AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. CONTRACT D CODE	PAGE OF PAGES
	1 24

2. AMENDMENT/MODIFICATION NO.	3. EFFECTIVE DATE	4. REQUISITION/PURCHASE REQ. NO.	5. PROJECT NO. *(If applicable)*
M0003	See Block 16C	RES-18-0330	

6. ISSUED BY CODE NRCHQ

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

7. ADMINISTERED BY *(If other than Item 6)* CODE

8. NAME AND ADDRESS OF CONTRACTOR *(No., street, county, State and ZIP Code)*

NUMARK ASSOCIATES INC
ATTN PAUL EDELSTEIN
1220 19TH ST NW STE 500
WASHINGTON DC 200362444

CODE 788247377 FAC LITY CODE

(x) 9A. AMENDMENT OF SOLICITATION NO.

9B. DATED *(SEE ITEM 11)*

X 10A. MODIFICATION OF CONTRACT/ORDER NO.
NRC-HQ-25-14-E-0004
NRC-HQ-60-17-T-0003

10B. DATED *(SEE ITEM 13)*
09/28/2017

11. THIS ITEM ONLY APPLIES TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in Item 14. The hour and date specified for receipt of Offers ☐ is extended ☐ is not extended.
Offers must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation or as amended , by one of the following methods: (a) By completing tems 8 and 15, and returning _____ copies of the amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted ; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FA LURE OF YOUR ACKNOWLEDGEMENT TO BE RECEIVED AT THE PLACE DESIGNATED FOR THE RECEIPT OF OFFERS PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER If by virtue of this amendment you desire to change an offer already submitted , such change may be made by telegram or letter, provided each telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

12. ACCOUNT NG AND APPROPRIATION DATA *(If required)*
2018-X0200-FEEBASED-60-60D001-60B101-1032-11-6-154 Net Increase: $269,294.00

13. THIS ITEM ONLY APPLIES TO MODIFICATION OF CONTRACTS/ORDERS. IT MODIFIES THE CONTRACT/ORDER NO. AS DESCRIBED IN ITEM 14.

CHECK ONE	
	A. THIS CHANGE ORDER IS ISSUED PURSUANT TO: *(Specify authority)* THE CHANGES SET FORTH IN ITEM 14 ARE MADE IN THE CONTRACT ORDER NO. IN ITEM 10A.
	B. THE ABOVE NUMBERED CONTRACT/ORDER IS MODIF ED TO REFLECT THE ADM NISTRATIVE CHANGES *(such as changes in paying office, appropriation date, etc.)* SET FORTH N ITEM 14, PURSUANT TO THE AUTHORITY OF FAR 43.103(b).
X	C. THIS SUPPLEMENTAL AGREEMENT IS ENTERED INTO PURSUANT TO AUTHORITY OF: FAR 52.243-2 Changes-Cost Reimbursement
	D. OTHER *(Specify type of modification and authority)*

E. IMPORTANT Contractor ☐ is not, ☒ is required to sign this document and return 1 copies to the issuing office.

14. DESCRIPTION OF AMENDMENT/MODIFICATION *(Organized by UCF section headings, including solicitation/contract subject matter where feasible.)*

Task Order Entitled, "Reactor Pressure Vessel Integrity and FAVOR Support," under Enterprise-Wide Contract NRC-HQ-25-14-E-0004.

The purpose of this modification is to revise the task order to accommodate additional contractor support related to migrating the REAP database to NRC controlled servers and to add incremental funding in the amount of $269,294.00, thereby increasing total obligations from $679,001.92 to $948,295.92. Accordingly the following changes are made to the task order:

(1) SECTION B.1, paragraph (b) Summary Work Description, is modified to include Migration of the existent public domain database REAP.

Continued ...

Except as provided herein, all terms and conditions of the document referenced in Item 9 A or 10A, as heretofore changed, remains unchanged and in full force and effect.

15A. NAME AND TITLE OF SIGNER *(Type or print)*		16A. NAME AND TITLE OF CONTRACT NG OFFICER *(Type or print)*	
		MONIQUE B. WILLIAMS	
15B. CONTRACTOR/OFFEROR	15C. DATE SIGNED	16B. UNITED STATES OF AMERICA	16C. DATE SIGNED
(Signature of person authorized to sign)		[redacted] *(Signature of Contracting Officer)*	09/20/2018

ITEM NO. (A)	SUPPL ES/SERVICES (B)	QUANTITY (C)	UNIT (D)	UNIT PRICE (E)	AMOUNT (F)
	(2) The task order ceiling for the base is increased by [redacted], from [redacted] to [redacted], and subsequently the task order ceiling for the base and all options is increased [redacted] to $2,234,337.90. See continuation pages of this modification for specific changes to SECTION B.2 CONSIDERATION AND OBLIGATION-TASK ORDERS and SECTION B.3 PRICE/COST SCHEDULE of the task order as result of the ceiling increase and additional incremental funding. (3) TASK ORDER STATEMENT OF WORK is hereby deleted in its entirety and replaced with the attached Statement of Work with changes shown in bold. (4) SECTION H, 2052.215-70 KEY PERSONNEL. (JAN 1993), paragraph (a), is revised to add [redacted] (5) SECTION J - Attachment 2, Applicable Clauses, is hereby added to the task order. Total Obligations to Date: $948,295.92 (Changed) Base and Exercised Options: [redacted] (Changed) Base and All Options: $2,234,337.90(Changed) Period of Performance: 9/29/2017 to 8/18/2020(Unchanged) Period of Performance: 09/29/2017 to 08/18/2020				

SECTION SF 30 BLOCK 14 CONTINUATION PAGES

The following changes are hereby made to the task order:

(1) SECTION B.1 BRIEF PROJECT TITLE AND WORK DESCRIPTION, paragraph (b), is deleted in its entirety and replaced as follows:

(b) Summary work description: The objective of this task order is to provide technical support to NRC staff with the following:

- The development of in-depth knowledge, verification, validation, documentation, and modernization of the public domain probabilistic fracture mechanics (PFM) code FAVOR
- The assessment of current RPV safety issues, including in particular the possible effect of shallow flaws in the RPV cladding on reactor fracture safety.
- Migration, Maintenance, user support, data entry, and as an Option, Development, for the existent public domain database REAP

(2) SECTION B.2 CONSIDERATION AND OBLIGATION-TASK ORDERS, is deleted in its entirety and replaced as follows:

(a) The ceiling of this order for services is **$2,234,337.90 (inclusive of Options) and** [redacted] **(inclusive of Base and Exercised Options)**.

