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Department of Energy
Washington, DC 20585

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DNF SAFETY BOARD

OCT 30 1998

The Honorable John T. Conway
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue, N.W.
Suite 700
Washington, D.C. 20004

Dear Mr. Chairman:

The Implementation Plan for Defense Nuclear Facilities Safety Board Recommendation 97-2 requires a quarterly status report. Enclosed is the Department of Energy's quarterly status report for the fourth quarter, Fiscal Year (FY) 1998.

Overall, the Department has made significant progress in implementing Recommendation 97-2, thereby maintaining important criticality safety infrastructure. The following 97-2 Implementation Plan (IP) milestones/deliverables were completed during the quarter:

- IP Commitment 6.3, Deliverable 1: Technical Program Plan for the Applicable Ranges of Bounding Curves and Data Project (attached to this report);
- IP Commitment 6.2.1, Milestone 5: Publish data and calculations from the Criticality Safety Information Resource Center pilot program;
- IP Commitment 6.4, Milestone 2: Y-12 evaluations on the DOE web site;
- IP Commitment 6.5.1, Milestone 1: Revise DOE-STD-3007-93.

The Department has completed the actions identified under Commitments 6.2.1 and 6.5.1 above, and proposes closure of these commitments.

[redacted]

Finally, resumption of operations at the Los Alamos Critical Experiments Facility is a top priority activity for the Los Alamos National Laboratory and the Department.. Los Alamos is committed to resolving safety issues which precipitated the self-imposed stand-down and has begun executing a rigorous resumption program supported by mentors. I will keep you informed about this situation as we work on resolving this important issue.

Sincerely,

Robin Staffin
Deputy Assistant Secretary
for Research and Development
Defense Programs

Enclosures

cc (w/encl):
M. Whitaker, S-3.1

QUARTERLY STATUS OF THE IMPLEMENTATION PLAN FOR DEFENSE NUCLEAR FACILITIES SAFETY BOARD RECOMMENDATION 97-2 FOURTH QUARTER FY 1998

The Department of Energy (DOE) began implementing Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 97-2 in January 1998, by formally establishing the Nuclear Criticality Safety Program (NCSP). Each of the seven NCSP Elements (Critical Experiments, Benchmarking, Analytical Methods, Nuclear Data, Training and Qualification, Information Preservation and Dissemination, and Applicable Ranges of Bounding Curves and Data) is dependent upon the others for a successful program.

The Nuclear Criticality Safety Program Management Team (NCSPMT) and the Criticality Safety Support Group (CSSG) are performing their respective chartered functions in supporting the Response Manager's execution of the Implementation Plan (IP). During the quarter, the CSSG conducted numerous teleconferences and one meeting in Idaho Falls in support of NCSPMT efforts to coordinate completion of IP deliverables and prepare budget execution documents for Fiscal Year (FY) 1999. Important CSSG contributions included: (1) a review and subsequent recommendation of support for the Applicable Ranges of Bounding Curves and Data (AROBCAD) technical program plan; and, (2) significant progress in laying the foundation for the Department's criticality safety training and qualification programs. Implementation of the NCSP is being accomplished according to the Five-Year NCSP plan which was provided to the DNFSB on August 4, 1998. No changes in either the Five-Year Plan or membership of the NCSPMT or the CSSG occurred during this quarter.

Funding for FY 1999, as delineated in the Five-Year Plan, will be allocated to performing organizations in October except for the AROBCAD project. Funding for this activity will be provided in November. Additional time was required to provide a thorough technical and programmatic review of this new activity.

This quarterly report will provide a status of activities for each of the seven NCSP elements as well as Recommendation 97-2 IP Deliverables. Accomplishments and key issues which arose during the period are as follows:

- **Critical Experiments:** The Los Alamos Critical Experiments Facility (LACEF) has been under a self-imposed stand-down since August 12, 1998, for identified deficiencies in conduct of operations. The facility is conducting a rigorous resumption of operations program which is scheduled for completion in December 1998. The Department recognizes the importance of LACEF to the NCSP and is providing additional support necessary to resolve safety issues and resume operations. The NCSPMT is monitoring the situation and will provide assistance wherever possible. The most important NCSP impacts of the LACEF stand-down include the need to postpone scheduled nuclear criticality safety training until Calendar Year 1999 and further delay of the ZEUS critical experiment.

- **Benchmarking:** In September, the International Criticality Safety Benchmarking Evaluation Program (ICSBEP) published its 1998 version of the "International Handbook of Evaluated Criticality Safety Benchmark Experiments." This edition includes 53 new evaluations that were approved during FY 1998. The Handbook now contains 229 evaluations with benchmark specifications for nearly 1,700 critical or near critical configurations. Of the 229 evaluations in the Handbook, 108 came from the Russian Federation, 95 from the United States, 5 from France, 5 From the United Kingdom, 4 from Japan, 2 from the Republic of Korea, and 1 from Hungary. There are also 5 joint United States/French evaluations and 4 joint United States/ Russian evaluations in the Handbook. The ICSBEP Internet address is: icsbep.inel.gov/icsbep/.

- **Analytical Methods:** Staff at the Oak Ridge National Laboratory (ORNL) and the Los Alamos National Laboratory (LANL) continued to maintain KENO and MCNP software and assist the nuclear criticality safety community in use of this software. At ORNL, modifications and upgrades to KENO-Va and KENO-VI were made, and the software was released in the SCALE System, Version 4.4 through the Radiation Shielding Information and Computational Center (RSICC), in September. Testing and verification of the prototypic CENTRM resonance shielding software were also conducted. Funding shortfalls in this area precluded planned work on analytical methods at the Argonne National Laboratory (ANL) during this quarter. All indications are that, in FY 1999, analytical methods activities at ORNL, LANL, and ANL will be funded according to the projections in the NCSP Five-Year Plan.

- **Nuclear Data:** Nuclear Data measurement and evaluation activities during the quarter continued, albeit at a slower pace due to funding shortfalls at ORNL and ANL. Measurement activities at the Oak Ridge Electron Linear Accelerator included: (1) preliminary chlorine capture cross section data acquisition; (2) installation of a cryostat in the flight path to enhance resolution capability; and, (3) acquisition of uranium-233 samples for upcoming measurements. Data evaluation activities included: (1) resonance analysis with SAMMY on oxygen-16; (2) SAMMY analysis of aluminum-27 for capture and transmission data; and, (3) further evaluation of the uranium-235 unresolved resonance region and the uranium-233 resolved resonance region. At LANL, MCNP4X software containing the resolved resonance treatment was tested. Results show significant changes for systems dependent on intermediate energy neutron spectra. A limited release to DOE users of the new MCNP4X software should be made through the RSICC in November 1998. As reported by LANL at the Cross Section Evaluation Working Group meeting in October 1998, results also indicate that important situations in which the reactivity effects associated with uranium-238 would typically be calculated to be conservative, without unresolved resonances, actually turn out to be non-conservative when the unresolved resonances are taken into account. These findings will be reported at the ANS meeting in November. Both LANL and ORNL continued reviewing fission product cross sections in ENDF/B-VI. Conclusions and recommendations should be issued during the first quarter FY 1999. Finally, planned improvements to the SAMMY code continued.

- **Training and Qualification:** This program element includes three sub-elements: (1) hands on criticality safety training at LACEF; (2) training development; and, (3) criticality safety qualification program development. One three-day criticality safety course was conducted at LANL during the quarter. Twelve people attended this training. Two scheduled classes had to be postponed due to the self-imposed stand-down at LACEF which began in August. One of these courses was the new pilot five-day course (IP Commitment 6.6.1, Deliverable 1). This pilot course, along with the other FY 1999 courses, will be rescheduled during the remainder of FY 1999 following resumption of operations at LACEF. The Department recognizes the importance of this training and has directed LACEF to make it a high priority activity within the LACEF operations resumption process. Training development and training and qualification program development activities have made significant progress during this quarter. The CSSG used the results of the training needs assessment (IP Commitment 6.6.2, Deliverable 1, which was completed in June 1998) to identify areas where additional training programs were needed and will propose a training program to address identified needs during the next quarter. In the area of qualification, the CSSG developed a qualification training matrix which will serve as the basis for contractor qualification guidance (IP Commitment 6.6.3, Deliverables 2 and 3) and for a Federal qualification standard (IP Commitment 6.6.4, Deliverable 1). Paths forward for these activities have been established which result in completion of cited deliverables by February 1999.

