ORDER FOR SUPPLIES OR SERVICES

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

1. DATE OF ORDER	09-16-2009
2. CONTRACT NO. (If any)	NRC-04-07-094
3. ORDER NO. / MODIFICATION NO.	**NRC TASK ORDER 008**
4. REQUISITION/REFERENCE NO.	04-07-094T008 RES-C09-738 (FFS #)
5. ISSUING OFFICE (Address correspondence to)	U.S. Nuclear Regulatory Commission Div. of Contracts Attn: H. (Eddie) Colón, Jr. 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: KENNETH W. SUTER YOUNG HALL
c. STREET ADDRESS	302 WOOD STREET
d. CITY	WEST LAFAYETTE
e. STATE	IN
f. ZIP CODE	479072108

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.

☒ 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
960-15-111-205 N6910 252A 31X0200.960
OBLIGATE: $40,000.00 (FFS Commitment #: RES-C09-738)
DUNS #: 072051394

10. REQUISITIONING OFFICE RES
RES/DRASP/NRCA

11. BUSINESS CLASSIFICATION (Check appropriate box(es))

☐ a. SMALL ☒ b. OTHER THAN SMALL ☐ c. DISADVANTAGED ☐ g. SERVICE-DISABLED VETERAN-OWNED
☐ d. WOMEN-OWNED ☐ e. HUBZone ☐ f. EMERGING SMALLBUSINESS

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)	16. DISCOUNT TERMS
			As stated in SOW	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. 008 entitled "**TRACE CODE MODELS CORRELATIONS DEVELOPMENT**" under NRC ID/IQ Contract No. NRC-04-07-094 In accordance with Section G4, Task Order Procedures, this action definitizes TASK ORDER NO. 008. 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. 008 shall be effective October 1, 2009 through December 31, 2011 with a total cost ceiling of $212,584.00. Reference is made to your email proposal dated 8/31/2009 in response to this effort and Purdue SPS Development Number 00022633.					

SEE BILLING INSTRUCTIONS ON REVERSE

18. SHIPPING POINT	
19. GROSS SHIPPING WEIGHT	
20. INVOICE NO.	
17(h) TOTAL (Cont. pages)	

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: $40,000.00

22. UNITED STATES OF AMERICA BY (Signature) H. Colón

23. NAME (Typed) Heriberto Colón, Jr.
Contracting Officer
TITLE: CONTRACTING/ORDERING OFFICER

NRC-04-07-094 NRC TASK ORDER 008

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 $212,584.00.

(b) The amount presently obligated with respect to this Task Order is $40,000.00. 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 and 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 with 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.

9/22/09

Mary Millsaps
Assistant Director, Sponsored Programs

STATEMENT OF WORK

TASK ORDER NO. 008

CONTRACT NO. NRC-04-07-094

Contract Title:	TRACE Code Models and Correlations Development
Contractor:	Purdue University, Thermal Hydraulics Institute (THI)
Principal Investigator:	Dr. Fan-Bill Cheung, PSU
Period of Performance:	October 1, 2009 – December 31, 2011
NRC project Manager(s):	Andrew Ireland (301-251-7553) Andrew.Ireland@nrc.gov

Purdue SPS Development Number: 00022633

I. BACKGROUND

The NRC has sponsored thermal-hydraulic research in order to provide high quality experimental data to improve the TRACE code performance. This research has included reflood tests in the Rod Bundle Heat Transfer (RBHT) facility at the Pennsylvania State University and interfacial area transport tests conducted through the Thermal Hydraulics Institute (THI) and Purdue University. These newly acquired data represent a unique source of information that should enable the improvement of several models and correlations used by TRACE. Results from the RBHT facility confirm a first-order effect of spacer grids on rod bundle thermal-hydraulics and can be expected to provide information to improve models for steam cooling, dispersed flow film boiling, inverted annular flow film boiling, grid rewet, droplet break up at spacer grids, and convective enhancement downstream of spacer grids. Currently, TRACE overpredicts cladding temperatures in rod bundle assessment cases and the RBHT data is expected to improve this.

This Scope of Work (SOW) outlines Tasks necessary to improve TRACE by utilizing the data obtained in the RBHT and THI experimental programs. Models and correlations obtained through evaluation of the data are to be made suitable for inclusion in TRACE. To accommodate the interfacial area calculations and simulation of droplet breakup at spacer grids, it will likely be necessary to expand TRACE beyond its present two-field formulation, using the multifield update previously developed for that purpose.

II. OBJECTIVES

The primary objectives of this Task Order are to:

1. Develop improved models for the interaction of spacer grids with entrained droplets. The models are to account for droplet breakup on dry grids, droplet generation from films on wet grids, for prediction of conditions at which the grid may rewet.
2. Develop improved models to account for enhancement of heat transfer downstream of a spacer grid. The models are to account not only for the enhancement to convective heat

transfer of single phase steam but also the enhancement when flow downstream of the spacer grid contains droplets.

III. WORK REQUIREMENTS

This work consists of the five individual tasks. Each task performs an evaluation of a phenomena investigated in RBHT experiments, and develops a model or correlation suitable for TRACE. To insure that the model is acceptable, assessment against applicable data is performed throughout the development process.

Evaluation of the experimental data is also intended as means of obtaining an improved understanding of the processes and phenomena involved. Since the RBHT facility used advanced instrumentation, it may be possible to identify sensitivities or behavior that was not previously identified. These finding should be described in the documentation for the evaluations of these data.

