ORDER FOR SUPPLIES OR SERVICES

PAGE 1 OF PAGES 2

IMPORTANT: Mark all packages and papers with contract and/or order numbers. BPA NO.

1. DATE OF ORDER: SEP 30 2010
2. CONTRACT NO. (If any): NRC-04-07-094
3. ORDER NO.: 009
MODIFICATION NO.:
4. REQUISITION/REFERENCE NO.: RES-07-094, FFS# RES-C10-734

5. ISSUING OFFICE (Address correspondence to)
U.S. Nuclear Regulatory Commission
Div. of Contracts
Attn: Morie Gunter-Henderson
Mail Stop TWB-01-010M
Washington, DC 20555

6. SHIP TO:
a. NAME OF CONSIGNEE: U.S. Nuclear Regulatory Commission
b. STREET ADDRESS: Office of Nuclear Regulatory Research, Attn: Andrew Ireland, MS: CSB-3A07M
c. CITY: Washington
d. STATE: DC
e. ZIP CODE: 20555
f. SHIP VIA:

7. TO:
a. NAME OF CONTRACTOR: PURDUE UNIVERSITY
b. COMPANY NAME: ATTN: Sponsored Programs, YOUNG HALL
c. STREET ADDRESS: 155 South Grant Street
d. CITY: WEST LAFAYETTE
e. STATE: IN
f. ZIP CODE: 47907-2114

8. TYPE OF ORDER
- [ ] a. PURCHASE
  REFERENCE YOUR ____
  Please furnish the following on the terms and conditions specified on both sides of this order and on the attached sheet, if any, including delivery as indicated.
- [X] b. DELIVERY
  Except for billing instructions on the reverse, this delivery order is subject to instructions contained on this side only of this form and is issued subject to the terms and conditions of the above-numbered contract.

9. ACCOUNTING AND APPROPRIATION DATA
060-15-111-205 V6148 252A 31X0200.060
OBLIGATE: $75,000.00
DUNS #: 072051394

10. REQUISITIONING OFFICE: RES
RES/DSA/CDB

11. BUSINESS CLASSIFICATION (Check appropriate box(es))
- [ ] a. SMALL
- [X] b. OTHER THAN SMALL
- [ ] c. DISADVANTAGED
- [ ] g. SERVICE-DISABLED VETERAN-OWNED
- [ ] d. WOMEN-OWNED
- [ ] e. HUBZone
- [ ] f. EMERGING SMALL BUSINESS

12. F.O.B. POINT: Destination

13. PLACE OF: a. INSPECTION; b. ACCEPTANCE
14. GOVERNMENT B/L NO.:
15. DELIVER TO F.O.B. POINT ON OR BEFORE (Date): As stated in SOW
16. DISCOUNT TERMS: NET 30

17. SCHEDULE (See reverse for Rejections)

ITEM NO. (a)	SUPPLIES OR SERVICES (b)	QUANTITY ORDERED (c)	UNIT (d)	UNIT PRICE (e)	AMOUNT (f)	QUANTITY ACCEPTED (g)
	TASK ORDER NO. 009 entitled "Void Fraction in large pipes" under NRC ID/IQ Contract No. NRC-04-07-094 In accordance with Section G4, Task Order Procedures, this action definitizes TASK ORDER NO. 009. This effort shall be performed in accordance with the Statement of Work (Encl. 1) and the terms and conditions of Contract No. NRC-04-07-094. DUNS #: 072051394 TASK ORDER NO. 009 shall be effective October 1, 2010 through March 31, 2012 with a total cost ceiling of $269,985.00. Reference is made to your email proposal dated 9/14/2010 in response to this effort and Purdue SPS Development Number 00029478.					

