INTERAGENCY AGREEMENT	1. IAA NO. 31310018F0052	PAGE 1 OF 8

2. ORDER NO.	3. REQUISITION NO.	4. SOLICITATION NO.
	RES-18-0379	

5. EFFECTIVE DATE	6. AWARD DATE	7. PERIOD OF PERFORMANCE
08/20/2018	08/15/2018	08/20/2018 TO 06/30/2020

8. SERVICING AGENCY
ARGONNE NATIONAL LAB
ALC:
DUNS: 000000005 +4:
US DEPARTMENT OF ENERGY
9800 SOUTH CASS AVENUE
LEMONT IL 60439

POC Jacquelyn Brocker, Contracting Ofc.
TELEPHONE NO. 630-252-2193

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

10. REQUESTING AGENCY
ACQUISITION MANAGEMENT DIVISION
ALC: 31000001
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
SAM DEVELOPMENT AND MODELING SUPPORT FOR ADVANCED

16. ACCOUNTING DATA
2018-X0200-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
	Agreement No. NRC-HQ-25-14-D-0003 Task Order No 31310018F0052 Title: SAM Development and Modeling Support for Advanced Non-Light Water Reactors The NRC and Argonne National Laboratory (ANL) hereby enter into this Agreement for the project entitled SAM Development and Modeling Support for Advanced Non-Light Water Reactors Period of Performance: August 20, 2018 - June Continued ...				

23. PAYMENT PROVISIONS	24. TOTAL AMOUNT
	$1,162,507.00

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	9/ 12/18

30, 2020

Consideration and Obligations:

(a) Authorized Cost Ceiling $1,162,507.00

(b) The amount presently obligated with respect to this DOE Agreement is $1,162,507.00. 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 documents are 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.

Non-fee Recoverable Work

ANL PI: Rui Hu, 630-252-1461, rhu@anl.gov

NRC COR: Tarek Zaki, 301-414-0994, tarek.zaki@nrc.gov

DUNS: 040535809 TAS: 31X0200.320
ALC: 31000001
Master IAA: NRCHQ2514D0003

00001	Authorized TO Ceiling Line Item Ceiling: $1,162,507.00	1,162,507.00

Continued ...

Incrementally Funded Amount: $1,162,507.00

The total amount of award: $1,162,507.00. The obligation for this award is shown in box 24.

STATEMENT OF WORK

NRC Agreement Number	NRC Agreement Modification Number	NRC Task Order Number (If Applicable)	NRC Task Order Modification Number (If Applicable)
NRC-HQ-25-14-D-0003		31310018F0052	

Project Title
SAM Development and Modeling Support for Advanced Non-Light Water Reactors

Job Code Number	B&R Number	DOE Laboratory
		Argonne National Laboratory

NRC Requisitioning Office
Office of Nuclear Regulatory Research

Period of Performance
August 20, 2018 – June 30, 2020

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) N/A	**Inspection Report Number (If Fee Recoverable/Applicable)**
Technical Assignment Control Number (If Fee-Recoverable/Applicable) N/A	**Technical Assignment Control Number Description (If Fee-Recoverable/Applicable)**

CONTRACTING OFFICER'S REPRESENTATIVE

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

GOVERNMENT-FURNISHED PROPERTY (GFP)

N/A

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. The System Analysis Module (SAM) is a modern system analysis tool being developed at Argonne National Laboratory for advanced non-LWR safety analysis. SAM takes advantage of advances in physical modeling, numerical methods, and software engineering to enhance modeling flexibility and accuracy. The NRC is also evaluating the NEK5000 Computational Fluid Dynamics (CFD) code for analysis of the detailed flow phenomena that may be of interest in LWR and non-LWR safety analysis.

This work supports the development and utilization of the SAM code for advanced reactor safety analysis and licensing at NRC. SAM has primarily been developed as an advanced modeling and simulation tool for liquid metal cooled fast reactors. In addition, DOE has supported development tasks to extend SAM's capabilities to the modeling of MSR designs.

2.0 OBJECTIVES

The objectives of this work are to add capabilities to SAM for the modeling of both molten salt-fueled reactors (MSR) and heat pipe cooled micro reactors and to support the NRC's use of SAM for the analysis of advanced non-LWR designs, and also to provide technical support for the setup and execution of the NEK5000 code as needed. To accomplish, this a number of development tasks are enumerated below in the "Scope of Work" section together with the development of a model for the Molten Salt Reactor Experiment (MSRE). During the performance of this task order, the contractor shall also provide support to NRC staff members in their use of the SAM code.

3.0 SCOPE OF WORK

The Contractor shall provide fully qualified, competent, and trained personnel to perform the required technical assistance and support services under this contract:

In this work, the following enhancements to the SAM code will be made to support its use for the analysis of both MSRs and heat pipe cooled micro reactor designs. Specific tasks include:

1. Modeling of axial and radial thermal expansion feedback effects. This task consists of the following three subtasks:
    a. Develop example problem demonstrating the calculation of axial thermal expansion for metallic fuel by coupling the MOOSE mechanics module with SAM. The change in core height would subsequently be used as a reactivity feedback parameter.
    b. Develop a thermo-mechanical example problem demonstrating the calculation of the radial expansion of a core support plate using the MOOSE mechanics module and 3D conduction capability. The change in assembly pitch would then be used as a reactivity feedback parameter.
    c. Add reactivity feedback parameters for both axial and radial expansion effects to SAM's point kinetics model.

2. Develop a component model for a heat pipe. This component should be based on a 1D superconducting material for the vapor core and a 3D solid material for the heat pipe wick and wall.