Task 1: Droplet Breakup on Dry Spacer Grids

The contractor is to develop a physics based mechanistic model for droplet breakup suitable for TRACE that will account for the change in Sauder mean diameter as droplets interact with a dry spacer grid. This will be accomplished by considering the mass flux and distribution, and well as the kinetic energy of the approaching droplet field. Comparisons of the model predictions with experimental data obtained in the Rod Bundle Heat Transfer Facility along with other sources will be made to validate the model. Documentation for this Task is to include a letter report describing the model and validation.

Deliverables	**Estimated Completion Date**
Letter report on Dry Grid Droplet Breakup	9 months after award

Task 2: Droplet Entrainment from Wet Grids

The contractor shall develop model(s) for the generation of droplets from a wet spacer grid. In this task, the formation and breakup of liquid ligaments due to the shearing action of steam passing through the grid will be studied and modeled. Drop entrainment into the steam flow, which is to be characterized by a Sauder mean diameter and entrained mass flux, will consider breakup of the liquid ligaments as the kinetic energy of the steam flow exceeds the surface energy requirements to hold the ligaments together. Comparisons of the model predictions with experimental data will be made to validate the model. This task will also investigate the data to determine the conditions for grid rewet and formation of films on the grid. The droplet entrainment model for wet grids thus is to consider not only mass loss by entrainment, but mass addition to the film by de-entrainment of droplets from the approaching fluid. Documentation is to include a letter report describing the model(s) and validation.

Deliverables	Estimated Completion Date
Letter report on Droplet Formation from Wet Grids	12 months after award

Task 3: Single Phase Convective Enhancement

The contractor is to develop an expression for single phase convective enhancement downstream of spacer grids based on experimental data from RBHT and similar facilities. The correlation may be similar in form to those previously proposed for convective enhancement downstream of a grid, but is to be based on correlation(s) for fully-developed flow used in TRACE. Various forms of the correlation should be investigated so that uncertainty in the correlation can be minimized. Comparisons of the model predictions with experimental data will be made to validate the model. Documentation is to include a letter report describing the model(s) and validation.

Deliverables	Estimated Completion Date
Letter report on Single Phase Downstream Convective Enhancement	12 months after award

Task 4: Two-Phase Convective Enhancement Downstream of Grids Spacers

The contractor is to develop models for the droplet induced two-phase heat transfer downstream of spacer grids, consider conditions in which the grid is either wet or dry. Models from the previous tasks should be used to estimate the two-phase conditions (local quality, droplet size distribution) downstream of the grid. Physical models are to be developed considering the two-phase mixture flowing through the grid, the formation of ligaments and/or droplets downstream of the grid, and their effect on the local downstream heat transfer from the rod surface. Comparisons of model predictions are to be made with experimental data from RBHT and other facilities in order to validate the model. Documentation for this Task is to include a report describing the model(s) and validation.

Deliverables	Estimated Completion Date
Letter report on Two-Phase Downstream Convective Enhancement	18 months after award

Task 5: Comprehensive Assessment of Grid Models

The contractor is to assess the new spacer grid models by comparing model predictions to a set of reflood and blowdown separate effects tests. The simulations are to include:

a. RBHT Reflood
b. FLECHT-SEASET
c. THTF Blowdown
d. RBHT Steam Cooling
e. FLECHT Top Skewed Power.

Comparisons between predicted and measured results are to demonstrate the improvement in prediction of local heat transfer. Results are to be documented in an assessment report.

Deliverables	**Estimated Completion Date**
Assessment Report	27 months after award

IV. 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.

V. REPORTING REQUIREMENTS

1. Monthly Letter Status Report (MLSR)

A MLSR should 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:

Project Manager (Andrew Ireland, Mail Stop C3-A07M)

Technical Monitor (Stephen M. Bajorek, Mail Stop C3-A07M)
Division Management Analyst, (TBD, Mail Stop)
Contracting Officer, (Mail Stop: TWB-01-010M)

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. 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.

VI. DELIVERABLES AND DELIVERY SCHEDULE

1. Letter report describing the dry grid breakup model (Task #1) to be delivered 9 months following the award date.

2. Letter report detailing the models for wet grid droplet generation (Task #2) to be delivered 12 months following the award date.

3. Letter report describing the single phase convective enhancement model (Task #3) to be delivered 12 months after the award date.

4. Letter report describing the two phase convective enhancement model (Task #4) to be delivered 18 months after the award date.

5. Final report describing the assessment of the spacer grid models to the prescribed separate effects tests (Task #5) to be delivered 27 months following the award date.

VII. MEETINGS AND TRAVEL REQUIREMENTS

For domestic travel, the contractor is expected to attend two annual meetings at the NRC in Rockville, MD, for research review. The trips will be of approximately two days duration. All trips have to obtain approval from the NRC project manager in advance.

VIII. PERIOD OF PERFORMANCE

The period of performance of this task order is 27 months after the date of award.

IX. TECHNICAL DIRECTION

Technical direction will be provided by the Project Manager:

Andrew Ireland
U.S. Nuclear Regulatory Commission
Mail Stop: C3-A07M
Washington, D.C. 20555-0001
Phone: (301) 251-7553
Fax: (301) 251-7436
Email: (Andrew.Ireland@nrc.gov)