VERIFICATION AND VALIDATION PLAN FOR THE SCALE CODE SYSTEM

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Date Prepared: April 10, 1996

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1.0 PURPOSE AND SCOPE

1.1 The purpose of this plan is to describe the methods to be used for baseline verification and validation of the SCALE system in the specific analysis areas defined in 1.2 below, and to establish specific responsibilities for accomplishing the verification and validation tasks.

1.2 The scope of this plan is limited to establishing a baseline verification and validation of the SCALE computer code system as developed and maintained at Oak Ridge National Laboratory (ORNL) by the Nuclear Engineering Applications Section (NEAS) under References 2.1-2.2. Suitability of the SCALE system for use in performing criticality, shielding, heat transfer, and source generation calculations for a variety of applications will be determined. References that demonstrate the validity of the nuclear data, solution techniques, and modeling capabilities in the SCALE modules are provided in Section 2.0 as References 2.6 through 2.39.

1.3 Other installations may use the process and results of this baseline verification and validation at their discretion as a guide for the verification and validation of their system.

1.4 The initial baseline work will be performed with a baseline version of the SCALE system specified by the SCALE Project Leader. The problems included in this baseline verification and validation will be used, at the direction of the SCALE Project Leader, to establish the performance of future versions of the SCALE system as maintained and distributed by ORNL.

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3.0 DEFINITIONS AND ACRONYMS

3.1 V&V - Verification and Validation

3.2 OCRWM - Office of Civilian Radioactive Waste Management at the U.S. Department of Energy

3.3 OECD/NEA - Organization for Economic Cooperation and Development/Nuclear Energy Agency

3.4 ORNL - Oak Ridge National Laboratory

3.5 NEAS - Nuclear Engineering Analysis Section

3.6 SCALE - Standardized Computer Analyses for Licensing Evaluation code system. See Reference 2.5.

3.7 SNF - Spent Nuclear Fuel

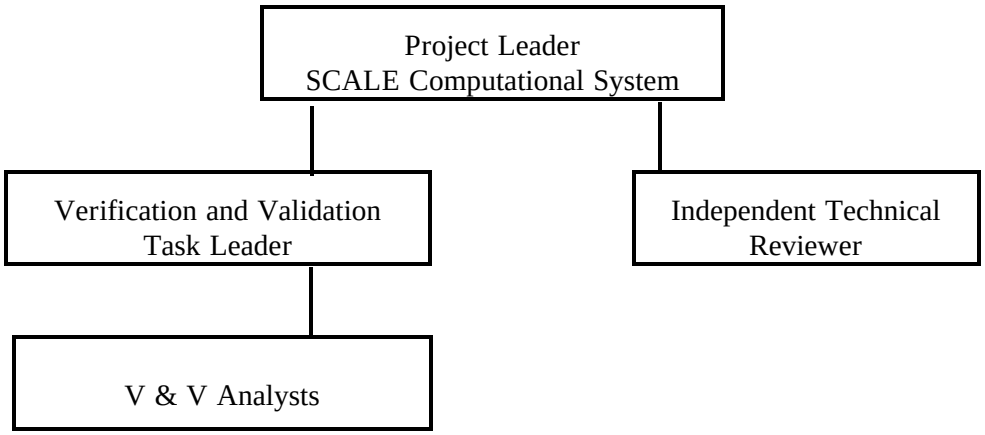
3.8 Validation - Assurance that a model as embodied in a computer code is a correct representation of the process or system for which it is intended. This is usually accomplished by comparing code results to either physical data or a validated code designed to perform the same type of analysis.

3.9 Verification - Assurance that a computer code correctly performs the operations specified in a numerical model. This is usually accomplished by comparing code results to a hand calculation, an analytical solution or approximation, or a verified code designed to perform the same type of analysis.

