INTERAGENCY AGREEMENT	1. IAA NO. 31310019F0015	PAGE 1 OF 10

2. ORDER NO.	3. REQUISITION NO.	4. SOLICITATION NO.
	RES-19-0151	

5. EFFECTIVE DATE	6. AWARD DATE	7. PERIOD OF PERFORMANCE
05/30/2019	05/28/2019	05/30/2019 TO 09/30/2021

8. SERVICING AGENCY
ENERGY IDAHO OPERATIONS OFFICE UNITED STATES DEPT OF
ALC:
DUNS: 048105530 +4:
1955 FREMONT AVE
IDAHO FALLS ID 834021510

POC [redacted]
TELEPHONE NO. [redacted]

9. DELIVER TO
TAREK ZAKI
US NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REGULATORY RESEARCH
11555 ROCKVILLE PIKE
ROCKVILLE MD 20852

10. REQUESTING AGENCY
ACQUISITION MANAGEMENT DIVISION
ALC: 3100000
DUNS: 040535809 +4:
US NUCLEAR REGULATORY COMMISSION
ONE WHITE FLINT NORTH
11555 ROCKVILLE PIKE
ROCKVILLE MD 20852-2738

POC Sandra Nesmith
TELEPHONE NO. 301-415-6836

11. INVOICE OFFICE
US NUCLEAR REGULATORY COMMISSION
ONE WHITE FLINT NORTH
11555 ROCKVILLE PIKE
MAILSTOP O3-E17A
ROCKVILLE MD 20852-2738

12. ISSUING OFFICE
US NRC - HQ
ACQUISITION MANAGEMENT DIVISION
MAIL STOP TWFN-07B20M
WASHINGTON DC 20555-0001

13. LEGISLATIVE AUTHORITY
Energy Reorganization Act of 1974

14. PROJECT ID

15. PROJECT TITLE
DEVELOPMENT AND MODELING SUPPORT FOR ADVANCED NON-

16. ACCOUNTING DATA
2019-X0200-FEEBASED-ADVRX-60-60D003-60B301-1061-1A-6-220-253D-1A-6-220-1061

17. ITEM NO.	18. SUPPLIES/SERVICES	19. QUANTITY	20. UNIT	21. UNIT PRICE	22. AMOUNT
	INL Contract No. DE-AC07-05ID14517 NRC Agreement No. 31310019N0006 Task Order No: 31310019F0015 Title: Development and Modeling Support for Advanced Non-Light Water Reactors The NRC and Idaho National Laboratory (INL) hereby enter into this Agreement for the task order titled, "Development and Modeling Support for Advanced Non-Light Water Reactors." Continued ...				

23. PAYMENT PROVISIONS	24. TOTAL AMOUNT
	$400,000.00

25a. SIGNATURE OF GOVERNMENT REPRESENTATIVE (SERVICING)		26a. SIGNATURE OF GOVERNMENT REPRESENTATIVE (REQUESTING)	
		Monique B. Williams	
25b. NAME AND TITLE	25c. DATE	26b. CONTRACTING OFFICER	26c. DATE
		MONIQUE B. WILLIAMS	06/11/2019

Period of Performance: May 30, 2019 - September 30, 2021

Consideration and Obligations:

(a) Authorized Cost Ceiling $1,801,687.00

(b) The amount presently obligated with respect to this DOE Agreement is $400,000.00. When and if the amount(s) paid and payable to the DOE Laboratory hereunder shall equal the obligated amount, the DOE Laboratory shall not be obligated to continue performance of the work unless and until the NRC Contracting Officer shall increase the amount obligated with respect to this DOE Agreement. Any work undertaken by the DOE Laboratory in excess of the obligated amount specified above is done so at the DOE Laboratory's sole risk.

The following document is hereby made a part of this Agreement:

Attachment No. 1: Statement of Work

This agreement is entered into pursuant to the authority of the Energy Reorganization Act of 1974, as amended (42 U.S.C 5801 et seq.). This work will be performed in accordance with the NRC/DOE Memorandum of Understanding dated November 24, 1998. To the best of our knowledge, the work requested will not place the DOE and its contractor in direct competition with the domestic private sector.