- **Information Preservation and Dissemination:** This program element currently contains three sub-elements: (1) the Criticality Safety Information Resource Center (CSIRC); (2) web book development; and, (3) standards and guides development. The CSIRC activity at LANL completed its pilot program with publication of original logbook pages on the LANL web site in August 1998 (IP Commitment 6.2.1, Milestone 5). Completion of this deliverable fulfills IP Commitment 6.2.1. Continued execution of the CSIRC program involves archiving remaining critical experiment logbooks (from the Lawrence Livermore National Laboratory (LLNL) and ORNL) and screening logbooks with the original experimenter where it makes sense to do so. A CSIRC program plan will be developed during the next quarter. Regarding the web book development, the NCSPMT has approved a criticality safety web architecture which will involve multiple web pages at DOE sites hyper linked together in a coordinated fashion. The NCSPMT has assigned the responsibility for coordinating this activity to LLNL with support from the CSSG. Web related deliverable status is as follows. The calculations compiled by the Parameter Study Work Group, which should have been placed on the web in September 1998 (IP Commitment 6.4, Milestone 3), will be published on the LLNL web site in December 1998. The delay is due to a redirection of effort which took longer than anticipated.

One accomplishment during the quarter was to publish the Y-12 evaluations on the Los Alamos web site (orion.lanl.gov/ncs/index.htm) in August 1998 (IP Commitment 6.4, Milestone 2). In the area of standards and guides development, the NCSPMT, with support from the CSSG, published a revised DOE-STD-3007-93 (Change 1), *Guidelines for Preparing Criticality Safety Evaluations at Department of Energy Non-Reactor Nuclear Facilities,* in September 1998. The guide can be found on the DOE Technical Standards Home Page. This action fulfills IP Commitment 6.5.1.

- **Applicable Ranges of Bounding Curves and Data:** The Technical Program Plan for *Development of Guidance for Defining Applicable Ranges of Bounding Curves and Data Relative to Nuclear Criticality Safety* (IP Commitment 6.3. Deliverable 1), was submitted to the NCSPMT in July 1998 and was approved in September 1998. Work on this project will begin in November. The objective of this project is to provide the criticality safety practitioner with information, tools, and guidance that will assist in establishing and using applicable bounding values. The Technical Program Plan is attached (Attachment C).

- IP Commitment 6.7 Milestone 1, which is related to line management responsibility for criticality safety, is monitored by the NCSPMT separate from the 7 NCSP technical program elements. Individual site surveys to assess line ownership of criticality safety were completed by DOE at Savannah River, Rocky Flats, Idaho, Chicago, Oak Ridge, and Richland. DOE Oakland is conducting the survey in conjunction with implementing Integrated Safety Management at Building 332, which will not be completed until January 1999. DOE Albuquerque staff has completed surveys of line ownership of criticality safety at Los Alamos, Sandia, and Pantex and has briefed its management but has not documented the results. This documentation should be completed in November 1998. This commitment will remain open until all surveys have been completed.

There are three attachments to the quarterly report. Attachment A contains a complete IP commitment and deliverable/milestone status. Attachment B provides a summary of deliverables/milestones due during the next quarter. Attachment C is the Technical Program Plan for *Development of Guidance for Defining Applicable Ranges of Bounding Curves and Data Relative to Nuclear Criticality Safety* (IP Commitment 6.3. Deliverable 1).

The Department has made significant progress in implementing Recommendation 97-2, thereby maintaining important criticality safety infrastructure. Funding for FY 1999 has been stabilized. To address long-term funding stability for the Nuclear Criticality Safety Program, the Department has completed a Memorandum of Understanding (MOU) between the offices of Defense Programs; Environmental Management; Environment, Safety and Health; Energy Research; and the Chief Financial Officer. The MOU formalizes the budget development and execution process for criticality safety activities by explicitly defining the roles and responsibilities between the 97-2 Responsible Manager, affected Program Offices, and the Chief Financial Officer. If adequate funding cannot be achieved, the MOU provides a process for handling deviations and shortfalls. This action should provide greater funding stability in the out-years.

ATTACHMENT A: IP COMMITMENT AND DELIVERABLE/MILESTONE STATUS

Commitment	Deliverable/Milestone	Due Date	Status
6.1 Reexamine the experimental program in criticality research	1. Assessment report of criticality research program	March 1998	Completed
6.2.1 Perform CSIRC pilot program	1. Identify an experiment to archive	November 1997	Completed
	2. Archive logbook(s) and calculation(s) for that experiment	December 1997	Completed
	3. Videotape the original experimenter	January 1998	Completed
	4. Digitize data and calculations	February 1998	Completed
	5. Publish data and calculations	April 1998	Completed
6.2.2 Continue to implement the CSIRC program	1. Collocate logbooks (copies or originals) from all U.S. critical mass laboratories	December 1998	On Schedule
	2. Screen existing logbooks with original author/experimenter	December 1998	On Schedule
	3. CSIRC program plan	December 1998	On Schedule
6.3 Continue and expand work on ORNL sensitivity methods development	1. Technical program plan	July 1998	Completed
	2. Document initiation of priority tasks from the program plan in the quarterly report to the Board	January 1999	On Schedule
6.4 Make available evaluations, calculational studies, and data by establishing searchable databases accessible through a DOE Internet web site	1. DOE criticality safety web site	March 1998	Completed
	2. Y-12 evaluations on DOE web site	June 1998	Completed
	3. Calculations compiled by the Parameter Study Work Group on DOE web site	September 1998	Overdue: Should be completed in December 1998
	4. Nuclear Criticality Information System Database on DOE web site	March 1999	On Schedule
6.5.1 Revise and reissue DOE-STD-3007-93	1. Revise DOE-STD-3007-93	September 1998	Completed
6.5.2 Issue a guide for the review of criticality safety evaluations	1. Departmental guide for reviewing criticality safety evaluations	May 1999	On Schedule

Commitment	Deliverable/Milestone	Due Date	Status
6.6.1 Expand training course at LACEF	1. Expanded LACEF training course	July 1998	Overdue: Should be completed by March 1999
6.6.2 Investigate existing additional curricula in criticality safety	1. Assessment of additional training needs and review of available supplementary curricula	June 1998	Completed
	2. Initiate a program which addresses identified needs	December 1998	On Schedule
6.6.3 Survey existing contractor site-specific qualification programs	1. Report on the review of site qualification programs	June 1998	Completed
	2. Guidance for site-specific criticality safety training and qualification programs	September 1998	Overdue: Should be completed in February 1999
	3. Guidance to procurement officials specifying qualification criteria for contractor criticality safety practitioners	September 1998	Overdue: Should be completed in February 1999
	4. DOE Field will provide line management dates upon which contractors will have implemented guidance in Deliverable #2, above	March 1999	On Schedule
6.6.4 Federal staff directly performing criticality safety oversight will be qualified	1. Qualification program for Departmental criticality safety personnel	December 1998	Expected completion date is February 1999
	2. DOE criticality safety personnel qualified	December 1999	On Schedule
6.7 Each site will conduct surveys to assess line ownership of criticality safety	1. Individual sites issue report of findings	June 1998	Partially overdue: All surveys have been completed except for DOE-AL and DOE-OAK; these surveys should be completed by January 1999
5.8 The Department will form a group of criticality safety experts	1. Charter for Criticality Safety Support Group approved by the NCSPMT	January 1998	Completed
6.9 Create NCSPMT charter and program plan	1. NCSPMT charter	January 1998	Completed
	2. NCSPMT program plan	June 1998	Completed

ATTACHMENT B: DELIVERABLES/MILESTONES DUE DURING THE NEXT QUARTER

Commitment	Deliverable/Milestone	Due Date	Status
6.2.2 Continue to implement the CSIRC Program	1. Collocate logbooks (copies or originals) from all U.S. critical mass laboratories.	December 1998	On schedule: All logbooks have been collocated at LANL except the ones from ORNL and LLNL. Plans are to scan in those logbooks and archive the electronic files at LANL.
	2. Screen existing logbooks with original author/ experimenter.	December 1998	On schedule: Some logbooks have already been screened. This activity will continue and will be described in the CSIRC Program Plan.
	3. CSIRC Program Plan.	December 1998	On schedule: The CSIRC Program Plan will be reviewed by the CSSG in November and published in December 1998.
6.6.2 Investigate existing additional curricula in criticality safety	2. Initiate a program which addresses identified needs.	December 1998	On Schedule: Draft program plan will be reviewed in November by the CSSG, and initiated in December 1998.
6.6.4 Federal Staff directly performing criticality safety oversight will be qualified	1. Qualification program for Departmental criticality safety personnel.	December 1998	Expected completion date is February 1999. The qualification training matrix (which is the basis for guidance) was reviewed by the CSSG in September. A Federal Criticality Safety Qualification Standard will be reviewed in November, and submitted to DOE-HR for formal coordination in December. The new Criticality Safety Technical Qualification Standard should be published in February 1999.

