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Assessment of V&V Efforts of the Fracture Analysis of Vessels – Oak Ridge (FAVOR) Software Product – Version 16.1

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Prepared in response to Task 1.1 in User Need Request NRR-2017-007, by:

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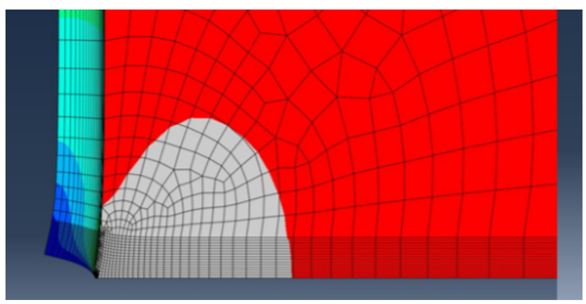

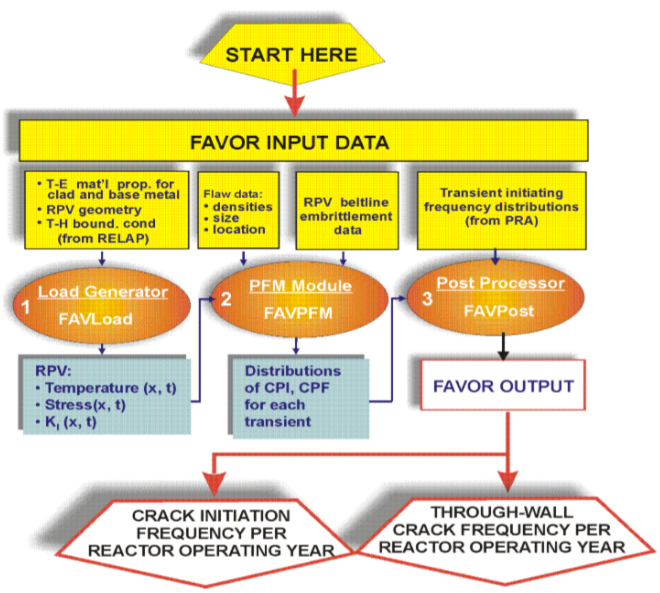

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2 Executive Summary

This report provides an assessment and summary of previous Software Quality Assurance (SQA) and Verification and Validation (V&V) efforts for the FAVOR software program used to evaluate reactor pressure vessel (RPV) integrity of both Pressurized Water Reactors (PWRs) and Boiling Water Reactors (BWRs). NUMARK had reviewed and assessed the level of V&V documents previously performed under NUREG/BR-0167 [2]. In addition, NUMARK assessed the current documentation against the methodology described in the American Society of Mechanical Engineers (ASME) Code, *Requirements for the Verification and Validation in Computational Modeling and Simulation* [3][4].

Review activities were commensurate with the risk associated with the failure of FAVOR. Factors affecting this risk include the potential impact on nuclear safety and/or operation, complexity of computer program design, degree of standardization, state of the art, and similarity with previously proven computer programs. Ultimately, the assessment reviewed and evaluated the existing FAVOR documentation in the public domain against the following requirements:

- FAVOR should correctly and adequately perform all intended critical functions;
- Data sources used to create the FAVOR computer code models should be valid and be applied correctly;
- The FAVOR code manual and user documentation should clearly define all inputs and outputs;
- FAVOR should not perform any unintended function that either by itself or in combination with other functions can degrade the entire system; and
- All non-functional requirements (e.g., performance, design constraints, attributes, and external interfaces) should be met.

NUMARK then identified gaps to the requirements and developed actions and resources to close these gaps. The key findings are as follows:

1. A living SQA plan for FAVOR does not exist. Other nuclear codes used by the NRC (e.g., xLPR, FRAPCON/FRAPTRAN, FAST, MELCOR, SCALE, and TRACE) have an SQA plan.
2. The gathered FAVOR SQA related documents do not cover the design phase aspects of NUREG BR-0167. No documents were found that showed inspection, qualification test plan, acceptance test plan, preliminary design review, or critical design review of the FAVOR software **prior** to implementing the new version. This would be information surrounding how the software design change would be tested and accepted **prior to release**. Some documents captured qualification testing and acceptance testing **following FAVOR version release**.
3. Evidence of a software configuration management plan or process for FAVOR is not available. The FAVOR theory and user manual provided most of the information on

how FAVOR changed over time. NUMARK was unable to identify and capture documents or procedures on how FAVOR's source and configuration are controlled.

4. Other than the FAVOR Theory and User Manuals, a documented FAVOR baseline in accordance to an SQA plan has not been identified. As described in Findings 1 and 3, the SQA plan and configuration management plan would require a baseline as described in both NUREG/BR-0167 and ASME software standards.
5. Regarding functionality, FAVOR does not have the ability to provide as-found flaw characterization. FAVOR flaw input is based on the VFLAW characterization described in NUREG/CR-6817, Rev. 1, "*A Generalized Procedure for Generating Flaw-Related Inputs for the FAVOR Code*". This approach is primarily focused on characterizing possible flaw populations and not based on incorporating in-service inspection-based results at operating nuclear plants. NUMARK believes this is a missing critical function, which would allow to assess actual found conditions at operating nuclear plants.

NUMARK has identified actions to close each of the above findings. The major effort includes creating a documented baseline for FAVOR, documenting both a FAVOR SQA plan and configuration management plan, and incorporating a critical function within FAVOR to analyze as-found flaws.

All of the above findings relate to gaps in SQA based on an assessment against the rigorous SQA standards of the ASME Code. It is important to note that despite these gaps in SQA, the FAVOR code has been extensively validated and benchmarked against a combination of independent calculations and codes, including finite element models (see Section 4.1 "Historical Perspective on FAVOR"). These independent assessments have shown that FAVOR produces correct and reliable output within the range of applicability of the code. As a result, the NRC has determined that the FAVOR version 16.1 code has a sufficient level of quality and technical rigor for use in the confirmation of reactor pressure vessel toughness regulatory requirements within a risk-informed decision making process.

3 Introduction

The NRC had contracted with NUMARK to perform an assessment and summary of previous Software Quality Assurance (SQA) and Verification and Validation (V&V) activities of the FAVOR software program. FAVOR evaluates RPV integrity using algorithms, methods, and principles focused on thermal hydraulics, probabilistic risk assessment, materials embrittlement, fracture mechanics, and flaw characteristics. Key calculated outputs of FAVOR are K_I (applied stress-intensity factor) time history, through-wall temperature time history, and RT_{NDT} (Reference Nil-Ductility Transition Temperature) at the crack tip. These FAVOR outputs are further used in determining flaw propagation and determining CPI (Conditional Probability of crack Initiation) and CPF (Conditional Probability of Failure).

As noted in the FAVOR project scope of work, NUREG/BR-0167 was developed in 1993. Oak Ridge National Lab's personnel developed FAVOR under the auspices of NUREG/BR-0167 [2]. 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* [3][4].

NUMARK has identified the software quality assurance documentation previously created during development of the FAVOR code following NUREG/BR-0167. Attachment 2 and Attachment 3 list the documentation in two categories:

- Category 1: from the first version of FAVOR through the development of 10 CFR 50.61a (through FAVOR v6.1) – Attachment 2.
- Category 2: post 10 CFR 50.61a (all versions following FAVOR v6.1 up through v16.1) – Attachment 3.

These gathered documents form the basis of the assessment.

3.1 Approach to FAVOR V&V

As shown in Figure 1 (from NUREG-1874), the FAVOR computer code is one of the three main models (shown as solid blue squares), that are used together to estimate of the annual frequency of through-wall cracking in RPVs:

1. SAPHIRE – probabilistic risk assessment (PRA) event sequence analysis
2. RELAP – TH analysis
3. FAVOR – probabilistic fracture mechanics (PFM) analysis

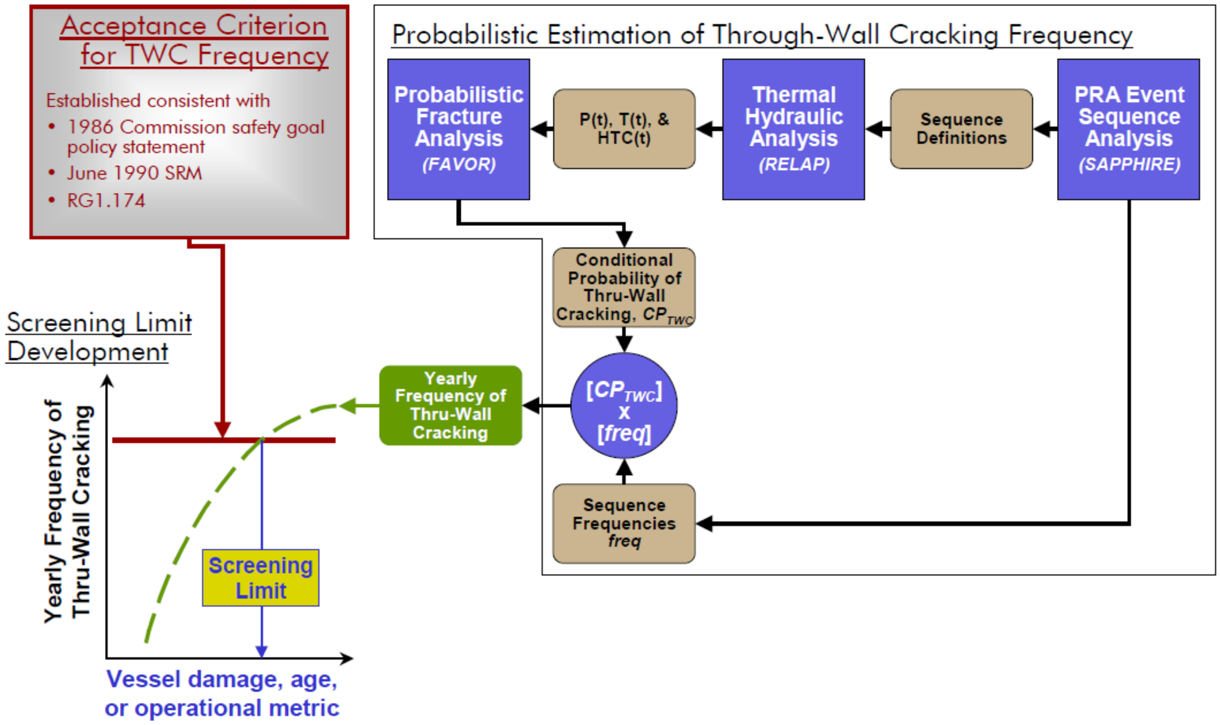

Figure 1: Schematic showing how a probabilistic estimate of TWCF is combined with a TWCF acceptance criterion to arrive at a proposed revision of the PTS screening limit

Because of the requirement to use FAVOR as part of an overall evaluation model for PRV failure probability (shown in Figure 1), NUMARK included processing of data from other computer codes in the V&V of the FAVOR code. Because the FAVOR computer code includes models that have been developed based on the evaluation of data from various tests and experiments, the review also included how this data was collected and validated for use in FAVOR.

3.2 FAVOR Project Subtask 1.2 Objectives

The objective of this task is to assess the documentation from previous FAVOR V&V efforts (compiled in Subtask 1.1 of [1]) against the guidelines in NUREG/BR-0167 [2], and to determine whether previous FAVOR V&V {efforts are consistent with the methodology described in the ASME Code Standards for V&V [3][4].

In order to assess the SQA aspects of FAVOR, this report summarizes the ASME standard on requirements for V&V of computer codes. In addition, a detailed assessment of whether previous V&V efforts meet each requirement in the standard is tabulated. Finally, if the ASME standard requirements are not met, the report provides 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.

4 Software Quality Assurance Background

4.1 Historical Perspective on FAVOR

Based on [5], prior releases of FAVOR and its predecessors were developed primarily to address the Pressurized Thermal Shock (PTS) issue. Therefore, they were limited to applications involving Pressurized Water Reactors (PWRs) subjected to cool-down transients with thermal and pressure loading applied to the inner surface of the RPV wall. These earlier versions of FAVOR were applied in the PTS Re-evaluation Project to successfully establish a technical basis to inform the revision of the original PTS Rule (Title 10 of the Code of Federal Regulations, Chapter I, Part 50, Section 50.61, 10CFR50.61). The FAVOR code continued to evolve and to be extensively applied by analysts from the nuclear industry and by regulators at the NRC, to ensure that the structural integrity of aging RPVs is maintained throughout the plant's operational service life. The v12.1 release of FAVOR represented a significant generalization over previous releases insofar as it included the ability to encompass a broader range of transients (i.e., both heat-up and cool-down) and vessel geometries, including both PWR and Boiling Water Reactor (BWR) RPVs. FAVOR v15.3, included improvements in the consistency and accuracy used for the calculation of K_I for internal surface-breaking flaws. FAVOR, v16.1, includes updates to the flaw-accounting logic in the FAVPFM module and corrections to some cladding influence coefficients for finite internal surface-breaking flaws.

The FAVOR code was subjected to both internal ORNL and external independent verification and validation studies throughout its development lifecycle. At the time of its initial release in 2001, FAVOR was being developed under the Software Quality Assurance (SQA) program at Oak Ridge National Laboratories (ORNL). Subsequent releases of FAVOR were subjected to periodic internal SQA audits; in all cases, the FAVOR code was judged compliant with ORNL SQA procedures and requirements. As the ORNL consensus standard, the ORNL SQA Program is registered to and compliant with the ISO 9001:2008 standard. In 2012, a formal ORNL SQA exemption was granted to FAVOR because the FAVOR software was being developed and maintained with funding from the NRC. The NRC support required that FAVOR be compliant with the terms and conditions of NRC Management Directive 11.7, which requires that all software development, modification, or maintenance follow the general guidance provided in NUREG/BR-0167. ASME Guides and Standards for Verification and Validation (V&V) studies and other references provided more specific guidance (specific to scientific computing applications) during the development of FAVOR. This most recent effort to assess the FAVOR SQA against the ASME Code SQA standards has identified some gaps in the documentation as outlined below. However, the NRC has determined that the FAVOR version 16.1 code has a sufficient level of quality and technical rigor for use in the confirmation of reactor pressure vessel toughness regulatory requirements within a risk-informed decision making process.

4.2 ASME V&V 10-2006 Requirements

ASME V&V 10-2006, "Guide for Verification and Validation in Computational Solid Mechanics," along with its illustrative associated standard ASME V&V 10.1-2012, "An Illustration of the Concepts of Verification and Validation in Computational Solid Mechanics," provide general guidance for implementing Verification and Validation (V&V) of computational models for complex systems in solid mechanics. Since FAVOR is a software code associated with fracture mechanics, the standards are appropriate for this assessment. The guidance is based on the following key principles:

1. Verification (i.e., addressing programming errors and estimating numerical errors) must precede validation (assessing a model's predictive capability by comparing calculations with experiments).
2. The need for validation experiments and the associated accuracy requirements for computational model predictions are based on the intended use of the model and should be established as part of V&V activities.
3. Validation of a complex system should be pursued in a hierarchical fashion from the component level to the system level.
4. Validation is specific to a computational model for an intended use.
5. Simulation results and experimental data must have an assessment of uncertainty to be meaningful.

With the above guiding principles, V&V activities and their products establish the evidence, credibility, and confidence to ensure that computer models are adequately accurate and detailed for their intended use. The standards recognize that different definitions exist for V&V within the industry. In these ASME standards, "Verification" assesses the numerical accuracy of a computational model, irrespective of the physics being modeled. Both code verification (e.g., addressing errors in the software) and calculation verification (e.g., estimating numerical errors due to under-resolved discrete representations of the mathematical model) need to be addressed. Whereas, "Validation" assesses the degree to which the computational model accurately represents the physics being modeled. Comparisons between numerical simulations and relevant experimental data form the bases of validation. Validation activities must ascertain the predictive capability of the model in the physical realm of interest, with consideration of uncertainties that arise from both experimental and computational procedures.

Figure 2 and Figure 3 are graphical representations of the ASME definition of validation and of V&V activities and products, respectively. As shown in Figure 2, the V&V processes begin with a statement of the intended use of the model so that the relevant physics are included in both the model and the experiments performed to validate the model. Both modeling and experimental activities must be guided by the response features of interest and accuracy requirements for the intended use. To ensure independence, experimental outcomes for component-level, subsystem-level, or system-level tests should be provided to method modelers only after the numerical simulations have been performed with a verified model. Accounting for uncertainties in both, the V&V process ends when acceptable agreement between model predictions and experimental outcomes are achieved. If the agreement between model and experiment is not acceptable, the processes of V&V are repeated by updating the model and performing additional experiments. The ASME standard emphasizes the importance of documentation in all the V&V activities. Sound documentation builds confidence and credibility in the predictive capability of computational models. Documentation also provides the historical record, traceability during audits, and captures valuable learning experiences for others.

With respect to Figure 3, activities are broken up into two categories, “mathematical modeling” and “physical modeling”. Modelers or method developers follow the left branch to develop, exercise, and evaluate the simulation model (e.g., time-dependent stress-intensity factors, K_{IC}, and RT_{NDT}). Experimenters follow the right branch to obtain the relevant experimental data (e.g., flaw and fracture data) by physical testing (e.g., thermal and pressure-shock vessel experiments). Modelers and experimenters collaborate in developing the conceptual model, conducting preliminary calculations for the design of experiments, and specifying initial and boundary conditions for calculations for validation.