[X] Non-fee Recoverable Work

[redacted]

NRC COR: Tarek Zaki, tarek.zaki@nrc,gov, 301-415-0994

DUNS: 040535809 TAS: 31X0200.320 ALC: 31000001
Master IAA: 31310019N0006

STATEMENT OF WORK (SOW)

NRC Agreement Number 31310019N0006	**NRC Agreement Modification Number**	**NRC Task Order Number (If Applicable)** 31310019F0015	**NRC Task Order Modification Number (If Applicable)**
Project Title Development and Modeling Support for Advanced Non-Light Water Reactors			
Job Code Number	**B&R Number**	**DOE Laboratory** Idaho National Laboratory	
NRC Requisitioning Office Office of Nuclear Regulatory Research		**Period of Performance** 5/30/19 – 9/30/21	
NRC Form 187, Contract Security and Classification Requirements ☐ Applicable ☒ Not Applicable		☐ Involves Proprietary Information ☐ Involves Sensitive Unclassified	
☒ Non-Fee Recoverable		☐Fee-Recoverable (If checked, complete all applicable sections below)	
Docket Number (If Fee-Recoverable/Applicable)		**Inspection Report Number (If Fee Recoverable/Applicable)**	
EPID:		**CAC:** 001225 – OFF FEE-ADVRXNON-LWRSTRATEGY 2-Development of Non-LWR Computer Models and Analytical Tools	

CONTRACTING OFFICER'S REPRESENTATIVE

Contracting Officer's Representative

Name: Tarek Zaki
Agency: U.S. Nuclear Regulatory Commission
Office: Nuclear Regulatory Research
Mail Stop: 10B58
Washington, DC 20555-0001
E-Mail: tarek.zaki@nrc.gov
Phone: 301-415-0994

STATEMENT OF WORK

1.0 BACKGROUND

In preparation for the anticipated license review of advanced non-LWR designs, the NRC is assembling the necessary computational tools to perform confirmatory analyses of these designs. It is expected that the resulting evaluation model will be composed of both legacy codes and new MOOSE-based tools developed under DOE's Nuclear Energy Advanced Modeling & Simulation program (NEAMS). The objective of this task order is to obtain support for the development and validation of the NRC's evaluation model for advanced non-LWR designs from the Idaho National Laboratory (INL). In particular, this task order will require support for application development using the Multiphysics Object-Oriented Simulation Environment (MOOSE) as well as the following MOOSE-based applications developed by the INL: Pronghorn, Mammoth/Rattlesnake and Bison.

2.0 OBJECTIVES

This work supports the development and utilization of INL MOOSE-based applications (viz., Pronghorn, Mammoth/Rattlesnake and Bison) for advanced non-LWR reactor safety analysis and licensing at NRC. The objectives of this task are to enhance the capabilities of the INL code suite for non-LWR analysis and to facilitate the NRC's usage of these codes through the generation of a number of "tutorial style" example problems. The specific development tasks and example problems for each code are described below. In addition, this task will develop an input model for a "reference plant" for a pebble bed reactor with molten salt coolant. During the performance of this task order, the contractor shall also provide support to NRC staff members in their use of the INL MOOSE-based tools and the Serpent Monte Carlo code.

3.0 SCOPE OF WORK

The DOE Laboratory must provide all resources necessary to accomplish the tasks and deliverables described in this Statement of Work (SOW).

In this work, both modeling enhancements and example problems will be developed to support the usage of the INL MOOSE-based tools for the analysis of gas-cooled reactors, molten salt reactors (MSR), and heat pipe cooled micro reactor designs.

Specific tasks include:

1. Pronghorn Development & Validation - this task consists of the following four subtasks:
    a. Develop a reactor cavity cooling system model (RCCS) for radiation/convection from the vessel wall to the heat exchanger panel. The model shall include the RCCS panel but the heat removal from the panel can be accomplished via a temperature boundary condition. It is expected that an "effective thermal conductivity" model would be sufficient for this task.
    b. Add the capability to model a 1D flow channel embedded in a 3D solid such as the upcomer in a pebble bed reactor design. This feature is expected to be directly incorporated within Pronghorn and not require coupling to another external code.

c. Implement the property relations for gas mixtures so that the air/helium natural circulation phase of a depressurized loss-of-forced-cooling (D-LOFC) event can be modeled.
d. Perform RCCS model validation using data from the ANL flat panel tests and the HTTR-VCS tests.

2. Pronghorn Example Problems - this task consists of the following three subtasks:
    a. Develop a sample problem demonstrating how to apply a thermal resistance for gaps between graphite blocks at both radial and axial faces. The thermal resistance should be formulated to include both conduction and radiation effects. The sample problem input should include scripts as needed to facilitate the placement of thermal resistances upon the finite element mesh for a complicated 3-D geometry such as the reflector region of a gas-cooled reactor.
    b. Develop a sample problem demonstrating how to model the radiation/conduction/natural convection heat transfer across a stagnant gas gap such as that between the core barrel and the vessel wall in a pebble bed design.
    c. Develop a sample problem demonstrating the explicit modeling of the pebble transient temperature response. One prototypic pebble should be modeled for every element in the pebble bed; the pebble transient conduction equation should be coupled to the porous medium solid energy equation with the solid temperature used as the boundary condition for the pebble. Coupling should be bidirectional, that is, porous medium solid temperature to pebble, and pebble heat flux as volumetric heat source to porous medium.

