# ANALYSIS OF NUCLEAR CRITICALITY SAFETY TECHNOLOGY SUPPORTING THE ENVIRONMENTAL MANAGEMENT PROGRAM

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## 1.0 INTRODUCTION

This report documents an analysis of nuclear criticality safety technology support needs of the Environmental Management Program. The purpose of this activity is to identify criticality safety technologies, funding levels, and deliverables that directly contribute to accomplishing the accelerated, risk-based cleanup and closure mission of Environmental Management. The review focused on selected technologies maintained under the Department of Energy's Nuclear Criticality Safety Program (NCSP) established in response to Defense Nuclear Facilities Safety Board Recommendation 97-2 and managed by the National Nuclear Security Administration (NNSA). NNSA has the responsibility for funding and maintaining the NCSP infrastructure capability. The NCSP technology areas included in this review are Nuclear Data, Methods and Codes, Applicable Ranges of Bounding Curves and Data (AROBCAD), and Integral Experiments. These four areas of the NCSP have the greatest potential to impact the accelerated, risk-based cleanup and closure mission. Proper application of these technologies can enable criticality safety engineers to better understand the criticality safety margin, reduce or eliminate subjective conservatism in setting criticality safety limits for fissile material operations thereby making operations more efficient, and facilitate licensing processes as needed.

The key to successfully applying criticality safety technologies to EM missions is integration of criticality safety into the advance project planning process at the site level. The technical complexity of the various criticality safety technologies and the high degree of coordination required among various DOE laboratories requires project planning at least two years in advance in order to ensure that operations can benefit from these technologies. Typically, criticality safety considerations are considered very late in the project life-cycle which short-circuits the ability to benefit from improved nuclear data and methods. This often results in embedded layers of subjective conservatism in determining operating criticality safety limits as criticality safety engineers work around the supporting technical and data inadequacies to accomplish the mission on schedule. These conservatisms increase cost and stretch out time-lines of EM projects. The increased costs are difficult to measure because they are buried in assumptions and technical analysis within criticality safety evaluations. Criticality safety evaluations are rarely, if ever, scrutinized by competent DOE staff with a view toward improving efficiency. In any event, there is no alternative available to avoid potentially costly and time-consuming technical work-arounds by the criticality safety staff if out-year advance project planning is not performed that integrates criticality safety technology considerations in the process.

This review attempted to identify EM missions being planned in one to three years at three important EM sites where there are potential gaps in the available nuclear data, methods, or experiments. Contractor and DOE criticality safety staff were contacted at Hanford, Savannah River, and the Idaho National Environmental Engineering Laboratory to identify out year projects that could benefit from improved criticality safety technologies. Nuclear Regulatory Commission criticality safety staff were also interviewed for their perspectives on technical issues related to licensing of DOE operations and facilities. Rocky Flats was not included in this process because fissile material disposition is expected to be completed within the next eighteen months and new technologies cannot be brought to bear in that time frame. The sites provided information on specific missions and milestones in addition to requesting specific criticality safety technology needs that have the potential to improve the efficiency of the planned operation or result in an overall cost savings to the site.

The site input was used as a starting point to coordinate with the criticality safety technology providers at various DOE laboratories to identify specific deliverables, funding targets, and milestones meeting the site needs. Site visits were made to Idaho to meet with DOE ID senior management, Oak Ridge National Laboratory, and Argonne National Laboratory. Discussions with ORNL technical staff and with the members of the newly formed DOE Nuclear Data Advisory Group (NDAG) that met at ANL brought together the end-user mission needs and the nuclear data/methods experts so that useful products could be proposed to meet the site's needs. This report describes the site mission needs, the specific criticality safety technology products, and the challenges of managing and coordinating these tasks in the future.

## 2.0 BACKGROUND

In May 1997 the Defense Nuclear Facilities Safety Board issued Recommendation 97-2 dealing with the continuation of criticality safety at DOE defense nuclear facilities. Recommendation 97-2 reinforced and extended Recommendation 93-2 dealing with maintenance of criticality safety predictability technology. In Recommendation 97-2 the Board stated:

"The above problems have had a significant effect on the productivity of several DOE operations. They have adversely affected safety by extending the period of time required for meeting safety commitments, such as those responding to Board Recommendation 94-1. In so doing, they have absorbed resources potentially needed for other safety-related activities at DOE's defense nuclear facilities. In this light, the Board believes action should be taken to eliminate these problems and to ensure that criticality safety can continue to be achieved efficiently in DOE's future operations."