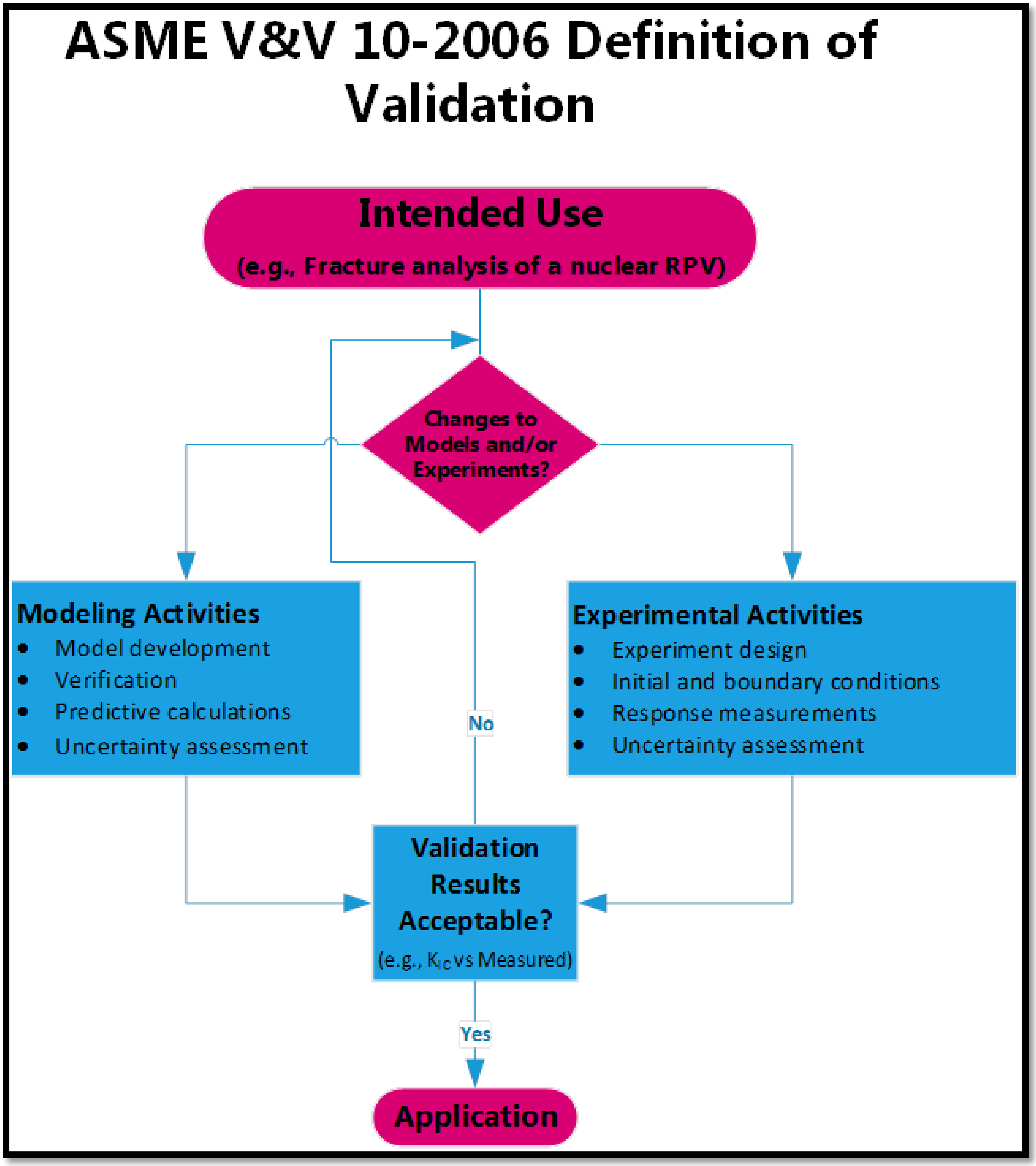

Figure 2: ASME V&V 10-2006 Definition of Validation

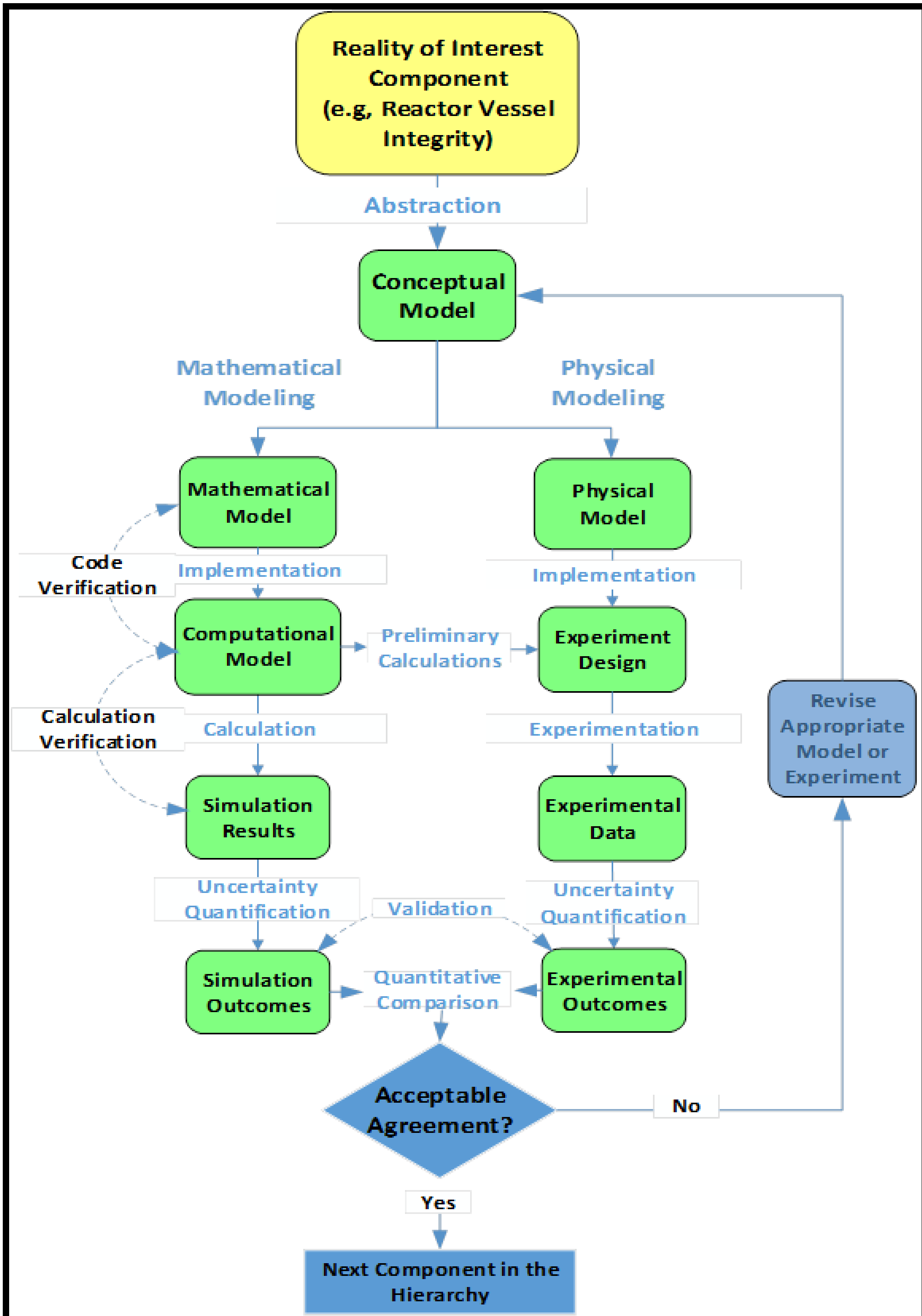

Figure 3: ASME V&V 10-2006 Validation and Verification Activities

The process shown in Figure 3 is repeated for each sub-system or sub-process until the whole system or process is evaluated. This approach in V&V requires the identification of the domain of interest, important physical processes (e.g., flaw propagation, brittle fracture, ductile tearing, etc.), important assumptions (e.g., flaw distribution), and system-response quantities of interest. Ultimately these lead to producing the modeling approach. The V&V plan that establishes the validation requirements use these considerations as input to the development of the overall V&V plan. For instance, the types of experiments to be performed and the required accuracy between the experimental outcomes and simulated results are goals of the V&V plan. This approach is typically iterative in nature between developers, experimenters, and decision makers.

In the mathematical modeling activity, the model developer constructs a mathematical representation of the conceptual model that describes physical reality, including the geometric description, governing equations, initial and boundary conditions, constitutive equations, and external forces. Following this activity, the developer creates the computational model on a specific computing platform using forms of numerical discretization, solution algorithms, and convergence criteria. Numerical procedures can include finite element (e.g., as used in ABAQUS), finite difference (e.g., used in the Initiation-Growth-Arrest model within FAVOR), or other numerical solution schemes. When verifying the code, the developer uses the computational model on a set of problems with known solutions. These problems typically have much simpler geometry, loads, and boundary conditions than the validation problems, to assist in identifying and eliminating algorithmic and/or programming errors.

Following the preliminary code verifications of simple problems, a version of the computational model is used for validation problems (i.e., using geometries, thermal and pressure loads, and boundary conditions typical of those problems for which the software was designed). These verifications are used to identify if sufficient mesh resolution exists to arrive at a solution with acceptable tolerance, including the effects of finite arithmetic precision. Calculation verification ultimately yields a quantitative estimate of the numerical precision and discretization accuracy for calculations made with the computational model for the validation experiments. In the next block of the flowchart in Figure 3, the code developer runs the computational model to generate the simulation results for the validation experiments. The simulation results can also be post-processed to generate response features for comparison with experimental data. In the subsequent uncertainty quantification activity, the developer quantifies the uncertainties in the simulation results that are due to the inherent variability in model parameters (i.e., aleatory uncertainty) or to lack of knowledge of the parameters or the model form (i.e., epistemic uncertainties). The results of the parameter and model-form uncertainty quantification should be combined with those of the calculation verification to yield an overall uncertainty estimate associated with simulation results. Features of interest extracted from simulation results and estimates of uncertainty combine to form the simulation outcomes that are used for comparison with the experimental outcomes.

In the first two activities of the right experimental branch of Figure 3, experimenters conceive validation experiments (e.g., Heavy-Section Steel Technology Program Intermediate Pressure Vessel Tests) based on the physical modeling activity and designed as part of the implementation activity. The purpose of validation experiments is to assess the accuracy of the mathematical model; therefore, all assumptions should be understood, well defined, and controlled. To assist with experiment design, preliminary calculations (including sensitivity and uncertainty analyses) are recommended, for example, to identify the most effective locations and types of measurements needed from the experiment. These data should include not only response measurements, but also measurements needed to define model inputs and model input uncertainties associated with loading, initial conditions, boundary conditions, etc. The code developer and experimenter should continue to work together, so that they are both continually aware of model and/or experiment assumptions (e.g., ductile and/or brittle fracture failures). By observing the preparations for the experiment, for example, the developer will frequently detect incorrect assumptions in the model. However, experimenters should not prematurely release results to the developer to prevent inadvertent or intentional tuning of the model to match experimental results.

The experimentation activity involves the collection of raw data from various instruments used in the experiment (e.g., strain and pressure gauges, processed data, and/or high-speed photos/videos). To quantify uncertainties, the experiments are repeated. Experimenters will consider many sources of uncertainty, such as measurement error, design tolerances, manufacturing and assembly variations, unit-to-unit fabrication differences, and variations in performance characteristics of experimental apparatuses.

Following experimental and simulation outcomes for the actual test conditions, both code developer/ modeler and experimenter perform the validation assessment activity by comparing the outcomes. The comparison metrics that were specified during the formulation of the V&V plan, including the acceptance criteria, are used to assess the model's predictive capability. Depending on the comparison results, a decision is made on whether improvements are initiated in the conceptual, mathematical, and computational models and/or in the experiments (e.g., inclusion of both ductile and brittle fracture models).

The process within Figure 3 is repeated for any additional sub models or higher-level models that need to be validated. Ultimately, all models are validated, and the results are propagated to the full-system level.

Regarding V&V planning, the ASME standard states that the V&V program should be thoughtfully planned before model development and experimentation begins. Typically, the most difficult part of V&V planning is to establish the relationship between validation experiments and the reality of interest (e.g., vessel failure for FAVOR). Determination of the type and number of cases to demonstrate predictive capability relies heavily on the required confidence that the computer model can predict the reality of interest with the required accuracy. A consensus of experts and decision makers usually defines the set of conditions for which the system model's predictive capability is demonstrated to be accepted for its intended use.

Due to the complexity of physical systems and the model simulations that predict their behavior, typically only a limited number of measurements can be made in validation experiments. This is the case for the FAVOR code and RPV embrittlement. Therefore, V&V plans must identify the features of interest before the experiments are designed. Application requirements usually drive the features to measure. Usually these are tied to safety or reliability (e.g., for FAVOR, RPV integrity). At this level, this may require product safety or reliability parameters to be defined in objective engineering terms (e.g., through wall crack frequency). Specifications for metrics used for comparisons of outcomes, such as root-mean-square (RMS) differences, should also be developed.

The accuracy requirements for predicting the response features of interest (e.g., through-wall crack frequency) with the computer software model are based on the intended use and may rely on engineering judgment (e.g., 360° circumferential flaw) or a formal risk analysis (e.g., Probabilistic Fracture Mechanics(PFM)). Specification of accuracy requirements allows for a quantitative answer to the "acceptable agreement" question.

Sensitivity analyses of individual components on the complete system can be used to estimate the contribution of each model (e.g., heat load on through wall crack frequency). The estimated contributions can then be used to establish commensurate accuracy requirements. It is reasonable to expect that the accuracy requirement for component behavior will be more stringent than the accuracy requirements for the complete system due to the simpler nature of problems at the component level and the compounding effect of propagating inaccuracy up through the hierarchy.

Documentation of the various V&V activities and products is important not only for the current intended use, but also for potential future uses. V&V documentation allows a knowledge base to be built. For example, in many applications, derivative or closely related product designs are used in the development of future designs. If a thorough execution and documentation of V&V has been performed, the elements of the V&V may be reusable.

The above discussion of the ASME standard [3] provides an outline of the basic principles and characteristics of a careful and logical approach to implementing V&V activities. The standard along with the accompanying illustrative standard [4] continues with further detail of each of the V&V processes and activities, which will not be repeated herein.

4.3 NUREG/BR-0167 V&V Requirements

NUREG/BR-0167, "*Software Quality Assurance Program and Guidelines*," [2] provides guidelines for NRC organizations and NRC contractors for software life cycle, verification and validation activities, documentation and deliverables, project management, configuration management, nonconformance reporting and corrective action, and quality assessment and improvement. Section 3 of NUREG/BR-0167 covers Verification and Validation (V&V). Similarly noted in the previous section for ASME SQA requirements, other sections within the NUREG standard also contain important information related to quality assurance, such as software quality procedures, configuration control, record keeping, problem reporting and corrective action, and system support software. No evidence was found that FAVOR was built under these requirements other than the FAVOR historical perspective which was taken from [5]. For the purposes of Subtask 1.2, the focus will be only on V&V.

Different than the ASME V&V 10-2006, NUREG/BR-0167 defines <u>verification</u> as the process of ensuring that the products and processes of each major activity of the life cycle meet the standards for the products and the objectives of that major activity. Whereas <u>validation</u> is the process of demonstrating that the as-built software meets its requirements. Testing is the process of detecting errors and verifying performance. Testing typically includes unit, integration, qualification, and acceptance testing.

The guideline further states that "independent" V&V is performed by an organization that is both technically and managerially separate from the organization responsible for developing the software. A special consideration is made for sponsors and users of Level I software that they should together decide if the expense of a separate independent V&V contractor is warranted for the project. Typically, the sponsor is the NRC organization that sponsors and manages the software development/maintenance effort. The sponsor acts as the acquirer or buyer for the user. A developer is the organization that develops or maintains the software, often a contractor.

According to the guideline, examples of verification activities include:

1. Formal major life cycle reviews and audits (e.g., Preliminary Design Review);
2. Formal peer inspections (e.g., code inspections, documentation reviews); and
3. Informal tests (e.g., unit and integration testing).

Testing is the primary method of software validation. Qualification and acceptance testing, which are formal tests, are validation activities. Validation is accomplished by review and demonstration in a live or simulated environment. The objectives of validation activities are to ensure that:

1. The as-built software correctly and adequately performs all intended functions;
2. The software does not perform any unintended function that either by itself or in combination with other functions can degrade the entire system; and
3. All non-functional requirements (e.g., performance, design constraints, attributes, and external interfaces) are met.

Software validation activities include the development of test plans, test procedures, and test reports.

Regarding software modifications, selective regression testing is used to validate the modifications to previously validated software. The objectives of regression testing are to:

1. Detect possible errors introduced during the modification process;
2. Ensure that the modifications have not caused unintended adverse effects; and
3. Validate that the modified software still meets specified requirements.

Section 3.2 of the guideline provides V&V activities expected during the software life cycle. A specific note is made to not apply the guideline rigidly and to use it in conjunction with management and engineering judgement, and with cost-effectiveness in mind. The first aspect covered is the planning activity. Planning for verification and validation takes place during the sponsor's initial planning for the project (e.g., the proposal stage) as well as during the requirements definition, design, and implementation of major activities in the life cycle. Planning activities include:

1. Development or tailoring of procedures for conducting formal life cycle reviews;

2. Development or tailoring of procedures for reviewing documentation and other deliverables;
3. Development or tailoring of procedures for conducting inspections;
4. Definition of a detailed test methodology including standards for test documentation, specifically for test plans, test procedures, and test reports for both qualification and acceptance testing;
5. Preparation of a validation matrix showing the relationship of software requirements to the software architecture down to the unit level and to the tests used to verify the requirements; and
6. Identification of needs for development and test tools, equipment, and data.

The guideline provides two tables of the various V&V activities by major life cycle activity. These two tables were combined in Table 1. Formal reviews by the sponsor, developer management, and participating technical personnel are held at or near the end of each major activity of the life cycle. This review covers the deliverable products, the progress, and to a limited extent the processes of the most recent life-cycle phase. The guideline provides further specifics of each review.

Formal peer inspections are performed during the various life cycle activities. These inspections examine in detail on a step-by-step or line-by-line basis the software product of interest and are dependent on the classification level of the software. Three levels of software are defined in the guideline. Level 1 software is technical application software used in a safety decision by the NRC (e.g., RELAP5). Level 2 software is technical or non-technical software not used in a safety decision by the NRC (e.g., agency financial system). Level 3 software is technical or non-technical allocation software not used in a safety decision and having low or limited use by the NRC (e.g., a macro for Lotus 1-2-3 or Excel). For level 1 software, the developer must subject each intermediate and final product to an internal peer inspection, make available to the sponsor the written procedure and the product standards that govern the peer inspection, and make available the peer inspection results to the sponsor. For level 2 software, the developer is “encouraged” to work toward subjecting each intermediate product and final product of development to an internal peer inspection. It should be noted that no FAVOR documentation was found that classified the software level. Based on the contractor’s review of FAVOR applications, FAVOR should be categorized as level 1 software.

Table 1: Verification and Validation Activities by Major Life Cycle Activity (Source: NUREG/BR-0167)

Major Life Cycle Activity	Verification and Validation Activities	Formal Reviews and Audits
Requirements Definition	• Inspect requirements • Develop overall V&V plan • Conduct the Software Requirements Review	• Software Requirements Review
Design	• Inspect design • Develop qualification test plan • Develop acceptance test plan • Conduct the Preliminary Design Review • Conduct the Critical Design Review	• Preliminary Design Review • Critical Design Review
Implementation	• Develop unit test plans • Inspect unit designs, unit code, and unit test plans • Perform unit testing • Inspect unit test results • Develop integration test plans • Inspect integration test plans • Develop qualification test procedures	• Qualification Test Readiness
Qualification Testing	• Perform qualification testing • Write qualification test report • Develop acceptance test procedure	• Software Configuration Audit
Installation and Acceptance	• Perform acceptance testing • Write acceptance test report	• Software Configuration Audit • Post Mortem Review
Sustaining Engineering and Operations	• Perform, as appropriate, the verification and validation activities defined above for requirements definition, design, implementation, qualification testing, and installation and acceptance. • Perform regression testing as well as new tests for all levels of testing, as appropriate.	• The formal reviews and audits above, as applicable

NUREG/BR-0167 guideline covers four levels of software testing including unit testing, integration testing, qualification testing, and acceptance testing. “Unit” refers to an element of the software design that can be compiled or assembled and is relatively small (e.g., 100 lines of code). “Integration” focuses on a collection of related “units” that performs an identifiable functional requirement (i.e., something provided in the software requirements document). "Qualification" is the process that allows the sponsor to determine whether the software product complies with its requirements. "Acceptance" refers to the process that allows the sponsor to determine whether the software product complies with its requirements after it has been installed in its operational environment.

The guideline further describes requirements-driven and design-driven testing. Design-driven testing is accomplished by selecting input data and other parameters to verify all paths through the code, interfaces between units (e.g., FAVLoad, FAVPFM, and FAVPost), and size and timing of critical elements of code. Requirements-driven (i.e., black-box) testing is focused on software requirements and observing output and software response. This testing verifies computations, proper handling of boundary conditions (i.e., extreme inputs and extreme outputs), state transitions, proper behavior under stress or high load, and adequate error detection, handling and recovery. Other testing includes "operational testing" or the common name "beta" testing. Operational testing would be considered qualification testing and are requirements-driven.

For level 1 and level 2 software as defined in the guideline, formal testing is always requirements-driven, and its primary purpose is to demonstrate that the software meets its requirements. Formal tests include a sponsor-approved test plan and procedures, test witnesses, a record of all nonconformance, and a test report. When software is developed in increments, there may be incremental qualification and acceptance tests. Of note, following acceptance of a software product, all changes to the product should only be accepted following a successful formal test. Regression testing is one means for post-acceptance testing and involves rerunning previously used acceptance test cases to ensure that the change did not inadvertently introduce an error into the previously accepted software.

4.4 FAVOR Critical Inputs, Functions, and Outputs

To assess whether the FAVOR code meets the requirements for V&V in ASME V&V 10-2006 and NUREG-BR-0167, a list of key inputs to FAVOR, the important functions and algorithms used in FAVOR, and the FAVOR outputs used in critical decisions need to be listed. Some key calculated outputs of FAVOR are K_I (applied stress-intensity factor) time history, through-wall temperature time history, and RT_{NDT} (Reference Nil-Ductility Transition Temperature) at the crack tip. These FAVOR outputs are further used in determining flaw propagation and determining CPI (Conditional Probability of crack Initiation) and CPF (Conditional Probability of Failure). A review of both the FAVOR theory manual [5] and user input guide [6] is the main source for this information.

Table 2 provides a detailed listing of those items that are key attributes to be used in the V&V. The table is split up into 3 areas; key inputs, FAVOR functions, and critical outputs.