4.0 ORGANIZATION

4.1 V&V Interfaces

The verification/validation activities described in this plan shall be conducted by personnel who are knowledgeable of the code(s) to be analyzed; and who are qualified by education, experience and training to successfully perform their assigned procedures. Education shall include a B.S., M.S., or Ph.D. in engineering or related fields (e.g. math, physics, etc.). The personnel selected to perform the verification/validation activities and their relationship to the SCALE Computational System are as follows.



4.2 Qualifications

Task Leader - The Task Leader should have at least five years experience as a user of the module(s) and data for a variety of applications.

Technical Reviewer - The Technical Reviewer should have at least five years experience in one or more of the areas for which the SCALE system is used: cross-section processing, criticality safety, radiation shielding, heat transfer, or spent fuel and HLW source characterization. The reviewer should also have similar experience in the use of the modules and/or data selected for verification/validation.

V&V Analyst - A V&V Analyst should have at least two years experience in the use of the SCALE system.

5.0 RESPONSIBILITIES

5.1 Project Leader - The person responsible for managing the maintenance, development and verification/validation of the SCALE computational system.

5.2 Task Leader - The person responsible for the verification/validation of the SCALE module(s) and data to be used in the criticality, shielding, heat transfer and source

generation analyses. The Task Leader shall perform the analyses directly or supervise and subsequently review the analyses as performed by experienced users of the modules and data.

5.3 Technical Reviewer - The person responsible for reviewing and checking the analyses performed under one of the verification/validation tasks in accordance with Section 6.5.

5.4 V&V Analyst - The V&V analyst that actually performs the V&V activities should not have been directly involved in the development of the code or data being validated.

6.0 VERIFICATION/VALIDATION PROCEDURES

6.1 Verification/Validation of the SCALE Criticality Analysis Modules - Verification of SCALE for criticality calculations shall be conducted by performing calculations of critical benchmarks previously modeled in an unpublished verification study in Reference 2.6. These calculations will verify the CSAS criticality control module and the associated functional modules BONAMI, NITAWL-II, XSDRNPM, and KENO V.a in SCALE. The analysis will be performed using the ENDF/B-IV-based 27-neutron-group cross-section library provided in SCALE. Verification shall be accomplished by cross-checking the results of each module in the sequence with the results obtained from independent methods. These verification problems are, to the extent possible, exhaustive of the various code options. Any areas not covered shall be documented. Further verification is provided by the sample problems documented by the developers in Reference 2.5 and run for each module under the SCALE Configuration Management Plan (Reference 2.2). These sample problems are run and kept on file at ORNL as required under the SCALE Configuration Management Plan. The acceptance criteria for the k_{eff} and cross section comparisons shall be separately established, justified and documented in V&V reports for each verification activity.

The validation effort shall consist of a merging of the various validation projects previously reported in References 2.9-2.11 and 2.26-2.33. A combined database of problems shall be created and executed with the cross section libraries to be validated on the current standard computing platform. Consistency with previously reported values and internal consistency of the combined set with measured values shall be reported. k_{eff} acceptance criteria shall be established, justified, and documented in the V&V report for each validation activity. Limitations of the validation study shall be reported. Other problems may be added to the V&V activities in the future as needed.

6.2 Verification/Validation of the Shielding Analysis Codes - Verification of the SCALE-4 shielding modules SAS1 and SAS4 shall be accomplished by performing dose rate calculations for a benchmark configuration (denoted Problem 1a) as defined by the OECD/NEA working group on shielding assessment of transportation packages (see Reference 2.12). Results from an analysis of problem 1a with both SAS1 and SAS4 using the SCALE 27-18 group library are given in Reference 2.13.

Concurrence with the results in Table 7.10 of Reference 2.13 should be within 5% (after consideration of the standard deviations in SAS4). Internal consistency checks will be used to verify the XSDOSE module which is the only SAS1 module not used by the criticality codes. Additional SAS4 verification problems are discussed in Reference 2.7

and will be included in this work. In addition, the SAS1 and SAS4 documentation (Reference 2.5) contains a series of sample problems prepared by the code developers. These sample problems are run and kept on file at ORNL as required under the SCALE Configuration Management Plan. These verification problems are to the extent possible exhaustive of the various code options. Any areas not covered shall be documented.