(b) (b) This order is subject to the minimum and maximum ordering requirements set forth in the contract.

(c) (c) The amount presently obligated with respect to this order is **$948,295.92** ([redacted] The obligated amount shall, at no time, exceed the 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 order, in accordance with FAR Part 43 - Modifications. Any work undertaken by the Contractor in excess of the obligated amount specified above is done so at the Contractor's sole risk and may not be reimbursed by the Government.

(d) Fixed Fee Holdback Amount: [redacted]

(3) SECTION B.3 PRICE/COST SCHEDULE is deleted in its entirety and replaced as follows to reflect an increase for the base period of performance:

[redacted]

[redacted]

[redacted]	[redacted]
Total Order Ceiling (Inclusive of Options)	**$2,234,337.90**

(4) DESCRIPTION/SPECIFICATIONS/STATEMENT OF WORK is deleted in its entirety and replaced as follows:

REVISED TASK ORDER STATEMENT OF WORK (SOW)

1. PROJECT TITLE

Reactor Pressure Vessel Integrity and FAVOR Support

2. BACKGROUND

The operational integrity of nuclear reactor pressure vessel (RPV) and piping systems relies on sound knowledge of nuclear power plants and their applied loadings, their materials of construction, and of how these materials degrade over time (e.g., changes to properties, development of cracks, changes of dimension, etc.). Over the preceding decades the U.S. Nuclear Regulatory Commission (NRC), its contractors, and the national and international nuclear community in general have done considerable work on these topics.

As the pressure-retaining systems (i.e., piping, vessels) of nuclear power plants age, there is a continued need to evaluate these systems for the continued operating safety of these systems. The conclusions of these evaluations rarely remain fixed over the full operational lifetime of the plant for the following reasons:

- The continued action of time-dependent materials degradation (e.g., neutron irradiation embrittlement, pressurized water stress corrosion cracking) and the evolving state of knowledge of these mechanisms. Sometimes this evolving knowledge reveals that past safety assessments have been overly pessimistic, while at other times new or unanticipated damage mechanisms are discovered to be active. In the latter case, existing assessment protocols need to be augmented with new procedures to account for these new mechanisms.
- To remain commercially viable in an increasingly diverse and deregulated electricity marketplace nuclear power plants often find it useful to operate at higher than their original power rating, and/or for longer operational periods. Both changes to the existent licensing basis require regulatory action, and that action needs to be informed by an engineering evaluation of the impact of the more severe operating conditions on plant and public safety.

Realistic assessment of operating safety requires the development of advanced probabilistic assessment tools and the gathering of empirical evidence of the processes underlying the age related material damage.

Since the mid-1990s, the NRC contracted with Oak Ridge National Laboratory (ORNL) to develop the FORTRAN-based computer code FAVOR (**F**racture **A**nalysis of **V**essels, **O**ak **R**idge). ORNL developed the FAVOR code pursuant to NUREG/BR-0167 ("Software Quality Assurance Program and Guidelines)." The software quality assurance (SQA) guidance in NUREG/BR-0167 applies to technical applications software used in a safety decision by the NRC. FAVOR enables users to estimate the frequency with which a crack can be expected to propagate through the wall of a RPV as a result of thermal-hydraulic loading events. Since 1999, this code has been a key component of the NRC's assessment methodology. It has been

used to support both the pressurized thermal shock (PTS) Re-evaluation Project as well as efforts to update the technical basis for 10 CFR 50 Appendix G. While considerable progress has been made under previous acquisitions, certain issues remain that will need to be resolved as part of this effort.

In past NRC-sponsored efforts, modelling work demonstrated that a shallow surface breaking flaw having a depth just slightly more than the thickness of the austenitic stainless steel cladding on the RPV ID exhibit an unexpectedly large impact on the structural integrity of the RPV. This past work identified the added driving force for fracture generated by the mismatch in the coefficient of thermal expansion between the austenitic stainless steel cladding and the ferritic steel base metal as the primary cause of this effect.

Both the NRC and the nuclear power industry have, over the years, generated significant amounts of data that characterize the properties of materials used in power plant construction, as well as the effect of the power plant environment on these properties. This data was generally found in individual reports or letters and had not been catalogued and archived in a sustainable way, nor had the ample data from these documents been stored in a matter that enables their efficient retrieval and use. Therefore, under a previous contract, ORNL developed a material database and archive for the NRC called **REAP** (**R**adiation **E**mbrittlement **A**rchive **P**roject). REAP consists of two major parts: (1) a document archive, and (2) a relational database. REAP is currently focused on data that quantify the effects of irradiation embrittlement on RPV steels. The REAP users consist of domestic and international members of the nuclear industry (utilities, vendors, and other industry research entities), as well as international regulatory and government technical support organizations (national laboratories and public research institutes). [redacted]

3. OBJECTIVE(S)

The objective of this task order is to provide technical support to NRC staff with the following:

- The development of in-depth knowledge, verification, validation, documentation, and modernization of the public domain probabilistic fracture mechanics (PFM) code FAVOR
- The assessment of current RPV safety issues, including in particular the possible effect of shallow flaws in the RPV cladding on reactor fracture safety.
- **Migration,** maintenance, user support, data entry, and as an Option, Development, for the existent public domain database REAP
- Preparation and publication of related peer-reviewed technical papers, and as an Option, analysis of emergent RPV issues.