18. SHIPPING POINT:
19. GROSS SHIPPING WEIGHT:
20. INVOICE NO.:

17(h) TOTAL (Cont. pages)

SEE BILLING INSTRUCTIONS ON REVERSE

21. MAIL INVOICE TO:
a. NAME: Department of Interior, National Business Center
b. STREET ADDRESS (or P.O. Box): Attn: Fiscal Services Branch - D2270, 7301 W. Mansfield Avenue
c. CITY: Denver
d. STATE: CO
e. ZIP CODE: 80235-2230

17(i). GRAND TOTAL: OBLIGATED: $75,000.00

22. UNITED STATES OF AMERICA BY (Signature): Morie Gunter-Henderson 9/30/10

23. NAME (Typed): Morie Gunter-Henderson, Contracting Officer
TITLE: CONTRACTING/ORDERING OFFICER

A.1 CONSIDERATION AND OBLIGATION—TASK ORDER

(a) The total estimated amount of this Task Order (ceiling) for the products/services ordered, delivered, and accepted under this contract is $269,985.00.

(b) The amount presently obligated with respect to this Task Order is $75,000.00. This obligated amount may be unilaterally increased from time to time by the Contracting Officer by written modification to this contract. The obligated amount shall, at no time, exceed the Task Order ceiling as specified in paragraph (a) above. When and if the amount(s) paid any payable to the Contractor hereunder shall equal the obligated amount, the Contractor shall not be obligated to continue performance of the work unless and until the Contracting Officer shall increase the amount obligated respect to this contract. Any work undertaken by the Contractor in excess of the obligated amount specified above is done so at the Contractor's sole risk.

ACCEPTANCE: **Purdue University**

Mark Pearson

NAME

Mark Pearson
Sr. Contract Analyst

TITLE SEP 30 2010

DATE

CONTRACTOR SIGNATURE

STATEMENT OF WORK FOR COMMERCIAL
Task Order #9 under Contract No. NRC-04-07-094
(Follow-on for Task Order #1)

TITLE: Void Fraction in Large Diameter Pipes

NRC Project Manager: Carl Thurston
Phone: (301) 251-7517
E-mail: Carl.Thurston@nrc.gov

Contractor: Purdue University
M. Ishii
Phone: (765) 494-4587
E-mail: ishii@purdue.edu

Period of Performance: Award date plus 18 months

Total Level of Effort: 14 staff months

BACKGROUND

The USNRC system thermal-hydraulic analysis code TRACE (TRAC RELAP Advanced Computational Engine) is being developed to provide a best-estimate accident analysis capability for both operating pressurized and boiling water reactors as well as the next generation of evolutionary water reactor designs. In partnership with the code development, a comprehensive code assessment activity is being conducted. Results from this assessment have identified a code modeling limitation for the prediction of void fraction in large diameter pipes. A previous similar task (Task Order 1) was completed in 2009, but the analysis has shown that additional data is needed at an even larger pipe diameter and higher mass fluxes. Correction of this modeling limitation remains a high priority due to its potential impact on calculations for advanced boiling-water reactor (BWR) designs (e.g., SBWR, ESBWR, ABWR).

In most advanced BWR designs, a tall chimney region exists above the reactor core to provide the gravity head necessary to drive the two-phase natural circulation flow through the core. For this chimney region, the TRACE code uses the same interfacial drag models as for 1-D vertical pipes. That is, for the bubbly/slug flow regime, the Kataoka-Ishii drift flux model for large diameter pipes is converted to an interfacial friction correlation. For the annular/mist flow regime, the Wallis annular flow interfacial friction model is used for the liquid film. When entrained droplets are predicted to exist, the drop volume fraction is estimated and the associated interfacial drag is added to that for the liquid film. For the transition region between these two regimes, TRACE uses a simple power-law weighting scheme to provide a continuous and smooth transition.