The DOE's Implementation Plan for Recommendation 97-2 proposed joint EM and DP funding of infrastructure capability in seven key areas. These are Training, Information Preservation and Dissemination, Nuclear Data, Methods and Codes, Integral Experiments, Benchmarking, and AROBCAD. The IP also set up a management structure for the DOE Nuclear Criticality Safety Program and established an expert group called the Criticality Safety Support Group (CSSG) to advise DOE management on criticality safety issues. A key element of Recommendation 97-2 was to establish funding stability for the infrastructure capability.

The DOE found it challenging to establish funding stability under the joint funding approach because such a technology infrastructure maintenance program does not fit within EM's site cleanup and closure mission. In March 2002 NNSA agreed to solely fund the DOE NCSP with a goal of maintaining criticality safety technology capability. At that point EM initiated this study to identify criticality safety technologies needed to improve the efficiency of it's cleanup and closure missions with a view toward providing funding for specific NCSP deliverables (See Attachment A).

The four nuclear criticality safety technology programs identified as contributing most directly to accelerated site cleanup and closure are described at length in the DOE NCSP Five-Year Plan. The Five-Year Plan may be found by going to the DOE criticality safety website http://ncsc.llnl.gov:8080/NCSC.html.

## 3.0 SITE CLOSURE AND CLEANUP ACTIVITIES NEEDING CRITICALITY SAFETY TECHNOLOGY SUPPORT

This section summarizes the site-specific projects that were identified as needing additional criticality safety technology support to ensure efficient operations. The specific deliverables, costs, and milestones for criticality safety technology products are included. Anticipated improvements in project efficiency or cost savings are discussed as well.

### 3.1 Savannah River

#### 3.1.1 H-Canyon Processing of Waste Plutonium Solution

One project currently being planned at Savannah River involves processing plutonium solutions from H-Canyon through the waste tank farm and eventually through the DWPF. In order to assure subcriticality when the solutions are transferred to large waste tanks the solution will be poisoned with gadolinium (Gd). Other soluble poisons under consideration are iron (Fe) and manganese (Mn). Gadolinium is a much stronger thermal neutron absorber than either iron or manganese. However, the neutron capture cross section resonances in Gd are large and narrow and Gd is not a strong absorber for intermediate or high-energy neutrons. While the plutonium is in solution, the large thermal neutron capture cross section of Gd will provide an adequate margin of subcriticality. When the solution is processed through the DWPF into glass logs, the moderator content drops and the neutron spectrum hardens thus reducing the effectiveness of the Gd. A much smaller volume of Gd will be required to poison the solution compared to Fe or Mn. If Fe or Mn were to be used it would significantly increase the number of glass logs produced. The cost of each glass log is on the order of $100K. The ability to show Gd is a useful nuclear poison in the DWPF and in the resulting glass logs with the higher energy neutron flux may cut the number of glass logs needed by 10-20% compared to using alternative nuclear poisons.

The ANSI/ANS Criticality Safety Standards require criticality safety calculations to be validated against experiment to determine the bias and uncertainty in the bias of the calculated reactivity. Validation is accomplished by computing the reactivity of critical experiments having similar physics attributes as the system being studied. The available plutonium-gadolinium benchmark experiments appear to be only in the thermal neutron energy range. Extending the area of applicability from what appears to be thermal benchmarks to epithermal and fast systems will involve large uncertainties and application of substantial subjective conservatism if traditional analysis techniques are used. This could result in abandoning Gd as the neutron absorber with the result being production of a substantially larger number of glass logs.

WSMS has identified the need to utilize AROBCAD to analyze the existing experimental benchmarks. AROBCAD will be used to test whether the existing benchmarks exhibit similar sensitivities and uncertainties as a function of energy to the nuclides involved in the process. In addition, AROBCAD will be used to quantitatively estimate the bias and the uncertainty in the bias, and, if necessary, to design new integral experiments with like nuclear cross section sensitivities and uncertainties to the SR process being planned.