ATTACHMENT C

U.S. Department of Energy

Technical Program Plan

for

Development of Guidance for Defining Applicable Ranges of Bounding Curves and Data Relative to Nuclear Criticality Safety (NCS)

Revision 4

September 28, 1998

1. BASIS OF WORK SCOPE

This Technical Program Plan has been developed to assist the DOE in providing technical guidance and analytic tools that address the issues related to Subrecommendation 3 from the Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 97-2:

Establish a program to interpolate and extrapolate such existing calculations and data as a function of physical circumstances that may be encountered in the future, so that useful guidance and bounding curves will result.

In the context of this subrecommendation, the DNFSB has accepted the following meanings for "bounding" and "data":

Bounding values, as it relates to criticality, are those enveloping dependent values (masses, volumes, concentrations, densities, temperatures, flow rates, vessel dimensions, etc.) that describe specific systems given assumed limits of independent parametric variation.

Data, as it relates to criticality, refers to values obtained directly from experimental measurements of critical or near critical systems. For nuclear cross section data within the context of the Recommendation 93-2 Nuclear Criticality Predictability Program, "data" additionally refers to values obtained from: 1) the experimental measurements of nuclear cross section data, 2) the generation of the corresponding Evaluated Nuclear Data Files (ENDF/B), and 3) the analytical processing methods needed for the calculational codes to utilize those files.

This plan has been developed consistent with Element 8 of the DOE Nuclear Criticality Safety Program (NCSP) Five-Year Plan (issued June 1998). Element 8 of the five-year plan and this program plan specifically address Commitment 6.3 of the DOE Implementation Plan (IP) for DNFSB Recommendation 97-2 (issued December 1997). The five technical tasks identified herein are in addition to the continuing methods and data work established with committed funding from DOE in response to DNFSB 93-2, now subsumed in the DOE response to DNFSB 97-2. The activities established by this technical program plan were developed to meet the objectives of the DOE IP for DNFSB 97-2 and are proposed with a level of effort commensurate with that established by the five-year plan. None of these activities are funded under other elements of the NCSP.

2. PLAN OBJECTIVE

The appropriate technique(s) and methodology(ies) to establish, interpolate, and extrapolate bounding values related to criticality safety are not straightforward. The objective under this plan is to provide the NCS practitioner with practical information, tools, and guidance that will assist in the development and use of experienced judgement relative to establishing and using applicable bounding values. To meet this goal, the identified issues that should be investigated are:

1) efficient methods to help the practitioner establish bounding values;
2) understanding of previously recognized anomalies and calculated-to-measured discrepancies[1] in order to assure their proper consideration in the calculation of bounding values;
3) approaches to identify and justify potential experiments that could efficiently provide necessary bounding data or address applications for which there is insufficient experimental measurement data (i.e., critical or near critical systems and nuclear cross section) for proper validation of analytic methods;
4) processes to establish and potentially extend the range over which the bounding values are applicable;
5) development of a consistent approach to establishing subcritical margins; and
6) techniques that assure preservation of an adequate margin of subcriticality both within the range of applicability (interpolation) and when extension of the range of applicability (ROA) is needed (extrapolation).

To investigate these issues and subsequently provide the guidance and tools needed for effective development and use of bounding curves and data, this plan incorporates five technical tasks:

1) investigate the utilization of optimization techniques[2] in the calculation of bounding values and design of experimental systems and operations (relevant to issue 1);
2) investigate means (including sensitivity and uncertainty analysis) to resolve or incorporate anomaly and discrepancy effects (relevant to issue 2);
3) investigate sensitivity and uncertainty (S/U) methods together with statistical techniques to help identify and justify experimental needs (relevant to issue 3);
4) illustrative preparation and use of bounding curves and data pertinent to one or more realistic NCS applications (relevant to issues 4 - 6);
5) development of consistent and coherent guidance on techniques to establish adequate subcritical margins that are clear and defensible (relevant to issues 4 - 6).

Understanding and resolution of discrepancies/anomalies, coupled with preparation of systematic and consistent processes for establishing, interpolating, and extrapolating bounding values will help the Department obtain bounding curves and/or limiting data that can be used for efficiently performing nuclear criticality safety analyses in areas where here-to-fore insufficient critical experiments were available. These areas include current and future Department operations requiring use of special actinides, the Fissile Material Disposition Program where the Department will have responsibility for mixed-oxide operations, and the permanent disposal programs (EM, RW, and DP) where mixtures of fissile materials do not fall within available critical data.

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[1]C. M. Hopper, "DOE Spent Nuclear Fuel - Nuclear Criticality Safety Challenges and Safeguards Initiatives," p. 363, *Proceedings of the Topical Meeting on DOE Spent Nuclear Fuel Challenges and Initiatives*, December 13-14, 1994, American Nuclear Society.

[2]Y. Karni and E. Greenspan, "The Swan Code for Minimum Critical Mass and Maximum k_{eff} Determination," p. 181, *Topical Meeting on Criticality Safety Challenges in the Next Decade*, September 8-11, 1997, American Nuclear Society.

An important element of this program plan is the transition of the knowledge and processes to the NCS practitioner. It is anticipated that the pertinent information will be provided to the NCS practitioner via the following means:

1) a series of papers and reports will be issued to describe the lessons-learned and provide recommended guidance based on project experience with realistic NCS applications;
2) pertinent enhancements to analytic methods and ancillary software will be released to the NCS community by providing the software to the Radiation Safety Information Computational Center at ORNL;
3) training will be offered to the NCS practitioner using either existing DOE-sponsored NCS training courses or separate seminars and training courses developed under the project;
4) as needed, project staff will be available to assist and consult with the DOE NCS community relative to implementation of the recommended guidance to specific applications of interest, and
5) the above task products (e.g., papers, reports, available software, training courses and seminars, etc.) will be offered to the DOE NCSP Program Element for Information Preservation and Dissemination via DOE Web Sites and possible bulletin boards.

It is anticipated that the work described within this program plan could result in the identification of additional techniques or improved methods that might aid the NCS practitioner in establishing, interpolating, and extrapolating bounding values. Timely transition of tested guidance to the NCS community is important, but it should be recognized that an ongoing program may need to be maintained to assure the guidance can be updated to assess and implement changing technology or identified technical issues that effect preparation and use of bounding values.

3. TECHNICAL BACKGROUND AND APPROACH

Preparation and use of prudently conservative (i.e., bounding) values that prescribe operating limits, control parameters, or acceptance criteria is a primary activity for the criticality safety practitioner. As recognized by both the DNFSB and the DOE, there is strong preference for experimental confirmation of the parameter limits and controls established for criticality safety. The DOE IP for DNFSB 97-2 recognizes the need to establish a methodology for interpolating validated analyses between defined areas (ranges) of applicability and to extrapolate validated analyses as allowed by ANSI/ANS-8.1. Calculations are considered validated only within the range of applicable experimental data that are analyzed. Current analytical methods are of limited value when used outside the ranges of applicable experimental data. If experimental data do not exist for fissile systems which are similar to the application of interest, validation of criticality safety calculations for that application is not possible and overly conservative subcritical margins must be adopted. This situation is further complicated by the fact that there is very limited guidance for establishing the applicability of an experiment to a system of interest, maintaining a sufficient subcritical margin while interpolating over broad ranges of experimental data, and extending the ROA as necessary. With so little guidance, it can be extremely difficult to provide quantitative justification for establishing the ROA, justifying subcritical margins, or identifying the needed experiments that will best supply new criticality safety data. Understanding and quantifying the sources of uncertainties that should be considered in establishing adequate bounding values and associated margins of subcriticality is also an integral portion of assuring an adequate margin of subcriticality. There are known fundamental discrepancies and anomalies which are not well understood and for which there is no ready means to incorporate within a criticality safety analysis. These discrepancies need to be investigated.