Two other sources of data have been identified to assess these models for hydraulic diameters of about the same size as the ESBWR chimney: pool data (Wilson & Carrier bubble rise tests) and the Ontario-Hydro transient upflow tests. In the assessment against the Wilson data, the TRACE code performed quite well up to void fractions of about 50-60% (probably because these tests are included in the database used to develop the Kataoka-Ishii drift flux model). There are few data points in the void fraction range 60-80%, where TRACE significantly under-predicts void fraction. TRACE comparisons to the Wilson and Ontario-Hydro data sets are shown in Figures 1 and 2, respectively.

In the TRACE assessment against Ontario-Hydro transient upflow tests, predictions compared well up to about 50% void fraction. For higher void fractions, however, TRACE progressively under-predicts void fraction. For a data value of 78%, the TRACE calculated value was only 67%. To put this into perspective, this means that TRACE over-predicted the liquid inventory in the chimney region by ~50% thereby providing a non-conservative initial condition for a LOCA analysis. So, Task Order 1 was initiated to provide data of flow in large diameter with void fractions primarily above 60% and up to 80%.

For Task Order 1, TRACE void fraction predictions were compared to measured void fractions at each of the five axial locations in the experiments. As shown in Figure 3, overall, there was good agreement with experimental void fractions at both low and high up to about 70% void fractions. However, at intermediate void fractions, say 35 to 50% voided, there is a trend of slight over-prediction. This trend is also consistent with that seen in comparisons with the Wilson Bubble Rise data. This trend indicates a pattern of concern since above about 75% void fraction TRACE predictions progressively diverge from and under predict the data, possibly indicating there is some other parameter physically dominating the behavior that is not currently represented by existing models.

The results also indicated that TRACE void fraction predictions for the 8-inch (0.203 m) diameter pipe were slightly worse than for the 6-inch (0.152 m) diameter pipe. This indicates a larger than expected effect of pipe diameter on void fraction prediction. This then leads to the conclusion that larger diameters need to be tested and preferably at higher mass fluxes. Unfortunately these changes may require upgrading and/or replacing certain equipment at the test facility that limited the test parameters used for Task Order 1. The previous test only included void fraction up to 80%, and the proposed extension shall consider void fractions that approach 100%.

In summary, assessment of the TRACE code with Task Order 1 data has revealed that more test data is needed to provide a basis for understanding geometry effects and appropriate modification of existing correlations and/or development of new models to correct the under-prediction of the void fraction in large diameter pipes in the transition region between the bubbly/slug and annular/mist regimes. Consequently, the work, initiated in the previous Thermal-Hydraulic Institute (THI) contract, should be extended to generate the additional data needed to better comprehend this flow behavior in regard to diameter size, mass flux, and higher void fractions in large diameter pipes.

OBJECTIVE

Collect two-phase flow data needed to address a modeling limitation of the TRACE code for the prediction of void fraction in large diameter vertical pipes. Further, this task includes a model development component to produce a model for ready inclusion into TRACE. The ability of TRACE to accurately predict two-phase flow behavior is necessary for any foreseeable audit calculations and in particular for the chimney region of advanced BWR designs. Specific objectives are:

1. To augment the existing void fraction database with new air-water void fraction and void profile data that extends into the transition region between the bubbly/slug and annular/mist regimes;

2. To either select or develop a model for interfacial shear that significantly improves the ability of TRACE to predict void fraction in large diameter pipes;
3. To develop a database of interfacial area concentration, bubble velocity, and bubble size for both pool and upflow conditions for large pipe diameters and for a wide range of flow conditions;
4. To benchmark the existing interfacial area transport equation (IATE) using the above data;
5. To improve the IATE model by developing sink and source term models for interfacial area concentration, and bubble drag models for upwards two-phase flow in large diameter pipes.