Table 2: FAVOR Critical Inputs, Functions, and Outputs

Type	Description
Key Inputs	• Thermo-Mechanical Material Properties for clad and base metal of the RPV (i.e., thermal conductivity, specific heat, density, Young's Elastic Modulus, thermal expansion coefficient, Poisson's ratio) • RPV geometry • Thermal Hydraulic boundary conditions (from RELAP or similar Transient T-H code) • Fast Neutron fluence maps (entered as f_o on Embrittlement Data, described below) • Flaw densities, size, and location (plates, welds, and forgings) • Embrittlement Data (i.e., Cu, Ni, P, Mn, f_o, RT_{NDT0}) • Transient Initiating Frequency distributions (from PRA) • Probability distributions (aleatory and epistemic)

Important Functions and Algorithms	• FAVLoad Deterministic analyses
	  ○ Thermal analysis
	  ○ Stress analysis
	  ○ Linear-Elastic Fracture Mechanics (LEFM)
	  ○ Handling of residual stresses in welds
	  ○ Handling of crack-face pressure for surface breaking flaws
	• Calculation of Nil-Ductility Transition Temperature, RT_{NDT}
	• Radiation embrittlement correlations
	• Fast-neutron fluence attenuation and sampling
	• Handling of K_{IC} and K_{Ia} Databases and calculations of K_{IC} and K_{Ia}
	• Sampling of RT_{NDT} and RT_{Arrest}
	• Sampling of Material Chemistry
	• Flaw characterizations and uncertainty
	• FAVPFM algorithms and models
	  ○ Warm prestressing logic
	  ○ Truncation for probability distributions
	  ○ Conditional Probability of Initiation (CPI) and Failure (CPF)
	  ○ Post initiation of flaw geometries and orientation
	  ○ Ductile tearing models
	  ○ Initiation-Growth-Arrest (IGA) model

Critical Outputs	• Temperature as a function of time throughout vessel wall location • Stress as a function of time throughout vessel wall (circumferential and axial) • K_I as a function of time throughout vessel wall • Probability distributions of crack initiation and vessel failure • Crack initiation frequency per reactor operating year • Through-wall crack frequency per reactor operating year

5 FAVOR Assessment

A review of the referenced documents gathered in Subtask 1.1 against the key attributes in Table 2 provided the main source information in assessing whether the FAVOR code meets the requirements for V&V in ASME V&V 10-2006 and NUREG-BR-0167. Attachment 2 and Attachment 3 provide a list of the acquired FAVOR supporting documents pre-2006 and post-2006, respectively.

To assess whether the FAVOR code meets the requirements for V&V in ASME V&V 10-2006 and NUREG-BR-0167, a comparative matrix was developed (Attachment 4, Attachment 5, and Attachment 6). The first column of the matrix contains those key inputs to FAVOR, the important functions and algorithms used in FAVOR, and the FAVOR outputs used in critical decisions. Columns 2 through the end of the matrix contain the requirements from the ASME and NUREG standards. For each field in the matrix a comparison is made between the applicable FAVOR parameter and its applicable requirement. A reference is provided in that field if there is adequate evidence of meeting the requirement. Otherwise, the text "Gap" is entered to identify that sufficient evidence is not provided. A table cell which only contains the text "Gap" in both pre- and post-2006 versions of FAVOR is considered a deficiency and is captured in a finding

5.1 General Observations

Many independent and technically competent organizations in the nuclear industry have been involved in FAVOR V&V activities. Some of these companies include Electric Power Research Institute (EPRI), Westinghouse, Pacific Northwest National Lab (PNNL), Idaho National Engineering Environmental Laboratory (INEEL), and Center for Nuclear Waste Regulatory Analyses (CNWRA). Other organizations, such as Brookhaven National Labs and Sandia Labs, have been involved in developmental activities. This historical review and development have improved FAVOR's methods and models over time. As shown in the comparative matrices (Attachment 4, Attachment 5, and Attachment 6), FAVOR has undergone a comprehensive review of its critical inputs, functions, and outputs (Table 2).

The review identified that most V&V activities focused on benchmark calculations comparing FAVOR inputs, functions, and outputs against another independent tool. The primary benchmark tool for the inputs (e.g., geometry, thermal-hydraulic, and material properties), algorithms (e.g., finite element stress analysis, and stress intensity factors), and outputs (temperature and stress as a function of time throughout vessel wall and K_I as a function of time) is ABAQUS. ABAQUS is an independent software program that performs finite element analysis of structures with the ability to model crack propagation. ABAQUS is an industry recognized tool that is used in sophisticated engineering problems covering a wide spectrum of applications.

Other benchmark tools used in FAVOR's V&V activities include SAS and Microsoft Excel. These tools assisted in assessing FAVOR's sampling algorithms, flaw sampling, and probability distributions (probability distributions of crack initiation and vessel failure, and other statistics). Both SAS and Microsoft Excel are widely used and recognized as accurate tools within the industry.

Overall, the NRC has determined that the FAVOR version 16.1 code has a sufficient level of quality and technical rigor for use in the confirmation of reactor pressure vessel toughness regulatory requirements within a risk-informed decision making process..

5.2 Detailed Findings

5.2.1 Finding 1: Absence of SQA Plan

Following initial review of the current FAVOR related documentation from Subtask 1.1 and discussions with the NRC, the team determined that a literature search for SQA plans of other nuclear codes should be completed. The team identified four other codes, FRAPCON/ FRAPTRAN, MELCOR, SCALE, and TRACE. A brief description of each software program is provided below;

1. FRAPCON/FRAPTRAN – Pacific Northwest National Labs (PNNL) developed nuclear fuel rod performance codes that predict the steady-state (FRAPCON) and transient (FRAPTRAN) behavior of light-water reactor fuel rods during. These codes calculate (among many other outputs) the temperature, pressure, and deformation of a fuel rod as functions of time-dependent fuel rod power and coolant boundary conditions.
2. MELCOR – Sandia National Lab developed nuclear severe accident code that models a comprehensive spectrum of severe accident phenomena, including thermal-hydraulic response of the reactor coolant system, containment, reactor cavity, and confinement buildings. In addition, the code has the capability of modeling core heat-up and degradation, radionuclide release and transport, hydrogen production and transport and combustion, core-concrete attack, heat structure response, and the impact of engineered safety features.
3. SCALE – ORNL developed nuclear code that provides modeling and simulation capabilities for cross-section processing, criticality safety, reactor physics, radiation shielding, radioactive source term quantification, including radiation spectra, decay heat, nuclide generation and decay, as well as sensitivity and uncertainty analysis.
4. TRACE – NRC thermal-hydraulic code that analyzes large/small break LOCAs and system transients in both PWRs and BWRs. The code has the capability to model transient thermal hydraulic phenomena in both one-dimensional and three-dimensional space. TRACE integrates the capabilities of TRAC and RELAP.

The SQA plans for these codes are quite similar in content in that they incorporate the elements described herein from NUREG/BR-0167 and ASME standards (e.g., configuration management/control requirements, software requirement document, test plans, software development documents, error reporting, and V&V). **A similar SQA plan was not identified for the FAVOR code, and therefore a significant gap exists regarding SQA for FAVOR (Finding 1).** The gaps identified in Attachment 4, Attachment 5, and Attachment 6 under the design phase provides evidence that an SQA plan does not exist, because a plan would require these design activities to be performed. The design and configuration control of FAVOR would greatly benefit from an SQA plan similar to one such as FRAPCON/FRAPTRAN.

The finding that FAVOR has no SQA plan impacts the initial approach for V&V. Since no SQA plan exists for FAVOR, the following cannot be confirmed with high confidence and credibility:

1. Current software code and version;
2. All errors have been reported and addressed;
3. Documentation consistency between code and theory manual and user's guide; and
4. Previous testing that was for V&V efforts was on the actual intended version.

An updated approach requires making assumptions on the prior developmental and testing activities for FAVOR and creating a baseline for FAVOR that would bring it up to SQA standards with a configuration management/control that allows for future controlled code modifications.

5.2.2 Action to Close Finding 1

The action to close this finding is to develop an SQA plan. This SQA plan would incorporate the following suggested sections:

1. Purpose, reference documents, roles and responsibilities;
2. Software risk determination and description;
3. Code development planning and assignment;
4. Software requirements,
5. Design elements, such as tools and techniques, reviews, code development (standards and unit testing);
6. Configuration management aspects, such as tools and techniques, verification testing, validation testing;
7. Issue reporting and change control;
8. Training aspects and personnel qualifications;
9. Procurement related activities; and
10. User documentation.

As a part of the SQA plan, a documented baseline of FAVOR is recommended. Since FAVOR has been in development over many years, establishing a new baseline could be achieved by performing the following activities:

1. Select a series of test cases that encompass the previous V&V activities, and code version changes. The number of test cases should be commensurate with the desired level of risk, confidence, and reliability. For instance, a high number of cases are required in a high-level risk area if a high level of confidence is desired. The selection should consider the following:
    a. Previous code modifications: select several cases commensurate with the risk and complexity of the change;
    b. Cases that benchmark the code to measurements, tests, or standards (e.g., vessel failure tests and ABAQUS benchmarks); and
    c. Cases that test parameter boundaries (e.g., transient severity, flaw sizes and flaw locations).
2. Run the FAVOR v16.1 code, which is the assumed current and correct version, for all selected test cases. Record and document date/time creation date of the FAVOR code

source and executables (FAVLoad, FAVPFM, FAVPost) and create a unique identifier (i.e., something that a user or programmer cannot inadvertently change).

3. Document the input of all the selected test cases and their key output files along with date/time creation in a letter report or paper. These cases should be saved maintaining their date/time of creation. These will be used in the future to test modifications to FAVOR and/or verifying portability of FAVOR to other users and platforms.
4. Compare the test case results to those of the previous V&V activities or benchmarks. Document the findings in a letter report or paper.
    a. If results match those of the past V&V activities and/or benchmark, then assurance and confidence has been achieved that the current FAVOR code(s) meet the theory and methods as described in [5] and [6].
    b. If results don't match, then investigations need to be performed to explain the difference. Once the cause is understood, it should be corrected. If the difference is well within numerical accuracy of the method, then the difference may be accepted. In all cases, the differences and corrections should be documented in a letter report or paper.
5. From the matrix, compare the test case results to those of the previous V&V activities or benchmarks. Document the findings in a letter report or paper.

5.2.3 Finding 2: Absence of Change Control and Documentation

As identified in Attachment 4, Attachment 5, and Attachment 6 of the gap analysis, the gathered Category 1 and 2 documents do not cover the design phase aspects of NUREG BR-0167. No documents were found that showed inspection, qualification test plan, acceptance test plan, preliminary design review, or critical design review of the FAVOR software **prior** to implementing the new version. This would be information surrounding how the software design change would be tested and accepted **prior to release**. Some documents captured qualification testing and acceptance testing **following FAVOR version release**.

5.2.4 Action to Close Finding 2

The action that addresses Finding 1 would partially address Finding 2 in that it would re-baseline FAVOR. Going forward, an SQA plan would specify the requirements for inspection, the qualification test plan, the acceptance test plan, the preliminary design review, and the critical design review prior to developing a new version of FAVOR. This focus is primarily on documentation on the various testing prior to FAVOR production release. Completion of the action to close Finding 1 will also close Finding 2.

5.2.5 Finding 3: Absence of Software Configuration Management

Evidence of a software configuration management plan or process for FAVOR is not available. The FAVOR theory and user manual provided most of the information on how FAVOR changed over time. NUMARK was unable to identify and capture documents or procedures on how FAVOR's source and configuration are controlled. A configuration management plan would help ensure the following:

1. FAVOR's versions and baselines could be uniquely identified;

2. Specific versions of FAVOR deliverables (e.g., software source, sample problems, theory and user manuals) can be easily retrieved (or reproduced);
3. Unintended and/or conflicting changes are prevented by users, administrators, and programmers;
4. Unintended use is prevented;
5. Software changes would be tracked and controlled from concept, design, various testing (as identified in ASME V&V 10-2006 and NUREG-BR-0167), through implementation;
6. FAVOR error reporting and corrective action process would be established.

5.2.6 Action to Close Finding 3

The SQA plan that addresses Finding 1 would identify that it would require a configuration management process or plan for FAVOR. The configuration management plan would cover the following FAVOR software requirements:

1. Software Baseline (addressed in Finding 4);
2. Roles and responsibilities for activities within the plan;
3. Configuration identification - describing how each configuration of the revised software is uniquely identified and cannot be easily circumvented;
4. Configuration change control - describing how initiation, evaluation, and disposition of a software change request would be handled;
5. Control and approval of changes to the software baseline prior to implementation;
6. Requirements for retesting (e.g., regression testing) and acceptance of the test results;

5.2.7 Finding 4: Absence of FAVOR Baseline

Other than the FAVOR Theory and User Manuals, a documented FAVOR baseline in accordance to an SQA plan has not been identified. As described in Findings 1 and 3, the SQA plan would require a baseline as described in both NUREG/BR-0167 and ASME software standards. A FAVOR baseline would be formally reviewed and agreed upon by the developer and sponsor, and thereafter serves as the basis for further development. Changes would only occur as defined in the SQA plan and configuration management plan. Change control is the process by which a change to a baseline is proposed, evaluated, approved or rejected, scheduled, and tracked. Another key aspect of the baseline is having a set of sample problems covering key attributes so future FAVOR modifications can be tested against them. These sample problems, when run, help to identify and correct any unintentional changes in software logic, design, input specification, or results.

5.2.8 Action to Close Finding 4

The action that addresses Findings 1 and 3 would address Finding 4 in that it would create a baseline for FAVOR and a set of sample problems that would test the key FAVOR attributes over a range of input values representing operating both PWRs and BWRs. In order to document a baseline, the actions that close Findings 1 and 3 would be required, to ensure that the baseline is accurate.

5.2.9 Finding 5: Key Capability Deficiency: As-Found Flaw Modeling

FAVOR, primarily FAVPFM, does not have the capability to provide as-found flaw characterization. An aspect of this assessment is ensuring that key attributes of FAVOR have been specified and incorporated in its models for evaluating reactor vessel integrity (FAVOR's main intended purpose in Figure 2). A part of ensuring reactor vessel integrity is performing in-service inspection activities as defined in 10 CFR 50 Appendix H, "Reactor Vessel Material Surveillance Program Requirements." These surveillance activities are focused on Drop-Weight and Charpy V-Notch impact tests that measure radiation embrittlement (i.e., RT_{NDT}) over vessel lifetime. Much of the FAVOR models are based on this approach (e.g., Regulatory Guide 1.99, Rev. 2 and other incorporated models). However, another type of reactor vessel surveillance includes the requirements from Section XI of the ASME code (§ 50.55a of 10 CFR Part 50) and NRC Regulatory Guide 1.150, "Ultrasonic Testing of Reactor Vessel Welds during Preservice and Inservice Examinations". Regulatory Guide 1.150 states "Reactor vessels must periodically be volumetrically examined according to Section XI of the ASME Code, which is incorporated by reference, with NRC staff modifications, in § 50.55a of 10 CFR Part 50. The rules of Section XI require a program of examinations, testing, and inspections to evidence adequate safety. To ensure the continued structural integrity of reactor vessels, it is essential that flaws be reliably detected and **evaluated**." Evaluation of identified flaws are essential in meeting this part of the regulation. FAVOR does not have the direct capability to evaluate as-found flaws.

The current FAVOR flaw input is based on the VFLAW characterization described in NUREG/CR-6817, Rev. 1, "*A Generalized Procedure for Generating Flaw-Related Inputs for the FAVOR Code"*. This approach is primarily focused on characterizing possible flaw populations and not based on incorporating in-service inspection-based results at operating nuclear plants or addressing specific flaw locations within the vessel wall. When developing VFLAW, Pacific Northwest National Labs (PNNL) had applied an expert judgment elicitation process and used the PRODIGAL flaw simulation model developed in the United Kingdom by Rolls-Royce and Associates. Then based on that data, PNNL has developed statistical distributions to characterize the number and sizes of flaws in the various regions of RPVs.

5.2.10 Action to Close Finding 5

This action would require a software change. Per the NUREG/BR-0167 and ASME standards and the future SQA plan for FAVOR, changes to software would be formally documented. This documentation would include the following:

1. A change request document (or form) that provides a description of the change, rationale for the change, and the identification of affected software routines and baseline;
2. A document (form or email) review, evaluation, and approval by the NRC of the change request document;
3. A qualification test plan identifying the appropriate verification activities, including any retests or regression tests;
4. If required, procedures on how to run the tests. Due to the simplicity of the change (i.e., specification of different flaw file), the test plan in the previous step can capture how the tests would be performed;

5. An acceptance/qualification test plan that identifies acceptance criteria for the various identified tests (performed prior to official release of the new version);
6. If required, procedures on how to perform acceptance testing. Due to the simplicity of the output checks (i.e., flaw characterization vs RT_{NDT}, CPI, and CPF), the acceptance test plan in the previous step can accomplish this requirement;
7. A document capturing the results of acceptance and qualification testing (acceptance/ qualification testing shall be performed prior to formal version release);
8. The change shall be appropriately reflected in the theory and user guide manuals; and
9. Traceability of the change to the software design requirement shall be maintained.

A number of options exist to proceed with this software change. One option is to complete closure actions 1 through 4 prior to implementing the software modification. This would delay implementation of the modification but would increase its quality and credibility. Another option is to capture the key documentation (change description with NRC review and approval, list of qualification tests, acceptance test plan, results of the test, etc.) during the software change. The documentation gathered during the software change can be captured in the closure of all the findings. The latter approach is recommended as less time will elapse to implement the change with reasonable quality and credibility.

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Attachment 1. Historical Verification and Validation References Identified in Appendix G of FAVOR v16 Theory and Code Manual

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Attachment 2. References of Historical Validation and Verification (V&V) Efforts for FAVOR Category 1 (Prior to FAVOR Version 6.1)

File Name	Authors, Title, Date, Report Number and FAVOR Version	Document Type and Verification Topic
1994-1 Validation of FAVOR Code OCR.pdf	Bryson, John W. Dickson, Terry L. Keeney, Janis A., Validation of Favor Code Linear Elastic Fracture Solutions for Finite-Length Flaw Geometries, 1994, CONF-950740--16, 94.01	Verification of FAVOR KI solutions using SIFICS for axially and circumferentially oriented semielliptical inner surface breaking flaws; base and clad, R/t=10, ABAQUS and other solutions.
1999-1 Embedded Validation.pdf	Bass B.R., Dickson T.L., Williams P.T., Validation of a Linear-Elastic Fracture Methodology For Postulated Flaws Embedded in the Wall of a Nuclear Reactor Pressure Vessel,1999	Verification of FAVOR KI solutions for embedded flaws in RPV wall; comparison of FAVOR KI solutions with ABAQUS solutions.
2000-1 Comparison of K1 Factors for Embedded Flaws.pdf	Bass, B.R. Dickson, T.L., Giles, Jr. G.E., McAfee, W.J., Williams, P.T., Comparison of KI Factors for Embedded Flaws: FAVOR Implementation of ASME Section XI – Appendix A Methodology versus Three-Dimensional 2000, ORNL/NRC/LTR-99/26	Verification of FAVOR KI solutions for embedded flaws in RPV wall; comparison of FAVOR KI solutions with ABAQUS solutions.
2002-1 Validation of the Treatment of Flaw Related Inputs.pdf	Simonen F.A., Validation of the Treatment of Flaw Related Inputs by the FAVOR Code, March 2002, Draft, FAVOR 02.01	Verification that FAVOR is correctly reading, interpreting, and processing the output from the VFLAW computer code.
2003-1 ERPI MRP90.pdf	B. Bishop, R. Gamble, Materials Reliability Program: Validation and Verification of FAVOR v02.4(MRP-90), 2003	Verification of PFM algorithms and sampled variables in FAVOR by comparing them against independent calculations, based on the descriptions provided in the FAVOR Theory manual.
2003-3 INEEL 2.4 task 3 OCR.pdf	FAVOR 2.4 Validation Post Processing Module INEEL 1. INEEL TEST ACTIVITIES TASK (III), VALIDATION OF FAVPost 2003	Verification (by INEEL) that the FAVPost module correctly works (as described in the Theory manual) by comparing the results against independent calculations.
2003-4 INEEL favor 2.4 task II a and b OCR.pdf	Process for Validation of Embrittlement Parameter Sampling in FAVOR, 4/21/2004, FAVOR 3.1	Verification (by INEEL) of the sampling of embrittlement related parameters described in the Theory manual by comparing the results against independent (SAS) calculations.