4. STATEMENT OF WORK TASKS

Task 1: Technical Support to FAVOR

Subtask 1.1: Collection of Software Quality Assurance (SQA) Documentation

The contractor shall assemble all software quality assurance documentation previously created during development of the FAVOR code following NUREG/BR-0167. The information to be collected shall consist of publicly available information or non-public information that is accessible to the NRC and will be provided to the contractor by the COR. The contractor shall sort the documentation into two categories:

- Category 1: from the first version of FAVOR through the development of 10 CFR 50.61a (through FAVOR v6.1)
- Category 2: post 10 CFR 50.61a (all versions following FAVOR v6.1 up through v16.1)

The contractor shall provide all the documentation electronically separated into two folders indicating clearly which category the documentation belongs. In addition, the contractor shall provide a list of all the documents in tabulated format.

Subtask 1.1 Deliverables

1) A ZIP file containing all the documentation collected for this task, with a folder structure/substructure that clearly indicates which of the two categories described above each document belongs to.
2) A tabulated list of all the documents in the ZIP file, including the following information: date, authors, title, report number, corresponding FAVOR version number, and any other relevant bibliographical information in separate columns.

Subtask 1.2: Assessment & Summary of Previous SQA & Verification & Validation (V&V)

NUREG/BR-0167 was developed in 1993. Since then, software development, capabilities and complexity have increased greatly. In response to this increasing complexity, the American Society of Mechanical Engineers (ASME) Code incorporated a new standard, *Requirements for the Verification and Validation in Computational Modeling and Simulation.* V&V is part of the SQA process. Both documents will be made available to the contractor by the COR.

Using the consolidated documentation after completion of Subtask 1.1, the contractor shall assess the level of V&V previously performed under NUREG/BR-0167 and whether it is consistent or inconsistent with the methodology described in the ASME Code standard. The contractor shall document the evaluation and findings in a Technical Letter Report (TLR).

Subtask 1.2 Deliverables

1) Draft TLR that includes:
    - Summary of the requirement of the ASME standard on requirements for V&V of computer codes
    - Detailed assessment of whether previous V&V efforts meet each requirement in the standard

- If the ASME standard requirements are not met, a listing of actions required to meet the V&V requirements, accompanied by an estimate of time and effort to perform the needed actions, and a detailed plan to perform the needed actions

2) Final TLR that incorporates NRC comments on the draft TLR

Subtask 1.3: Knowledge Management Workshop for FAVOR Code Users

The contractor shall develop a knowledge management (KM) workshop and the associated materials aimed at imparting knowledge to the NRC staff on how to use the FAVOR code. The KM workshop shall cover:

- Review of important concepts described in the FAVOR Theory Manual and FAVOR User Manual
- Uses of FAVOR
- Structure of FAVOR
- All steps required to perform any applicable pre- processing and post-processing for a FAVOR analysis
- Step-by-step instructions for a novice to be able to perform a FAVOR analysis
- Hands-on application examples with FAVOR, as well as the pre- and post-processing tools

The contractor shall prepare an Outline for the KM workshop and User Manual. Upon receiving approval of the outlines from the COR, the contractor shall develop all necessary materials (slides, other visual aids, and hands-on exercises), as well as the User Manual that compiles and navigates through the KM materials. Specifically, the contractor shall design all KM materials in such a way that NRC staff could acquire the knowledge without contractor assistance. Further, the contractor shall assemble the KM materials into a User Manual such that NRC staff who cannot attend the KM workshop described below can later obtain the knowledge from the workshop. This implies that highly detailed materials shall be prepared, along with an introduction describing the order in which each module/phase/step of the KM workshop should occur.

The contractor shall conduct one KM workshop to NRC users of FAVOR. The workshop shall be held at NRC Headquarters in Rockville, Maryland. The workshop shall be no more than three (3) business days. The NRC will provide all necessary equipment and facilities to hold the KM workshop. The contractor shall project up to 15 NRC participants to attend the KM workshop. This KM workshop shall consist of guiding NRC staff through the User Manual, including presentation of the contents and hands-on applications with the FAVOR code, as well as the pre- and post-processors.

<u>Subtask 1.3 Deliverables</u>

1) FAVOR User KM Workshop Outline that includes: a list of topics to be covered, a schedule for presenting the topics, and a list of any hands-on exercises to be performed during the session
2) Outline for the FAVOR KM User Manual
3) FAVOR User KM Workshop supporting materials (slides, other visual aids, and hands-on exercises)

4) Draft FAVOR KM User Manual that includes all materials necessary for independent knowledge acquisition by NRC staff on the use of the FAVOR code, as described in detail above
5) Final FAVOR KM User Manual that incorporates all NRC comments on the draft User Manual

Subtask 1.4: Knowledge Management Workshop for FAVOR Code Developers

In addition to knowledge transfer for FAVOR users, the contractor shall perform knowledge transfer for up to three NRC staff simultaneously on the in-depth workings of FAVOR and its pre- and post-processors. The contractor shall develop a FAVOR Developer KM workshop that includes the following:

- History of the development of FAVOR
- A detailed overview of the source code (each subroutine, module, common, function, or other code unit shall be described, including where it sits in the call tree, its inputs and outputs as applicable, and its function in FAVOR).
- Description of any known deficiencies of the code and any recommended improvements
- Any other information/tips/programming advice useful to NRC staff in charge of maintaining and developing FAVOR in the future.
- Hands-on application activities that may include as agreed upon with the COR, but is not limited to, implementation one or more the changes to FAVOR approved by the COR in Task 2.

The contractor shall conduct one hands-on FAVOR Developer KM workshop to be held at NRC Headquarters in Rockville, Maryland, length to-be-determined and agreed upon between the COR and the contractor, but 5 days maximum.

Subtask 1.4 Deliverables

Materials developed for the FAVOR Developer KM Workshop, including slides, other visual supports, and any hands-on activities.

Subtask 1.5: Support for Development of a Software Requirements Document

Section 4 of NUREG/BR-0167, “Documentation and Deliverables,” specifically identifies the documentation and software deliverables essential to a successful software development project. Section 4.3, “Software Requirements Documentation,” provides additional detail by specifying software requirements documentation and describes the requirements that must be met, including the following:

1. Functionality - the functions that the software is to perform
2. Performance - the time-related requirements of software operation such as speed, response time, etc.
3. Design constraints imposed on implementation activities - any elements that will restrict design options (e.g., specifying the hardware platform or the programming language)
4. Attributes - characteristics of the software, its acceptance, or use (e.g., portability, acceptance criteria, access control, availability, maintainability, etc.)
5. External interfaces - interactions with people, hardware, and other software.