In FY1996, ORNL began an NRC-funded program of work[3] focused on developing a defensible, technically-based approach to establishing the range of applicability (issue 4 under Plan Objective). The goal was to investigate use of integral parameters that can best characterize "similarity" between experiments and applications and to determine to what extent sensitivity and uncertainty (S/U) analyses could be utilized to this end. ORNL formed a project team composed of specialists in S/U analyses and specialists in criticality safety analyses. Using a revitalized and enhanced FORSS[4] system that was prototypically interfaced to a one-dimensional (1-D) deterministic sequence of the SCALE code system[5], the project team has investigated the use of numerous integral parameters and correlation coefficients calculated using S/U methods. In FY1997 ORNL began to recognize the benefit of enabling practitioners to perform a S/U analyses as a component of their criticality safety analyses. The difficulty envisioned was the implementation of a viable S/U methodology within a three-dimensional (3-D) code routinely used by criticality safety analysts. Thus, within a methods development research project[6] funded by the DOE Environmental Management Science Program (EMSP), ORNL staff began work in FY1998 to investigate the potential for using Monte Carlo methods to perform the necessary S/U analyses. Under the EMSP project, a code that will improve the geometry modeling flexibility of 2-D deterministic codes is also being developed for use in criticality safety studies.

The NRC work utilized a Generalized Linear Least Squares Methodology (GLLSM) module from the FORSS system as a research tool in developing guidance in the use of certain integral parameters and correlation coefficients for determining ROA. The GLLSM tool allowed for the limits of applicability to be better defined, rather than relying strictly on expert judgement. With increased experience in the tool for criticality safety applications, it became evident that it could also be very useful for extending applicability into many areas with little or no critical benchmark data. Under these circumstances, the tool must be supplemented with information on the *completeness* of the underlying benchmark database. This concept will be further explored and developed under Task 4 of this program plan, hopefully leading to a fully-functional procedure for taking widely varying critical benchmark data and applying it to areas with little or no benchmark support.

ORNL intends to use the results of their NRC study to provide guidance on appropriate criteria to substantiate that the experiments used for code validation are applicable to criticality safety analyses and a demonstration (via 1-D and limited 2-D analyses) of how one can estimate the uncertainty in k_{eff} due to uncertainties in the nuclear data applied by the practitioner. Under this program plan, work will be performed to incorporate the knowledge gleaned from the NRC project together with the methods development work of the EMSP project in order to

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[3]NRC JCN W6479, "Development and Applicability of Criticality Safety Software for Licensing Review"; Revision 0 dated 9/13/95, Revision 1 dated 4/26/96 and Revision 2 dated 05/27/97.

[4]J. L. Lucius et. al., *A User's Manual for the FORSS Sensitivity and Uncertainty Analysis Code System,* ORNL-5316 (January 1981).

[5]*SCALE: A Modular Code System for Performing Standardized Computer Analysis for Licensing Evaluation*, April 1995. NUREG/CR-0200, Rev. 4 (ORNL/NUREG/CSD-2/R4), Vols. I, II, and III, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[6]DOE FWP EMSP102,"Development of Nuclear Analysis Capabilities for DOE Waste Management Activities" dated 04/11/97.

establish the process and tools that the criticality safety practitioner can readily utilize to address the issues (identified under the Plan Objective) for developing and applying bounding curves and limiting data. Demonstrated technologies such as S/U analysis, optimization techniques, and standard statistical techniques will be utilized as appropriate to address the identified issue and fulfill the task objectives. Each technical task has an investigative component where the use of these technologies will be studied and a problem-solving component where current or emerging DOE applications of interest will be addressed to assist in development of guidance, to provide an illustration for the criticality safety practitioner, and to demonstrate relevance to "physical circumstances" as requested by Subrecommendation 3 of DNFSB 97-2.

The NRC project on range of applicability continues through FY1999 and the remaining work will focus on refining the ROA criteria that has been developed and demonstrating its utility to NRC applications of interest. The primary application of interest to the NRC has been issues related to the extension of light-water-reactor fuel enrichments beyond the 5 wt% value (the vast majority of relevant experiments exist below 5 wt %). During FY1999, this DOE program plan will focus on Tasks 1-3 which are areas that were either not investigated under the NRC project (Tasks 1 and 2) or had very limited investigation (Task 3). In FY2000, the project will continue work on Tasks 1-3 while accelerating efforts under Tasks 4-5. These latter tasks will utilize the knowledge and lessons-learned as compiled within the NRC project to expand and improve on the available guidance to better address extension of the ROA, establishment of an adequate subcritical margin (within the full limits of an "extended" ROA), and development of illustrations of importance to DOE needs. This enhanced and expanded guidance will be provided by the end of FY2001 along with practical examples and tools for the criticality safety practitioner. In FY2000 the EMSP project will be in its last year and the 3-D methods under development will potentially be to the point they can be prototypically tested in FY2000 and subsequently utilized in FY2001. Depending on their assessed value, these methods could be prepared for production use in FY2002 and beyond.

The DOE Headquarters Project Manager for this DOE Nuclear Criticality Safety Program Element will manage the project within the framework of the DOE NCSP Program Management Team's approval and direction for this Program Element as outlined in the DOE Implementation Plan for DNFSB Rec. 97-2 section 5, "Organization and Management." The work will draw expertise from various technical resources; primarily those in the DOE complex (e.g., ORNL, ANL, LANL), academia, and other national institutes (e.g.,NIST), with ORNL as the lead laboratory. The project work will be coordinated with related endeavors and/or, as appropriate, some project work will be performed by institutions other than ORNL. For example, the optimization techniques prepared at the University of California - Berkeley[2] (UCB) have been reviewed by ORNL and utilization of UCB for prototypic incorporation of these techniques within a portion of the SCALE code system is considered the likely approach for Task 1. Again as appropriate, the investigation of discrepancies proposed under Task 2 and the investigation of S/U methods for DOE applications proposed under Task 3 will require the involvement of ANL and my also involve other institutions (e.g., LANL, NIST, etc.) which have experimental and analytical capabilities pertinent to these endeavors. NIST may be contracted to perform additional neutron slowing-down experiments to extend the range of those performed previously. ANL and LANL each support continuous-energy Monte-Carlo codes (VIM, MCNP) which can be utilized for benchmarking purposes. Potential applications include the determination of code bias as distinguished from data bias, spot checks on the relative performance of ENDF/B-V versus ENDF/B-VI data compilations, and the generation of physical parameters other than k-effective to be included in S/U analyses of well-characterized experiments. Also with regard to potential applications under Task 3,The Section for Criticality Safety Studies within the French Institute for Nuclear Safety and Protection (IPSN) has initiated a task with goals similar to those of this task (quantified justification of experimental needs). ORNL and IPSN have agreed to coordinate and share information relative to achieving the stated goals.

Similarly, the work under this plan will be coordinated with the activities of the appropriate DOE NCSP element(s). All training activities will be coordinated with the Training and Qualification program element. Identified enhancements useful for production analytic methods will be presented to the Analytic Methods program element for consideration and experimental needs identified incidentally within the course of this project will be presented to the Critical Experiments or Nuclear Data program elements for consideration.

This coordination within the NCSP elements is important. The technical approach being pursued will initially utilize multigroup methods because mature multivariable S/U code packages for radiation transport (e.g. FORSS) were all developed with the multigroup approach. Thus, it is envisioned that effective processes that can be used in a timely fashion by criticality safety practitioners have a better assurance of success with this approach. However, once the guidance and processes that address the objectives have been established, the NCSP may seek to consider the potential for implementing the same approach but utilizing continuous energy codes (VIM, MCNP). In addition, full implementation of S/U methods for the purpose being pursued requires covariance (uncertainty) information for the nuclear cross-section data. Currently, the Nuclear Data Element has an objective to improve and generate additional covariance information for new cross sections being evaluated for ENDF/B-VI. This overall effort is being coordinated with the Cross Section Evaluation Working Group, which now has formal activities in support of criticality safety technology. Although adequate for demonstration purposes, the existing cross section uncertainty and covariance data within both the ENDF/B-V and ENDF/B-VI compilations is known to be incomplete and in need of improvement. Another related task in the NCSP Nuclear Data Element is the updating and upgrading of the software designed to process this data. Thus, as this information becomes available, the importance of having an ENDF/B-VI multigroup library for criticality safety analyses will be enhanced. The generation and validation of this ENDF/B-VI based library is a major, long-term objective of the NCSP. However, the guidance and tools being developed under this program plan are not necessarily dependent on the pedigree of the nuclear data; rather, they will be based on the available covariance information. The practitioner should be able to use the guidance and available tools to help assess the contribution of the nuclear data uncertainties to the system for which a subcritical margin must be determined. The guidance will provide details on the use of these tools including limitations on their application.