File Name	Authors, Title, Date, Report Number and FAVOR Version	Document Type and Verification Topic
2004-1 EPRI MRP 125.pdf	B. Bishop, R. Gamble, Materials Reliability Program: Validation and Verification of FAVOR v03.1(MRP-125), 2004	To perform verification of incremental changes between FAVOR version 03.1 and version 02.4 with respect to sampling of embrittlement related parameters.
2004-2 Large-Scale Pressurized Thermal Shock Experiment Assessment.pdf	Dickson T.L., Kirk M.T., Assessment of Large-Scale Pressurized Thermal-Shock Experiments Using the FAVOR Fracture Mechanics Computer Code, 2004	Verification of FAVOR by comparing results against data generated during large scale pressurized thermal shock experiments performed at ORNL.
2004-6 FAVOR 3.1 modifications for embrittlement sampling 2272004 OCR.pdf	Appendix C. FAVOR 3.1 Modifications for Embrittlement Sampling Validation. Upper Shelf Embrittlement Parameter Sampling--INEEL, 2/27/2004, FAVOR 3.1	Incremental verification of new algorithms and associated sampled variables in version 04.1 for the evaluation of vessel failure due to ductile flaw extension.
2004-8 INEEL FAVOR Ver 3-1 Upper Shelf Energy Validation.doc	INEEL Test Activities Validation of Unirradiated Upper-Shelf Energy Embrittlement Parameter Sampling –INEEL, 2/27/2004, FAVOR 3.1	Test Plan for validation of unirradiated upper-shelf energy embrittlement sampling using independent (SAS) calculations.
2004-9 Deterministic Load Variables Validation.pdf	B.R. Bass, T.L. Dickson, P.T. Williams, A.-V. Phan, and K.L. Kruse, Verification and Validation of the FAVOR Code—Deterministic Load Variables, ORNL/NRC/LTR-04/11, FAVOR 2.2	Computation study of Deterministic Load Variables against independent ABAQUS calculations.
2004-10 Flaw Distributions Input Validation.pdf	F.A. Simonen, PNNL, Validation of the Treatment of Flaw Related Inputs by the FAVOR Code, Draft Report 2004, FAVOR 2.3	Verification that FAVOR correctly assigns the number, size, and locations of flaws to the weld and base metal regions of an RPV using independent PPNL calculations.
2005-1 NUREG-1795 FAVOR 2.4 AND 3.1.pdf	Shah N.M Malik, NUREG-1795 FAVOR Code Versions 2.4 and 3.1 Verification and Validation Summary Report, 2005	NUREG-1795 FAVOR Code Versions 2.4 and 3.1 Verification and Validation Summary Report 2005.

File Name	Authors, Title, Date, Report Number and FAVOR Version	Document Type and Verification Topic
2005-2 FAVOR v04.1 Validation and Verification.pdf	B. Bishop, R. Gamble, Materials Reliability Program: Validation and Verification of FAVOR v04,1, 2005, EPRI MRP-171	Incremental verification of new algorithms and associated sampled variables in version 04.1 for the evaluation of vessel failure due to ductile flaw extension.
2007-3 FAVOR v06.1 Validation and Verification MRP-226.pdf	B. Bishop, R. Gamble, Materials Reliability Program: Validation and Verification of FAVOR v06,1, 2005, EPRI MRP-171.	Validation and Verification Report on FAVOR v06.1(MRP-226).

Attachment 3. References of Historical Validation and Verification (V&V) Efforts for FAVOR Category 2 (Post FAVOR Version 6.1)

File Name	Authors, Title, Date, Report Number and FAVOR Version	Document type and verification topic
2010-1 Load Module New Capability Verification.pdf	Bass B.R., Dickson T.L., Shengjun Yin, Williams P.T., Verification of New Capabilities of Deterministic Load Module of Favor 09.01, 2010, PVP2010- 25439, FAVOR 09.01	ASME paper describing verification of FAVOR KI solutions versus ABAQUS solutions for internal surface breaking flaws, external surface breaking flaws, and embedded flaws in BWR geometries.
2011-1 Verification and Validation of the FAVOR 9.1 Code.pdf	Adams G., Simonen F., Wilt T. Verification and Validation of the Version 09.1 Code, 2011, FAVOR 09.1	Incremental verification of 09.1 version of FAVOR relative 06.1 version of FAVOR. Performed by (SWRI). Scope is limited to: new warm pre-stress options, new embrittlement trend curves.
2016-7 FAVOR v16.1 Verification and Validation Studies.pdf	P.T. Williams, T.L. Dickson, B.R. Bass. H.B. Klasky, Fracture Analysis of Vessels - Oak Ride FAVOR, v. 16.1, Computer Code: Appendix G Verification and Validation Studies	Procedures and processes used to ensure that FAVOR meets its software requirements.
2017-1 Fracture Mechanics Computer Code Analysis of Nuclear Reactor Pressure Vessels.pdf	Bass B.R., Dickson T.L., Klasky Hilda B. Williams P.T., FAVOR Version 16.1-A Computer Code for Fracture Mechanics Analyses of Nuclear Reactor Pressure Vessels, 2017, PVP2017-65262, FAVOR 16.1	FAVOR v16.1 computer code for fracture mechanics of nuclear reactor pressure vessels.

Attachment 4. FAVOR V&V Checklist Results – Prior to FAVOR Version 6.1

Interpretation of FAVOR V&V Checklist Results - Prior to FAVOR Version 6.1

The cells in the tables below are colored based on the degree to which the V&V requirements are met for each FAVOR attribute, as follows:

- Green cells: the V&V requirement is met for this attribute for the last version of the code in the time period considered.
  - For the table about FAVOR prior to version 6.1 (Attachment 4), this means the requirements are met for version FAVOR v03.1 based on documentation through 2005.
  - For the table about FAVOR from version 6.1 to version 16.1 (Attachment 5), this means the requirements are met for FAVOR v16.1 based only on the documentation produced from 2006 to 2016.
  - For the table about all past versions of FAVOR (Attachment 6) up to version 16.1 (the current version as of the date of this report), this means the requirements are met based on all documentation available for all past versions.
- Yellow cells: the V&V requirements were met for an earlier version of FAVOR, but not the latest for the time period considered.
- Red cells: the V&V requirements were not met for any version of FAVOR within the period considered.

When cells are empty and have no color coding, this means the FAVOR attribute was either nonexistent (for versions prior to v6.1, see Attachment 4), or that the FAVOR attribute was not modified (when considering only the 2006 to 2016 period, see Attachment 5).

Notes:

1. **Validation** is based on whether the attribute meets the metric of a measurement (e.g., vessel failure, crack propagation), benchmark (e.g., ABAQUS), regulatory requirement (NRC, ASME, ASTM), or defined conservatism. Identifiers are **M** = Measurement, **B** = Benchmark, **R** = Regulatory, and **C** = Conservativism. The ASME standard focuses on Measurement as true validation.
2. **Field Key Description**: Report/paper number prefix as identified in SQA Cat 1 and Cat 2 documents ("year-sequence#"). For example, "2000-1" corresponds to the letter report entitled, "Comparison of *KI* Factors for Embedded Flaws: FAVOR Implementation of ASME Section XI – Appendix A Methodology versus Three-Dimensional Finite-Element Solutions", ORNL/NRC/LTR-99/26, April 2000. Additional fields are provided following the Report/paper reference. Under requirements inspected column (second column in table) and for the key attribute being evaluated, the FAVOR version is specified (e.g., v9401). All other fields following the Report/paper reference provides information related to Gaps, Yes/No responses, uncertainties, or validation information (as discussed in Note 1).
3. **2003-4, 2003-5, and 2006-1 reports:** Identical in content but 2003-4 is an Adobe pdf file while 2003-5 and 2006-1 are MS Word draft documents. Did not reproduce 2003-5 and 2006-1 results as 2003-4 results are representative.
4. **2004-8 and 2005-3 reports:** Identical in content but 2005-3 is an updated draft. Results are similar. Did not reproduce 2005-3 results as 2004-8 results are representative.
5. **Fluence (f_o)** is only entered on the embrittlement map. Fluence usually comes from RVID data base or some intermediate program that takes the detailed fast neutron fluence maps from a 3-D neutronics code and populates the embrittlement map record.

	NUREG/BR-0167 Requirement														
	Requirements Definition		Design Phase					Implementation			Qualification Testing			Installation and Acceptance Testing	
FAVOR ATTRIBUTE	Requirements Inspected?	V&V Plan Developed?	Design Inspected?	Qualification Test Plan Developed?	Acceptance Test Plan Developed?	Preliminary Design Review Conducted?	Critical Design Review Conducted?	Unit designs, unit code, and unit test plans Developed and Inspected?	Unit Testing Performed and Inspected?	Integration Test Plans Developed and Inspected?	Qualification Testing Performed	Qualification Report Written?	Acceptance Test Procedure Developed?	Acceptance Testing Performed?	Acceptance Test Report Written?
FAVOR INPUTS															
Thermo-Mechanical Material Properties for clad and base metal of the reactor vessel (i.e., thermal conductivity, specific heat, density, Young's Elastic Modulus, thermal expansion coefficient, Poisson's ratio)	1994-1 v9401 1999-1 v9401 2000-1 v9401 2003-1 v0204 2004-2 v0301 2004-9 v0202 2005-1 v0301	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1
Reactor pressure vessel geometry	2003-1 v0204 2004-2 v0301 2004-9 v0202 2005-1 v0301	2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes	Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1	2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes	2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes	Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1
Thermal Hydraulic boundary conditions (from RELAP or similar Transient T-H code)	2003-1 v0204 2004-9 v0202 2005-1 v0301	2003-1 Yes 2004-9 Yes 2005-1 Yes	2003-1 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-9 Gap 2005-1 Yes	2003-1 Gap 2004-9 Gap 2005-1 Yes	2003-1 Gap 2004-9 Gap 2005-1 Yes	2003-1 Yes 2004-9 Yes 2005-1 Yes	Report 2003-1 Report 2004-9 Report 2005-1	2003-1 Yes 2004-9 Yes 2005-1 Yes	2003-1 Yes 2004-9 Yes 2005-1 Yes	Report 2003-1 Report 2004-9 Report 2005-1
Fast Neutron fluence maps (Note 5)															
Flaw densities, size, and location (plates, welds, and forgings)	1994-1 Surface 1999-1 Embedded 2000-1 Embedded 2002-1 v0201 Cat 1 - 3 2004-7 v0203 Cat 1 - 3 2004-10 v0203 Cat 1 - 3 2005-1 v0301 Cat 1 - 3	1994-1 Gap 1999-1 Gap 2000-1 Gap 2002-1 Yes 2004-7 Yes 2004-10 Yes 2005-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2002-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2002-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2002-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2002-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2002-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2002-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2002-1 Yes 2004-7 Yes 2004-10 Yes 2005-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2002-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2002-1 Yes 2004-7 Yes 2004-10 Yes 2005-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2002-1 Report 2004-7 Report 2004-10 Report 2005-1	1994-1 Gap 1999-1 Gap 2000-1 Gap 2002-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2002-1 Yes 2004-7 Yes 2004-10 Yes 2005-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2002-1 Report 2004-7 Report 2004-10 Report 2005-1
Embrittlement Data (i.e., Cu, Ni, P, Mn, f_o, RT_{NDT0})	2003-1 v0204 2003-4 v0204 2004-8 v0301 2005-1 v0301 2007-3 v0601	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes 2007-3 Yes	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Yes 2007-3 Yes	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Yes 2007-3 Yes	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Yes 2007-3 Yes	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes 2007-3 Yes	Report 2003-1 Report 2003-4 Report 2004-8 Report 2005-1 Report 2007-3	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes 2007-3 Yes	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes 2007-3 Yes	Report 2003-1 Report 2003-4 Report 2004-8 Report 2005-1 Report 2007-3
Transient Initiating Frequency distributions (from PRA)	2003-3 v0204 2005-1 v0301	2003-3 Yes 2005-1 Yes	2003-3 Gap 2005-1 Gap	2003-3 Gap 2005-1 Gap	2003-3 Gap 2005-1 Gap	2003-3 Gap 2005-1 Gap	2003-3 Gap 2005-1 Gap	2003-3 Gap 2005-1 Yes	2003-3 Gap 2005-1 Yes	2003-3 Gap 2005-1 Yes	2003-3 Yes 2005-1 Yes	Report 2003-3 Report 2005-1	2003-3 Yes 2005-1 Yes	2003-3 Yes 2005-1 Yes	Report 2003-3 Report 2005-1
Probability distributions (aleatory and epistemic)	2003-3 v0204 2005-1 v0301	2003-3 Yes 2005-1 Yes	2003-3 Gap 2005-1 Gap	2003-3 Gap 2005-1 Gap	2003-3 Gap 2005-1 Gap	2003-3 Gap 2005-1 Gap	2003-3 Gap 2005-1 Gap	2003-3 Gap 2005-1 Yes	2003-3 Gap 2005-1 Yes	2003-3 Gap 2005-1 Yes	2003-3 Yes 2005-1 Yes	Report 2003-3 Report 2005-1	2003-3 Yes 2005-1 Yes	2003-3 Yes 2005-1 Yes	Report 2003-3 Report 2005-1

	NUREG/BR-0167 Requirement														
	Requirements Definition		Design Phase					Implementation			Qualification Testing			Installation and Acceptance Testing	
FAVOR ATTRIBUTE	Requirements Inspected?	V&V Plan Developed?	Design Inspected?	Qualification Test Plan Developed?	Acceptance Test Plan Developed?	Preliminary Design Review Conducted?	Critical Design Review Conducted?	Unit designs, unit code, and unit test plans Developed and Inspected?	Unit Testing Performed and Inspected?	Integration Test Plans Developed and Inspected?	Qualification Testing Performed	Qualification Report Written?	Acceptance Test Procedure Developed?	Acceptance Testing Performed?	Acceptance Test Report Written?
FAVOR FUNCTIONS AND ALGORITHMS															
FAVLoad Deterministic analyses															
Thermal analysis	2003-1 v0204 2004-2 v0301 2004-9 v0202 2005-1 v0301	2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes	Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1	2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes	2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes	Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1
Stress analysis	1994-1 v9401 1999-1 v9401 2000-1 v9401 2004-9 v0202 2005-1 v0301	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Yes 2005-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2004-9 Yes 2005-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2004-9 Report 2005-1	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Yes 2005-1 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2004-9 Yes 2005-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2004-9 Report 2005-1
Linear-Elastic Fracture Mechanics (LEFM)	1994-1 v9401 1999-1 v9401 2000-1 v9401 2004-9 v0202 2005-1 v0301	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Yes 2005-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2004-9 Yes 2005-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2004-9 Report 2005-1	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Yes 2005-1 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2004-9 Yes 2005-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2004-9 Report 2005-1
Handling of residual stresses in welds															
Handling of crack-face pressure for surface breaking flaws															
Calculation of Nil-Ductility Transition Temperature, RT_{NDT}	2003-1 v0204 2004-1 v0301 2005-1 v0301 2007-3 v0601	2003-1 Yes 2004-1 Yes 2005-1 Yes 2007-3 Yes	2003-1 Gap 2004-1 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2004-1 Yes 2005-1 Yes 2007-3 Yes	2003-1 Gap 2004-1 Yes 2005-1 Yes 2007-3 Yes	2003-1 Gap 2004-1 Yes 2005-1 Yes 2007-3 Yes	2003-1 Yes 2004-1 Yes 2005-1 Yes 2007-3 Yes	Report 2003-1 Report 2004-1 Report 2005-1 Report 2007-3	2003-1 Yes 2004-1 Yes 2005-1 Yes 2007-3 Yes	2003-1 Yes 2004-1 Yes 2005-1 Yes 2007-3 Yes	Report 2003-1 Report 2004-1 Report 2005-1 Report 2007-3

Attachment 4: FAVOR V&V Checklist Results – Prior to FAVOR Version 6.1

	NUREG/BR-0167 Requirement														
	Requirements Definition		Design Phase					Implementation			Qualification Testing			Installation and Acceptance Testing	
FAVOR ATTRIBUTE	**Requirements Inspected?**	**V&V Plan Developed?**	**Design Inspected?**	**Qualification Test Plan Developed?**	**Acceptance Test Plan Developed?**	**Preliminary Design Review Conducted?**	**Critical Design Review Conducted?**	**Unit designs, unit code, and unit test plans Developed and Inspected?**	**Unit Testing Performed and Inspected?**	**Integration Test Plans Developed and Inspected?**	**Qualification Testing Performed**	**Qualification Report Written?**	**Acceptance Test Procedure Developed?**	**Acceptance Testing Performed?**	**Acceptance Test Report Written?**
Radiation embrittlement correlations	2004-1 v0301 2005-1 v0301 2007-3 v0601 (Eason2006)	2004-1 Yes 2005-1 Yes 2007-3 Yes	2004-1 Gap 2005-1 Gap 2007-3 Gap	2004-1 Gap 2005-1 Gap 2007-3 Gap	2004-1 Gap 2005-1 Gap 2007-3 Gap	2004-1 Gap 2005-1 Gap 2007-3 Gap	2004-1 Gap 2005-1 Gap 2007-3 Gap	2004-1 Yes 2005-1 Yes 2007-3 Yes	2004-1 Yes 2005-1 Yes 2007-3 Yes	2004-1 Yes 2005-1 Yes 2007-3 Yes	2004-1 Yes 2005-1 Yes 2007-3 Yes	Report 2004-1 Report 2005-1 Report 2007-3	2004-1 Yes 2005-1 Yes 2007-3 Yes	2004-1 Yes 2005-1 Yes 2007-3 Yes	Report 2004-1 Report 2005-1 Report 2007-3
Fast-neutron fluence attenuation and sampling	2003-1 v0204 2003-4 v0204 2004-8 v0301 2005-1 v0301	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Yes	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Yes	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Yes	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes	Report 2003-1 Report 2003-4 Report 2004-8 Report 2005-1	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes	Report 2003-1 Report 2003-4 Report 2004-8 Report 2005-1
Handling of K_{IC} and K_{Ia} Databases and calculations of K_{IC} and K_{Ia}	2003-1 v0204 2004-2 v0301 2005-1 v0301	2003-1 Yes 2004-2 Gap 2005-1 Yes	2003-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2005-1 Yes	2003-1 Gap 2004-2 Gap 2005-1 Yes	2003-1 Gap 2004-2 Gap 2005-1 Yes	2003-1 Yes 2004-2 Yes 2005-1 Yes	Report 2003-1 Paper 2004-2 Report 2005-1	2003-1 Yes 2004-2 Gap 2005-1 Yes	2003-1 Yes 2004-2 Yes 2005-1 Yes	Report 2003-1 Paper 2004-2 Report 2005-1
Sampling of RT_{NDT} and RT_{Arrest}	2003-1 v0204 2003-4 v0204 2005-1 v0301 2007-3 v0601	2003-1 Yes 2003-4 Yes 2005-1 Yes 2007-3 Yes RTNDT	2003-1 Gap 2003-4 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2005-1 Yes 2007-3 Yes RTNDT	2003-1 Gap 2003-4 Gap 2005-1 Yes 2007-3 Yes RTNDT	2003-1 Gap 2003-4 Gap 2005-1 Yes 2007-3 Yes RTNDT	2003-1 Yes 2003-4 Yes 2005-1 Yes 2007-3 Yes RTNDT	Report 2003-1 Report 2003-4 Report 2005-1 Report 2007-3	2003-1 Yes 2003-4 Yes 2005-1 Yes 2007-3 Yes RTNDT	2003-1 Yes 2003-4 Yes 2005-1 Yes 2007-3 Yes RTNDT	Report 2003-1 Report 2003-4 Report 2005-1 Report 2007-3
Sampling of Material Chemistry	2003-1 v0204 2003-4 v0204 2004-8 v0301 2005-1 v0301 2007-3 v0601	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes 2007-3 Yes	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Yes 2007-3 Yes	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Yes 2007-3 Yes	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Yes 2007-3 Yes	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes 2007-3 Yes	Report 2003-1 Report 2003-4 Report 2004-8 Report 2005-1 Report 2007-3	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes 2007-3 Yes	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes 2007-3 Yes	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes 2007-3 Yes
Flaw characterizations and uncertainty	2002-1 v0201 Cat 1 - 3 2003-1 v0204 2004-7 v0203 Cat 1 - 3 2004-10 v0203 Cat 1 - 3 2005-1 v0301 Cat 1 - 3	2002-1 Yes 2003-1 Yes 2004-7 Yes 2004-10 Yes 2005-1 Yes	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Gap	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Gap	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Gap	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Gap	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Gap	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Yes	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Yes	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Yes	2002-1 Yes 2003-1 Yes 2004-7 Yes 2004-10 Yes 2005-1 Yes	Report 2002-1 Report 2003-1 Report 2004-7 Report 2004-10 Report 2005-1	2002-1 Gap 2003-1 Yes 2004-7 Gap 2004-10 Gap 2005-1 Yes	2002-1 Yes 2003-1 Yes 2004-7 Yes 2004-10 Yes 2005-1 Yes	Report 2002-1 Report 2003-1 Report 2004-7 Report 2004-10 Report 2005-1