The contractor shall assist the NRC staff in developing a Software Requirements Document (SRD) for the FAVOR code. Specifically, the contractor shall assist the NRC staff in developing the SRD by providing technical assistance consisting of:

- answering questions in response to COR written requests related to FAVOR and to the development of the SRD, as well as providing information and references in support of the responses provided
- up to 3 rounds of review of successive drafts of the SRD developed by NRC staff
- writing a limited number of sections of the SRD, as needed and as directed in writing by the COR

Subtask 1.5 Deliverables

1) Written responses to NRC staff questions about FAVOR and related to the development of the SRD for FAVOR
2) References used to develop the responses to NRC staff questions
3) Up to 3 reviews of the draft SRD, using tracked changes and comments in MSWord
4) Draft written sections of the SRD as directed by the COR , and revised drafts of these sections of the SRD after receiving comments from the COR

OPTION Task - Subtask 1.6: Support of Independent V&V (IV&V) Effort

OPTION - Subtask 1.6

Upon assessing the V&V efforts to date and how they compare to the ASME standard for computer code V&V, the NRC may decide to perform additional independent V&V of FAVOR. If such an endeavor is undertaken, the NRC staff will constitute the “FAVOR Independent V&V Group”, whose membership will be defined if and when needed. This group will develop a V&V plan, and subsequently execute this plan.

The contractor shall review the IV&V plan produced by the FAVOR IV&V Group for completeness and accuracy and provide comments to the COR .

The contractor shall be available to respond to any inquiries from the FAVOR IV&V Group related to the performance of the IV&V effort.

OPTION Task - Subtask 1.6 Deliverables

1) Comments on the IV&V plan, with tracked changes and comments in MSWord
2) Written answers to written inquiries generated by the FAVOR IV&V Group, relating to the IV&V effort, that are transmitted to the contractor by the COR

Task 2: Assessment of RPV Safety Issues Associated with Shallow Flaws

The purpose of this task is to further examine the impact of shallow surface breaking flaws on RPV structural integrity, and in particular to determine if improvements to the realism with which the flaws and the cladding are modelled produce any significant change to the conclusions of the previous study. The contractor shall support the NRC staff in their assessment of current and emergent potential RPV safety issues, including in particular the possible effect of shallow flaws in the RPV cladding on reactor fracture safety.

Subtask 2.1: Warm Pre-Stress

Use of a warm-pre stress (WPS) brittle failure model has long been a standard part of FAVOR. While there are multiple ways to model WPS effects, the FAVOR model requires that the following two conditions be true for there to be a possibility of vessel failure:

- the applied value of K should exceed the minimum value of K resistance, and
- the applied value of K should both be increasing with time and exceed all previous maximums during the loading event being considered.

Past analyses conducted by the NRC have focused on accident loadings, such as PTS. Since PTS is a rare event, it was justifiable to consider only the single loading event associated with the postulated accident. However, when FAVOR is used to assess the safety impact of more routine loading events it seems also necessary to evaluate the complete vessel loading history dating to the time the vessel was first placed into service.

The contractor shall determine if modelling of WPS over the full history of RPV loading influences the perceived impact of shallow surface breaking flaws on RPV structural integrity. To meet this objective, it is expected that the contractor shall:

- Determine load histories based on loadings modeled in previous NRC efforts and on the results of a search for prototypical loadings in PWRs and BWRs in publicly available documentation. If deemed necessary because of the lack of publicly available information, potentially relevant non-public records will be provided by the COR to the contractor. The contractor shall then search the non-public records for the needed information.
- Develop a matrix of analyses to be performed, including a clear identification of the different WPS models that will be considered, with identification of which approaches require FAVOR source code modification and which do not. The analysis matrix shall outline the loading conditions that will be studied, the WPS models that will be used, and all other conditions pertinent to the analysis, including, but not limited to, reactor vessel geometry, embrittlement condition, flaw population, etc.
- Perform FAVOR analyses with the prototypical loadings for PWRs and BWRs per the analysis matrix developed. As part of this step, the contractor shall develop FAVOR input files to perform as many analyses as needed to fully assess the range of possible prototypical loadings.
- Analyze the results of the FAVOR analyses to assess the effect of WPS on the integrity of the vessel.
- As needed, and if approved by the COR , develop new WPS models that meet the ASME Standard and the requirements of NUREG/BR-0167 and incorporate them into FAVOR, as well as assess the impact of these models by performing sensitivity analyses with the FAVOR code. The FAVOR Theory and Users' Manuals shall be modified accordingly.

<u>Subtask 2.1 Deliverables</u>

1) Analysis matrix with loading conditions, WPS models, and all other conditions pertinent to the analysis:
   a) Draft analysis matrix

   b) Final analysis matrix that incorporates comments from COR
2) Report:
   a) The contractor shall prepare a draft TLR summarizing the results of the entire subtask, including all of the items in the task description.
   b) The final TLR that incorporates COR comments on the draft shall be prepared by the contractor.
3) Source and Executable Code: If FAVOR is modified in order to perform this task the source code, the executable code, and text-based descriptions of all changes to the computer code shall be provided.
4) If FAVOR is modified in order to perform this task, Updated FAVOR Theory and Users' Manuals
5) Input decks and FAVOR outputs: Input decks and all resultant outputs shall be complied and provided to the NRC on a CD or other suitable electronic format. The COR and the contractor shall agree upon the format to be used.

Subtask 2.2: Cladding Residual Stress

The model of cladding residual stresses now used in FAVOR that led to the finding of potential shallow flaw risk significance is, while a standard model used in PFM studies, also a simplified one. A limited sensitivity study subsequently performed with a more sophisticated model showed a slight reduction in, although not elimination of, the so-called shallow flaw effect.