A final important element of the approach planned for this project is that this project plan will be reviewed and updated annually to assure that the planned work is appropriately modified to include necessary changes of scope or direction based on evolving technical information obtained under this or related projects. Suggestions on alternative applications that might be studied under this project will be carefully considered by the project staff and the members of the DOE Criticality Safety Support Group.

4. TASK AND MILESTONE DESCRIPTION

The technical program plan includes five evolving technical tasks and a single general planning, administration and reporting task. A brief description of each of the tasks, with estimated costs and deliverables/dates, is provided in Table 3.1. The costs for each task, particularly beyond FY1999, is an estimate and the actual level of effort on any one task may vary depending on the needs relative to meeting the plan objectives. A more detailed description of the planned activities under each task is provided following the table.

Table 3.1. Program Tasks, Costs, Deliverables by FY

		Deliverables (All delivery dates are 9/30 of cited FY)		
#	Task	FY 99	FY 00	FY 01
1	Implement use of optimization techniques for establishing bounding values	$150K	$150K	$100K
		Technical report on the expanded optimization theory, implementation approach, and prototypic testing.	Development of SCALE optimization sequence: a) documentation of sequence within SCALE; b) sequence pre-production version to requesting users; c) determination of minimum critical parameters for selected applications	a) Release of sequence to RSICC within SCALE-5 b)Technical report with guidance and illustrative applications. Include recommendations to use expanded optimization process for design of experiment/operation.
2	Investigate means to resolve or incorporate anomaly and discrepancy effects into bounding values.	$200K	$210K	$210K
		Technical report on investigation of neutron slowing down & leakage discrepancies in NIST experiments.	a) Technical report on S/U analysis of epithermal systems. b) Initiate study of loosely coupled uranyl nitrate units	Technical reports on S/U analysis of uranyl nitrate arrays and US vs. French experiment anomalies.
3	Investigate utilization of S/U and statistical methods for identifying experimental needs (i.e., critical or near critical and cross section)	$150K	$100K	$100K
		Initiate studies using application(s) of interest to DOE (e.g., Hanford Waste Tanks, and plutonium salts)	Technical reports discussing viability of approach and recommendations from applications.	Guidance report with demonstration using ^{233}U systems (or appropriate substitute).
4	Develop guidance for interpolating and extrapolating bounding values	$35K	$100K	$150K
		Technical report on parametric phase space appropriate for establishing bounding curves and data useful to the NCS community	Technical report demonstrating preparation and use of bounding curves and data using GLLSM approach.	Guidance report with examples pertinent to DOE applications.
5	Develop guidance for establishing bounding margins of subcriticality	$30K	$100K	$100K
		Report summarizing current approaches to characterizing acceptable margins of subcriticality.	Technical guidance on recommended statistical approach(es). Initiate investigation to combine S/U and statistical methods for defining bounding margins of subcriticality.	Technical guidance for incorporating S/U analyses with statistical approach to define bounding margins of subcriticality.
6	Planning, administration, and reporting	$35K	$40K	$40K
		Budgeting, scheduling, planning, quarterly progress reports, etc.	Budgeting, scheduling, planning, quarterly progress reports, etc.	Budgeting, scheduling, planning, quarterly progress reports, etc.

Task 1 – Implement use of optimization techniques for establishing bounding values

ORNL staff has had considerable experience with the analytic process of searching for the optimum parameter values that provide the bounding criticality safety limit for a problem of interest. When the problem involves multiple parameters or functional representations (spatial distribution of fissile material), determination of the parameter combination or functional representation that assures bounding NCS values can be a formidable undertaking. The objective of this task will seek to provide a methodology and guidance to simplify this process.

The work under this task will expand the optimization techniques of Greenspan (see Ref. 2) to function with problem-dependent resonance processing included within the iterative procedure. This expanded technique will be implemented within the SCALE code system to test and demonstrate the potential advantages. The goal is to provide the NCS practitioner with an automated optimization scheme that can assist in the determination of a desired bounding value (e.g., minimum fissile mass or concentration) for safety applications. The techniques and subsequent tool will also be investigated to determine their value in optimizing a critical experiment or operation against functional constraints or limits such as reactivity, cost, weight, etc. Use of the tool will be demonstrated via application on several bounding value problems such as minimum critical mass for non-uniform spatial distributions and minimum critical mass values of interest to the ANSI 8.15 Work Group.

In FY1999 the work to expand the optimization techniques will be completed under subcontract with the University of California - Berkeley. Initial testing of the approach using simple NCS problems of interest to DOE will be performed. An approach for utilization within the SCALE code system will be developed and implementation will begin. A report documenting the theory, initial testing, and planned implementation of automated sequence within SCALE will be prepared by September 30, 1999.

In FY2000 a SCALE criticality safety sequence which incorporates the optimization software will be prepared and utilized for selected applications of interest to DOE. The sequence capabilities will be demonstrated by determining minimum critical parameters for various applications which will be selected based on their relevance to DOE issues, application to American Nuclear Society (ANS) criticality safety standards (e.g. ANSI-8.15), and benefit to US participation in the activities of the Organization for Economic Co-operation and Development (OECD) Working Party on Criticality Safety, or the criticality safety standards under development by the International Standards Organization (ISO). This software version and documentation will be made available to requesting users as a beta-test version by September 30, 2000. As pertinent, results of the selected applications will be provided to the appropriate working groups, issued in papers, or transmitted to DOE facilities with identified immediate needs.

In FY2001, the final production version of the software capability will be prepared and issued to the Radiation Safety Computational Center at ORNL as part of the SCALE-5 package. A separate report providing guidance on using the software to assist in establishment of bounding values will be issued. The guide will include the applications identified above as examples. As appropriate a sensitivity analysis of the higher actinide systems will be performed to characterize areas where the results would be sensitive to large uncertainties in the nuclear data. Also, investigations on using the optimization capabilities to assist in experiment or operations design will be completed and recommendations will be included in the guidance report. This guidance document and the illustrative applications will complement and be consistent with the guidance developed under Tasks 3, 4 and 5. The software and final report will be issued by September 30, 2001.

Task 2 – Investigate anomaly and discrepancy effects relative to bounding values

The work under this task will apply S/U methodologies to seek an understanding of well-documented anomalies or discrepancies[1] and seek recommendations for their successful resolution. One major goal of this task is to demonstrate the applicability of the S/U methods for examining measured-to-calculated sensitivities and uncertainties. Understanding of the technical factors that contribute to these anomalies and discrepancies enable development of information that would guide the NCS practitioner in their consideration of when (type of problems) and how (increase in subcritical margin) to include allowance for these known discrepancies within bounding values. Recommendations on resolution of these long-standing discrepancies are important to the guidance of future methods development and data work

The initial discrepancy to be investigated in FY1999 will be the neutron-slowing-down experiments[7, 8, 9] from water spheres of different diameters. These experiments were performed at the National Institute of Standards and Technology (NIST). The project will revisit the analyses of these experiments with the latest computational methods and data and perform S/U analyses to seek the bases for the calculated-to-experimental differences. Possible discrepancies include improper $S(\alpha, \beta)$ for water scattering, bare and cadmium covered fission detector materials cross-section data, etc. The performance of the S/U analysis offers the ability to identify potential likely contributors to these differences. Results of these analyses are to be provided in a document by September 30, 1999.

In FY2000, work will commence on an in-depth S/U analysis of anomalies related to intermediate energy systems. Besides S/U analyses of computational benchmarks related to this energy range, the LANL experiments planned for the intermediate energy region (ZEUS) will be investigated using S/U methods in an effort to extract as much information as possible from these experiments (which are limited but unique in their range of applicability). The documented analysis results will provide further details, examples and applications of the existing methodologies for the user community in their development of applicable ranges of bounding curves and data. This technical report will be prepared for publication by September 30, 2000.

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[7]D. M. Gilliam, J. F. Briesmeister, "Neutron Leakage Benchmarks for Water Moderators," Reactor Dosimetry, ASTM STP 1228, Harry Farrar IV, E. Parvin Lippincott, and John G. Williams, Eds., American Society for Testing and Materials, Philadelphia, 1994.

[8]D. M. Gilliam (NIST), J. F. Briesmeister (LANL), "Benchmark Measurements and Calculations of Neutron Leakage from Water Moderators," Proceedings of the International Topical Meeting on Advances in Mathematics, Computations, and Reactor Physics, Pittsburgh, PA, April, 1991, American Nuclear Society, La Grange Park, IL, 1991, Chapter 9.1, p 4-1.

[9]D. M. Gilliam, V. Spege, C. M. Eisenhauer, Eiping Quang (NIST), Judith F. Briesmeister (LANL), Jabo Tang (ORNL), "Neutron Leakage Benchmark for Criticality Safety Research," TANSAO 62 pg 340 (1990).