AROBCAD analysis is needed as soon as possible and certainly before the end of FY02 to support initial criticality safety analysis and a key decision point on whether or not to commit to Gd versus some other absorber. Processing through the DWPF that involves the drying/precipitation process is expected in the next one year to eighteen months. This time frame is barely sufficient to perform the necessary AROBCAD analyses, design and perform new integral experiments, and analyze the integral experiments if work starts early in FY03.

The project will incur increased costs due to conservatisms in establishing the criticality safety margin if AROBCAD analyses and subsequent new integral experiments (if needed) are not performed. An increase of from 10-20% in the total number of glass logs may result from these conservatisms at a cost in excess of $100K/glass log. This represents a significant project impact and would more than offset the expense of AROBCAD analysis and performing integral experiments.

### 3.1.2 Receipt and Storage of Hanford U & Pu Oxides and Metals Mixed with Beryllium

The Hanford Plutonium Finishing Plant (PFP) is a closure facility dependent upon being able to package and ship various fissile wastes to Savannah River to support closure and cleanup milestones. PFP plans to ship uranium and plutonium oxides and metals in a beryllium matrix to Savannah River beginning in the spring of CY03. This material is currently slated for storage at the K-area material storage (KAMS) project.

The existing integral experiments with interstitial beryllium are thought to be too thermal to be applicable to the oxide and metal matrices involved in the PFP material. Additional conservative margins will have to be applied to compensate for the inadequacy of the available experimental benchmarks. This may result in significant additional spacing requirements in KAMS and/or reduced shipping payloads. The conservative criticality analysis may result in the available storage in KAMS being exceeded so that an additional storage facility will be required. The cost of a new storage facility will be multiples of $10M.

AROBCAD analysis of the existing experimental benchmarks needs to be performed to establish which experiments are applicable and to quantitatively determine safety margins. If no existing experiments are applicable then the site will be forced to impose the AROBCAD derived conservative safety margins or use AROBCAD to design new integral experiments. With enough lead time, new experiments could be performed and analyzed with the result that excessive conservatism in the limits could be eliminated.

Without AROBCAD analysis in time to perform new integral experiments, if needed, EM will incur increased costs. These will result from increased spacing requirements, reduced fissile payloads, increased number of shipments from Hanford, and the potential need for a new storage facility at Savannah River.

## 3.2 Hanford

All cleanup projects at Hanford are under continuous review to compress schedule and reduce cost while maintaining or improving the safety posture. With respect to criticality safety considerations increased efficiency is associated with improving confidence in the safety margins. This can be achieved by use of sophisticated analysis tools, by the availability of better nuclear data, and by a well-trained staff. All projects identified the need for more extensive structural material inclusion in criticality analysis, consideration of non-fissile matrix materials or the use of configurations laced by special neutron absorbers. The need for cross-section evaluations or measurements as well as critical testing with layered materials was common to most projects. The magnitude of the safety margins is dependent on the scarcity and uncertainty associated with nuclear data. Safety margins must allow for how well cross-sections are known, the range of validation biases, and computer code capabilities. Large uncertainties in the safety margin manifest themselves in more restrictive criticality limits and associated adverse impacts on production and flexibility.

There are 4100 MT of fissionable materials at Hanford that require disposition. Any refinements in safety margin due to improved experimental data or cross-section information could result in large-scale savings in preparatory activities, packaging operations, or eventual off-site transport. Well-supported margins can also be achieved by more extensive consideration of neutron absorbers, deliberate use of engineered safety features, and by explicitly crediting these absorbers and design features in criticality analyses. Application of engineered safety features tends to reduce reliance on administrative controls and therefore reduce limit violations that could slow down processing activities. In addition, the licensing process is easier if engineered features are relied upon rather than administrative controls.

The site provided the descriptions of the programmatic needs in the section that follows. What is clear is that the ability to credit steel constituents and other non-fissile nuclides in the criticality safety analyses is needed. The first step toward understanding if the existing nuclear data and/or benchmarks are adequate is performing AROBCAD analysis of the specific system. Hanford does not have the capability to perform AROBCAD analysis. This capability only exists at the ORNL. Therefore, in each case where the site identifies the potential for data inadequacies and the potential need for new integral experiments, only an AROBCAD analysis followed by consultation with the NDAG can reveal whether new differential data, a new evaluation of existing nuclear data, and/or if new integral experiments are needed.