The contractor shall determine if improvements to the accuracy of the clad residual stress model influences the perceived impact of shallow surface breaking flaws on RPV structural integrity. To meet this objective, it is expected that the contractor shall:

- Perform a review of previous literature/studies on clad residual stress modeling, including but not limited to, the references found in Section 5 of this SOW. Other sources of information on clad residual stress modeling shall include a review of publically available technical literature.
- Develop options for improved residual stress modelling in FAVOR considering at a minimum the following factors: the accuracy of the model, the need for input data to drive the predictions, and computational efficiency within a PFM computer code. The contractor shall assess the availability of data if needed to drive the accuracy of the model options.
- Develop a matrix of analyses to be performed, including a clear identification of the different residual stress models that will be considered, with identification of which approaches require FAVOR source code modification and which do not. The analysis matrix shall outline the loading conditions that will be studied, the residual stress models that will be used, and all other conditions pertinent to the analysis, including, but not limited to, reactor vessel geometry, embrittlement condition, flaw population, etc.
- Perform FAVOR analyses with variations on residual stress per the analysis matrix developed. As part of this step, the contractor shall develop FAVOR input files to perform as many analyses as needed to fully assess the range of plausible residual stresses.
- Analyze the results of the FAVOR analyses to assess the effect of clad residual stresses on the integrity of the vessel.
- As needed, and if approved by the COR , develop new clad residual stress models that meet the ASME Standard and the requirements of NUREG/BR-0167 and incorporate them into FAVOR, as well as assess the impact of these models by performing

sensitivity analyses with the FAVOR code. The FAVOR Theory and Users' Manuals shall be modified accordingly.

Subtask 2.2 Deliverables

1) Analysis matrix with loading conditions, clad residual stress models, and all other conditions pertinent to the analysis:
   a) Draft analysis matrix
   b) Final analysis matrix that incorporates comments from COR
2) Report :
   a) The contractor shall prepare a draft TLR summarizing the results of the entire subtask, including summarizing references reviewed other than those identified in Section 5.0 and documenting the references, e.g. Identifying the author, year, and title and, summarizing the options for improved residual stress modelling in FAVOR, and an assessment of the impact of the different cladding residuals stress models on RPV failure probability.
   b) The final TLR that incorporates COR comments on the draft shall be prepared by the contractor.
3) Source and Executable Code: If FAVOR is modified in order to perform this task the source code, the executable code, and text-based descriptions of all changes to the computer code shall be provided.
4) If FAVOR is modified in order to perform this task, Updated FAVOR Theory and Users' Manuals
5) Input decks and FAVOR outputs: Input decks and all resultant outputs shall be complied and provided to the NRC on a CD or other suitable electronic format. The COR and the contractor shall agree upon the format to be used.

OPTION Task - Subtask 2.3: Loading

Previous NRC and contractor analyses conducted at ORNL have demonstrated that if a RPV could be cooled down along the currently allowed pressure-temperature limit curve, and if that RPV had a shallow surface breaking flaw, then in some instances the estimated conditional probability of vessel failure would exceed 10^{-6} events/reactor-year. Likewise analyses have also demonstrated that cooling down the vessel following pressure/temperature transients recorded in operation plants leads to much lower conditional vessel failure probabilities. These two findings suggest that between these two extremes there exists combinations of pressures and temperatures that are both operationally viable and, from a risk perspective, leads to acceptably low vessel failure probabilities. The aim of this task is to explore possibilities to identify such pressure/temperature combinations.

The contractor shall perform a review of the existing literature to determine if there is a pressure/temperature corridor that is both operationally viable and from a risk perspective, leads to acceptably low vessel failure probabilities. The review shall include documents provided by the COR arising out of previously completed work at ORNL (relevant technical sections of monthly letter status reports, summary memos, etc.), as well as the open literature.

To assess the viability of a new pressure/temperature corridors, the contractor shall develop a draft matrix for computational analyses using FAVOR, finite element modeling, or other appropriate tools. The contractor shall then prepare a final analysis matrix that incorporates comments from the COR.

The contractor shall perform supporting analyses (FAVOR analyses, finite element analyses, etc.) per the approved analysis matrix.

The contractor shall attend a meeting at NRC headquarters to discuss the results of this task. The meeting will be a round-table discussion with the NRC staff and, possibly, industry representatives. The outcome of the meeting will be to inform the COR's decision regarding whether or not further work is needed on this topic. Should further be needed, it will be conducted within the context of Task 5.

OPTION - Subtask 2.3 Deliverables

1) Analysis matrix with type of analysis and parameters needed for each analysis (as determined in the literature review):
   a) Draft analysis matrix
   b) Final analysis matrix that incorporates comments from COR

2) Report:
   a) The contractor shall prepare a draft letter report summarizing the results of the entire subtask, and addressing the possibility for combinations of pressures and temperatures that are both operationally viable and, from a risk perspective, lead to acceptably low vessel failure probabilities,
   b) The final letter report that incorporates COR comments on the draft shall be prepared by the contractor.
3) Input decks and outputs from analyses performed in subtask 2.3: Input decks and all resultant outputs shall be complied and provided to the NRC on a CD or other suitable electronic format. The COR and the contractor shall agree upon the format to be used.

Task 3: Technical Support to Radiation Embrittlement Archive Project (REAP)

Subtask 3.1: REAP maintenance and user support

The contractor shall host the REAP database on a publically accessible website, shall process new user requests, shall service the needs of existing users having problems with their accounts, and shall correct any data errors identified by users. At the beginning of the project the COR will provide a list of already approved users to the contractor. The contractor shall consult with the COR prior to approving any user request, and prior to resolving any significant issues (significant means taking more than 1 work day to resolve). For cost estimation purposes the contractor should assume that these activities should be limited to one full working day per month.

Subtask 3.1 Deliverables

In the Monthly Letter Status Report (MLSR) for this task order, the contractor shall include: (1) a complete list of users (names, organizations, e-mail addresses); (2) identifying any new users added in the reporting month; and (3) a description of any significant issues identified, and their resolution.

Subtask 3.2: REAP data entry

From time-to-time the operators of power reactors in the United States produce additional surveillance data. The contractor shall scan these reports, which will be provided to the contractor by the COR, for the document archive, and shall enter data from the reports into the relational database. For cost estimation purposes the contractor should assume that an initial data entry from six reports will be needed. After this data entry a rate of two new reports per year shall be assumed.