The work scheduled for FY2001 is to investigate a series of critical experiments[10] that consist of multiple units which have loose (via essentially no reflector) and close (via neutron reflection) neutron coupling between units. The experiments are a selected series of critical bare and reflected (Plexiglas and paraffin) arrays of 5 liter units filled with uranyl nitrate enriched to 93 wt % ^{235}U. Results of computational studies for the critical systems showed the reflected arrays calculated 2 to 3 % higher than the bare arrays. The work under this task will re-visit analysis of the experiments with the latest computational methods and data and apply S/U analyses to seek understanding of the potential sources of uncertainty. The document results of the analyses and S/U approaches and methodologies will be issued by September 30, 2001. The value of this report will be the further demonstration of the methodology for user familiarization and subsequent use of the technology while identifying the potential likely sources of discrepancy.

Additionally work in FY2001 will include a review of the recently recognized disparity between calculated-to-experimental ratios observed for critical experiments performed in the US versus those performed in France. An informal presentation of summary results by the Russian contingent to the International Handbook of Evaluated Criticality Safety Benchmark Experiments Project of the OECD in June 1998 indicated a strong, very consistent, positive computational bias for US-reported experiments whereas there was a strong, very consistent, negative computational bias for French-reported experiments when using identical computational tools and data. Due to the complexity and uncertainty of these biases, this aspect of the task may be extended into the out-years of the project.

Task 3 – Investigate and apply quantitative methods for identifying experimental needs

The purpose of this task is aimed at developing a quantitative technique that uses S/U methodology (perhaps with other statistical tools) to quantitatively identify **where** in phase space a critical experiment **needs** to be performed in order to reduce the estimated subcritical margin. To gain experience in this area, it will be necessary to apply the methodology to DOE areas of interest. This task will explore alternative methodologies, proposed and applied, by the French for quantifying techniques for identifying experimental needs. ORNL has already discussed collaboration on this issue with the IPSN in France. The OECD/NEA Working Group on Experimental Needs (headed by Patrick Cousinou of IPSN) has also laid out in its charter such an objective. Reliance on experimental data is highlighted by the DNFSB as an important element of the DOE NCS program and this effort will seek to provide an approach that can help optimize resources to assure the experimental program addresses the most important needs.

In FY1999, work will be performed to study DOE-related operations where experiments are perceived to be needed or beneficial (e.g., safe concentration limits for plutonium in various Hanford waste tanks, RFETS plutonium-salt residues, long -term disposal of spent fuel, etc.). Additional systems of specific interest to DOE will be identified and reported upon in the future. A report on the progress and results of the analyses will be provided by September 30, 1999.

In FY2000 the identified evaluations will be completed and a technical report discussing the viability of the approach and recommendations related to each application will be included in a technical report due September 30, 2000.

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[10]J. T. Thomas, "Critical Three-Dimensional Arrays of Neutron-Interacting Units," ORNL-TM-719, October 1, 1963.

In FY2001, a report that provides recommended guidance for establishing and justifying an experimental need will be prepared. The report will include an evaluation of ^{233}U experiments and operations as a demonstration of the recommended guidance. The report will be finalized by September 30, 2001.

Task 4 – Guidance for interpolating and extrapolating bounding values

The purpose of this task is to develop and demonstrate guidance for the preparation and use of bounding curves and data. The methodologies and lessons-learned from this and other related work (i.e. the NRC project) will be formulated into guidance that will be subsequently applied to realistic NCS applications in order to illustrate the recommended preparation of bounding curves and data and the techniques and criteria for proper interpolation and extrapolation. Under this task the criteria for utilizing the concept of *completeness*, whereby information from a variety of widely varying experiments might be used to establish the validity of the computational methodology in an area of interest, will be investigated. This task will be a learning/iterative process that will entail the interaction with criticality safety practitioners and the activities of the other tasks under this project.

In FY1999 the task will examine future criticality safety analysis needs in the DOE and will define and report on the parametric phase space (e.g., waste processes, waste matrixes, spent/waste fuel disposition methods, etc.) for which S/U and other recommended methodologies should be used to establish useful bounding curves and data. This activity relates the desire to identify and use "physical circumstances that may be encountered in the future" per Subrecommendation 3 of DNFSB 97-2.

Work in FY2000 will develop validated curves and data for initial illustration and test of the approach required for interpolation and extrapolation with an associated margin of subcriticality. This first set of criticality data and the demonstrations of their use via interpolation and extrapolation will be documented by September 30, 2000.

In FY2001 the final report that provides guidance on defining the range of applicability, proper interpolation over the range, and proper extrapolation beyond the range will be issued together with supplemental analyses and practical illustrations to address the DOE needs as identified (e.g., adequacy of experimental data or acceptability of subcritical-margin uncertainties relating to DOE processes/operations). The guidance report will be provided by September 30, 2001.

Task 5 – Develop guidance for establishing bounding margins of subcriticality

This task will review the evolving techniques (statistical or otherwise) for establishing subcritical margins in the process of validation against experimental data and provide 1) guidance and recommendations that provides coherent and consistent guidance for the DOE on how to use these methods and 2) demonstration of the use of GLLSM with a recommended statistical-based methodology in order to assure that margins of subcriticality are adequately maintained during interpolation and extrapolation. A recommended approach to properly include known experimental uncertainties will also be studied.

In FY1999 work will focus on preparation of a report that reviews the various methodologies for defining acceptable margins of subcriticality. This report will be issued by September 30, 1999.

In FY2000 the review report developed in FY1999 will serve as the basis for the development of a clear and concise methodology for estimation of appropriate subcritical margins. It is anticipated that criticality safety practitioners familiar with the development or use of the available processes will be surveyed and or utilized to assist in the preparation of the recommendation. If multiple statistical approaches are recommended, the criteria and basis for when and how to use each will be provided. As needed, method-specific guidance for interpolation and extrapolation will be developed in conjunction with Task 4. A technical report documenting the recommendations and guidance will be issued by September 30, 2000. During this fiscal year, work will also begin on a S/U-based statistical method for defining bounding margins of subcriticality throughout the applicable ranges of benchmark interpolation or extrapolation.

In FY2001 the work on an S/U-based statistical methodology will continue. A final recommendation for use of the methodology for estimating subcritical margins will be completed. The recommended methodology will take into account the sensitivities and uncertainties associated with broad interpolations and extrapolations of experimental data as used for criticality safety applications. The guidance and results of selected application(s) will be reported by September 30, 2001.

Task 6 – Planning, Administration, and Reporting

This task provides for the planning, administration and reporting of the project tasks during the duration of the project. Work under this task includes, but is not limited to, management of the ORNL project team, interaction with the DOE NCS Program Criticality Safety Support Group (CSSG), development of supporting subcontracts, and preparation of quarterly letter progress reports to the DOE Nuclear Criticality Safety Program Management Team (NCSPMT). Also, costs associated with preparing modifications to this program plan in response to needs or suggested changes by the CSSG, in concert with the NCSPMT, are included in this task.

5. ANTICIPATED FOLLOW-ON WORK

The work under this program plan calls for documented guidance and examples for establishment and use of bounding values to be prepared by the end of FY2001. Prior to that time, special assistance to address a specific DOE concern can be provided on an as-needed basis and the status of the work will be presented in papers and reports issued under the plan. Beginning in FY2002, efforts to develop structured training for a wider audience of NCS professions should begin. A separate course on the issue with hands-on examples could be developed. A formal course in the 2nd or 3rd quarter of FY2002 is anticipated.

Other potential activities that might extend this NCSP element are largely dependent on the lessons-learned and any identified improvements that can not be addressed under the scope and level-of-effort in the current plan. Additional work under Task 1 may be needed to address the issue of optimizing experiments or operations against functional parameters of interest to criticality safety. Additional discrepancies or anomalies as called for under Task 2 may be identified for investigation. As the work unfolds and the processes for addressing and resolving the issues related to bounding values becomes clearer, additional activities may be required pursuant to appropriate review and consideration by the NCSP.

6. TECHNICAL PROGRAM ASSUMPTIONS

This technical program plan has been constructed with the knowledge and expectation that companion NCSP Program Element projects of the DOE IP for DNFSB Recommendation 97-2 will be supported and products of those projects will be available for use by this technical program. This conceptual assumption is inherent to the maintenance of a coherent DOE-wide Nuclear Criticality Safety Program as outlined in the IP.