The site provided the need dates for additional and improved technical information. They are front loaded to support aggressive schedules for clean up missions especially for SNF and PFP. The sustained investment in improved nuclear and experimental data, enhanced data analysis methods, and needed documentation would increase efficiency and schedule of cleanup operations at Hanford.

### 3.2.1 Spent Nuclear Fuel Program (SNF)

The SNF program objective is expeditious clean-out of the K Reactor fuel storage basins containing irradiated nuclear fuels (N Reactor and Single Pass Reactor) and sludges produced from oxidation of such fuel. Fuel and sludge clean out are expected to be finished late in FY 2004. Termination of basin D & D activities should occur in FY 2007. Criticality support to accelerate the program requires the allowance for burnup credit and accounting for Fe, Cr, Mn, Ni, Cu in structural components in the analysis. Cross-section data for these elements, as well as for fission products needs to be confirmed as being adequate, or if not, additional cross-section measurements are required (Need Date: FY 2003). Furthermore, criticality measurements evaluating the impact of structural materials such as steel, stainless steel, and Cu need to be performed and included in the benchmark library (Need Date: FY 2003). The subcritical measurements performed with N Reactor fuel have to be documented in the benchmark library to facilitate consistent use of such information for burnup credit consideration (Need Date:
Fy 2002/2003).

The benefits derived from improved and documented nuclear data would enhance the analysis and yield more robust criticality safety margins. Inclusion of burnup consideration in fuel packaging into Multi-Canister Overpack (MCO) baskets can speed up the process significantly. Burnup allowance for sludge would render sludge transport containers inherently subcritical and thereby limit the number of containers needed. Inclusion of burnup credit and structural materials in MCO analysis will ensure substantial subcriticality even for more stringent off-site NRC/DOT transportation requirements and could preclude possible criticality reanalysis before shipment off-site.

### 3.2.2 Plutonium Finishing Plant (PFP)

The PFP program objectives are to stabilize fissile material, package the material for off site and on site shipment, and Decontaminate and Decommission (D & D) the facility. The major stabilization activity will be completed in FY 2004 and D & D will terminate in 2009. To expedite the process within the existing criticality safety requirements necessitates availability of improved nuclear data, additional experiments, the use of fixed neutron absorbers, and possible in situ measurements. Improved knowledge of the following cross-sections: Cl, Fe, Ni, Mn, Cr, Si, Ce and Ca is needed to improve criticality safety margins for nuclear operations (Need Date: FY 2003). Additional critical experimental data of layered steel, water, plastics, and fissile materials are required for computer code validations (Need Date: FY 2003). Furthermore, uncertainties associated with water content of concrete as a neutron reflector or as a moderator have to be resolved to reduce excess conservatism (Need

Date: FY 2004). Computer code input formulation needs to be simplified to expedite modeling and to reduce input errors (Need Date:
FY 2003).

As a result of the improved data, limits and controls could be simplified resulting in greater operational flexibility. The Decontamination and Decommissioning (D & D) process could be enhanced with better utilization of shipping containers and simplified limits. Improvements in computer code input formulation could facilitate criticality control coverage modeling and subsequent criticality accident alarm system detector removal during the D & D process.

### 3.2.3 Waste Management

The waste management program prepares waste containers for off site shipment or on-site burial. The major challenge is handling and repacking large quantities of previously buried containers. Waste management activities are expected to last for the next 10 to 20 years. Improved knowledge of cross-sections of shipping container structural materials (Fe, Ni, Cn, Mn), as well as additional experimental information on layered media (steel, plastics, water, fissile material, soil) could help reduce over-conservatism in criticality safety margins (Need Date: FY 2004). Criticality analysis and measurements would be needed to configure shipping containers with built-in fixed neutron absorbers (Need Date: FY 2005). Any standard shipping container modification would require new SARP's (Need Date: FY 2005). The benefits derived from the added technical information in conjunction with modified shipping containers would result in more realistic criticality margins, more efficient shipping container usage, reduction of the number of containers needed and reduction in the number of off-site shipments.