The shielding validation work shall consolidate a series of results reported in References 2.12 - 2.25. A set of representative problems from these references will be collected and executed using the cross section libraries to be validated both to determine consistency with previous results and validity as compared to measured values where possible. Reference 2.25 contains descriptions of a number of problems with experimental results available and will be the primary source for the validation problem set. Acceptance criteria shall be established, justified, and documented in the V&V report for each validation activity. Limitations of the validation study shall be reported. Other problems may be added to the V&V activities in the future as needed.

6.3 Verification/Validation of Heat Transfer Codes - The verification/validation of the heat transfer codes in the SCALE system will generally follow the same procedure as the criticality and shielding procedures. A set of sample problems that test the various functions and options of the code shall be generated and analyzed, comparing the results to an independent procedure. The validation shall consist of analyzing a set of problems with known solutions (either measurements or analytical). The results of such a study for the HEATING6 code is given in Reference 2.8. This study will be updated to the current code version. Some or all of this work will be repeated for subsequent major updates to the code. The verification problems shall be to the extent possible exhaustive of the various code options. Any areas not covered shall be documented. Acceptance criteria for the validation effort shall be established, justified, and documented in the V&V report for each validation activity. Other problems may be added to the V&V activities in the future as needed.

6.4 Verification/Validation of Source Generation Codes - Verification of the SCALE source generation module SAS2H shall be accomplished by analyzing a set of Light Water Reactor (LWR) spent fuel problems and cross checking with results from other similar codes. Examples of problems that can be used for verification are given in References 2.12-2.13 and 2.34-2.39. In addition, the sample problems included with the code documentation exercise a number of options available for use. These problems will be analyzed and included as well as a number of input variations that should further verify the various program options. These verification problems are to the extent possible exhaustive of the various code options. Any areas not covered shall be documented.

Validation activities shall include analysis of a number of irradiated LWR nuclear fuel elements whose isotopic contents have been experimentally determined. Reference 2.35 contains the results of such a study. The problem set will be executed using the cross section libraries to be validated and results will be compared with measurements. Acceptance criteria shall be established, justified, and documented in the V&V report for each validation activity. Limitations of the validation study shall be reported. Other problems may be added to the V&V activities in the future as needed.

6.5 The technical review shall evaluate the verification/validation report and enclosed verification/validation analyses to ensure adequacy of the findings and conclusions. The reviewer shall indicate concurrence with findings and conclusions via completion of an independent review sheet (See Appendix A). Any unresolved issues from the technical review shall be resolved by the Project Leader.

6.6 The SCALE system contains a number of utility codes designed to perform format conversions, editing and plotting of the various SCALE data sets. These codes will not be verified directly. The format conversion and editing functions are typically used to install the code system on the given host machine and are thus verified indirectly when the verification problem sets are executed. Other utility codes are tested via the sample problems in the Configuration Management Plan.

7.0 REPORTING

7.1 At the conclusion of the verification/validation process the Task Leader shall prepare (or guide preparation of) a report or reports which includes:

- Brief description of what was verified/validated
- Summary of the verification/validation activities conducted
- Results and findings
- Conclusions and recommendations
- References

7.2 An independent technical review as cited in Section 6.5 shall be performed prior to review and approval by the SCALE Project Leader. The Quality Assurance Specialist at ORNL shall also review the report for conformance to this plan. Review comments shall be resolved by the Task Leader with the reviewers. Unresolved issues shall be elevated to the Project Leader for resolution.

7.3 Discrepancies revealed by the V&V activities shall be processed in accordance with Reference 2.2.

8.0 SCHEDULE

Each verification and validation activity shall be scheduled and tracked by the SCALE Project Leader.

9.0 QA RECORDS

The following items shall be maintained as QA records in the SCALE Project QA Records system:

- V/V Plan
- V/V Report
- Electronic Copies of Input Files
- Electronic or Microfiche Copies of Output Files
- Technical Review Forms
- Personnel Qualification Records