The four general assumptions of this program plan are:

1) The continuing resources and products of the past and subsumed DOE IP for DNFSB 93-2 activities supported by EM, DP and EH will be provided;
2) The EMSP project work must be maintained to provide multi-dimensional analytical capabilities to the S/U technology and ROA determination;
3) To minimize expense and focus capabilities and efforts on the technology, the SCALE system will be used as the "test bed" for the methods developments;
4) ORNL staff will maintain liaison/involvement in inter-Laboratory (i.e., LANL, LLNL, INEEL, etc.), and international collaboration (i.e., OECD, IAEA and ISO Work Groups) relating to nuclear criticality safety issues impacting the objectives of this program plan (e.g., OECD Work Groups on Minimum Critical Parameters, Subcritical Measurements Interpretations, Experimental Needs, etc.) to assure synergism of efforts.

7. PROPOSED PERSONNEL

C. M. Hopper will serve as the contractor project manager and co-principal investigator with C. V. Parks. As the project manager Hopper will be responsible for project personnel, overall coordination of the project activities, and interface with the DOE Nuclear Criticality Safety Program as a member of the DOE NCS Program Criticality Safety Support Group (CSSG). As a principal investigator he will work with Parks in the performance of Tasks 1 – 5. The Nuclear Engineering Applications Section at ORNL has several staff with considerable knowledge and experience in the area of criticality safety and development and use of computational analysis of sensitivities and uncertainties. These co-investigators' expertise will be used as appropriate for Tasks 1 – 5. These co-investigators include B. L. Broadhead, R. L. Childs, M. D. DeHart, and L. M. Petrie. Additional personnel resources and expertise may be obtained both internally to ORNL and externally with supporting National Laboratories or Institutes. See attached résumés.

8. MEETINGS/TRAVEL

It is anticipated that up to 8 person-trips/year may be required to conduct or participate in meetings to address CSSG, NCSPMT, and other possible administrative and technical needs. Travel to meet technical needs may involve domestic and foreign travel to share and acquire useful information and data in support of this project. Examples include information/data/methodologies exchange opportunities through OECD, ISO, and IAEA participation.

9. DOE FURNISHED MATERIALS

Information and products of the DOE NCS Program will be made available to ORNL for use in this project as needed - see section 4. TECHNICAL PROGRAM ASSUMPTIONS.

10. REPORTING REQUIREMENTS

Quarterly letter status/progress reports will be issued to the DOE NCSPMT and CSSG Chairs.

11. SUBCONTRACTOR/CONSULTANT AND MAJOR PROCUREMENT INFORMATION

- Subcontractor/Consultant:

  The use of subcontractor/consultants is anticipated to address specific project needs as in the case of Task 1.

- Capital Equipment: Not applicable.

- Major Procurement: Not applicable.

Attachment

Résumés

Bryan L. Broadhead

Reactor and Fuel Cycle Analysis Group
Nuclear Engineering Applications Section
Computational Physics and Engineering Division
Oak Ridge National Laboratory

Education: Ph.D. Nuclear Engineering, University of Tennessee, 1983
M.S. Nuclear Engineering, University of Tennessee, 1979
B.S. Nuclear Engineering, Mississippi State University, 1977

Relevant Work Experience:

Principal investigator for NRC project responsible for evaluation of sensitivity and uncertainty analysis to assist in defining the range of applicability related to validation of criticality safety computational methods.

Performed perturbation theory analysis of selected CERES worth measurements for burnup credit applications. Developed approach for using SCALE modules to determine central worth of small samples in center of DIMPLE core.

Participated in project to reduce uncertainties in the calculated fluence values in the pressure vessel of operating LWRs by applying a least-squares unfolding technique. Code developer for LEPRICON code system to implement final techniques.

Performed sensitivity/uncertainty analysis on the free-in-air tissue doses at both Hiroshima and Nagasaki as a part of the Dose Re-evaluation Effort undertaken by the National Academy of Sciences and the Department of Energy.

Dissertation topic involved study of the sensitivity of multigroup cross sections to resonance parameters. Performed prototypic adjustment of resonance parameter using Generalized Linear Least Squares Methodology.

Directed a major validation task for validation of the source term and shielding codes using benchmark shielding experiments and measured dose rates for five storage cask configurations loaded with PWR spent fuel assemblies.

Presented the shielding portion of numerous SCALE workshop/training courses held in the United States and internationally.

Participated in analyses for U.S. contribution to International OECD NEA Working Group on Shielding Codes and Methods for Transport Casks.

Responsible for analyses to validate methods for prediction of spent fuel source terms and subsequent use of methodologies in source characterization.

Responsible for numerous criticality safcty analyses included enrichment upgrades for UF_6 cylinders and evaluation of degraded core operations at TMI-2.

Principal analyst for NRC project to prepare slide rule for use in characterizing, evaluating, and responding to potential criticality events.

Robert L. Childs

Reactor and Fuel Cycle Analysis Group
Nuclear Engineering Applications Section
Computational Physics and Engineering Division
Oak Ridge National Laboratory

Education: B.S. Nuclear Engineering, University of Tennessee, 1969
M.S. Nuclear Engineering, University of Tennessee, 1972
Ph.D. Nuclear Engineering, University of Tennessee, 1979

Relevant Work
Experience: Co-author of the DORT and TORT Discrete Ordinates Transport Codes

Author of the GRTUNCL, FALSTF, VIP, and Group-band ANISN Computer Codes

Supported development of the FORSS sensitivity/uncertainty code system. Responsible for revitalization, expansion, and interface of FORSS modules to the SCALE code system for prototypic study of sensitivity and uncertainty analysis for criticality safety applications.

Performed shielding Analyses for the FFTF and CRBR fast reactors. This work included analysis of experiments performed at the Tower Shielding Facility

Performed a Sensitivity and Uncertainty Analysis for the Mixed-Oxide Thermal Lattice U-L212 (PhD dissertation on sensitivity analysis methods development)

Calculated the TMI-2 Source-Range Monitor Reading for Several Core Water Levels.

Calculated the radiation dose received by persons in large concrete buildings at Hiroshima an Nagasaki.

Worked on NRC-funded project to analyze radiation dose from potential criticality events.

Mark David DeHart

Reactor and Fuel Cycle Analysis Group
Nuclear Engineering Applications Section
Computational Physics and Engineering Division

Education:

Ph.D. (Nuclear Engineering), 1992; Texas A&M University. Dissertation: "A Discrete Ordinates Approximation to the Neutron Transport Equation Applied to Generalized Geometries."
M.S. (Nuclear Engineering) 1986; Texas A&M University. Thesis: "Heat Pipe Transient Analysis Incorporating Visual Methods."
B.S. (Nuclear Engineering) 1984; Texas A&M University.

Awards & Honors:

ORNL Significant Event Award: Burn-up Credit Technical Guidance, August 1996
George Westinghouse Bronze Signature Award of Excellence; nomination for Corporate Silver Award (1993 - Development of Extended Step Characteristic Formulation).
George Westinghouse Bronze Signature Award of Excellence (1992 - LOCA Limits Team).
SRL Total Quality Achievement Award (1992 - LOPA Limits Team).
Appointment as a US DOE Nuclear Engineering Fellow (1984-1988).
Outstanding Senior Award, Department of Nuclear Engineering, 1984

Professional Experience:

1996-Present: Development Staff Member II; Nuclear Engineering Applications Section, Computational Physics and Engineering Division, Oak Ridge National Laboratory primarily involved in various aspects of radiation transport methods, including criticality safety, depletion and shielding analyses including the development and testing of multidimensional neutron transport methods within the SCALE code system.

1993-1996: Development Staff Member I; Nuclear Engineering Applications Section, Computational Physics and Engineering Division, Oak Ridge National Laboratory primarily involved in various aspects of criticality safety analysis methods, including validation of cross-section libraries for the SCALE-4 code system. Principle Investigator for Burn-up Credit technical support activities at ORNL.

1992-1993: Senior Engineer; Applied Physics Group, Scientific Computations Section, Savannah River Laboratory developing and testing of advanced neutron transport algorithms; upgrade, verification and validation of site-specific discrete-ordinates codes and utility modules within the SRS JOSHUA physics/database system.

1989-1992: Engineer, Senior Engineer; Applied Reactor Technology Group, Nuclear Engineering Section, Savannah River Laboratory involved in the calculation of core neutronic and decay heat responses for all design-basis accident scenarios, applied in thermal-hydraulics systems analyses used for determining operating power limits for the SRS K-Reactor. Also responsible for development, improvement and defense before DOE-appointed review panels of methodology used in the above calculations.