Attachment 4: FAVOR V&V Checklist Results – Prior to FAVOR Version 6.1

	NUREG/BR-0167 Requirement														
	Requirements Definition		Design Phase					Implementation			Qualification Testing			Installation and Acceptance Testing	
FAVOR ATTRIBUTE	Requirements Inspected?	V&V Plan Developed?	Design Inspected?	Qualification Test Plan Developed?	Acceptance Test Plan Developed?	Preliminary Design Review Conducted?	Critical Design Review Conducted?	Unit designs, unit code, and unit test plans Developed and Inspected?	Unit Testing Performed and Inspected?	Integration Test Plans Developed and Inspected?	Qualification Testing Performed	Qualification Report Written?	Acceptance Test Procedure Developed?	Acceptance Testing Performed?	Acceptance Test Report Written?
FAVPFM ALGORITHMS and MODELS															
Warm prestressing logic	2003-1 v0204 2004-1 v0301 2005-1 v0301	2003-1 Yes 2004-1 Yes 2005-1 Yes	2003-1 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2004-1 Yes 2005-1 Yes	2003-1 Gap 2004-1 Yes 2005-1 Yes	2003-1 Gap 2004-1 Yes 2005-1 Yes	2003-1 Yes 2004-1 Yes 2005-1 Yes	Report 2003-1 Report 2004-1 Report 2005-1	2003-1 Yes 2004-1 Yes 2005-1 Yes	2003-1 Yes 2004-1 Yes 2005-1 Yes	Report 2003-1 Report 2004-1 Report 2005-1
Truncation for probability distributions	2003-1 v0204 2005-1 v0301	2003-1 Yes 2005-1 Yes	2003-1 Gap 2005-1 Gap	2003-1 Gap 2005-1 Gap	2003-1 Gap 2005-1 Gap	2003-1 Gap 2005-1 Gap	2003-1 Gap 2005-1 Gap	2003-1 Gap 2005-1 Yes	2003-1 Gap 2005-1 Yes	2003-1 Gap 2005-1 Yes	2003-1 Yes 2005-1 Yes	Report 2003-1 Report 2005-1	2003-1 Yes 2005-1 Yes	2003-1 Yes 2005-1 Yes	Report 2003-1 Report 2005-1
Conditional Probability of Initiation (CPI) and Failure (CPF)	2003-1 v0204 2003-3 v0204 2003-6 v0204 2004-1 v0301 2004-2 v0301 2005-1 v0301 2007-3 v0601	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Gap 2005-1 Yes 2007-3 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2004-2 Gap 2005-1 Yes 2007-3 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2004-2 Gap 2005-1 Yes 2007-3 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2004-2 Gap 2005-1 Yes 2007-3 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Yes 2005-1 Yes 2007-3 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Paper 2004-2 Report 2005-1 Report 2007-3	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Gap 2005-1 Yes 2007-3 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Yes 2005-1 Yes 2007-3 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Paper 2004-2 Report 2005-1 Report 2007-3
Post initiation of flaw geometries and orientation	1994-1 v9401 1999-1 v9401 2000-1 v9401 2005-1 v0301 2007-3 v0601	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Yes 2007-3 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Gap 2007-3 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Gap 2007-3 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Gap 2007-3 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Gap 2007-3 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Gap 2007-3 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Yes 2007-3 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Yes 2007-3 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Yes 2007-3 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2005-1 Yes 2007-3 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2005-1 Report 2007-3	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Yes 2007-3 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2005-1 Yes 2007-3 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2005-1 Report 2007-3
Ductile tearing models	2004-1 v0301 2004-8 v0301 (USE) 2005-1 v0301 2005-2 v0401 2007-3 v0601	2004-1 Yes 2004-8 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes	2004-1 Gap 2004-8 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap	2004-1 Gap 2004-8 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap	2004-1 Gap 2004-8 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap	2004-1 Gap 2004-8 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap	2004-1 Gap 2004-8 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap	2004-1 Yes 2004-8 Gap 2005-1 Yes 2005-2 Yes 2007-3 Yes	2004-1 Yes 2004-8 Gap 2005-1 Yes 2005-2 Yes 2007-3 Yes	2004-1 Yes 2004-8 Gap 2005-1 Yes 2005-2 Yes 2007-3 Yes	2004-1 Yes 2004-8 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes	Report 2004-1 Report 2004-8 Report 2005-1 Report 2005-2 Report 2007-3	2004-1 Yes 2004-8 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes	2004-1 Yes 2004-8 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes	Report 2004-1 Report 2004-8 Report 2005-1 Report 2005-2 Report 2007-3
Initiation-Growth-Arrest (IGA) model	2003-1 v0204 2004-1 v0301 2005-1 v0301 2005-2 v0401 2007-3 v0601	2003-1 Yes 2004-1 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes	2003-1 Gap 2004-1 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap	2003-1 Gap 2004-1 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes	2003-1 Gap 2004-1 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes	2003-1 Gap 2004-1 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes	2003-1 Yes 2004-1 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes	Report 2003-1 Report 2004-1 Report 2005-1 Report 2005-2 Report 2007-3	2003-1 Yes 2004-1 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes	2003-1 Yes 2004-1 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes	Report 2003-1 Report 2004-1 Report 2005-1 Report 2005-2 Report 2007-3

	NUREG/BR-0167 Requirement														
	Requirements Definition		Design Phase					Implementation			Qualification Testing			Installation and Acceptance Testing	
FAVOR ATTRIBUTE	Requirements Inspected?	V&V Plan Developed?	Design Inspected?	Qualification Test Plan Developed?	Acceptance Test Plan Developed?	Preliminary Design Review Conducted?	Critical Design Review Conducted?	Unit designs, unit code, and unit test plans Developed and Inspected?	Unit Testing Performed and Inspected?	Integration Test Plans Developed and Inspected?	Qualification Testing Performed	Qualification Report Written?	Acceptance Test Procedure Developed?	Acceptance Testing Performed?	Acceptance Test Report Written?
FAVOR CRITICAL OUTPUTS															
Temperature as a function of time throughout vessel wall location	2003-1 v0204 2004-2 v0301 2004-9 v0202 2005-1 v0301	2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes	Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1	2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes	2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes	Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1
Stress as a function of time throughout vessel wall (circumferential and axial)	2000-1 v9401 2003-1 v0204 2004-9 v0202 2005-1 v0301	2000-1 Gap 2003-1 Yes 2004-9 Yes 2005-1 Yes	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Gap	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Gap	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Gap	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Gap	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Gap	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Yes	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Yes	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Yes	2000-1 Yes 2003-1 Yes 2004-9 Yes 2005-1 Yes	Report 2000-1 Report 2003-1 Report 2004-9 Report 2005-1	2000-1 Gap 2003-1 Yes 2004-9 Yes 2005-1 Yes	2000-1 Gap 2003-1 Yes 2004-9 Yes 2005-1 Yes	Report 2000-1 Report 2003-1 Report 2004-9 Report 2005-1
K_I as a function of time throughout vessel wall	1994-1 v9401 1999-1 v9401 2000-1 v9401 2003-1 v0204 2004-2 v0301 2004-9 v0202 2005-1 v0301	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1
Probability distributions of crack initiation and vessel failure	2003-1 v0204 2003-3 v0204 2003-6 v0204 2004-1 v0301 2004-2 v0301 2005-1 v0301	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Gap 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2004-2 Gap 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2004-2 Gap 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2004-2 Gap 2005-1 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Yes 2005-1 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Paper 2004-2 Report 2005-1	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Gap 2005-1 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Yes 2005-1 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Paper 2004-2 Report 2005-1
Crack initiation frequency per reactor operating year	2003-1 v0204 2003-3 v0204 2003-6 v0204 2004-1 v0301 2005-1 v0301	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2005-1 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Report 2005-1	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Report 2005-1
Through-wall crack frequency per reactor operating year	2003-1 v0204 2003-3 v0204 2003-6 v0204 2004-1 v0301 2005-1 v0301	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2005-1 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Report 2005-1	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Report 2005-1

	ASME V&V 10-2006 Requirement				
FAVOR ATTRIBUTE	**Mathematical Model compared to Computational Model?**	**Simulation Results compared to Computational Model?**	**Simulation Model Uncertainties Quantified?**	**Experimental Data Uncertainties Quanitified?**	**Simulation Outcomes Quantitatively compared to Experimental Outcomes?**
FAVOR INPUTS					
Thermo-Mechanical Material Properties for clad and base metal of the reactor vessel (i.e., thermal conductivity, specific heat, density, Young's Elastic Modulus, thermal expansion coefficient, Poisson's ratio)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	1994-1 1 to 2% KI 1999-1 -5.5 to 17.5% KI 2000-1 -1 to 23.2% KI 2003-1 Yes - Various 2004-2 No 2004-9 Yes - Various 2005-1 Yes - Various	1994-1 No 1999-1 No 2000-1 No 2003-1 No 2004-2 No 2004-9 No 2005-1 No	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-2 Yes (M) (PTSE 1B/1C) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)
Reactor pressure vessel geometry	2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	2003-1 Yes - Various 2004-2 No 2004-9 Yes - Various 2005-1 Yes - Various	2003-1 No 2004-2 No 2004-9 No 2005-1 No	2003-1 Various Independent (B) 2004-2 Yes (M) (PTSE 1B/1C) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)
Thermal Hydraulic boundary conditions (from RELAP or similar Transient T-H code)	2003-1 Various Independent (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	2003-1 Yes - Various 2004-9 Yes - Various 2005-1 Yes - Various	2003-1 No 2004-9 No 2005-1 No	2003-1 Various Independent (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)
Fast Neutron fluence maps (Note 5)					
Flaw densities, size, and location (plates, welds, and forgings)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2002-1 PNNL Calc (B) 2004-7 PNNL Calc (B) 2004-10 PNNL Calc (B) 2005-1 Various Independent (B)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2002-1 PNNL Calc (B) 2004-7 PNNL Calc (B) 2004-10 PNNL Calc (B) 2005-1 Various Independent (B)	1994-1 1 to 2% KI 1999-1 -5.5 to 17.5% KI 2000-1 -1 to 23.2% KI 2002-1 Flaw Dist. Matched 2004-7 Flaw Dist. Matched 2004-10 Flaw Dist. Matched 2005-1 Flaw Dist. Matched	1994-1 No 1999-1 No 2000-1 No 2002-1 No 2004-7 No 2004-10 No 2005-1 No	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2002-1 PNNL Calc (B) 2004-7 PNNL Calc (B) 2004-10 PNNL Calc (B) 2005-1 Various Independent (B)
Embrittlement Data (i.e., Cu, Ni, P, Mn, f_o, RT_{NDT0})	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Yes - Various 2003-4 SAS (B) 2004-8 SAS (B) 2005-1 Yes Various 2007-3 Errors Identified	2003-1 No 2003-4 No 2004-8 No 2005-1 No 2007-3 No	2003-1 Yes - Various 2003-4 SAS (B) 2004-8 SAS (B) 2005-1 Yes Various 2007-3 Errors Identified
Transient Initiating Frequency distributions (from PRA)	2003-3 INEEL/SAS (B) 2005-1 Various Independent (B)	2003-3 INEEL/SAS (B) 2005-1 Various Independent (B)	2003-3 Yes - Various 2005-1 Yes - Various	2003-3 No 2005-1 No	2003-3 INEEL/SAS (B) 2005-1 Various Independent (B)
Probability distributions (aleatory and epistemic)	2003-3 INEEL/SAS (B) 2005-1 Various Independent (B)	2003-3 INEEL/SAS (B) 2005-1 Various Independent (B)	2003-3 Yes - Various 2005-1 Yes - Various	2003-3 No 2005-1 No	2003-3 INEEL/SAS (B) 2005-1 Various Independent (B)

	ASME V&V 10-2006 Requirement				
FAVOR ATTRIBUTE	**Mathematical Model compared to Computational Model?**	**Simulation Results compared to Computational Model?**	**Simulation Model Uncertainties Quantified?**	**Experimental Data Uncertainties Quanitified?**	**Simulation Outcomes Quantitatively compared to Experimental Outcomes?**
FAVOR FUNCTIONS AND ALGORITHMS					
FAVLoad Deterministic analyses					
Thermal analysis	2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	2003-1 Yes - Various 2004-2 No 2004-9 Yes - Various 2005-1 Yes - Various	2003-1 No 2004-2 No 2004-9 No 2005-1 No	2003-1 Various Independent (B) 2004-2 Yes (M) (PTSE 1B/1C) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)
Stress analysis	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	1994-1 1 to 2% KI 1999-1 -5.5 to 17.5% KI 2000-1 -1 to 23.2% KI 2004-9 Yes - Various 2005-1 Yes - Various	1994-1 No 1999-1 No 2000-1 No 2004-9 No 2005-1 No	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2004-9 ABAQUS(B) 2005-1 Various Independent (B)
Linear-Elastic Fracture Mechanics (LEFM)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	1994-1 1 to 2% KI 1999-1 -5.5 to 17.5% KI 2000-1 -1 to 23.2% KI 2004-9 Yes - Various 2005-1 Yes - Various	1994-1 No 1999-1 No 2000-1 No 2004-9 No 2005-1 No	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2004-9 ABAQUS(B) 2005-1 Various Independent (B)
Handling of residual stresses in welds					
Handling of crack-face pressure for surface breaking flaws					
Calculation of Nil-Ductility Transition Temperature, RT_{NDT}	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Yes - Various 2004-1 No 2005-1 Yes - Various 2007-3 Yes - Eason	2003-1 No 2004-1 No 2005-1 No 2007-3 No	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)

	ASME V&V 10-2006 Requirement				
FAVOR ATTRIBUTE	Mathematical Model compared to Computational Model?	Simulation Results compared to Computational Model?	Simulation Model Uncertainties Quantified?	Experimental Data Uncertainties Quanitified?	Simulation Outcomes Quantitatively compared to Experimental Outcomes?
Radiation embrittlement correlations	2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2004-1 No 2005-1 Yes - Various 2007-3 Yes - Eason	2004-1 No 2005-1 No 2007-3 No	2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)
Fast-neutron fluence attenuation and sampling	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B)	2003-1 Yes - Various 2003-4 SAS (B) 2004-8 SAS (B) 2005-1 Yes - Various	2003-1 No 2003-4 No 2004-8 No 2005-1 No	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B)
Handling of K_{IC} and K_{Ia} Databases and calculations of K_{IC} and K_{Ia}	2003-1 Various Independent (B) 2004-2 No 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2004-2 No 2005-1 Various Independent (B)	2003-1 Yes - Various 2004-2 No 2005-1 Yes - Various	2003-1 No 2004-2 No 2005-1 No	2003-1 Various Independent (B) 2004-2 Yes (M) (PTSE 1B/1C) 2005-1 Various Independent (B)
Sampling of RT_{NDT} and RT_{Arrest}	2003-1 Various Independent (B) 2003-4 SAS (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Various Independent (B) 2003-4 SAS (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Yes - Various 2003-4 SAS (B) 2005-1 Yes - Various 2007-3 Yes	2003-1 No 2003-4 No 2005-1 No 2007-3 No	2003-1 Various Independent (B) 2003-4 SAS (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)
Sampling of Material Chemistry	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Yes - Various 2003-4 SAS (B) 2004-8 SAS (B) 2005-1 Yes - Various 2007-3 Errors Identified	2003-1 No 2003-4 No 2004-8 No 2005-1 No 2007-3 No	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)
Flaw characterizations and uncertainty	2002-1 PNNL Calc (B) 2003-1 Various Independent (B) 2004-7 PNNL Calc (B) 2004-10 PNNL Calc (B) 2005-1 Various Independent (B)	2002-1 PNNL Calc (B) 2003-1 Various Independent (B) 2004-7 PNNL Calc (B) 2004-10 PNNL Calc (B) 2005-1 Various Independent (B)	2002-1 Flaw Dist. Matched 2003-1 Yes - Various 2004-7 Flaw Dist. Matched 2004-10 Flaw Dist. Matched 2005-1 Yes - Various	2002-1 No 2003-1 No 2004-7 No 2004-10 No 2005-1 No	2002-1 PNNL Calc (B) 2003-1 Various Independent (B) 2004-7 PNNL Calc (B) 2004-10 PNNL Calc (B) 2005-1 Various Independent (B)

	ASME V&V 10-2006 Requirement				
FAVOR ATTRIBUTE	**Mathematical Model compared to Computational Model?**	**Simulation Results compared to Computational Model?**	**Simulation Model Uncertainties Quantified?**	**Experimental Data Uncertainties Quanitified?**	**Simulation Outcomes Quantitatively compared to Experimental Outcomes?**
FAVPFM ALGORITHMS and MODELS					
Warm prestressing logic	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B)	2003-1 Yes - Various 2004-1 No 2005-1 Yes - Various	2003-1 No 2004-1 No 2005-1 No	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B)
Truncation for probability distributions	2003-1 Various Independent (B) 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2005-1 Various Independent (B)	2003-1 Yes - Various 2005-1 Yes - Various	2003-1 No 2005-1 No	2003-1 Various Independent (B) 2005-1 Various Independent (B)
Conditional Probability of Initiation (CPI) and Failure (CPF)	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2004-2 No 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2004-2 No 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Yes - Various 2003-3 Yes - Various 2003-6 Yes - Various 2004-1 No 2004-2 No 2005-1 Yes - Various 2007-3 No	2003-1 No 2003-3 No 2003-6 No 2004-1 No 2004-2 No 2005-1 No 2007-3 No	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2004-2 Yes (M) (PTSE 1B/1C) 2005-1 Various Independent (B) 2007-3 Various Independent (B)
Post initiation of flaw geometries and orientation	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	1994-1 1 to 2% KI 1999-1 -5.5 to 17.5% KI 2000-1 -1 to 23.2% KI 2005-1 Yes - Various 2007-3 No - Errors Identified	1994-1 No 1999-1 No 2000-1 No 2005-1 No 2007-3 No	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)
Ductile tearing models	2004-1 EPRI MS EXCEL (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2005-2 Various Independent (B) 2007-3 Various Independent (B)	2004-1 EPRI MS EXCEL (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2005-2 Various Independent (B) 2007-3 Various Independent (B)	2004-1 No 2004-8 No 2005-1 Yes - Various 2005-2 No 2007-3 Yes	2004-1 No 2004-8 No 2005-1 No 2005-2 No 2007-3 No	2004-1 EPRI MS EXCEL (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2005-2 Various Independent (B) 2007-3 Various Independent (B)
Initiation-Growth-Arrest (IGA) model	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2005-2 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2005-2 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Yes - Various 2004-1 No 2005-1 Yes - Various 2005-2 No 2007-3 No	2003-1 No 2004-1 No 2005-1 No 2005-2 No 2007-3 No	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2005-2 Various Independent (B) 2007-3 Various Independent (B)