<u>Figure 1</u>

Wilson Bubble Rise: - Steam flow in a stagnant water column, - 18-inch diam. chan., 25-ft tall
- 600-2000 psi. - 0.2-1.3 m/s superficial steam velocity

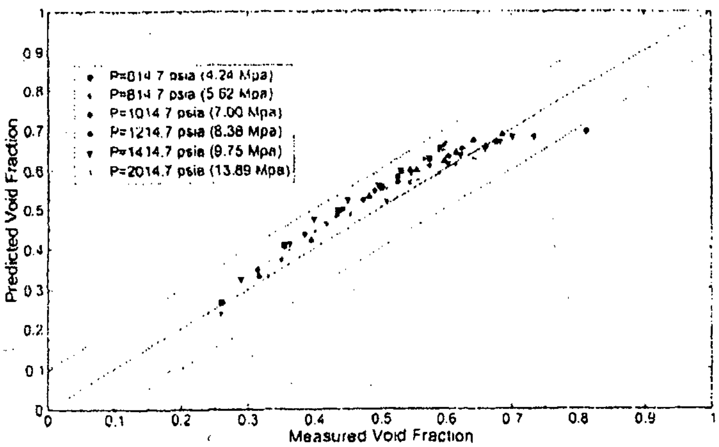


Figure 2

Ontario Hydro: - Co-current two-phase upflow, -400-930 psi
- 20-inch diam. pipe, 22-ft tall, - 0-2 m/s vapor velocity, 0-2.2 m/s liquid velocity

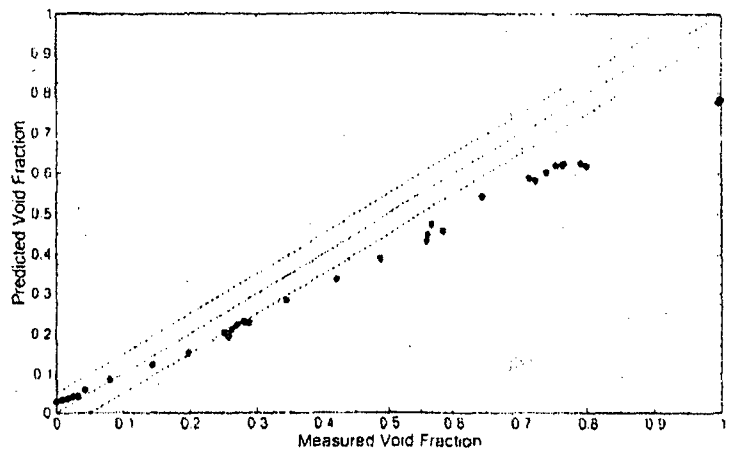
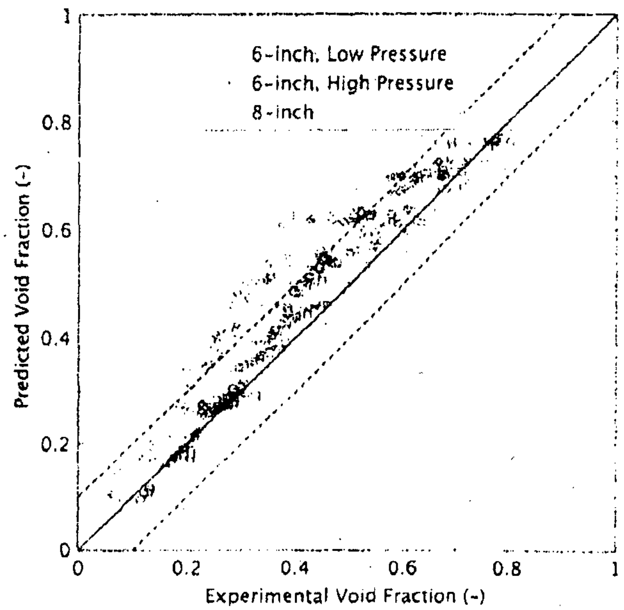


Figure 3

Task 1 Experimental Result: - Co-current two-phase upflow, - 8-inch diameter pipe, 20-ft tall
- 6-inch diam. pipe, 14-ft tall, - 26-40 psi
- 0.1-6 m/s vapor velocity, - 0.05-1.0 m/s liquid velocity



SCOPE OF WORK

The contractor shall:

Task 1: Generate Void Fraction Data

Run air-water experiments to generate void fraction, flow regime, void profile, and pressure drop data for 15.24 cm (6 in.), 20.32 cm (8 In.), and 30.48 cm (12 In.) diameter test sections over a wide range of flow conditions. The test matrix shall include at least two pressure levels, mass fluxes ranging from pool conditions up to 2000 kg/m2-s and void fractions near 100%. The test matrix shall be proposed by the contractor in a letter report and concurred upon by the NRC project manager and should highlight test parameters that are an economical extension of the existing data already collected.