### 3.2.4 Tank Farms

The Hanford radioactive waste tank operations involve maintaining and moving tank contents between tanks such that the risk to people and the environment is minimal. Consolidation of single shell tanks into double shell tanks is part of the operation. Eventually the radioactive tank contents will be prepared for vitrification into logs. The first glass logs are to be produced in FY 2007. Subcriticality has to be maintained during in-tank storage, tank content movement, and eventual chemical mechanical processing. Subcriticality is dependent on keeping fissile material concentration low and a high ratio of absorbers to fissile materials. Fissile materials and neutron absorber concentrations vary between the different material layers in the tanks. Knowledge of cross-sections of elements such as Fe, Mn, Cr, Ni, Ca, Cl is very important (Need Date: FY 2004), as well as criticality measurement of layers of fissile materials of different enrichments interspersed with moderator and neutron absorbers (Need Date: FY 2005). The aim should be to simulate sludge and saltcake compositions with various material compositions and perform critical mass measurements (Need Date: FY 2005).

The benefits derived from improved cross-sections data and from criticality measurements of sludge and saltcake simulants would strengthen reliance on elemental ratios for existing tank contents and for changes in tank make up as a result of clean up efforts. The improved knowledge in subcritical margins would provide for greater flexibility in tank-to-tank movement of liquids and in process selection for saltcake or sludge removal.

### 3.2.5 Fuel Storage

Large quantities of fuel both irradiated and unirradiated are stored in casks on special storage pads or in designated facilities. Storage is expected to last for 40 years. Incorporation of container structural details in analysis would be very beneficial. Improved knowledge of neutron absorber cross-sections such as Fe, Ni, Cr, Mn (Need Date: FY 2005), as well as criticality measurements simulating spacing configurations would be needed (Need Date: FY 2006). The benefits derived from such data or measurements would eliminate container spacing requirements, thereby allowing improved utilization of storage space, maximizing loading of casks and eliminating of contentious spacing requirements. Higher operating efficiency and cost savings from fewer containers needed should be realized.

### 3.2.6 Legacy Facilities and Sites

There are two hundred legacy facilities and sites at Hanford. These locations contain generally ill-defined amounts of fissile material. The fissile material needs to be characterized and quantified. Legacy facilities and sites disposition should occur over the next 10-20 years. Advantage of structural components and container walls should be considered. To accomplish this, improved knowledge of Fe, Ni, Cr, Mn cross-sections is required (Need Date: FY 2005). Experimental critical mass data on Si, moderators, steel, and fissile material systems would be essential benchmark information (Need Date: FY 2006).

Benefits derived from improved analysis capabilities and interrogation techniques could simplify legacy site characteristics, provide improved criticality limits and controls, and expedite disposition of fissile materials.

## 3.3 Idaho National Environmental Engineering Laboratory

The INEEL has over 141 metric tons of enriched uranium and many hundreds of kilograms of plutonium. The majority of the uranium is associated with reactor fuels and most of the plutonium is transuranic waste received from the Rocky Flats Plant. The INEEL fissile inventory also includes over 1200 kg of U-233 in both irradiated and unirradiated fuel elements. Most of the fissile materials at the INEEL are part of spent nuclear fuel, but there are significant amounts of metals and oxides stored in various containers. There are close to a hundred different fuel types in storage that vary widely in shape, fissile loading, and fuel matrix. Matrixes include aluminum, graphite, stainless steel and zirconium. Most of the material is highly enriched uranium but there is a significant amount of commercial and intermediate enriched fuels as well. There are also several legacy areas that contain fissile materials as sludges and waste.

### 3.3.1 Irradiated Fuel Storage Facility (IFSF)

The INEEL currently applies a large conservative bias when determining criticality safety limits for the (IFSF) and need to understand this system better. Neutron energies vary between thermal, intermediate and fast. ORNL is also developing a code (AROBCAD) to evaluate uncertainties in methods and data to determine where additional experiments are needed or show where existing experimental data is adequate. This methodology may be very cost effective since critical experiments are expensive and difficult to get approved.