	ASME V&V 10-2006 Requirement				
FAVOR ATTRIBUTE	**Mathematical Model compared to Computational Model?**	**Simulation Results compared to Computational Model?**	**Simulation Model Uncertainties Quantified?**	**Experimental Data Uncertainties Quanitified?**	**Simulation Outcomes Quantitatively compared to Experimental Outcomes?**
FAVOR CRITICAL OUTPUTS					
Temperature as a function of time throughout vessel wall location	2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	2003-1 Yes - Various 2004-2 No 2004-9 Yes - Various 2005-1 Yes - Various	2003-1 No 2004-2 No 2004-9 No 2005-1 No	2003-1 Various Independent (B) 2004-2 Yes (M) (PTSE 1B/1C) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)
Stress as a function of time throughout vessel wall (circumferential and axial)	2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	2000-1 Plots of hoop stress 2003-1 Yes - Various 2004-9 Yes - Various 2004-1 Yes - Various	2000-1 No 2003-1 No 2004-9 No 2005-1 No	2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)
K_I as a function of time throughout vessel wall	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	1994-1 1 to 2% KI 1999-1 -5.5 to 17.5% KI 2000-1 -1 to 23.2% KI 2003-1 Yes - Various 2004-2 No 2004-9 Yes - Various 2005-1 Yes - Various	1994-1 No 1999-1 No 2000-1 No 2003-1 No 2004-2 No 2004-9 No 2005-1 No	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-2 Yes (M) (PTSE 1B/1C) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)
Probability distributions of crack initiation and vessel failure	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2004-2 No 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2004-2 No 2005-1 Various Independent (B)	2003-1 Yes - Various 2003-3 Yes - Various 2003-6 Yes - Various 2004-1 No 2004-2 No 2005-1 Yes - Various	2003-1 No 2003-3 No 2003-6 No 2004-1 No 2004-2 No 2005-1 No	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2004-2 Yes (M) (PTSE 1B/1C) 2005-1 Various Independent (B)
Crack initiation frequency per reactor operating year	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B)	2003-1 Yes - Various 2003-3 Yes - Various 2003-6 Yes - Various 2004-1 No 2005-1 Yes - Various	2003-1 No 2003-3 No 2003-6 No 2004-1 No 2005-1 No	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B)
Through-wall crack frequency per reactor operating year	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B)	2003-1 Yes - Various 2003-3 Yes - Various 2003-6 Yes - Various 2004-1 No 2005-1 Yes - Various	2003-1 No 2003-3 No 2003-6 No 2004-1 No 2005-1 No	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B)

Attachment 5. FAVOR V&V Checklist Results – Post FAVOR Version 6.1

Interpretation of FAVOR V&V Checklist Results

The cells in the tables below are colored based on the degree to which the V&V requirements are met for each FAVOR attribute, as follows:

- Green cells: the V&V requirement is met for this attribute for the last version of the code in the time period considered.
    - For the table about FAVOR prior to version 6.1 (Attachment 4), this means the requirements are met for version FAVOR v03.1 based on documentation through 2005.
    - For the table about FAVOR from version 6.1 to version 16.1 (Attachment 5), this means the requirements are met for FAVOR v16.1 based only on the documentation produced from 2006 to 2016.
    - For the table about all past versions of FAVOR (Attachment 6) up to version 16.1 (the current version as of the date of this report), this means the requirements are met based on all documentation available for all past versions.
- Yellow cells: the V&V requirements were met for an earlier version of FAVOR, but not the latest for the time period considered.
- Red cells: the V&V requirements were not met for any version of FAVOR within the period considered.

When cells are empty and have no color coding, this means the FAVOR attribute was either nonexistent (for versions prior to v6.1, see Attachment 4), or that the FAVOR attribute was not modified (when considering only the 2006 to 2016 period, see Attachment 5).

Notes:

1. **Validation** is based on whether the attribute meets the metric of a measurement (e.g., vessel failure, crack propagation), benchmark (e.g., ABAQUS), regulatory requirement (NRC, ASME, ASTM), or defined conservatism. Identifiers are **M** = Measurement, **B** = Benchmark, **R** = Regulatory, and **C** = Conservativism. The ASME standard focuses on Measurement as true validation.
2. **Field Key Description**: Report/paper number prefix as identified in SQA Cat 1 and Cat 2 documents ("year-sequence#"). For example, "2000-1" corresponds to the letter report entitled, "Comparison of *KI* Factors for Embedded Flaws: FAVOR Implementation of ASME Section XI – Appendix A Methodology versus Three-Dimensional Finite-Element Solutions", ORNL/NRC/LTR-99/26, April 2000. Additional fields are provided following the Report/paper reference. Under requirements inspected column (second column in table) and for the key attribute being evaluated, the FAVOR version is specified (e.g., v9401). All other fields following the Report/paper reference provides information related to Gaps, Yes/No responses, uncertainties, or validation information (as discussed in Note 1).
3. **2016-7 Report:** Report only covers surface breaking flaws with cladding.
4. **2016-7 Report and 2017-1 Paper:** Paper is summary of the 2016-7 report.
5. **Referenced Papers/Reports**: The above referenced papers and reports are all incrementally based V&V efforts. That is, no fully integrated V&V was performed.
6. **Fluence (f_o)** is only entered on the embrittlement map. Fluence usually comes from RVID data base or some intermediate program that takes the detailed fast neutron fluence maps from a 3-D neutronics code and populates the embrittlement map record.

	NUREG/BR-0167 Requirement														
	Requirements Definition		Design Phase					Implementation			Qualification Testing			Installation and Acceptance Testing	
FAVOR ATTRIBUTE	**Requirements Inspected?**	**V&V Plan Developed?**	**Design Inspected?**	**Qualification Test Plan Developed?**	**Acceptance Test Plan Developed?**	**Preliminary Design Review Conducted?**	**Critical Design Review Conducted?**	**Unit designs, unit code, and unit test plans Developed and Inspected?**	**Unit Testing Performed and Inspected?**	**Integration Test Plans Developed and Inspected?**	**Qualification Testing Performed**	**Qualification Report Written?**	**Acceptance Test Procedure Developed?**	**Acceptance Testing Performed?**	**Acceptance Test Report Written?**
FAVOR INPUTS															
Thermo-Mechanical Material Properties for clad and base metal of the reactor vessel (i.e., thermal conductivity, specific heat, density, Young's Elastic Modulus, thermal expansion coefficient, Poisson's ratio)															
Reactor pressure vessel geometry	2010-1 v0901 2016-7 v1601 2017-1 v1601	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1
Thermal Hydraulic boundary conditions (from RELAP or similar Transient T-H code)	2010-1 v0901 2016-7 v1601 2017-1 v1601	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1
Fast Neutron fluence maps (Note 6)															
Flaw densities, size, and location (plates, welds, and forgings)	2011-1 v0901	2011-1 Yes	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Yes	2011-1 Yes	2011-1 Gap	2011-1 Yes	Report 2011-1	2011-1 Yes	2011-1 Yes	Report 2011-1
Embrittlement Data (i.e., Cu, Ni, P, Mn, f_o, RT_{NDT0})	2011-1 v0901	2011-1 Yes	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Yes	2011-1 Yes	2011-1 Gap	2011-1 Yes	Report 2011-1	2011-1 Yes	2011-1 Yes	Report 2011-1
Transient Initiating Frequency distributions (from PRA)															
Probability distributions (aleatory and epistemic)															

	NUREG/BR-0167 Requirement														
	Requirements Definition		Design Phase					Implementation			Qualification Testing			Installation and Acceptance Testing	
FAVOR ATTRIBUTE	Requirements Inspected?	V&V Plan Developed?	Design Inspected?	Qualification Test Plan Developed?	Acceptance Test Plan Developed?	Preliminary Design Review Conducted?	Critical Design Review Conducted?	Unit designs, unit code, and unit test plans Developed and Inspected?	Unit Testing Performed and Inspected?	Integration Test Plans Developed and Inspected?	Qualification Testing Performed	Qualification Report Written?	Acceptance Test Procedure Developed?	Acceptance Testing Performed?	Acceptance Test Report Written?
FAVOR FUNCTIONS AND ALGORITHMS															
FAVLoad Deterministic analyses															
Thermal analysis	2010-1 v0901 2016-7 v1601 2017-1 v1601	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1
Stress analysis	2010-1 v0901 2016-7 v1601 2017-1 v1601	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1
Linear-Elastic Fracture Mechanics (LEFM)	2010-1 v0901 2016-7 v1601 2017-1 v1601	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1
Handling of residual stresses in welds															
Handling of crack-face pressure for surface breaking flaws	2010-1 v0901 2016-7 v1601 2017-1 v1601	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1
Calculation of Nil-Ductility Transition Temperature, RT_{NDT}															

Attachment 5: FAVOR V&V Checklist Results – Post FAVOR Version 6.1

	NUREG/BR-0167 Requirement														
	Requirements Definition		Design Phase					Implementation			Qualification Testing			Installation and Acceptance Testing	
FAVOR ATTRIBUTE	Requirements Inspected?	V&V Plan Developed?	Design Inspected?	Qualification Test Plan Developed?	Acceptance Test Plan Developed?	Preliminary Design Review Conducted?	Critical Design Review Conducted?	Unit designs, unit code, and unit test plans Developed and Inspected?	Unit Testing Performed and Inspected?	Integration Test Plans Developed and Inspected?	Qualification Testing Performed	Qualification Report Written?	Acceptance Test Procedure Developed?	Acceptance Testing Performed?	Acceptance Test Report Written?
Radiation embrittlement correlations	2011-1 v0901	2011-1 Yes	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Yes	2011-1 Yes	2011-1 Gap	2011-1 Yes	Report 2011-1	2011-1 Yes	2011-1 Yes	Report 2011-1
Fast-neutron fluence attenuation and sampling															
Handling of K_{IC} and K_{Ia} Databases and calculations of K_{IC} and K_{Ia}															
Sampling of RT_{NDT} and RT_{Arrest}															
Sampling of Material Chemistry															
Flaw characterizations and uncertainty	2011-1 v0901	2011-1 Yes	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Yes	2011-1 Yes	2011-1 Gap	2011-1 Yes	Report 2011-1	2011-1 Yes	2011-1 Yes	Report 2011-1

	NUREG/BR-0167 Requirement														
	Requirements Definition		Design Phase					Implementation			Qualification Testing			Installation and Acceptance Testing	
FAVOR ATTRIBUTE	**Requirements Inspected?**	**V&V Plan Developed?**	**Design Inspected?**	**Qualification Test Plan Developed?**	**Acceptance Test Plan Developed?**	**Preliminary Design Review Conducted?**	**Critical Design Review Conducted?**	**Unit designs, unit code, and unit test plans Developed and Inspected?**	**Unit Testing Performed and Inspected?**	**Integration Test Plans Developed and Inspected?**	**Qualification Testing Performed**	**Qualification Report Written?**	**Acceptance Test Procedure Developed?**	**Acceptance Testing Performed?**	**Acceptance Test Report Written?**
FAVPFM ALGORITHMS and MODELS															
Warm prestressing logic	2011-1 v0901	2011-1 Yes	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Yes	2011-1 Yes	2011-1 Gap	2011-1 Yes	Report 2011-1	2011-1 Yes	2011-1 Yes	Report 2011-1
Truncation for probability distributions															
Conditional Probability of Initiation (CPI) and Failure (CPF)															
Post initiation of flaw geometries and orientation	2010-1 v0901 2016-7 v1601 (note 3) 2017-1 v1601 (note 4)	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1
Ductile tearing models	2011-1 v0901	2011-1 Yes	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Yes	2011-1 Yes	2011-1 Gap	2011-1 Yes	Report 2011-1	2011-1 Yes	2011-1 Yes	Report 2011-1
Initiation-Growth-Arrest (IGA) model	2011-1 v0901	2011-1 Yes	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Gap	2011-1 Yes	2011-1 Yes	2011-1 Gap	2011-1 Yes	Report 2011-1	2011-1 Yes	2011-1 Yes	Report 2011-1

Attachment 5: FAVOR V&V Checklist Results – Post FAVOR Version 6.1

	NUREG/BR-0167 Requirement														
	Requirements Definition		Design Phase					Implementation			Qualification Testing			Installation and Acceptance Testing	
FAVOR ATTRIBUTE	**Requirements Inspected?**	**V&V Plan Developed?**	**Design Inspected?**	**Qualification Test Plan Developed?**	**Acceptance Test Plan Developed?**	**Preliminary Design Review Conducted?**	**Critical Design Review Conducted?**	**Unit designs, unit code, and unit test plans Developed and Inspected?**	**Unit Testing Performed and Inspected?**	**Integration Test Plans Developed and Inspected?**	**Qualification Testing Performed**	**Qualification Report Written?**	**Acceptance Test Procedure Developed?**	**Acceptance Testing Performed?**	**Acceptance Test Report Written?**
FAVOR CRITICAL OUTPUTS															
Temperature as a function of time throughout vessel wall location															
Stress as a function of time throughout vessel wall (circumferential and axial)															
K_I as a function of time throughout vessel wall	2010-1 v0901 2016-7 v1601 2017-1 v1601	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1
Probability distributions of crack initiation and vessel failure															
Crack initiation frequency per reactor operating year															
Through-wall crack frequency per reactor operating year															

	ASME V&V 10-2006 Requirement				
FAVOR ATTRIBUTE	**Mathematical Model compared to Computational Model?**	**Simulation Results compared to Computational Model?**	**Simulation Model Uncertainties Quantified?**	**Experimental Data Uncertainties Quanitified?**	**Simulation Outcomes Quantitatively compared to Experimental Outcomes?**
FAVOR INPUTS					
Thermo-Mechanical Material Properties for clad and base metal of the reactor vessel (i.e., thermal conductivity, specific heat, density, Young's Elastic Modulus, thermal expansion coefficient, Poisson's ratio)					
Reactor pressure vessel geometry	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 Yes 2016-7 Yes 2017-1 Yes	2010-1 No 2016-7 No 2017-1 No	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)
Thermal Hydraulic boundary conditions (from RELAP or similar Transient T-H code)	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 Yes 2016-7 Yes 2017-1 Yes	2010-1 No 2016-7 No 2017-1 No	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)
Fast Neutron fluence maps (Note 5)					
Flaw densities, size, and location (plates, welds, and forgings)	2011-1 CNWRA Independent Calcs (B)	2011-1 CNWRA Independent Calcs (B)	2011-1 Yes	2011-1 No	2011-1 CNWRA Independent Calcs (B)
Embrittlement Data (i.e., Cu, Ni, P, Mn, f_o, RT_{NDT0})	2011-1 CNWRA Independent Calcs (B)	2011-1 CNWRA Independent Calcs (B)	2011-1 Yes	2011-1 No	2011-1 CNWRA Independent Calcs (B)
Transient Initiating Frequency distributions (from PRA)					
Probability distributions (aleatory and epistemic)					

Attachment 5: FAVOR V&V Checklist Results – Post FAVOR Version 6.1

	ASME V&V 10-2006 Requirement				
FAVOR ATTRIBUTE	**Mathematical Model compared to Computational Model?**	**Simulation Results compared to Computational Model?**	**Simulation Model Uncertainties Quantified?**	**Experimental Data Uncertainties Quanitified?**	**Simulation Outcomes Quantitatively compared to Experimental Outcomes?**
FAVOR FUNCTIONS AND ALGORITHMS					
FAVLoad Deterministic analyses					
Thermal analysis	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 Yes 2016-7 Yes 2017-1 Yes
Stress analysis	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 Yes 2016-7 Yes 2017-1 Yes
Linear-Elastic Fracture Mechanics (LEFM)	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 Yes 2016-7 Yes 2017-1 Yes
Handling of residual stresses in welds					
Handling of crack-face pressure for surface breaking flaws	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 Yes 2016-7 Yes 2017-1 Yes
Calculation of Nil-Ductility Transition Temperature, RT_{NDT}					

	ASME V&V 10-2006 Requirement				
FAVOR ATTRIBUTE	Mathematical Model compared to Computational Model?	Simulation Results compared to Computational Model?	Simulation Model Uncertainties Quantified?	Experimental Data Uncertainties Quanitified?	Simulation Outcomes Quantitatively compared to Experimental Outcomes?
Radiation embrittlement correlations	2011-1 Yes	Report 2011-1	2011-1 CNWRA Independent Calcs (B)	2011-1 CNWRA Independent Calcs (B)	2011-1 Yes
Fast-neutron fluence attenuation and sampling					
Handling of K_{IC} and K_{Ia} Databases and calculations of K_{IC} and K_{Ia}					
Sampling of RT_{NDT} and RT_{Arrest}					
Sampling of Material Chemistry					
Flaw characterizations and uncertainty	2011-1 Yes	Report 2011-1	2011-1 CNWRA Independent Calcs (B)	2011-1 CNWRA Independent Calcs (B)	2011-1 Yes

	ASME V&V 10-2006 Requirement				
FAVOR ATTRIBUTE	**Mathematical Model compared to Computational Model?**	**Simulation Results compared to Computational Model?**	**Simulation Model Uncertainties Quantified?**	**Experimental Data Uncertainties Quanitified?**	**Simulation Outcomes Quantitatively compared to Experimental Outcomes?**
FAVPFM ALGORITHMS and MODELS					
Warm prestressing logic	2011-1 Yes	Report 2011-1	2011-1 CNWRA Independent Calcs (B)	2011-1 CNWRA Independent Calcs (B)	2011-1 Yes
Truncation for probability distributions					
Conditional Probability of Initiation (CPI) and Failure (CPF)					
Post initiation of flaw geometries and orientation	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 Yes 2016-7 Yes 2017-1 Yes
Ductile tearing models	2011-1 Yes	Report 2011-1	2011-1 CNWRA Independent Calcs (B)	2011-1 CNWRA Independent Calcs (B)	2011-1 Yes
Initiation-Growth-Arrest (IGA) model	2011-1 Yes	Report 2011-1	2011-1 CNWRA Independent Calcs (B)	2011-1 CNWRA Independent Calcs (B)	2011-1 Yes

	ASME V&V 10-2006 Requirement				
FAVOR ATTRIBUTE	Mathematical Model compared to Computational Model?	Simulation Results compared to Computational Model?	Simulation Model Uncertainties Quantified?	Experimental Data Uncertainties Quanitified?	Simulation Outcomes Quantitatively compared to Experimental Outcomes?
FAVOR CRITICAL OUTPUTS					
Temperature as a function of time throughout vessel wall location					
Stress as a function of time throughout vessel wall (circumferential and axial)					
K_I as a function of time throughout vessel wall	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 Yes 2016-7 Yes 2017-1 Yes
Probability distributions of crack initiation and vessel failure					
Crack initiation frequency per reactor operating year					
Through-wall crack frequency per reactor operating year					

Attachment 6. FAVOR V&V Checklist Results – All Past FAVOR Versions

Interpretation of FAVOR V&V Checklist Results

The cells in the tables below are colored based on the degree to which the V&V requirements are met for each FAVOR attribute, as follows:

- Green cells: the V&V requirement is met for this attribute for the last version of the code in the time period considered.
  - For the table about FAVOR prior to version 6.1 (Attachment 4), this means the requirements are met for version FAVOR v03.1 based on documentation through 2005.
  - For the table about FAVOR from version 6.1 to version 16.1 (Attachment 5), this means the requirements are met for FAVOR v16.1 based only on the documentation produced from 2006 to 2016.
  - For the table about all past versions of FAVOR (Attachment 6) up to version 16.1 (the current version as of the date of this report), this means the requirements are met based on all documentation available for all past versions.
- Yellow cells: the V&V requirements were met for an earlier version of FAVOR, but not the latest for the time period considered.
- Red cells: the V&V requirements were not met for any version of FAVOR within the period considered.

When cells are empty and have no color coding, this means the FAVOR attribute was either nonexistent (for versions prior to v6.1, see Attachment 4), or that the FAVOR attribute was not modified (when considering only the 2006 to 2016 period, see Attachment 5).

Notes: See notes for tables in Attachment 4 and Attachment 5.