Add the new data to the database compiled in the previous THI contract.

Deliverables	Level of Effort	Completion Data
Data in electronic format	4 staff-months	8 months after award

Task 2: Interfacial Drag Model Development

Using the void fraction database generated in the previous THI contract and the new air-water data generated in Task 1 of this Task Order, the contractor shall either select or develop an improved model for interfacial drag in vertical pipes for inclusion in the TRACE code. The proposed model must cover the entire void fraction range from bubbly flow to annular flow and be suitable for Inclusion in a two-fluid model. Furthermore, the accuracy of the proposed model should be demonstrated to be equal to or superior to the existing TRACE model over all flow regimes and provide a substantial improvement in modeling performance for the transition regime.

Prepare a letter report detailing the proposed interfacial drag model for vertical pipes.

Deliverables	Level of Effort	Completion Data
Letter report	2 staff-months	10 months after award

Task 3: Generate Interfacial Area Transport Data

Run air-water experiments to generate Interfacial area concentration, bubble velocity, and bubble size data for 15.24 cm (6 in.), 20.32 cm (8 In.), and 30.48 cm (12 In.) pipe diameter test sections over a wide range of flow conditions. The test matrix shall include at least two pressure levels, mass fluxes ranging from pool conditions up to 2000 kg/m^2-s and void fractions near 100%. The test matrix shall be proposed by the contractor in a letter report and concurred upon by the NRC project manager.

Add the new data to the database generated in the previous THI contract.

Deliverables	Level of Effort	Completion Data
Data in electronic format	4 staff-months	16 months after award

Task 4: Interfacial Area Transport Model Development

Using the interfacial area data generated in Task 3 of this Task Order, the contractor shall benchmark the existing interfacial area transport equation models. Where necessary, mechanistic models for interfacial area concentration source and sink terms, and bubble drag models for two-phase flow in large diameter pipes shall be developed by the contractor.

Prepare a letter report describing the new data and detailing the proposed interfacial area and bubble drag models.

Deliverables	Level of Effort	Completion Data
Letter report	3 staff-months	18 months after award

Task 5: ACRS Thermal-Hydraulics Subcommittee Meeting Support

The Principal Investigator shall attend an ACRS Thermal-Hydraulics Subcommittee meeting on or about September 8th, 2010 to present and discuss current and past experimental research programs conducted at the Thermal Hydraulics Institute for the NRC. Additional information, when available, will be provided.

Deliverables	Level of Effort	Completion Data
ACRS Presentation	1 staff-months	On or about Sept. 8th, 2010

RESEARCH QUALITY

The quality of NRC research programs are assessed each year by the Advisory Committee on Reactor Safeguards. Within the context of their reviews of RES programs, the definition of quality research is based upon several major characteristics:

Results meet the objectives (75% of overall score)
- Justification of major assumptions (12%)
- Soundness of technical approach and results (52%)
- Uncertainties and sensitivities addressed (11%)

Documentation of research results and methods is adequate (25% of overall score)
- Clarity of presentation (16%)
- Identification of major assumptions (9%)

It is the responsibility of the contractor to ensure that these quality criteria are adequately addressed throughout the course of the research that is performed. The NRC project manager and technical monitor will review all research products with these criteria in mind.

TECHNICAL AND OTHER SPECIAL QUALIFICATIONS REQUIRED

The personnel must have expertise in experimental data measurement and analysis and familiarity with the PUMA-E test facility.