The INEEL would benefit from AROBCAD analyses to determine whether existing cross section data adequately determine interaction between thermal, intermediate, and fast neutron energy systems. This is a result of many different fuel types (aluminum, ceramic, graphite, oxide, hydrated-zirconium, metal, stainless steel, and various scrap materials) stored in the Irradiated Fuel Storage Facility (IFSF) at INEEL. By extending the area of applicability of existing benchmarks and reducing the conservative bias in limits, more efficient fuel storage will result. Performing these analyses in FY03 or early FY04 would meet the INEEL's needs.

### 3.3.2 Fuel and Fissile Material Storage and Shipping

Of particular interest to the INEEL is whether existing critical experimental data is adequate to validate systems with discrete steel, i.e., fuel stored in a thick stainless steel can or insert. The steel acts as a mild absorber and can reduce the overall reactivity of the system allowing increased fuel density. No credit is taken for the steel absorber in current calculations due to the absence of applicable integral experiment data which results in reduced masses, reduced payloads in shipping, and increased spacing requirements in storage.

Fissile material storage and handling could be more efficient if AROBCAD analyses were performed to determine whether existing critical experimental data is adequate to validate systems with discrete steel, i.e., fuel stored in a thick stainless steel cans or inserts. If the existing integral data is not adequate, either quantitatively determined biases can be developed or new integral experiments designed by the use of AROBCAD. Performing these analyses in FY03 or early FY04 would meet the INEEL's needs.

## 4.0 CRITICALITY SAFETY TECHNOLOGY SUPPORT BY SPECIFIC AREA

The specific areas needed to support the mission needs are discussed below. Near term (FY03) and out-year (FY04-FY10) funding and deliverables are provided. It should be noted that these activities and funding levels are over and beyond the infrastructure capability maintenance levels provided to the NCSP by NNSA. EM should support these tasks at the recommended levels of funding to be responsive to the site-specific needs identified in Section 3.0. A key assumption in all that follows is that cleanup and closure missions at the three sites will be completed to the point in FY10 where no funds over and above the NNSA infrastructure maintenance capability funding will be needed. Another assumption is that the NNSA funded NCSP will provide all the integral experiment capability needed for EM and will continue to be responsive to priority EM needs.

The basis of estimate for the costs of the following tasks was provided by ORNL. The full time equivalent (FTE) cost at ORNL is currently ~$270K. The FTEs needed to perform each task has been estimated based on extensive experience performing similar work. These are not new tasks at ORNL and, in fact, are based on extensive work performed on similar tasks for many years at ORNL including the past five years specifically for Recommendation 97-2 support. By comparison the FTE rate at ANL is about the same and LANL is about 10-15% less.

## 4.1 AROBCAD

AROBCAD is a technique to enable criticality safety engineers for the first time to quantitatively assess the applicability of integral experimental benchmarks to a given system and to determine bias and uncertainty in the bias. This is done by various techniques developed at ORNL for the NCSP including sensitivity, uncertainty, and generalized linear least squares analysis of the systems to perturbations in the nuclear cross-sections. For AROBCAD to be functional the most up to date evaluated nuclear cross sections, and importantly, the associated covariance data (i.e. cross-section uncertainties) must be available for the nuclides of interest.

During the past three years NCSP funding shortfalls delayed work in this very important area. The funding below represents the amounts needed to regain schedule and meet the various site mission needs in FY03 and out-years.

ORNL is the only DOE site capable of performing AROBCAD analysis at this time. If a site needs AROBCAD analysis they must contract with ORNL directly for them to perform the work with all of the attendant overhead costs associated with work done at a national laboratory. It should be noted that due to funding shortfalls in prior years the covariance data needed to perform the uncertainty analysis and the GLLSM analysis do not yet exist, even at ORNL, for all nuclides of interest to EM.

The three EM sites discussed in Section 3.0 all need AROBCAD analysis to make their operations more efficient. It is recommended that EM fund the tasks necessary to issue AROBCAD to EM sites, provide the best available cross-sections and covariance data, and provide training to the end-users so that the sites can utilize the tool on whatever site specific problems that arise. That is the goal of the following tasks. All work and funding is to be provided by the ORNL.

