formulation. Because VecTor4 uses a layered element formulation, the implementation will necessarily differ from that used in VecTor2 and will be somewhat more difficult to implement. However, the underlying theory and material modeling will be preserved.

The implementation will be verified by modeling the SC test specimens previously examined in the VecTor2 verification studies; namely, panel elements and wall specimens subjected to various conditions of in-plane shear, and beam specimens subjected to various conditions of out-of-plane shear. Note that there are no experiments reported in the literature wherein SC specimens were subjected to combined in-plane and out-of-plane shear.

The literature does contain isolated studies on the behavior of conventionally reinforced panel elements subjected to combined in-plane and out-of-plane shear and containing little or no shear reinforcement. Thus, verification studies will also be undertaken to confirm VecTor4's accuracy in modeling such structures.

Finally, specimens used for the verification of VecTor4 will also be analyzed with commercial software packages (e.g., ABAQUS, LS-DYNA) and the results will be compared and discussed.

4.2 Sub-Project 2: Force Redistribution in a SC Nuclear Safety-Related Structure

As was previously discussed, the ABAQUS modeling of the post–peak response of SC elements subjected to in-plane or out-of-plane shear conditions is of questionable accuracy. The constitutive models used to represent the compression stress-strain response of the concrete proved unable to capture the rapid decay in concrete stress capacity that can occur under post-peak conditions, particularly when the structure is shear-critical. Hence, such analyses may typically grossly overestimate the post-peak ductility of the structure.

In force-redundant structures, such as cylindrical structures subjected to lateral load, a redistribution of force can occur as one force-resisting mechanism is exhausted and another assumes a greater role in resisting the applied loads. In a cylindrical-type structure under lateral loading conditions (i.e., earthquake), this interplay will occur as the out-of-plane shear capacity of the walls is exceeded and more of the load is resisted by in-plane shear mechanisms. However, if the analysis model cannot accurately represent the decay in the out-of-plane strength capacity, there is a great potential for miscalculating the strength, ductility, and failure mode of the structure. Imposing artificial strain limits in the analyses, as Westinghouse did to compensate for the inadequate material modeling, will not result in a proper consideration of the force redistributions.

A generic capped cylindrical structure with steel-concrete composite walls will be modeled using VecTor4, once the program has been modified as per Sub-Project 1. The modeled structure will be given dimensions, wall section details, and material properties consistent with specifications for currently proposed prototypical designs. Analyses will be performed for push-over lateral load conditions as well as for various dynamic load conditions (e.g., representative earthquake records, localized impulse loads). The analysis results will be examined to determine the ultimate failure mode of the structure, the chronology of damage and distress in the structure particularly with respect to any localized out-of-plane shear failure, the redistribution of load that occurs as a result of localized damage, and the nature and magnitude of the ductility that is exhibited by the structure. This will provide some insight into whether localized out-of-plane shear failures are averted due to in-plane shear mechanisms quickly assuming load resisting functions, or whether a more brittle sequential or 'zipper-type' failure pattern is formed. Ultimately, it will provide insight into the safety and reliability of safety-related structures constructed using SC wall elements with minimal amounts of shear reinforcement.

The structure will also be analyzed with various commercially available software packages commonly used in industry for nonlinear modeling of concrete structures. The results of these analyses will be compared to those obtained from VecTor4. Conclusions will be sought as to the adequacy of these programs, and of the various concrete material models utilized therein, for the assessment of shear-critical response modes in safety-related structures.

4.3 Sub-Project 3: Preliminary Design of Experimental Investigation

Data from experimental investigations are required in order to obtain a reliable verification of the accuracy of the analytical tools developed (i.e., the DSFM-based formulations for SC elements, and the implementation into NLFEA program VecTor4) as they pertain to three-dimensional shell-type structures. As well, experimental investigations are required to confirm the nature of the interaction between in-plane and out-of-plane shear in SC elements containing little or no shear reinforcement. No such data are available. This scarcity of data exists partly because of the fact that performing such tests is exceedingly difficult, requiring elaborate or specialized test equipment.

One of the few existing facilities in the world that is capable of applying combined in-plane and out-of-plane shear forces on a reinforced concrete test panel is the Shell Element Tester at the University of Toronto (see Figure 5). The possibility using this facility to test SC elements will be investigated. The range of specimen parameters that can be accommodated, and the costs associated with constructing and testing a series of specimens, will be determined.

Alternatively, it may be more practical and cost-effective to construct a small-scale SC open cylindrical specimen for testing under lateral bending conditions; that is, under conditions similar to a simply-supported beam subjected to a midspan transverse point load. The specimen's wall thickness and overall shear-span-to-depth ratio could be designed such as to make the specimen shear-critical. Such a confirmatory experiment would provide a stringent test of the accuracy of the analytical procedures, as well as providing insight into the actual behavior of shear-critical SC shell structures. Again, a preliminary design of the test specimen would be undertaken and associated costs determined.

Given the practicalities, anticipated costs and relative merits for verification purposes associated with each of the two alternatives, a proposal for follow-up research program will be formulated.

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 to:
A-21 (now 2 CFR 220)
A-87 (now 2 CFR 225)
A-122 (now 2 CFR 230
A-102:

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

a. 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.

b. Grantees must comply with monitoring procedures and audit requirements in accordance with OMB Circular A-133. <
http://www.whitehouse.gov/omb/circulars/a133_compliance/08/08toc.aspx >

2. Award Package

§ 215.41 Grantee responsibilities.
The Grantee is obligated to conduct such 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.