TOTAL LEVEL OF EFFORT

The total level of effort for Tasks 1-5 is estimated at 14 staff-months, with approximately 2.5 at the Faculty (tenure/tenure track) level and 11.5 at the Research Assistant level.

PERIOD OF PERFORMANCE

The period of performance of this task order is 18 months after the date of award.

REPORTING REQUIREMENTS

NRC Project Managers will provide a concise list of reports to be provided; the desired level of contractor management review of reports; and the frequency, content, and distribution of the reports.

Monthly Letter Status Report.

A Monthly Letter Status Report (MLSR) is to be submitted to the NRC Project Manager by the 20th of the month following the month to be reported with copies provided to the following:

Resource Name: RESDSAMLSR.Resource@nrc.gov

The MLSR shall identify the title of the project, the job code, the Principal Investigator, the period of performance, the reporting period, summarize each month's technical progress, list monthly spending, total spending to date, and the remaining funds and shall contain information as directed in NRC Management Directive 11.1. Any administrative or technical difficulties which may affect the schedule or costs of the project shall be immediately brought to the attention of the NRC project manager.

PUBLICATIONS NOTE

RES encourages the publication of the scientific results from RES sponsored programs in refereed scientific and engineering journals as appropriate. If the laboratory proposes to publish in the open literature or present the information at meeting in addition to submitting the required technical reports, approval of the proposed article or presentation should be obtained from the NRC Project Manager. The RES Project Manager shall either approve the material as submitted, approve it subject to NRC suggested revisions, or disapprove it. In any event, the RES Project Manager may disapprove or delay presentation or publication of papers on information that is subject to Commission approval that has not been ruled upon or which has been disapproved. Additional information regarding the publication of NRC sponsored research is contained in NRC Management Directives 3.7, "NUREG Series Publications," and 3.9, "NRC Staff and Contractor Speeches, Papers, and Journal Articles on Regulatory and Technical Subjects."

If the presentation or paper is in addition to the required technical reports and the RES Project Manager determines that it will benefit the RES project, the Project Manager may authorize payment of travel and publishing costs, if any, from the project funds. If the Project Manager determines that the article or presentation would not benefit the RES project, the costs associated with the preparation, presentation, or publication will be borne by the contractor. For any publication or presentations falling into this category, the NRC reserves the right to require that such presentation or publication will not identify NRC sponsorship of the work.

NEW STANDARDS FOR CONTRACTORS WHO PREPARE NUREG-SERIES MANUSCRIPTS

The U.S. Nuclear Regulatory Commission (NRC) began to capture most of its official records electronically on January 1, 2000. The NRC will capture each final NUREG-series publication in its native application. Therefore, please submit your final manuscript that has been approved by your NRC Project Manager in both electronic and camera-ready copy.

All format guidance, as specified in NUREG-0650, Revision 2, will remain the same with one exception. You will no longer be required to include the NUREG-series designator on the bottom of each page of the manuscript. The NRC will assign this designator when we send the camera-ready copy to the printer and will place the designator on the cover, title page, and spine. The designator for each report will no longer be assigned when the decision to prepare a publication is made. The NRC Publishing Services Branch will inform the NRC Project Manager for the publication of the assigned designator when the final manuscript is sent to the printer.

For the electronic manuscript, the Contractor shall prepare the text in Microsoft Word, and use any of the following file types for charts, spreadsheets, and the like.

File Types to be Used for NUREG-Series Publications	
File Type	File Extension
Microsoft®Word®	.doc
Microsoft® PowerPoint®	.ppt
Microsoft®Excel	.xls
Microsoft®Access	.mdb
Portable Document Format	.pdf

This list is subject to change if new software packages come into common use at NRC or by our licensees or other stakeholders that participate in the electronic submission process. If a portion of your manuscript is from another source and you cannot obtain an acceptable electronic file type for this portion (e.g., an appendix from an old publication), the NRC can, if necessary, create a tagged image file format (file extension.tif) for that portion of your report. Note that you should continue to submit original photographs, which will be scanned, since digitized photographs do not print well.