### 4.1.1 FY03 AROBCAD Tasks, Milestones, and Deliverables

- Completion of Uncertainty analysis Capability (GLLSM), June'03, $150k
- Training on AROBCAD tools for SRS, RL and INEEL staff, June '03, $125k
- Three SRS, RL and INEEL AROBCAD studies (guidance, training sample cases)
- Site studies to be interactively defined & developed over FY03, $50k/study x 3 =$150k

**AROBCAD TOTAL = $425k**

These tasks will enable the three primary EM sites, Hanford, Savannah River, and Idaho to perform their own AROBCAD analyses in the future. The training will be provided in a two-week session at ORNL. The course will emphasize AROBCAD examples provided in advance by the three EM sites so that at the conclusion of the course the sites will have useable analysis for their site's missions. Funding is also provided for ORNL to assist the sites through the year with any other AROBCAD applications that arise to facilitate the effective use of the AROBCAD tool at the site level.

#### 4.1.2 FY04-10 AROBCAD Tasks, Milestones and Deliverables

It is recommended that $200k/yr be provided to ORNL to provide ongoing technical assistance to EM sites to best utilize AROBCAD. This will facilitate ORNL consultation on site-specific applications as they arise in the out-years and facilitate transfer and training on new code and analysis capabilities as they are developed by the NNSA funded portion of the program. For example, this level of funding would permit ORNL to assist on three site specific analyses and provide some small level of technology transfer support, as needed each year.

### 4.2 Methods and Codes

The Methods and Codes element of the NCSP is chartered to upgrade and maintain the criticality codes used by the sites' criticality safety engineers. Work has proceeded very slowly on development of SCALE 5.0 which contains the sensitivity and uncertainty analysis codes needed for AROBCAD analysis. The SCALE package of codes developed and maintained by ORNL contains the KENO Monte-Carlo criticality safety code and a host of cross-section processing codes needed to tailor the nuclear data for the site-specific application. Without additional EM funding SCALE 5.0 will NOT be released in FY03. All NNSA sites use MCNP or COG and do not need SCALE 5.0. EM is the primary beneficiary of this new code release because of its AROBCAD capabilities. SCALE 5.0 is also required to enable EM criticality safety engineers to use the most current nuclear cross sections, those in the ENDF/B-VI data set. Again, MCNP and COG users have capability to utilize ENDF/B-VI data but only the SCALE 5.0 package contains the AROBCAD software. It should be noted that the GLLSM capability will be developed and issued independently under an AROBCAD funded task.

#### 4.2.1 FY03 Methods and Codes Tasks, Milestones, and Deliverables

- Complete work on SCALE 5.0 and Issue to Users through RSIIC, March '03, **$300k**

#### 4.2.2 FY04-10 Methods and Codes Tasks, Milestones, and Deliverables

None beyond that provided by the NNSA supported infrastructure capability maintenance level NCSP.

### 4.3 Nuclear Data

This element of the NCSP involves measuring, evaluating, processing, and issuing nuclear cross section data to criticality safety engineers in forms amenable to use by the current criticality safety computer codes. Within this task is the measurement capability at the Oak Ridge Electron Linear Accelerator (ORELA). ORELA is a unique facility in the USA because it is the only facility with the required beam intensity, short pulse width, low neutron background, and long time-of-flight beamlines to permit high resolution neutron cross section measurements in the energy regime of interest to criticality safety.

The DOE NCSP recently formed the Nuclear Data Advisory Group (NDAG) to recommend nuclear data improvements. These recommendations could involve new ORELA measurements or new evaluations of existing measurements followed by issuing the best available, useable, nuclear data to the criticality safety engineers at the sites. NDAG brings together for the first time nuclear data experts and end-user criticality safety staff to facilitate identification of nuclear data needs and priorities.

The NDAG met for the first time at Argonne National Laboratory in March to discuss nuclear data needs, specifically those needed by EM. Nuclides are important to near term EM applications from a criticality safety viewpoint: Gd, Fe, U238, Be, and Stainless Steel constituents. The NDAG was asked to recommend a path forward to removing the suspected uncertainties in the respective cross section libraries. Are new cross section measurements needed at ORELA? Are new cross section evaluations and libraries needed? The consensus of the NDAG was that at this time no EM specific ORELA measurements are needed. The concerns with the underlying cross sections are probably due to evaluation/processing issues not with gaps or flaws in the basic differential cross section measurements. The NDAG has taken action to recommend a path forward to resolve the nuclear data issues with these nuclides during the remainder of FY02 and 03. (See Attachment 2)