3. Mammoth/Rattlesnake Development - this task consists of the following four subtasks:
    a. Improve control rod treatment. Develop heterogeneous control rod model and test cusping treatment. In particular, ensure that diffusion with SPH can be used for control rod withdrawal events.
    b. Improve the meshing scripts to be applicable to heat pipe cooled micro-Rx of both the prismatic and monolithic design including treatment for rotating control drums.
    c. Develop the capability to calculate the heat generation rate in the graphite moderator and reflector regions due to gamma absorption and neutron scattering.
    d. Implement the ability to use the local concentration of delayed neutron pre-cursors for the analysis of molten salt-fueled reactors. Eventually, the pre-cursor drift would be provided by a coupled thermo-fluids code. For this task, it is sufficient to simulate the transient pre-cursor distribution using analytical functions.

4. Mammoth/Rattlesnake Example Problems - this task includes the following four subtasks:
    a. Develop a sample problem for a small heat pipe cooled fast reactor of the “monolith” type demonstrating the reactivity effects associated with thermal expansion of the fuel and monolith. It is sufficient to model the cooling effect of the heat pipes through the application of a constant temperature boundary condition. A transient thermo-mechanical solution for the fuel and monolith should be performed for a reactivity insertion to calculate the thermal expansion effect and the peak stresses. It is sufficient to model a symmetry sector for the selected design.
    b. Develop a sample problem showing how to use Serpent 2 to calculate

macroscopic cross-sections for use in Mammoth for a typical sodium fast reactor unprotected loss-of-flow transient (ULOF). The complicating factor is the relatively large axial gradient of the coolant (and hence fuel) temperature and its evolution during the transient. Both a base Serpent model and a SAM model of the ABTR (Advanced Burner Test Reactor) will be provided by the NRC. This subtask supports the development of a plant reference model for a small SFR such as the VTR (Versatile Test Reactor).

c. Develop a sample problem illustrating the algorithm to find the equilibrium core burnup distribution for a pebble bed reactor. It is expected that this capability should be incorporated into Mammoth and be similar to the approach formerly used in PEBBED.
d. Develop a sample problem for the calculation of decay heat in metallic fuel assuming a heat pipe cooled geometry.

5. Bison Example Problem – develop a sample problem for one fuel element of a heat pipe cooled micro reactor that illustrates the burn up induced swelling effect of metallic fuel and how the resulting geometry changes can be used in a Rattlesnake model.

6. Modify the “reference plant” input model for the HTR-PM to perform a coupled thermo-fluid and neutronics transient calculation of a depressurized loss-of-forced-cooling (D-LOFC) event. The thermo-fluid analysis shall be conducted using the full momentum equation formulation in Pronghorn with all significant flow paths modeled. The reactor kinetics shall be handled by the Mammoth/Rattlesnake code using diffusion/SPH with the possibility of using a multi-scheme approach for the control rods.

7. Develop a “reference plant” input model for a molten salt cooled pebble bed reactor. A full 3D coupled thermo-fluids and reactor kinetics model will be required.

8. Support Tasks –
    a. Assist NRC staff in developing input model and performing China Experimental Fast Reactor (CEFR) neutronics benchmark calculations.
    b. Assist ANL in coupling of Mammoth/Rattlesnake to the SAM code. Incorporate SAM into the BlueCrab code suite repository.
    c. Assist NRC staff in developing input model and performing a coupled Mammoth/SAM calculation of an unprotected loss-of-flow transient for the ABTR.
    d. Assist NRC staff in developing input model and performing pre- and post-test analyses of the High Temperature Test Reactor (HTTR) DLOFC tests.
    e. Assist ANL in developing a coupled Mammoth/Rattlesnake/SAM model of the Molten Salt Reactor Experiment (MSRE).

The deliverables of these tasks are listed below.

This work will also support the general activities needed to support the use of the INL MOOSE-based tools at NRC, such as code training and regular user support. In particular, it is expected that support will be needed for: generation of multi-group macroscopic cross-sections for small fast reactors and coupling of the ANL SAM code to Rattlesnake.