If you choose to publish a compact disk (CD) of your publication, place on the CD copies of the manuscript in both (1) a portable document format (PDF); (2) a Microsoft Word file format, and (3) an Adobe Acrobat Reader, or, alternatively, print instructions for obtaining a free copy of Adobe Acrobat Reader on the back cover insert of the jewel box.

DELIVERABLES/SCHEDULE AND/OR MILESTONES

1. Void Fraction and flow regime data for both the 15.25 cm (6 in.) and 20.32 cm (8 in.) tests in an electronic format agreed to by the NRC project manager to be delivered 8 months after the award date.
2. Letter report detailing the proposed interfacial drag model for large diameter vertical pipes to be delivered 10 months after the award date.
3. Interfacial area transport data for both the 15.25 cm (6 in.) and 20.32 cm (8 In.) tests in an electronic format agreed to by the NRC project manager to be delivered 16 months after the award date.
4. Letter report describing the Interfacial area transport data and detailing the proposed interfacial area and bubble drag models to be delivered 18 months after the award date.

ORGANIZATIONAL CONFLICT OF INTEREST DISCLOSURE
(to be inserted by Division of Contracts)

MEETINGS AND TRAVEL

For domestic travel, the contractor is expected to attend an annual meeting at the NRC in Rockville, MD, for research review. The trips shall be of approximately two days duration.

In addition, the Principal Investigator shall attend one ACRS meeting to present and discuss thermal-hydraulics programs with the ACRS thermal-hydraulics subcommittee, as described in Task 5. This meeting is expected to occur on or about September 8^{th}, 2010. Additional details will be provided.

Contractor shall obtain approval from the NRC Project Manager in advance of all travel.

NRC-FURNISHED MATERIAL

Equipment is to be updated to enable testing at the new parameters specified.

APPROPRIATE USE OF GOVERNMENT FURNISHED INFORMATION TECHNOLOGY (IT) EQUIPMENT AND/ OR IT SERVICES/ ACCESS (APRIL 2003)

As part of contract performance the NRC may provide the contractor with information technology (IT) equipment and IT services or IT access as identified in the statement of work or subsequently as identified in the project. Government furnished IT equipment, or IT services, or IT access may include but is not limited to computers, copiers, facsimile machines, printers, pagers, software, phones, Internet access and use, and email access and use. The contractor (including the contractor's employees, consultants and subcontractors) shall use the NRC furnished IT equipment, and/or IT provided services, and/or IT access solely to perform the necessary efforts required under the contract. The contractor (including the contractor's employees, consultants and subcontractors) are prohibited from engaging or using the NRC IT equipment and government provided IT services or IT access for any personal use, misuse, abuses or any other unauthorized usage.

The contractor is responsible for monitoring its employees, consultants and subcontractors to ensure that NRC furnished IT equipment and/or IT services, and/or IT access are not being used for personal use, misused or abused. The NRC reserves the right to withdraw or suspend the use of its government furnished IT equipment, IT services and/ or IT access arising from contractor personal usage, or misuse or abuse; and/or to disallow any payments associated with contractor (including the contractor's employees, consultants and subcontractors) personal usage, misuses or abuses of IT equipment, IT services and/or IT access; and/or to terminate the project arising from violation of this provision.

TECHNICAL DIRECTION

Technical direction will be provided by the Project Manager, **Carl Thurston**, who can be reached at:

Mail Stop: C3A7M
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555-0001

Phone: (301) 251-7517
Fax: (301) 251-7423
Email: (carl.thurston@nrc.gov)

Express mail should be sent to:
U. S. Nuclear Regulatory Commission
Mail Stop: C3A7M
11545 Rockville Pike
Rockville, MD 20852-2738