3. Develop a coupled SAM/Rattlesnake sample problem for a small fast reactor demonstrating the reactivity effects associated with axial thermal expansion of a metallic fuel and radial thermal expansion of the core support plate. The neutronics solution should be diffusion corrected using either SPH or discontinuity factors and consider the core of a heat pipe cooled micro reactor. The thermo-mechanical models developed above for the axial and radial thermal expansion effects should be coupled to Rattlesnake for the reactivity feedback effects.

4. Improvement to heat transfer modeling capabilities. This task consists of the following four subtasks:
    a. Implement coupling of porous medium fluid energy equation to the solid energy equation.
    b. Implement coupling capability for a 1D flow channel embedded in a 3D solid to model both circular channels in a block and plate fuel geometries.
    c. Add coupling for a 2D heat structure (e.g., a fuel rod or heat exchanger tube) to the fluid in a 3D porous medium.
    d. Implement a package of effective thermal conductivity models for conduction in pebble beds (draft coding to be provided by the NRC). Perform V&V on the models using both liquid-solid and gas-solid data including the HTTU data.

5. Improvement to porous medium flow module. Specifically, modify the solution technique so that it is applicable to weakly compressible flows where the fluid density is also a function of pressure. Model verification should include simulations of the pressure drop in packed beds.

6. Develop an input model for the Molten Salt Reactor Experiment (MSRE). A full 3D thermo-fluids model will be required for the reactor vessel together with 1D components for the primary loop. In addition, code coupling support will be required for TRACE (to model secondary loop) and for Rattlesnake for 3D neutronics. Further, modifications to Rattlesnake will be needed to implement the ability to use the local concentrations of delayed neutron precursors calculated by SAM.

7. Continue development of SAM's reduced-order 3D flow module for the analysis of flow and heat transfer in a fast spectrum MSR core. This task includes the following subtasks:
    a. Perform a CFD simulation of an MSR fueled core at full flow and power conditions to serve as a reference solution.
    b. Add heat generation source term to fluid energy equation for the fission reaction.
    c. Develop appropriate closure relations for the shear stress and effective diffusivity for SAM's coarse grid CFD approach.
    d. Demonstrate 1D to 3D fluid component coupling.
    e. Extend the delayed neutron precursor drift model to the 3D flow module.

The deliverables of these tasks are listed below.

This work will also support the general activities needed to support the use of the coupled SAM/Rattlesnake code at NRC, such as code training and regular user support.

4.0 LIST OF DELIVERABLES

Deliverable Number[1]	Description	Format	Due Date
1	Report on axial and radial thermal expansion feedback effects and input models for associated example problems.	Microsoft Word and electronic files	NLT 6 months from the commencement of this agreement.
2	Report describing heat pipe component model and input model for associated example problem.	Microsoft Word and electronic files	NLT 9 months from the commencement of this agreement.
3	Report describing sample problem for small heat pipe cooled fast reactor and associated input model for SAM/Rattlesnake.	Microsoft Word and electronic files	NLT 12 months from the commencement of this agreement.
4	Report on improvements to heat transfer modeling capability and input models for associated example problems.	Microsoft Word and electronic files	NLT 15 months from the commencement of this agreement.
5	Report on improvements to porous medium flow module and input models for associated example problems.	Microsoft Word and electronic files	NLT 18 months from the commencement of this agreement.
6	Report describing plant model for the MSRE reactor and associated input model.	Microsoft Word and electronic files	NLT 20 months from the commencement of this agreement.
7	Report describing applicability of 3D flow module to fast MSR core and input model for associated example problem.	Microsoft Word and electronic files	NLT 22 months from the commencement of this agreement.
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 KEY PERSONNEL

Dr. Rui Hu, ANL Principal Investigator
Dr. Thomas Fanning
Dr. Guanheng Zhang

1 The deliverable number corresponds to the task number given in the scope of work section above.

6.0 CERTIFICATION AND LICENSE REQUIREMENTS

N/A

7.0 MEETINGS AND TRAVEL

No travel is anticipated for this task order.

8.0 REPORTING REQUIREMENTS

The DOE Laboratory is responsible for structuring the deliverable to follow agency standards. The current agency standard is Microsoft Office Suite 2010. The current agency Portable Document Format (PDF) standard is Adobe Acrobat 9 Professional. Deliverables must be submitted free of spelling and grammatical errors and conform to requirements stated in this section.

Monthly Letter Status Reports

In accordance with Management Directive 11.7, NRC Procedures for Placement and Monitoring of Work with the U.S. Department of Energy, the DOE Laboratory must electronically submit a Monthly Letter Status Report (MLSR) by the 20th day of each month to the Contracting Officer Representative (COR) with copies to the Contracting Officer (CO) and the Office Administration/Division of Contracts to ContractsPOT.Resource@nrc.gov. If a project is a task ordering agreement, a separate MLSR must be submitted for each task order with a summary project MLSR, even if no work has been performed during a reporting period. Once NRC has determined that all work on a task order is completed and that final costs are acceptable, a task order may be omitted from the MLSR.

The MLSR must include the following: agreement number; task order number, if applicable; job code number; title of the project; project period of performance; task order period of performance, if applicable; COR's name, telephone number, and e-mail address; full name and address of the performing organization; principal investigator's name, telephone number, and e-mail address; and reporting period.

9.0 REQUIRED MATERIALS, FACILITIES, HARDWARE/SOFTWARE

N/A

10.0 APPLICABLE PUBLICATIONS

N/A

11.0 DATA RIGHTS

N/A