<table>
<tr><td></td><td colspan="15">NUREG/BR-0167 Requirement</td></tr>
<tr><td></td><td colspan="2">Requirements Definition</td><td colspan="5">Design Phase</td><td colspan="3">Implementation</td><td colspan="3">Qualification Testing</td><td colspan="2">Installation and Acceptance Testing</td></tr>
<tr><td>FAVOR ATTRIBUTE</td><td>Requirements Inspected?</td><td>V&V Plan Developed?</td><td>Design Inspected?</td><td>Qualification Test Plan Developed?</td><td>Acceptance Test Plan Developed?</td><td>Preliminary Design Review Conducted?</td><td>Critical Design Review Conducted?</td><td>Unit designs, unit code, and unit test plans Developed and Inspected?</td><td>Unit Testing Performed and Inspected?</td><td>Integration Test Plans Developed and Inspected?</td><td>Qualification Testing Performed</td><td>Qualification Report Written?</td><td>Acceptance Test Procedure Developed?</td><td>Acceptance Testing Performed?</td><td>Acceptance Test Report Written?</td></tr>
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<tr><td>Thermo-Mechanical Material Properties for clad and base metal of the reactor vessel (i.e., thermal conductivity, specific heat, density, Young's Elastic Modulus, thermal expansion coefficient, Poisson's ratio)</td><td>1994-1 v9401
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2003-1 v0204
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2004-2 Gap
2004-9 Yes
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2003-1 Gap
2004-2 Gap
2004-9 Gap
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2004-9 v0202
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2010-1 v0901
2016-7 v1601
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2004-9 Yes
2005-1 Yes
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2016-7 v1601
2017-1 v1601</td><td>2003-1 Yes
2004-9 Yes
2005-1 Yes
2010-1 Gap
2016-7 Gap
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2005-1 Yes</td><td>2003-3 Gap
2005-1 Yes</td><td>2003-3 Yes
2005-1 Yes</td><td>Report 2003-3
Report 2005-1</td><td>2003-3 Yes
2005-1 Yes</td><td>2003-3 Yes
2005-1 Yes</td><td>Report 2003-3
Report 2005-1</td></tr>
</table>

Attachment 6: FAVOR V&V Checklist Results – All Past FAVOR Versions

	NUREG/BR-0167 Requirement														
	Requirements Definition		Design Phase					Implementation			Qualification Testing			Installation and Acceptance Testing	
FAVOR ATTRIBUTE	Requirements Inspected?	V&V Plan Developed?	Design Inspected?	Qualification Test Plan Developed?	Acceptance Test Plan Developed?	Preliminary Design Review Conducted?	Critical Design Review Conducted?	Unit designs, unit code, and unit test plans Developed and Inspected?	Unit Testing Performed and Inspected?	Integration Test Plans Developed and Inspected?	Qualification Testing Performed	Qualification Report Written?	Acceptance Test Procedure Developed?	Acceptance Testing Performed?	Acceptance Test Report Written?
FAVOR FUNCTIONS AND ALGORITHMS															
FAVLoad Deterministic analyses															
Thermal analysis	2003-1 v0204 2004-2 v0301 2004-9 v0202 2005-1 v0301 2010-1 v0901 2016-7 v1601 2017-1 v1601	2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes 2010-1 Gap 2016-7 Gap 2017-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes 2010-1 Gap 2016-7 Gap 2017-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes 2010-1 Gap 2016-7 Yes 2017-1 Yes	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes 2010-1 Gap 2016-7 Yes 2017-1 Yes	2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes 2010-1 Yes 2016-7 Yes 2017-1 Yes	Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1 Paper 2010-1 Report 2016-7 Paper 2017-1	2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes 2010-1 Gap 2016-7 Gap 2017-1 Gap	2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes 2010-1 Yes 2016-7 Yes 2017-1 Yes	Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1 Paper 2010-1 Report 2016-7 Paper 2017-1
Stress analysis	1994-1 v9401 1999-1 v9401 2000-1 v9401 2004-9 v0202 2005-1 v0301 2010-1 v0901 2016-7 v1601 2017-1 v1601	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Yes 2005-1 Yes 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Yes 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Yes 2010-1 Gap 2016-7 Yes 2017-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Yes 2010-1 Gap 2016-7 Yes 2017-1 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2004-9 Yes 2005-1 Yes 2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2004-9 Report 2005-1 Paper 2010-1 Report 2016-7 Paper 2017-1	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Yes 2005-1 Yes 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Yes 1999-1 Yes 2000-1 Yes 2004-9 Yes 2005-1 Yes 2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2004-9 Report 2005-1 Paper 2010-1 Report 2016-7 Paper 2017-1
Linear-Elastic Fracture Mechanics (LEFM)	1994-1 v9401 1999-1 v9401 2000-1 v9401 2004-9 v0202 2005-1 v0301 2010-1 v0901 2016-7 v1601 2017-1 v1601	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Yes 2005-1 Yes 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Yes 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Yes 2010-1 Gap 2016-7 Yes 2017-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Gap 2005-1 Yes 2010-1 Gap 2016-7 Yes 2017-1 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2004-9 Yes 2005-1 Yes 2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2004-9 Report 2005-1 Paper 2010-1 Report 2016-7 Paper 2017-1	1994-1 Gap 1999-1 Gap 2000-1 Gap 2004-9 Yes 2005-1 Yes 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Yes 1999-1 Yes 2000-1 Yes 2004-9 Yes 2005-1 Yes 2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2004-9 Report 2005-1 Paper 2010-1 Report 2016-7 Paper 2017-1
Handling of residual stresses in welds															
Handling of crack-face pressure for surface breaking flaws	2010-1 v0901 2016-7 v1601 2017-1 v1601	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Gap 2016-7 Yes 2017-1 Yes	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 Gap 2016-7 Gap 2017-1 Gap	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1
Calculation of Nil-Ductility Transition Temperature, RT_{NDT}	2003-1 v0204 2004-1 v0301 2005-1 v0301 2007-3 v0601	2003-1 Yes 2004-1 Yes 2005-1 Yes 2007-3 Yes	2003-1 Gap 2004-1 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2004-1 Yes 2005-1 Yes 2007-3 Yes	2003-1 Gap 2004-1 Yes 2005-1 Yes 2007-3 Yes	2003-1 Gap 2004-1 Yes 2005-1 Yes 2007-3 Yes	2003-1 Yes 2004-1 Yes 2005-1 Yes 2007-3 Yes	Report 2003-1 Report 2004-1 Report 2005-1 Report 2007-3	2003-1 Yes 2004-1 Yes 2005-1 Yes 2007-3 Yes	2003-1 Yes 2004-1 Yes 2005-1 Yes 2007-3 Yes	Report 2003-1 Report 2004-1 Report 2005-1 Report 2007-3

	NUREG/BR-0167 Requirement														
	Requirements Definition		Design Phase					Implementation			Qualification Testing			Installation and Acceptance Testing	
FAVOR ATTRIBUTE	Requirements Inspected?	V&V Plan Developed?	Design Inspected?	Qualification Test Plan Developed?	Acceptance Test Plan Developed?	Preliminary Design Review Conducted?	Critical Design Review Conducted?	Unit designs, unit code, and unit test plans Developed and Inspected?	Unit Testing Performed and Inspected?	Integration Test Plans Developed and Inspected?	Qualification Testing Performed	Qualification Report Written?	Acceptance Test Procedure Developed?	Acceptance Testing Performed?	Acceptance Test Report Written?
FAVOR FUNCTIONS AND ALGORITHMS															
FAVLoad Deterministic analyses															
Radiation embrittlement correlations	2004-1 v0301 2005-1 v0301 2007-3 v0601 (Eason2006) 2011-1 v0901	2004-1 Yes 2005-1 Yes 2007-3 Yes 2011-1 Yes	2004-1 Gap 2005-1 Gap 2007-3 Gap 2011-1 Gap	2004-1 Gap 2005-1 Gap 2007-3 Gap 2011-1 Gap	2004-1 Gap 2005-1 Gap 2007-3 Gap 2011-1 Gap	2004-1 Gap 2005-1 Gap 2007-3 Gap 2011-1 Gap	2004-1 Gap 2005-1 Gap 2007-3 Gap 2011-1 Gap	2004-1 Yes 2005-1 Yes 2007-3 Yes 2011-1 Yes	2004-1 Yes 2005-1 Yes 2007-3 Yes 2011-1 Yes	2004-1 Yes 2005-1 Yes 2007-3 Yes 2011-1 Gap	2004-1 Yes 2005-1 Yes 2007-3 Yes 2011-1 Yes	Report 2004-1 Report 2005-1 Report 2007-3 Report 2011-1	2004-1 Yes 2005-1 Yes 2007-3 Yes 2011-1 Yes	2004-1 Yes 2005-1 Yes 2007-3 Yes 2011-1 Yes	Report 2004-1 Report 2005-1 Report 2007-3 Report 2011-1
Fast-neutron fluence attenuation and sampling	2003-1 v0204 2003-4 v0204 2004-8 v0301 2005-1 v0301	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Yes	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Yes	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Yes	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes	Report 2003-1 Report 2003-4 Report 2004-8 Report 2005-1	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes	Report 2003-1 Report 2003-4 Report 2004-8 Report 2005-1
Handling of K_{IC} and K_{Ia} Databases and calculations of K_{IC} and K_{Ia}	2003-1 v0204 2004-2 v0301 2005-1 v0301	2003-1 Yes 2004-2 Gap 2005-1 Yes	2003-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2005-1 Yes	2003-1 Gap 2004-2 Gap 2005-1 Yes	2003-1 Gap 2004-2 Gap 2005-1 Yes	2003-1 Yes 2004-2 Yes 2005-1 Yes	Report 2003-1 Paper 2004-2 Report 2005-1	2003-1 Yes 2004-2 Gap 2005-1 Yes	2003-1 Yes 2004-2 Yes 2005-1 Yes	Report 2003-1 Paper 2004-2 Report 2005-1
Sampling of RT_{NDT} and RT_{Arrest}	2003-1 v0204 2003-4 v0204 2005-1 v0301 2007-3 v0601	2003-1 Yes 2003-4 Yes 2005-1 Yes 2007-3 Yes RTNDT	2003-1 Gap 2003-4 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2005-1 Yes 2007-3 Yes RTNDT	2003-1 Gap 2003-4 Gap 2005-1 Yes 2007-3 Yes RTNDT	2003-1 Gap 2003-4 Gap 2005-1 Yes 2007-3 Yes RTNDT	2003-1 Yes 2003-4 Yes 2005-1 Yes 2007-3 Yes RTNDT	Report 2003-1 Report 2003-4 Report 2005-1 Report 2007-3	2003-1 Yes 2003-4 Yes 2005-1 Yes 2007-3 Yes RTNDT	2003-1 Yes 2003-4 Yes 2005-1 Yes 2007-3 Yes RTNDT	Report 2003-1 Report 2003-4 Report 2005-1 Report 2007-3
Sampling of Material Chemistry	2003-1 v0204 2003-4 v0204 2004-8 v0301 2005-1 v0301 2007-3 v0601	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes 2007-3 Yes	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Yes 2007-3 Yes	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Yes 2007-3 Yes	2003-1 Gap 2003-4 Gap 2004-8 Gap 2005-1 Yes 2007-3 Yes	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes 2007-3 Yes	Report 2003-1 Report 2003-4 Report 2004-8 Report 2005-1 Report 2007-3	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes 2007-3 Yes	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes 2007-3 Yes	2003-1 Yes 2003-4 Yes 2004-8 Yes 2005-1 Yes 2007-3 Yes
Flaw characterizations and uncertainty	2002-1 v0201 Cat 1 - 3 2003-1 v0204 2004-7 v0203 Cat 1 - 3 2004-10 v0203 Cat 1 - 3 2005-1 v0301 Cat 1 - 3 2011-1 v0901	2002-1 Yes 2003-1 Yes 2004-7 Yes 2004-10 Yes 2005-1 Yes 2011-1 Yes	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Gap 2011-1 Gap	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Gap 2011-1 Gap	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Gap 2011-1 Gap	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Gap 2011-1 Gap	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Gap 2011-1 Gap	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Yes 2011-1 Yes	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Yes 2011-1 Yes	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Yes 2011-1 Gap	2002-1 Yes 2003-1 Yes 2004-7 Yes 2004-10 Yes 2005-1 Yes 2011-1 Yes	Report 2002-1 Report 2003-1 Report 2004-7 Report 2004-10 Report 2005-1 Report 2011-1	2002-1 Gap 2003-1 Gap 2004-7 Gap 2004-10 Gap 2005-1 Yes 2011-1 Yes	2002-1 Yes 2003-1 Yes 2004-7 Yes 2004-10 Yes 2005-1 Yes 2011-1 Yes	Report 2002-1 Report 2003-1 Report 2004-7 Report 2004-10 Report 2005-1 Report 2011-1

Attachment 6: FAVOR V&V Checklist Results – All Past FAVOR Versions

	NUREG/BR-0167 Requirement														
	Requirements Definition		Design Phase					Implementation			Qualification Testing			Installation and Acceptance Testing	
FAVOR ATTRIBUTE	Requirements Inspected?	V&V Plan Developed?	Design Inspected?	Qualification Test Plan Developed?	Acceptance Test Plan Developed?	Preliminary Design Review Conducted?	Critical Design Review Conducted?	Unit designs, unit code, and unit test plans Developed and Inspected?	Unit Testing Performed and Inspected?	Integration Test Plans Developed and Inspected?	Qualification Testing Performed	Qualification Report Written?	Acceptance Test Procedure Developed?	Acceptance Testing Performed?	Acceptance Test Report Written?
FAVPFM ALGORITHMS and MODELS															
Warm prestressing logic	2003-1 v0204 2004-1 v0301 2005-1 v0301 2011-1 v0901	2003-1 Yes 2004-1 Yes 2005-1 Yes 2011-1 Yes	2003-1 Gap 2004-1 Gap 2005-1 Gap 2011-1 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2011-1 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2011-1 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2011-1 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2011-1 Gap	2003-1 Gap 2004-1 Yes 2005-1 Yes 2011-1 Yes	2003-1 Gap 2004-1 Yes 2005-1 Yes 2011-1 Yes	2003-1 Gap 2004-1 Yes 2005-1 Yes 2011-1 Gap	2003-1 Yes 2004-1 Yes 2005-1 Yes 2011-1 Yes	Report 2003-1 Report 2004-1 Report 2005-1 Report 2011-1	2003-1 Yes 2004-1 Yes 2005-1 Yes 2011-1 Yes	2003-1 Yes 2004-1 Yes 2005-1 Yes 2011-1 Yes	Report 2003-1 Report 2004-1 Report 2005-1 Report 2011-1
Truncation for probability distributions	2003-1 v0204 2005-1 v0301	2003-1 Yes 2005-1 Yes	2003-1 Gap 2005-1 Gap	2003-1 Gap 2005-1 Gap	2003-1 Gap 2005-1 Gap	2003-1 Gap 2005-1 Gap	2003-1 Gap 2005-1 Gap	2003-1 Gap 2005-1 Yes	2003-1 Gap 2005-1 Yes	2003-1 Gap 2005-1 Yes	2003-1 Yes 2005-1 Yes	Report 2003-1 Report 2005-1	2003-1 Yes 2005-1 Yes	2003-1 Yes 2005-1 Yes	Report 2003-1 Report 2005-1
Conditional Probability of Initiation (CPI) and Failure (CPF)	2003-1 v0204 2003-3 v0204 2003-6 v0204 2004-1 v0301 2004-2 v0301 2005-1 v0301 2007-3 v0601	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Gap 2005-1 Yes 2007-3 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap 2007-3 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2004-2 Gap 2005-1 Yes 2007-3 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2004-2 Gap 2005-1 Yes 2007-3 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2004-2 Gap 2005-1 Yes 2007-3 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Yes 2005-1 Yes 2007-3 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Paper 2004-2 Report 2005-1 Report 2007-3	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Gap 2005-1 Yes 2007-3 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Yes 2005-1 Yes 2007-3 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Paper 2004-2 Report 2005-1 Report 2007-3
Post initiation of flaw geometries and orientation	1994-1 v9401 1999-1 v9401 2000-1 v9401 2005-1 v0301 2007-3 v0601 2010-1 v0901 2016-7 v1601 2017-1 v1601	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Yes 2007-3 Yes 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Gap 2007-3 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Gap 2007-3 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Gap 2007-3 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Gap 2007-3 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Gap 2007-3 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Yes 2007-3 Yes 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Yes 2007-3 Yes 2010-1 Gap 2016-7 Yes 2017-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Yes 2007-3 Yes 2010-1 Gap 2016-7 Yes 2017-1 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2005-1 Yes 2007-3 Yes 2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2005-1 Report 2007-3 Paper 2010-1 Report 2016-7 Paper 2017-1	1994-1 Gap 1999-1 Gap 2000-1 Gap 2005-1 Yes 2007-3 Yes 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Yes 1999-1 Yes 2000-1 Yes 2005-1 Yes 2007-3 Yes 2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2005-1 Report 2007-3 Paper 2010-1 Report 2016-7 Paper 2017-1
Ductile tearing models	2004-1 v0301 2004-8 v0301 (USE) 2005-1 v0301 2005-2 v0401 2007-3 v0601 2011-1 v0901	2004-1 Yes 2004-8 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes 2011-1 Yes	2004-1 Gap 2004-8 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap 2011-1 Gap	2004-1 Gap 2004-8 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap 2011-1 Gap	2004-1 Gap 2004-8 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap 2011-1 Gap	2004-1 Gap 2004-8 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap 2011-1 Gap	2004-1 Gap 2004-8 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap 2011-1 Gap	2004-1 Yes 2004-8 Gap 2005-1 Yes 2005-2 Yes 2007-3 Yes 2011-1 Yes	2004-1 Yes 2004-8 Gap 2005-1 Yes 2005-2 Yes 2007-3 Yes 2011-1 Yes	2004-1 Yes 2004-8 Gap 2005-1 Yes 2005-2 Yes 2007-3 Yes 2011-1 Gap	2004-1 Yes 2004-8 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes 2011-1 Yes	Report 2004-1 Report 2004-8 Report 2005-1 Report 2005-2 Report 2007-3 Report 2011-1	2004-1 Yes 2004-8 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes 2011-1 Yes	2004-1 Yes 2004-8 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes 2011-1 Yes	Report 2004-1 Report 2004-8 Report 2005-1 Report 2005-2 Report 2007-3 Report 2011-1
Initiation-Growth-Arrest (IGA) model	2003-1 v0204 2004-1 v0301 2005-1 v0301 2005-2 v0401 2007-3 v0601 2011-1 v0901	2003-1 Yes 2004-1 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes 2011-1 Yes	2003-1 Gap 2004-1 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap 2011-1 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap 2011-1 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap 2011-1 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap 2011-1 Gap	2003-1 Gap 2004-1 Gap 2005-1 Gap 2005-2 Gap 2007-3 Gap 2011-1 Gap	2003-1 Gap 2004-1 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes 2011-1 Yes	2003-1 Gap 2004-1 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes 2011-1 Yes	2003-1 Gap 2004-1 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes 2011-1 Gap	2003-1 Yes 2004-1 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes 2011-1 Yes	Report 2003-1 Report 2004-1 Report 2005-1 Report 2005-2 Report 2007-3 Report 2011-1	2003-1 Yes 2004-1 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes 2011-1 Yes	2003-1 Yes 2004-1 Yes 2005-1 Yes 2005-2 Yes 2007-3 Yes 2011-1 Yes	Report 2003-1 Report 2004-1 Report 2005-1 Report 2005-2 Report 2007-3 Report 2011-1