The NDAG did identify a major gap in the nuclear data currently available for criticality safety analyses. There are no ENDF/B-VI covariance data available. AROBCAD uncertainty analysis and GLLSM analysis techniques cannot be performed without covariance data. This means that analysis of the available integral benchmark data will be restricted to sensitivity analysis only. That is, all that AROBCAD will be able to determine is if integral benchmarks are sensitive to the same degree to changes in the underlying cross sections supporting the criticality analysis as the process being studied. This is an incremental improvement in current practices. However, the real gain by AROBCAD is the ability to correlate nuclear data uncertainties as a function of energy between experiments and application (i.e. uncertainty analysis) and by adjustment of the underlying cross section libraries to quantitatively determine the bias and uncertainty in the bias (i.e. GLLSM).

Some modifications to the cross section processing codes will be required in order to produce the required ENDF/B-VI covariance data. The ORNL code that will be used to process the covariance data is called SAMMY. There are approximately 600 individual nuclides requiring cross-section covariance processing to support the entire data library. The task in FY03 is to process as many as possible but, at a minimum, to process those nuclides identified in Section 3.0 above.

### 4.2.1 FY03 Nuclear Data Tasks, Milestones, and Deliverables

- Utilize state of the art evaluations, upgrade covariance processing software; Software upgrades, January '03, $50k

- Covariance development on nuclides important to EM application studies; Covariance evaluations, FY03, $250k

### 4.2.2 FY04-10 Nuclear Data Tasks, Milestones, and Deliverables

Nuclear data is always being improved and new data formats are always being generated. A continuing level of support will be needed to ensure EM priority nuclear data needs are supported until the major site closure missions are completed. Each year EM and the NDAG should work to identify the EM specific nuclear data needs that will be met by the following funding commitments.

- New Nuclear Data Evaluations and/or Covariance Data Processing, $200K
- Cross-Section Processing Code Improvements, $100K
- ORELA differential cross section measurements, $100K

## 5.0 EM NCSP PROGRAM MANAGEMENT RECOMMENDATIONS

Pulling this analysis together in a short time frame pointed out several challenges that EM will need to address in the near future to ensure that its sites have the continuing criticality safety technology support they need to efficiently, expeditiously, and safely close and cleanup sites. EM will need to perform this type of analysis on at least an annual basis. The lessons learned in putting this report together are:

- EM site management must improve long term project planning to include criticality safety aspects (especially criticality safety technology related opportunities for improved efficiency) at least 2 years in advance for major closure/cleanup tasks.
- EM HQ needs to acquire criticality safety technical expertise either through hiring its own or by obtaining matrixed support from EH as was done for this analysis.
- Frequently, but at least annually, interact with the sites, the DOE laboratories, the NNSA led NCSP, the CSSG, and the NDAG to coordinate EM's program to ensure a coherent program focused on cleanup and closure needs is provided the necessary resources in the out years.

The key to successfully applying criticality safety technologies to EM missions is integration of criticality safety into the advance project planning process at the site level. The technical complexity of the various criticality safety technologies and the high degree of coordination required among various criticality safety disciplines and DOE laboratories requires project planning at least two years in advance in order to ensure that operations can benefit from these technologies. Typically, criticality safety considerations are considered very late in the project life-cycle which short-circuits the ability to benefit from improved nuclear data and methods. This often results in embedded layers of subjective conservatism in determining operating criticality safety limits as criticality safety engineers work around the supporting technical and data inadequacies to accomplish the mission on schedule. These conservatisms increase cost and stretch out time-lines of EM projects. The increased costs are difficult to measure because they are buried in assumptions and technical analysis within criticality safety evaluations. Criticality safety evaluations are rarely, if ever, scrutinized by competent DOE staff with a view toward improving efficiency. In any event, there is no alternative available to avoid potentially costly and time-consuming technical work-arounds by the criticality safety staff if out-year advance project planning is not performed that integrates criticality safety technology considerations in the process.

## ATTACHMENT 1

Memorandum from Jessie Hill Roberson to Distribution of March 14, 2002

## ATTACHMENT 2

Minutes of the Nuclear Data Advisory Group Meeting, May 7-8, 2002