Subtask 3.2 Deliverables

In the MLSR for this task order, the contactor shall include a summary of any new reports received that month and documentation of their entry into REAP. The documentation shall demonstrate the data entry and how the data was stored, and shall include evidence of cross-checking the new data with previous reports from the same plant to ensure consistency with data already collected.

OPTION Task - Subtask 3.3: REAP development

From time-to-time the NRC may find it necessary to further develop the data storage, retrieval, and analysis capabilities of REAP. Should this be needed in the future, the NRC will modify the statement of work to describe the specific development effort(s) required and the associated deliverables.

Subtask 3.4: REAP migration to NUMARK-controlled environment

The contractor shall investigate the contents of the REAP legacy archive provided by the COR and provide a summary of the contents of the archive to the COR. The contractor shall migrate the contents of REAP to a public web server controlled by the contractor, and restore REAP to its past functionality (i.e. as it was when still hosted on ORNL servers, based on the legacy archive provided by the COR). The contractor shall restrict access to the database to users approved by the COR, with the ability to securely create, manage, and delete user accounts. User accounts shall be attached to individuals and use unique user names and passwords. The COR shall have full authority on which users may have an account to access the database. Note: once established, the maintenance of the REAP database and website is covered under Subtask 3.1.

Subtask 3.4 Deliverables

1) **List of contents of the existing REAP legacy archive provided by the COR, either in a MS Word or MS Excel format.**
2) **Functional REAP database and public website, hosted on servers controlled by the contractor.**

Subtask 3.5: REAP migration to NRC-controlled environment

The contractor shall assist with the migration of the REAP database and website to the NRC's web servers. Specifically, the contractor shall provide the NRC with all the files required to host the REAP database, web application, and website. The contractor shall be available to interact with IT personnel at the NRC and answer questions from IT personnel at the NRC regarding REAP, as instructed in writing by the COR. The

contractor shall provide assistance in developing source code required to facilitate the REAP migration from servers controlled by the contractor to servers controlled by the NRC. For the purposes of this proposal, the contractor should assume up to 4 weeks of work related to source production in support of the REAP migration.

Subtask 3.5 Deliverables

1) **All digital files associated with the REAP database, web application, and website as hosted on the contractor controlled servers.**
2) **Written responses to IT questions related to REAP migration, as requested by the COR.**
3) **Source code related to the migration of REAP to NRC servers.**

Task 4: Related Technical Support

Subtask 4.1: Kickoff Meeting and Annual Program Review Meetings

Shortly after award, the contractor shall participate in a kickoff meeting at the NRC Headquarters in Rockville, Maryland. Each year of the contract, the contractor shall participate in an annual program review meeting with the COR and other NRC technical staff to discuss work performed during the year. The meetings are expected to be held at NRC Headquarters, in Rockville Maryland.

Subtask 4.1 Deliverables

The contractor shall prepare viewgraphs and other support materials, e.g. handouts, for the kickoff meeting and for each annual program review. In the viewgraphs for the kickoff meeting, the contractor shall go over the scope of the work for all awarded tasks, and provide any insights and suggestions to ensure a successful project. In the viewgraphs for the annual program reviews, the contactor shall summarize the work performed to date under this task order, highlight important test results, provide a snapshot of the project's financial status, highlight any potential problem areas and propose potential solutions, and outline the work to be performed during the following contract year.

Subtask 4.2: Peer-Reviewed Technical Paper

For each year of this task order, the contractor shall prepare a technical paper to be presented at a peer reviewed conference, technical meeting, or to be published in a technical journal. In this technical paper, the contractor shall describe one or more important aspects of the research performed during the year related to this research project. The contractor shall obtain COR written approval of the topics to be addressed in the technical paper prior to starting work on preparing the technical paper. If directed by the COR, the contractor shall present the paper.

Subtask 4.2 Deliverables

The contractor shall prepare a draft technical paper and a final technical paper that incorporates COR comments received on the draft technical paper.

OPTION Task - Task 5: Related Technical and Regulatory Analysis Support

The contractor shall perform technical and regulatory analysis on emerging issues related to RPV integrity in support of NRC licensing regulatory reviews or other NRC nuclear regulatory research. The contractor shall also provide technical expertise to address emerging issues associated with probabilistic modeling. The contractor shall provide support on an as-needed basis upon the written direction of the COR. Specifically, the contractor shall perform, as needed, probabilistic fracture mechanics analyses, finite element analyses, peer review of technical work, P-T limits calculations, code development and maintenance, and data retrieval and analysis. Such analyses shall be in support of RPV integrity licensing regulatory reviews, or other related NRC research.

OPTION - Task 5 Deliverables

For each technical or regulatory analysis support request, the contractor shall prepare and submit a short (e.g. anticipated to be no more than 10 pages) draft TLR that includes analysis results and/or other information as requested by the COR commensurate with the issue being addressed and the needs of the COR. The contractor shall prepare a final TLR incorporating any comments from the COR on the draft TLR.

5. APPLICABLE DOCUMENTS AND STANDARDS

[1] Fracture Analysis of Vessels – Oak Ridge FAVOR, v16.1, Computer Code: Theory and Implementation of Algorithms, Methods, and Correlations, ORNL/LTR-2016/309, ADAMS ML 16273A033.
[2] Fracture Analysis of Vessels – Oak Ridge FAVOR, v16.1, Computer Code: User's Guide, ORNL/LTR-2016/310, ADAMS ML 16273A034.
[3] Reactor Embrittlement Archive Project (REAP) website, https://2734-12533.el-alt.com.
[4] Dickson, T.L., Bass, B.R., Williams, P.T., "The Effect of Shallow Internal Surface-Breaking Flaws on the Probability of Brittle Fracture of Reactor Vessels Subjected to Normal Cool-Down Transients," ORNL/TM-2012/489, ADAMS ML14050A190.
[5] Kusnick, J., Kirk, M., Bass, B.R., Williams, P., and Dickson, T., "Effect of Cladding Residual Stress Modeling Technique on Shallow Flaw Stress Intensity Factor in a Reactor Pressure Vessel," 2015 ASME Pressure Vessel and Piping Conference, July 2015, Boston, MA, USA, PVP2015-45086
[6] American Society of Mechanical Engineers (ASME) Standard: *Requirements for the Verification and Validation in Computational Modeling and Simulation*