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	Requirements Definition		Design Phase					Implementation			Qualification Testing			Installation and Acceptance Testing	
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FAVOR CRITICAL OUTPUTS															
Temperature as a function of time throughout vessel wall location	2003-1 v0204 2004-2 v0301 2004-9 v0202 2005-1 v0301	2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes	2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes	Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1	2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes	2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes	Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1
Stress as a function of time throughout vessel wall (circumferential and axial)	2000-1 v9401 2003-1 v0204 2004-9 v0202 2005-1 v0301	2000-1 Gap 2003-1 Yes 2004-9 Yes 2005-1 Yes	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Gap	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Gap	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Gap	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Gap	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Gap	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Yes	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Yes	2000-1 Gap 2003-1 Gap 2004-9 Gap 2005-1 Yes	2000-1 Yes 2003-1 Yes 2004-9 Yes 2005-1 Yes	Report 2000-1 Report 2003-1 Report 2004-9 Report 2005-1	2000-1 Gap 2003-1 Yes 2004-9 Yes 2005-1 Yes	2000-1 Gap 2003-1 Yes 2004-9 Yes 2005-1 Yes	Report 2000-1 Report 2003-1 Report 2004-9 Report 2005-1
K_I as a function of time throughout vessel wall	1994-1 v9401 1999-1 v9401 2000-1 v9401 2003-1 v0204 2004-2 v0301 2004-9 v0202 2005-1 v0301 2010-1 v0901 2016-7 v1601 2017-1 v1601	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Gap 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes 2010-1 Gap 2016-7 Yes 2017-1 Yes	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Gap 2004-2 Gap 2004-9 Gap 2005-1 Yes 2010-1 Gap 2016-7 Yes 2017-1 Yes	1994-1 Yes 1999-1 Yes 2000-1 Yes 2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes 2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1 Paper 2010-1 Report 2016-7 Paper 2017-1	1994-1 Gap 1999-1 Gap 2000-1 Gap 2003-1 Yes 2004-2 Gap 2004-9 Yes 2005-1 Yes 2010-1 Gap 2016-7 Gap 2017-1 Gap	1994-1 Yes 1999-1 Yes 2000-1 Yes 2003-1 Yes 2004-2 Yes 2004-9 Yes 2005-1 Yes 2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 1994-1 Paper 1999-1 Report 2000-1 Report 2003-1 Paper 2004-2 Report 2004-9 Report 2005-1 Paper 2010-1 Report 2016-7 Paper 2017-1
Probability distributions of crack initiation and vessel failure	2003-1 v0204 2003-3 v0204 2003-6 v0204 2004-1 v0301 2004-2 v0301 2005-1 v0301	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Gap 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2004-2 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2004-2 Gap 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2004-2 Gap 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2004-2 Gap 2005-1 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Yes 2005-1 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Paper 2004-2 Report 2005-1	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Gap 2005-1 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2004-2 Yes 2005-1 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Paper 2004-2 Report 2005-1
Crack initiation frequency per reactor operating year	2003-1 v0204 2003-3 v0204 2003-6 v0204 2004-1 v0301 2005-1 v0301	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2005-1 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Report 2005-1	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Report 2005-1
Through-wall crack frequency per reactor operating year	2003-1 v0204 2003-3 v0204 2003-6 v0204 2004-1 v0301 2005-1 v0301	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Gap 2005-1 Gap	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2005-1 Yes	2003-1 Gap 2003-3 Gap 2003-6 Gap 2004-1 Yes 2005-1 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Report 2005-1	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	2003-1 Yes 2003-3 Yes 2003-6 Yes 2004-1 Yes 2005-1 Yes	Report 2003-1 Report 2003-3 Report 2003-6 Report 2004-1 Report 2005-1

	ASME V&V 10-2006 Requirement				
FAVOR ATTRIBUTE	**Mathematical Model compared to Computational Model?**	**Simulation Results compared to Computational Model?**	**Simulation Model Uncertainties Quantified?**	**Experimental Data Uncertainties Quanitified?**	**Simulation Outcomes Quantitatively compared to Experimental Outcomes?**
FAVOR INPUTS					
Thermo-Mechanical Material Properties for clad and base metal of the reactor vessel (i.e., thermal conductivity, specific heat, density, Young's Elastic Modulus, thermal expansion coefficient, Poisson's ratio)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	1994-1 1 to 2% KI 1999-1 -5.5 to 17.5% KI 2000-1 -1 to 23.2% KI 2003-1 Yes - Various 2004-2 No 2004-9 Yes - Various 2005-1 Yes - Various	1994-1 No 1999-1 No 2000-1 No 2003-1 No 2004-2 No 2004-9 No 2005-1 No	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-2 Yes (M) (PTSE 1B/1C) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)
Reactor pressure vessel geometry	2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B) 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B) 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2003-1 Yes - Various 2004-2 No 2004-9 Yes - Various 2005-1 Yes - Various 2010-1 Yes 2016-7 Yes 2017-1 Yes	2003-1 No 2004-2 No 2004-9 No 2005-1 No 2010-1 No 2016-7 No 2017-1 No	2003-1 Various Independent (B) 2004-2 Yes (M) (PTSE 1B/1C) 2004-9 ABAQUS (B) 2005-1 Various Independent (B) 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)
Thermal Hydraulic boundary conditions (from RELAP or similar Transient T-H code)	2003-1 Various Independent (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B) 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2003-1 Various Independent (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B) 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2003-1 Yes - Various 2004-9 Yes - Various 2005-1 Yes - Various 2010-1 Yes 2016-7 Yes 2017-1 Yes	2003-1 No 2004-9 No 2005-1 No 2010-1 No 2016-7 No 2017-1 No	2003-1 Various Independent (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B) 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)
Fast Neutron fluence maps					
Flaw densities, size, and location (plates, welds, and forgings)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2002-1 PNNL Calc (B) 2004-7 PNNL Calc (B) 2004-10 PNNL Calc (B) 2005-1 Various Independent (B) 2011-1 CNWRA Independent Calcs (B)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2002-1 PNNL Calc (B) 2004-7 PNNL Calc (B) 2004-10 PNNL Calc (B) 2005-1 Various Independent (B) 2011-1 CNWRA Independent Calcs (B)	1994-1 1 to 2% KI 1999-1 -5.5 to 17.5% KI 2000-1 -1 to 23.2% KI 2002-1 Flaw Dist. Matched 2004-7 Flaw Dist. Matched 2004-10 Flaw Dist. Matched 2005-1 Flaw Dist. Matched 2011-1 Yes	1994-1 No 1999-1 No 2000-1 No 2002-1 No 2004-7 No 2004-10 No 2005-1 No 2011-1 No	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2002-1 PNNL Calc (B) 2004-7 PNNL Calc (B) 2004-10 PNNL Calc (B) 2005-1 Various Independent (B) 2011-1 CNWRA Independent Calcs (B)
Embrittlement Data (i.e., Cu, Ni, P, Mn, f_o, RT_{NDT0})	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B) 2011-1 CNWRA Independent Calcs (B)	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B) 2011-1 CNWRA Independent Calcs (B)	2003-1 Yes - Various 2003-4 SAS (B) 2004-8 SAS (B) 2005-1 Yes Various 2007-3 Errors Identified 2011-1 Yes	2003-1 No 2003-4 No 2004-8 No 2005-1 No 2007-3 No 2011-1 No	2003-1 Yes - Various 2003-4 SAS (B) 2004-8 SAS (B) 2005-1 Yes Various 2007-3 Errors Identified 2011-1 CNWRA Independent Calcs (B)
Transient Initiating Frequency distributions (from PRA)	2003-3 INEEL/SAS (B) 2005-1 Various Independent (B)	2003-3 INEEL/SAS (B) 2005-1 Various Independent (B)	2003-3 Yes - Various 2005-1 Yes - Various	2003-3 No 2005-1 No	2003-3 INEEL/SAS (B) 2005-1 Various Independent (B)
Probability distributions (aleatory and epistemic)	2003-3 INEEL/SAS (B) 2005-1 Various Independent (B)	2003-3 INEEL/SAS (B) 2005-1 Various Independent (B)	2003-3 Yes - Various 2005-1 Yes - Various	2003-3 No 2005-1 No	2003-3 INEEL/SAS (B) 2005-1 Various Independent (B)

	ASME V&V 10-2006 Requirement				
FAVOR ATTRIBUTE	**Mathematical Model compared to Computational Model?**	**Simulation Results compared to Computational Model?**	**Simulation Model Uncertainties Quantified?**	**Experimental Data Uncertainties Quanitified?**	**Simulation Outcomes Quantitatively compared to Experimental Outcomes?**
FAVOR FUNCTIONS AND ALGORITHMS					
FAVLoad Deterministic analyses					
Thermal analysis	2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B) 2010-1 Yes 2016-7 Yes 2017-1 Yes	2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B) Paper 2010-1 Report 2016-7 Paper 2017-1	2003-1 Yes - Various 2004-2 No 2004-9 Yes - Various 2005-1 Yes - Various 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2003-1 No 2004-2 No 2004-9 No 2005-1 No 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2003-1 Various Independent (B) 2004-2 Yes (M) (PTSE 1B/1C) 2004-9 ABAQUS (B) 2005-1 Various Independent (B) 2010-1 Yes 2016-7 Yes 2017-1 Yes
Stress analysis	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B) 2010-1 Yes 2016-7 Yes 2017-1 Yes	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B) Paper 2010-1 Report 2016-7 Paper 2017-1	1994-1 1 to 2% KI 1999-1 -5.5 to 17.5% KI 2000-1 -1 to 23.2% KI 2004-9 Yes - Various 2005-1 Yes - Various 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	1994-1 No 1999-1 No 2000-1 No 2004-9 No 2005-1 No 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2004-9 ABAQUS(B) 2005-1 Various Independent (B) 2010-1 Yes 2016-7 Yes 2017-1 Yes
Linear-Elastic Fracture Mechanics (LEFM)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B) 2010-1 Yes 2016-7 Yes 2017-1 Yes	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B) Paper 2010-1 Report 2016-7 Paper 2017-1	1994-1 1 to 2% KI 1999-1 -5.5 to 17.5% KI 2000-1 -1 to 23.2% KI 2004-9 Yes - Various 2005-1 Yes - Various 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	1994-1 No 1999-1 No 2000-1 No 2004-9 No 2005-1 No 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2004-9 ABAQUS(B) 2005-1 Various Independent (B) 2010-1 Yes 2016-7 Yes 2017-1 Yes
Handling of residual stresses in welds					
Handling of crack-face pressure for surface breaking flaws	2010-1 Yes 2016-7 Yes 2017-1 Yes	Paper 2010-1 Report 2016-7 Paper 2017-1	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	2010-1 Yes 2016-7 Yes 2017-1 Yes
Calculation of Nil-Ductility Transition Temperature, RT_{NDT}	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Yes - Various 2004-1 No 2005-1 Yes - Various 2007-3 Yes - Eason	2003-1 No 2004-1 No 2005-1 No 2007-3 No	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)

Attachment 6: FAVOR V&V Checklist Results – All Past FAVOR Versions

	ASME V&V 10-2006 Requirement				
FAVOR ATTRIBUTE	**Mathematical Model compared to Computational Model?**	**Simulation Results compared to Computational Model?**	**Simulation Model Uncertainties Quantified?**	**Experimental Data Uncertainties Quanitified?**	**Simulation Outcomes Quantitatively compared to Experimental Outcomes?**
FAVOR FUNCTIONS AND ALGORITHMS					
FAVLoad Deterministic analyses					
Radiation embrittlement correlations	2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B) 2011-1 Yes	2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B) Report 2011-1	2004-1 No 2005-1 Yes - Various 2007-3 Yes - Eason 2011-1 CNWRA Independent Calcs (B)	2004-1 No 2005-1 No 2007-3 No 2011-1 CNWRA Independent Calcs (B)	2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B) 2011-1 Yes
Fast-neutron fluence attenuation and sampling	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B)	2003-1 Yes - Various 2003-4 SAS (B) 2004-8 SAS (B) 2005-1 Yes - Various	2003-1 No 2003-4 No 2004-8 No 2005-1 No	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B)
Handling of K_{IC} and K_{Ia} Databases and calculations of K_{IC} and K_{Ia}	2003-1 Various Independent (B) 2004-2 No 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2004-2 No 2005-1 Various Independent (B)	2003-1 Yes - Various 2004-2 No 2005-1 Yes - Various	2003-1 No 2004-2 No 2005-1 No	2003-1 Various Independent (B) 2004-2 Yes (M) (PTSE 1B/1C) 2005-1 Various Independent (B)
Sampling of RT_{NDT} and RT_{Arrest}	2003-1 Various Independent (B) 2003-4 SAS (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Various Independent (B) 2003-4 SAS (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Yes - Various 2003-4 SAS (B) 2005-1 Yes - Various 2007-3 Yes	2003-1 No 2003-4 No 2005-1 No 2007-3 No	2003-1 Various Independent (B) 2003-4 SAS (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)
Sampling of Material Chemistry	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Yes - Various 2003-4 SAS (B) 2004-8 SAS (B) 2005-1 Yes - Various 2007-3 Errors Identified	2003-1 No 2003-4 No 2004-8 No 2005-1 No 2007-3 No	2003-1 Various Independent (B) 2003-4 SAS (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B)
Flaw characterizations and uncertainty	2002-1 PNNL Calc (B) 2003-1 Various Independent (B) 2004-7 PNNL Calc (B) 2004-10 PNNL Calc (B) 2005-1 Various Independent (B) 2011-1 Yes	2002-1 PNNL Calc (B) 2003-1 Various Independent (B) 2004-7 PNNL Calc (B) 2004-10 PNNL Calc (B) 2005-1 Various Independent (B) Report 2011-1	2002-1 Flaw Dist. Matched 2003-1 Yes - Various 2004-7 Flaw Dist. Matched 2004-10 Flaw Dist. Matched 2005-1 Yes - Various 2011-1 CNWRA Independent Calcs (B)	2002-1 No 2003-1 No 2004-7 No 2004-10 No 2005-1 No 2011-1 CNWRA Independent Calcs (B)	2002-1 PNNL Calc (B) 2003-1 Various Independent (B) 2004-7 PNNL Calc (B) 2004-10 PNNL Calc (B) 2005-1 Various Independent (B) 2011-1 Yes

Attachment 6: FAVOR V&V Checklist Results – All Past FAVOR Versions

	ASME V&V 10-2006 Requirement				
FAVOR ATTRIBUTE	**Mathematical Model compared to Computational Model?**	**Simulation Results compared to Computational Model?**	**Simulation Model Uncertainties Quantified?**	**Experimental Data Uncertainties Quanitified?**	**Simulation Outcomes Quantitatively compared to Experimental Outcomes?**
FAVPFM ALGORITHMS and MODELS					
Warm prestressing logic	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2011-1 Yes	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) Report 2011-1	2003-1 Yes - Various 2004-1 No 2005-1 Yes - Various 2011-1 CNWRA Independent Calcs (B)	2003-1 No 2004-1 No 2005-1 No 2011-1 CNWRA Independent Calcs (B)	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2011-1 Yes
Truncation for probability distributions	2003-1 Various Independent (B) 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2005-1 Various Independent (B)	2003-1 Yes - Various 2005-1 Yes - Various	2003-1 No 2005-1 No	2003-1 Various Independent (B) 2005-1 Various Independent (B)
Conditional Probability of Initiation (CPI) and Failure (CPF)	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2004-2 No 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2004-2 No 2005-1 Various Independent (B) 2007-3 Various Independent (B)	2003-1 Yes - Various 2003-3 Yes - Various 2003-6 Yes - Various 2004-1 No 2004-2 No 2005-1 Yes - Various 2007-3 No	2003-1 No 2003-3 No 2003-6 No 2004-1 No 2004-2 No 2005-1 No 2007-3 No	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2004-2 Yes (M) (PTSE 1B/1C) 2005-1 Various Independent (B) 2007-3 Various Independent (B)
Post initiation of flaw geometries and orientation	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B) 2010-1 Yes 2016-7 Yes 2017-1 Yes	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B) Paper 2010-1 Report 2016-7 Paper 2017-1	1994-1 1 to 2% KI 1999-1 -5.5 to 17.5% KI 2000-1 -1 to 23.2% KI 2005-1 Yes - Various 2007-3 No - Errors Identified 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	1994-1 No 1999-1 No 2000-1 No 2005-1 No 2007-3 No 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2005-1 Various Independent (B) 2007-3 Various Independent (B) 2010-1 Yes 2016-7 Yes 2017-1 Yes
Ductile tearing models	2004-1 EPRI MS EXCEL (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2005-2 Various Independent (B) 2007-3 Various Independent (B) 2011-1 Yes	2004-1 EPRI MS EXCEL (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2005-2 Various Independent (B) 2007-3 Various Independent (B) Report 2011-1	2004-1 No 2004-8 No 2005-1 Yes - Various 2005-2 No 2007-3 Yes 2011-1 CNWRA Independent Calcs (B)	2004-1 No 2004-8 No 2005-1 No 2005-2 No 2007-3 No 2011-1 CNWRA Independent Calcs (B)	2004-1 EPRI MS EXCEL (B) 2004-8 SAS/Observations (B) 2005-1 Various Independent (B) 2005-2 Various Independent (B) 2007-3 Various Independent (B) 2011-1 Yes
Initiation-Growth-Arrest (IGA) model	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2005-2 Various Independent (B) 2007-3 Various Independent (B) 2011-1 Yes	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2005-2 Various Independent (B) 2007-3 Various Independent (B) Report 2011-1	2003-1 Yes - Various 2004-1 No 2005-1 Yes - Various 2005-2 No 2007-3 No 2011-1 CNWRA Independent Calcs (B)	2003-1 No 2004-1 No 2005-1 No 2005-2 No 2007-3 No 2011-1 CNWRA Independent Calcs (B)	2003-1 Various Independent (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B) 2005-2 Various Independent (B) 2007-3 Various Independent (B) 2011-1 Yes

Attachment 6: FAVOR V&V Checklist Results – All Past FAVOR Versions

	ASME V&V 10-2006 Requirement				
FAVOR ATTRIBUTE	Mathematical Model compared to Computational Model?	Simulation Results compared to Computational Model?	Simulation Model Uncertainties Quantified?	Experimental Data Uncertainties Quanitified?	Simulation Outcomes Quantitatively compared to Experimental Outcomes?
FAVOR CRITICAL OUTPUTS					
Temperature as a function of time throughout vessel wall location	2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	2003-1 Yes - Various 2004-2 No 2004-9 Yes - Various 2005-1 Yes - Various	2003-1 No 2004-2 No 2004-9 No 2005-1 No	2003-1 Various Independent (B) 2004-2 Yes (M) (PTSE 1B/1C) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)
Stress as a function of time throughout vessel wall (circumferential and axial)	2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)	2000-1 Plots of hoop stress 2003-1 Yes - Various 2004-9 Yes - Various 2004-1 Yes - Various	2000-1 No 2003-1 No 2004-9 No 2005-1 No	2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-9 ABAQUS (B) 2005-1 Various Independent (B)
K_I as a function of time throughout vessel wall	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B) 2010-1 Yes 2016-7 Yes 2017-1 Yes	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-2 No 2004-9 ABAQUS (B) 2005-1 Various Independent (B) Paper 2010-1 Report 2016-7 Paper 2017-1	1994-1 1 to 2% KI 1999-1 -5.5 to 17.5% KI 2000-1 -1 to 23.2% KI 2003-1 Yes - Various 2004-2 No 2004-9 Yes - Various 2005-1 Yes - Various 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	1994-1 No 1999-1 No 2000-1 No 2003-1 No 2004-2 No 2004-9 No 2005-1 No 2010-1 ABAQUS / ASME based SIFICs (B) 2016-7 ABAQUS / ASME based SIFICs (B) 2017-1 ABAQUS / ASME based SIFICs (B)	1994-1 ABAQUS (B) 1999-1 ABAQUS (B) 2000-1 ABAQUS/SUBCOR (B) 2003-1 Various Independent (B) 2004-2 Yes (M) (PTSE 1B/1C) 2004-9 ABAQUS (B) 2005-1 Various Independent (B) 2010-1 Yes 2016-7 Yes 2017-1 Yes
Probability distributions of crack initiation and vessel failure	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2004-2 No 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2004-2 No 2005-1 Various Independent (B)	2003-1 Yes - Various 2003-3 Yes - Various 2003-6 Yes - Various 2004-1 No 2004-2 No 2005-1 Yes - Various	2003-1 No 2003-3 No 2003-6 No 2004-1 No 2004-2 No 2005-1 No	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2004-2 Yes (M) (PTSE 1B/1C) 2005-1 Various Independent (B)
Crack initiation frequency per reactor operating year	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B)	2003-1 Yes - Various 2003-3 Yes - Various 2003-6 Yes - Various 2004-1 No 2005-1 Yes - Various	2003-1 No 2003-3 No 2003-6 No 2004-1 No 2005-1 No	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B)
Through-wall crack frequency per reactor operating year	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B)	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B)	2003-1 Yes - Various 2003-3 Yes - Various 2003-6 Yes - Various 2004-1 No 2005-1 Yes - Various	2003-1 No 2003-3 No 2003-6 No 2004-1 No 2005-1 No	2003-1 Various Independent (B) 2003-3 INEEL/SAS (B) 2003-6 INEEL/SAS (B) 2004-1 EPRI MS EXCEL (B) 2005-1 Various Independent (B)