Calvin M. Hopper

Criticality Safety Group
Nuclear Engineering Applications Section
Computational Physics and Engineering Division
Oak Ridge National Laboratory

Education: 1970 B.S., Physics, University of Southern Colorado

Professional Experience:

1995–present ORNL Senior Development Engineer. Responsibilities include Senior Investigator to NRC and DOE Projects related to the nuclear criticality safety specialty, advisor to ORNL and Y-12 Plant Nuclear Criticality Safety organizations.

1994–1995 Head, ORNL Nuclear Criticality Safety Section. Responsible for managing and expanding the nuclear criticality safety program at ORNL.

1989–1995 Principal Manager of the USDOE Criticality Practices & Safety Guide Project. Responsible for development of a "USDOE Contractor Nuclear Criticality Safety Program Guide."

1987–1994 Nuclear Criticality Safety Officer for the Oak Ridge National Laboratory. Responsible for reviewing, confirming, and recommending fissionable material operations safety analyses (process and computational) for approval or re-evaluation, and establishing a stand-alone ORNL nuclear criticality safety program and organization.

1982–present Member of the USDOE Albuquerque Office Weapon Criticality Committee. Responsible to assist in nuclear criticality safety reviews/analyses of production processes, transportation and storage issues for the US weapons complex.

1988–present Team Teacher, University of Tennessee NE 543, "Selected Topics in Nuclear Criticality Safety."

1989–1991 Principal Manager of the USDOE Nuclear Criticality Technology & Safety Project (NCT&SP). Responsible for planning, organizing, and conducting the annual USDOE NCT&SP Conference, assisting USDOE Headquarters in nuclear criticality safety program planning and prioritization, regulatory interpretations and coordination of steering committees for the USDOE.

1990–1991 Principal Manager of the USDOE Experiments to Address Discrepant Calculations Project. Responsible for coordinating the National Institute of Standards and Technology (formerly NBS) experimental measurements of neutron slowing down in idealized geometries/materials and ORNL and LANL computational analyses of measurements to study discrepant calculational analyses.

1987–1990 Periodic member of USDOE EH Technical Safety Appraisal (Tiger) Teams. Responsible to USDOE EH (through Oak Ridge Associated Universities' contracts) as a nuclear criticality safety specialist for performing technical safety appraisals.

1981–1984 Head of the Y-12 Plant Nuclear Criticality Safety Department. Responsible for conducting and managing the nuclear criticality safety program (staffing, process/computational analysis, review, approval, audit, and preparation of technical training materials) at the Oak Ridge Y-12 Plant.

1980–1981 Technical Manager of the Y-12 Health Physics Department. Responsible for the technical management of the whole body counter (fixed and mobile) systems development, deployment/scheduling, urinalysis program, external radiation monitoring, nuclear accident radiation monitoring systems, and radiation emergency preparedness programs.

1978–1980 Manager of Nuclear Safety (Health Physics, Criticality, Emergency Planning), Accountability and USNRC Licensing for the Texas Instruments Incorporated, Material and Electrical Products Group HFIR Project, USNRC License Number SNM-23. (1980 facility closure)

1970–1978 Nuclear Safety Engineer at the Oak Ridge Y-12 and K-25 Plants.

1974–1976 Criticality Safety Consultant to U.S. Nuclear, Inc., Oak Ridge, TN. Performed criticality safety evaluations as input for the USNRC facility license safety analysis.

1968–1970 Health Physics Technician for the Y-12 Plant Development Division and Oak Ridge Critical Experiments Facility.

Professional Involvements:

- Member and Past Chairman of American Nuclear Society (ANS) Nuclear Criticality Safety Division.
- Chairman of ANSI/ANS-8.7, *Nuclear Criticality Safety in the Storage of Fissile Materials*, Working Group
- Member ANS-8 Standards Subcommittee for Fissionable Materials Outside Reactors
- Past Technical Program Chairman for the ANS Nuclear Criticality Safety Division
- Deputy Convenor for International Standards (ISO) Technical Committee 85, Nuclear energy (TC 85) – Subcommittee 5, Nuclear Fuel Technology (SC 5) – Working Group 8, Standardization of calculations, procedures and practices related to criticality safety (WG 8).

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EDUCATION

1985 Ph.D in Nuclear Engineering, University of Tennessee.
1978 M.S. in Nuclear Engineering, N. C. State University.
1976 B. S. in Nuclear Engineering, N. C. State University.
1976 B. S. in Mechanical Engineering, N. C. State University..

SIGNIFICANT ACCOMPLISHMENTS at ORNL

1987 - 1998 Group Leader, Reactor and Fuel Cycle Analysis, Nuclear Engineering Applications Section, Computational Physics and Engineering Division.

1980 - 1995 Project Leader for maintenance and development of the SCALE code system used worldwide for evaluation of criticality safety, radiation shielding, heat transfer, and source characterization for nuclear facilities and transport/storage packages.

1992 - 1997 Consultant and US delegate to the IAEA on criticality issues related to the 1996 Revision of the IAEA Regulations on Transport of Radioactive Material (Safety Series 6). Secretary of Revision Panel Working Groups on Criticality Safety. Formulated and presented U.S. positions on criticality safety for Revision Panel Meetings. Chair at 1995 seven-country consultancy. Prepared and organized regulatory text and advisory material for 1996 Edition.

1989 - 1998 Consultant to NRC in area of nuclear safety evaluation for transport packages: validation issues, training in analysis methods, etc.

1994 - 1995 Author of criticality safety chapter for DOE Handbook on Transport Package Design. Co-author of chapter on shielding analysis.

1987 - 1995 Project Leader for ORNL studies on analysis issues related to use of burnup credit in criticality safety assessments for transport, storage, and disposal of spent fuel.

1992 - 1995 Task leader for work to prepare NRC criteria for assurance of criticality safety at low-level waste sites containing fissile material.

1987 - 1994 Project Leader for work to prepare technical basis of NRC Regulatory Guide on Spent Fuel Decay Heat.

1992 - 1994 Project Leader for joint DOE/EPRI project for validation of shielding analysis for spent fuel storage and transport packages.

1986 - 1992 United States representative to International OECD Nuclear Energy Agency Working Group on Shielding Codes and Methods for Transport Packages.

1985 - 1992 Responsible for criticality analyses related to TMI-2 Defueling Project.

PROFESSIONAL ACTIVITIES

1976 - 1996 Member: American Nuclear Society (ANS), Sigma Xi, Tau Beta Pi, Phi Kappa Phi

1988 - 1996 Session organizer and chair for technical sessions at national and international conferences.
1993 - 1995 Program Chair for the Nuclear Criticality Safety Division (NCSD) of ANS
1993, 1997 Assistant Technical Program Chair for NCSD Topical Meeting
1995 - 1998 Secretary, Treasurer, Vice-Chair for the Nuclear Criticality Safety Division of ANS

PUBLICATIONS

Over 100 publications in journals, conference proceedings and national laboratory reports related to computational methods and applications in criticality safety, radiation shielding, and source term characterization of nuclear facilities and packages.

Lester M. Petrie

Group Leader
Criticality Safety Group
Nuclear Engineering Applications Section
Computational Physics and Engineering Division
Oak Ridge National Laboratory

Education:	B.S. Chemical Engineering, Georgia Institute of Technology M.S. Nuclear Engineering, Massachusetts Institute of Technology Ph.D. Nuclear Engineering, Technology, Massachusetts Institute of Technology
Relevant Work Experience:	Principal Developer: KENO series of Monte Carlo criticality codes. Extensive experience in defining criticality analyses and other radiation transport studies. Manager: Nuclear Criticality Safety Methods Resource Center for the Department of Energy.

R. M. (Mike) Westfall

Section Head
Nuclear Engineering Applications Section
Computational Physics and Engineering Division
Oak Ridge National Laboratory

EDUCATION:

B.S. Engineering Sciences, University of Oklahoma
M.S. Nuclear Engineering, University of Washington
Ph.D. Nuclear Engineering, University of Virginia

RELEVANT WORK EXPERIENCE:

Initial manager of SCALE system project - Definition paper at PATRAM-78.

Neutronics support for Shipping Cask Critical Experiments Program performed at the Critical Mass Laboratory.

Technical support for the Burn-up Credit study conducted by Sandia National Laboratories.

Criticality and shielding support for DOE/RW request for proposals for casks.

Extensive experience in development and application of neutronics codes and data.

Technical background in neutral particle transport analyses and processing neutron cross sections into multigroup data suitable for systems analysis.