6. DELIVERABLES/MILESTONE SCHEDULE AND REPORTING REQUIREMENTS

The contractor shall provide the deliverables stated in the table below in electronic format unless otherwise directed by the COR. The electronic format shall be provided using a Microsoft-based product, (e.g., Outlook, Word, Excel, PowerPoint) unless the COR and the contractor specifically agree on another format, such as PDF for example. All deliverables, with the exception of the Monthly Letter Status Report (MLSR) shall be in the format of draft version, revision version with redline/strikeout with a change-control appendix, and a revised version which shall become the final version. The contractor shall maintain appropriate version control in an electronic format. The contractor shall explicitly state in its submittal(s) that the product provided is the deliverable for Task/Subtask XX, as further described below.

The deliverables below shall be submitted to the task order COR. The COR will review all draft deliverables (and coordinate any internal NRC staff review, if needed) and provide comments back to the contractor. The contractor shall revise the draft deliverable based on the comments provided by the COR and then deliver a revised version of the deliverable, which will then be considered the Final Version. When mutually-agreed upon between the contractor and the COR, the contractor may submit preliminary or partial drafts to help gauge the contractor's understanding of the particular work requirement. More than one round of drafts may be needed if the contractor does not successfully incorporate the COR's comments on the previous draft.

The contractor shall develop (as necessary), maintain, and control data, files, information, and deliverables pursuant to this task order.

Subtask	Deliverable	Estimated Due Date
1.1	ZIP file containing all previous SQA documentation collected for this task	5 months after start of project
1.1	A tabulated list of all SQA documents contained in the ZIP file	5 months after start of project
1.2	Draft TLR on Previous SQA and V&V Assessment	10 months after start of project
1.2	Final TLR on Previous SQA and V&V Assessment	2 weeks after receiving comments from COR
1.3	FAVOR User KM Workshop Outline	6 months after start of project
1.3	Outline for the FAVOR KM User Manual	6 months after start of project
1.3	FAVOR User KM Workshop supporting materials (slides, other visual aids, and hands-on exercises)	15 months after start of project
1.3	Draft FAVOR KM User Manual	15 months after start of project
1.3	Final FAVOR KM User Manual	1 month after receiving comments from COR
1.4	Materials developed for Developer KM Workshop, including slides, other visual supports, and any hands-on activities	1 week before knowledge transfer session, and no later than 24 months from the start of the project
1.5	Written responses to NRC staff questions about FAVOR and related to the development of the SRD for FAVOR	1 week after receipt of a question from COR
1.5	References used to develop the responses to NRC staff questions	1 week after receipt of a question from COR
1.5	Reviews of the draft SRD, using tracked changes in MSWord	1 month after receipt of draft SRD
1.5	Draft written sections of the SRD as directed by the COR	1 month after writing assignment by COR
1.5	Revised draft sections of the SRD	2 weeks after receipt comments from COR
1.6 (OPTION)	Review of the IV&V plan, with tracked changes and comments in MSWord	1 month after receipt of the IV&V plan
1.6 (OPTION)	Written answers to written inquiries generated by the FAVOR IV&V Group, relating to the IV&V effort	1 week after receipt of inquiry from the COR
2.1	Draft analysis matrix with loading conditions, WPS models, and all other conditions pertinent to the analysis	12 months after start of project
2.1	Final analysis matrix with loading conditions, WPS models, and all other conditions pertinent to the analysis	2 weeks after receiving comments from COR

Subtask	Deliverable	Estimated Due Date
2.1	Draft subtask 2.1 TLR	18 months after start of project
2.1	Final subtask 2.1 TLR	1 month after receiving comments from COR
2.1	Modified FAVOR code that allow for WPS modeling (source and executables)	18 months after start of project
2.1	Updated FAVOR Theory and Users' Manuals, as applicable	18 months after start of project
2.1	Input decks and FAVOR outputs for all subtask 2.1 analyses	18 months after start of project
2.2	Draft analysis matrix with loading conditions, clad residual stress models, and all other conditions pertinent to the analysis	18 months after start of project
2.2	Final analysis matrix with loading conditions, clad residual stress models, and all other conditions pertinent to the analysis	2 weeks after receiving comments from COR
2.2	Draft subtask 2.2 TLR	24 months after start of project
2.2	Final subtask 2.2 TLR	1 month after receiving comments from COR
2.2	Modified FAVOR code that allow for clad residual stress modeling (source and executables)	24 months after start of project
2.2	Updated FAVOR Theory and Users' Manuals, as applicable	24 months after start of project
2.2	Input decks and FAVOR outputs for all subtask 2.2 analyses	24 months after start of project
2.3 (OPTION)	Draft analysis matrix with all conditions pertinent to the analysis	24 months after start of project
2.3 (OPTION)	Final analysis matrix with all conditions pertinent to the analysis	2 weeks after receiving comments from COR
2.3 (OPTION)	Draft subtask 2.3 TLR	24 months after start of project
2.3 (OPTION)	Final subtask 2.3 TLR	1 month after receiving comments from COR
2.3 (OPTION)	Input decks and FAVOR outputs for all subtask 2.3 analyses	24 months after start of project
3.1	Within Monthly Letter Status Report to the NRC: complete list of users, identification of new users added during the period, and significant issues identified, and their resolution	20th Calendar day of the following month
3.2	Within Monthly Letter Status Report to the NRC: summary of any new reports received that month and documentation of their entry into REAP	20th Calendar day of the following month
3.3 (OPTION)	TBD determined on a task order modification basis	TBD
3.4	**List of contents of the existing REAP legacy archive**	**1 month from award of Modification M0003**
3.4	**Functional REAP database and public website**	**3 months from award of Modification M0003**
3.5	**All digital files associated with the REAP database, web application, and website as hosted on the contractor controlled servers**	**03/31/2019**
3.5	**Written responses to IT questions related to REAP migration, as requested by the COR**	**1 week after receipt of a question from COR**
3.5	**Source code related to the migration of REAP to NRC servers**	**To be agreed upon when requested by COR**
4.1	Viewgraphs and Other Supporting Materials for kickoff and annual review meetings	1 week before the meeting
4.2	Draft technical paper	2 weeks before draft