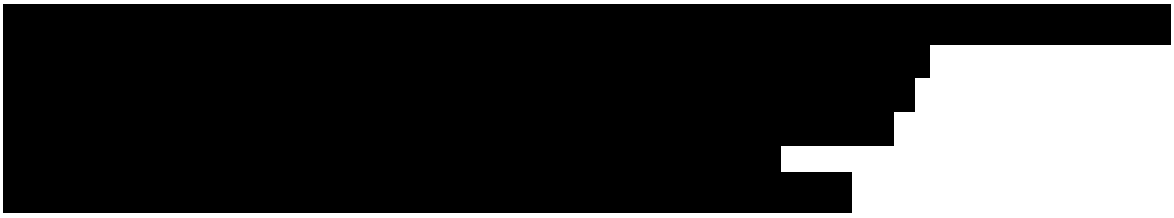
4.0 LIST OF DELIVERABLES

Deliverable Number	Description	Format	Due Date
1a	Report on Pronghorn development tasks (a-c) and input models for associated example problems.	Microsoft Word and electronic files	NLT 6 months from the commencement of this task order.
1b	Report on Pronghorn RCCS validation tasks (d) and input models.	Microsoft Word and electronic files	NLT 18 months from the commencement of this task order.
2a	Report describing Pronghorn example problems (a & b) and associated input models.	Microsoft Word and electronic files	NLT 9 months from the commencement of this task order
2b	Report describing Pronghorn example problem (c) and associated input model.	Microsoft Word and electronic files	NLT 15 months from the commencement of this task order
3a	Report on Mammoth/Rattlesnake development task for improved control rod treatment and associated input models.	Microsoft Word and electronic files	NLT 9 months from the commencement of this task order
3b	Inclusion of improved meshing scripts for micro-Rx designs in Mammoth repository.	N/A	NLT 6 months from the commencement of this task order.
3c	Report on Mammoth/Rattlesnake development task for heat generation in graphite moderator and associated input models.	Microsoft Word and electronic files	NLT 12 months from the commencement of this task order.
3d	Report on Mammoth/Rattlesnake development task for delayed neutron pre-cursor drift and associated input models.	Microsoft Word and electronic files	NLT 24 months from the commencement of this task order.
4a	Report describing Mammoth-Rattlesnake example problem for axial and radial expansion effects and associated input model.	Microsoft Word and electronic files	NLT 6 months from the commencement of this task order.
4b	Report describing Mammoth-Rattlesnake example problem for cross-section generation for SFR ULOF transient.	Microsoft Word and electronic files	NLT 9 months from the commencement of this task order.
4c	Report describing Mammoth-Rattlesnake example problem for pebble bed equilibrium burn up distribution and associated input model.	Microsoft Word and electronic files	NLT 18 months from the commencement of this task order.
4d	Report describing Mammoth-Rattlesnake example problem for	Microsoft Word and	NLT 18 months from the commencement

	decay heat in metallic fuel and associated input model.	electronic files	of this task order.
5	Report describing Bison example problem for metallic fuel swelling and associated input model.	Microsoft Word and electronic files	NLT 9 months from the commencement of this task order.
6	Report describing D-LOFC calculation for pebble bed reactor and associated input model.	Microsoft Word and electronic files	NLT 18 months from the commencement of this task order.
7	Report describing reference plant model for molten salt cooled pebble bed reactor and associated input model.	Microsoft Word and electronic files	NLT 30 months from the commencement of this task order
8	Monthly Letter Status Reports (MLSRs) Acceptance Criteria: Report contains all required information	Microsoft Word or Adobe PDF	NLT than 20th of the following month

5.0 ESTIMATED LABOR CATEGORIES, KEY PERSONNEL AND LEVELS OF EFFORT

Key personnel assigned to this task order include the following:



6.0 CERTIFICATION AND LICENSE

N/A

7.0 MEETINGS AND TRAVEL

The following trips have been budgeted in anticipation of travel required in support of the work under this task order.

Six (6) trips, with two (2) travelers each trip to NRC Headquarters in Rockville, MD, to discuss development and results of the modeling enhancements and example problems. The need for and details of these trips will be worked out cooperatively between INL and the NRC COR.

INL will be authorized travel expenses consistent with the Federal Travel Regulation (FTR) and the limitation of funds specified for the travel within this agreement/order. All travel requires prior approval from the NRC COR.

No foreign travel is anticipated.

8.0 REPORTING REQUIREMENTS

The DOE Laboratory is responsible for structuring the deliverables to current agency standards. The DOE Laboratory must submit deliverables free of spelling and grammatical errors and shall conform to requirements stated in this section.

8.1 Monthly Letter Status Report (MLSR)

The DOE Laboratory must provide a Monthly Letter Status Report which consists of a technical progress report and financial status report. This report will be used by the DOE Laboratory to assess the adequacy of the resources utilized by the DOE Laboratory to accomplish the work contained in this SOW and to provide status of the DOE Laboratory's progress in achieving tasks and producing deliverables. The report shall include agreement/order summary information, work completed during the specified period, milestone schedule information, problem identification and resolution, travel plans, and staff hour summary. Copies must be sent to the COR and AMD at ContractsPOT.Resource@nrc.gov.

9.0 REQUIRED MATERIALS, FACILITIES, HARDWARE/SOFTWARE

N/A