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 of, and obtained from, the NRC Grants Officer in advance of the change or obligation of funds. All requests for NRC prior approval should be made, in writing (which includes submission by e-mail), to the designated Grants Specialist and Program Office no later than 30 days before the proposed change. The request must be signed by both the PI and 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 shall 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 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 included on the Excluded Parties List System (http://epls.arnet.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.'

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 shall 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 regulation. 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 shall 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.

Procurement Standards
Procurement standards of this award shall follow provisions as established in 2 CFR 215.40-48

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. NRC participates in the trans-government Interagency Edison system (http://www.iedison.gov) and expects NRC funding Grantees to use this system to comply with Bayh-Dole and related intellectual property reporting requirements. The system allows for Grantees to submit reports electronically via the Internet. In addition, the invention must be reported in continuation applications (competing or non-competing).

Patent Notification Procedures- Pursuant to EO 12889, NRC is required to notify the owner of any valid patent covering technology whenever the NRC or its financial assistance 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. To ensure proper notification, 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 necessarily 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 are determined by 2 CFR 215.36. Such works may include data, databases or software. 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 for records of the Grantee shall follow established provisions in 2 CFR 215.53.

Organizational Prior Approval System
In order to carry out its responsibilities for monitoring project performance and for adhering to award terms and conditions, each Grantee organization shall have a system to ensure that appropriate authorized officials provide necessary organizational reviews and approvals in advance of any action that would result in either the performance or modification of an NRC supported activity where prior approvals are required, including the obligation or expenditure of funds where the governing cost principles either prescribe conditions or require approvals.

The Grantee shall designate an appropriate official or officials to review and approve the actions requiring NRC prior approval. Preferably, the authorized official(s) should be the same official(s) who sign(s) or countersign(s) those types of requests that require prior approval by NRC. The authorized organization official(s) shall not be the principal investigator or any official having direct responsibility for the actual conduct of the project, or a subordinate of such individual.

Conflict Of Interest Standards for this award shall 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 by default or by mutual consent shall follow provisions as established in 2 CFR 215.60-62,

Monitoring and Reporting § 215.50-53

a. Grantee Financial Management systems must comply with the established 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, shall 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

b. **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: Grants_FFR@NRC.GOV. ***(NOTE: There is an underscore between Grants and FFR).***

Period of Availability of Funds 2 CFR § 215.28

a. Where 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.

b. 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.

c. 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.

d. Requests for extensions to the period of performance should be sent to the Grants Officer at least 30 days prior to the grant/cooperative agreement expiration date. Any request for extension after the expiration date may not be honored.

Automated Standard Application For Payments (ASAP) Procedures
Unless otherwise provided for in the award document, payments under this award will be made using the Department of Treasury's Automated Standard Application for Payment (ASAP) system < http://www.fms.treas.gov/asap/ >. Under the ASAP system, payments are made through preauthorized electronic funds transfers, in accordance with the requirements of the Debt Collection Improvement Act of 1996. In order to receive payments under ASAP, 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 will be required to make withdrawals under ASAP: (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), for payments relating to their award.

III. Programmatic Requirements

Performance (Technical) Reports

a. The Grantee shall submit performance (technical) reports electronically to the NRC Project Officer and Grants Officer on a quarterly basis unless otherwise authorized by the Grants Officer. Performance reports should be sent to the Program Officer and Technical Analyst at the email address indicated in Block 12 of the Notice of Award, and to the Grants Officer at: Grants_PPR.Resource@NRC.GOV. ***(NOTE: There is an underscore between Grants and PPR).***

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

c. The Office of Regulatory Research requires the submission of progress reports on the SF-RPPR 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.

Unsatisfactory Performance

Failure to perform the work in accordance with the terms of the award and maintain at least a satisfactory performance rating or equivalent evaluation may result in designation of the Grantee as high risk and assignment of special award conditions or other further action as specified in the standard term and condition entitled "Termination."

Failure to comply with any or all of the provisions of the award may have a negative impact on future funding by NRC and may be considered grounds for any or all of the following actions: establishment of an accounts receivable, withholding of payments under any NRC award, changing the method of payment from advance to reimbursement only, or the imposition of other special award conditions, suspension of any NRC active awards, and termination of any NRC award.

Other Federal Awards With Similar Programmatic Activities

The Grantee shall immediately provide written notification to the NRC Project Officer and the Grants Officer in the event that, subsequent to receipt of the NRC award, other financial assistance is received to support or fund any portion of the program description incorporated into the NRC award. NRC will not pay for costs that are funded by other sources.

Prohibition Against Assignment By The Grantee

The Grantee shall not transfer, pledge, mortgage, or otherwise assign the award, or any interest therein, or any claim arising thereunder, to any party or parties, banks, trust companies, or other financing or financial institutions without the express written approval of the Grants Officer.

Site Visits

The NRC, through authorized representatives, has the right, at all reasonable times, to make site visits to review project accomplishments and management control systems and to provide such technical assistance as may be 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. All site visits and evaluations shall be performed in such a manner as will not unduly delay the work.

IV. Miscellaneous Requirements

Criminal and Prohibited Activities

a. 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.)

b. 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.

c. 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.

d. 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 herby notified that they are encouraged, to the greatest extent practicable, to purchase American-made equipment and products with funding provided under this award.

Increasing Seat Belt Use in the United States
Pursuant to EO 13043, Grantees should 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
Pursuant to EO 13513, Grantees should 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 generally 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 form 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)).

Award Term

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 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 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.ccr.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, 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.