Subtask	Deliverable	Estimated Due Date
		submittal deadline
4.2	Final technical paper	1 week before final submittal deadline
5 (OPTION)	Draft TLR that includes analysis results and/or other information as requested by the COR commensurate with the issue being addressed and the needs of the COR	1 month after completion of work required by COR
5 (OPTION)	Final TLR	2 weeks after receiving comments from COR
All	MLSR per Section F.3 of the Base Contract	20th Calendar day of the following month

The contractor shall submit all raw and processed data and worksheet and/or input files used in testing and analyses with the corresponding Draft TLR, and with the Final TLR, in a tabulated Excel format or other format as directed by the COR.

7. LABOR QUALIFICATIONS/ESTIMATED LEVEL OF EFFORT

Labor Type	Qualification Requirements
Project Manager (PM)	Minimum Qualifications Requirement 1) B.S. in Engineering, Science or similar technical field and 2) Minimum 5 years of regulatory research project management and oversight experience
Technical Staff	Minimum Qualifications Requirement 1) M.S. in Engineering, Science or similar technical field and 2) Individual Technical Staff, or team of Technical Staff as a whole performing work described herein must have a combined minimum 15 years knowledge and specialized experience in the following key technical areas: • Probabilistic fracture mechanics computer code development • Uncertainty characterization methodologies and sensitivity studies • Reactor pressure vessel fracture issues in light-water nuclear power plants • NRC regulation and guidance pertaining to reactor pressure vessel integrity • Use of the FAVOR code for regulatory purposes

Labor Type	Qualification Requirements
	• Development of the FAVOR code • Experience in performing software quality assurance activities, including verification and validation Education and Skillsets that are not Required, but Desired for this Task Order Requirement: In-depth technical experience and/or knowledge in the following areas: • Knowledge of, and practical experience in, NRC standards for software quality assurance • Experience in developing knowledge transfer course materials • Experience in delivering knowledge transfer seminars

8. GOVERNMENT-FURNISHED PROPERTY

Access to all deliverables from previous NRC research and development on the FAVOR code, as needed for this project per the COR's determination, including all past test data, analyses, and letter reports.

REAP legacy archive

9. PERIOD OF PERFORMANCE

See SECTION F – NRCF030A PERIOD OF PERFORMANCE ALTERNATE I.

10. PLACE OF PERFORMANCE

The work to be performed under this task order shall be performed at the Contractor's facility except for the travel described in Section 11.1 of this statement of work.

11. SPECIAL CONSIDERATIONS

11.1 TRAVEL/MEETINGS

The following travel may occur under this task order:

Travel Description	Task	Location	Date	Days	Attendees
FY 2018					
Program Review at NRC	4.1	Rockville, MD	09/2018	2	2

Technical Conference/Meeting	4.2	TBD	TBD	4	1
FY 2019					
Program Review at NRC	4.1	Rockville, MD	09/2019	2	2
Technical Conference/Meeting	4.2	TBD	TBD	4	1
User KM Workshop	1.3	Rockville, MD	TBD	3	3
Developer Workshop	1.4	Rockville, MD	TBD	5	2
FY 2020					
Program Review at NRC	4.1	Rockville, MD	05/2020	2	2
Technical Conference/Meeting	4.2	TBD	TBD	4	1

Travel Notes

a. All contractor travel requires prior written approval from the COR.
b. Number of trips, number of contractor personnel, duration, location, may be modified based on meeting circumstances and COR need for contractor support. Contractor shall implement travel cost-sharing measures (for example sharing rental car) if possible.
c. At the discretion of the COR, meetings may be conducted via telephone, video conference, or at the contractor site.
d. All travel conducted pursuant to this task order is billable at Federal per diem rates, in accordance with Federal Travel Regulations.

11.2 SECURITY

The work will be UNCLASSIFIED.

Work on this task order may involve the handling of documents that contain proprietary information. The contractor shall safeguard documents containing proprietary information against unauthorized disclosure. After completion of work, the contractor shall either destroy the documents or return them to the NRC. If they are destroyed, please confirm this in an e mail to the COR with a copy to the CO and include the date and manner in which the documents were destroyed.

11.3 KEY PERSONNEL

See Section H – 2052.215-70 KEY PERSONNEL

11.4 LICENSE FEE RECOVERY

All work under this task order is not license fee recoverable.

11.5 DATA RIGHTS

The NRC shall have unlimited rights to and ownership of all deliverables provided under this contract/order, including reports, recommendations, briefings, work plans and all other deliverables. All documents and materials, to include the source codes of any software, produced under this contract/order are the property of the Government with all rights and privileges of ownership/copyright belonging exclusively to the Government. These documents and materials may not be used or sold by the contractor without written authorization from the CO. All materials supplied to the Government shall be the sole property of the Government and

may not be used for any other purpose. This right does not abrogate any other Government rights. The definition of "unlimited rights" is contained in Federal Acquisition Regulation (FAR) 27.401, "Definitions." FAR clause at FAR 52.227-14, "Rights in Data-General**,"** is incorporated by reference under the base contract.

(5) SECTION H, 2052.215-70 KEY PERSONNEL. (JAN 1993), paragraph (a), is deleted in its entirety and replaced as follows:

(a) The following individuals are considered to be essential to the successful performance of the work hereunder:

NAME	LABOR CATEGORY/POSITION
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

*The contractor agrees that personnel may not be removed from the contract work or replaced without compliance with paragraphs (b) and (c) of this section.

(6) SECTION J - List of Documents, Exhibits and Other Attachments is revised to add Attachment 2 – Applicable Clauses.

All other terms and conditions of the task order remain the same.