A brief list of the more significant 2006 Accomplishments for each Nuclear Criticality Safety Program (NCSP) element is included below.

2.a International Criticality Safety Benchmark Evaluation Project (ICSBEP)

- Published the *International Handbook of Evaluated Criticality Safety Benchmark Experiments* in September 2006 including:
  - Twenty-six newly approved evaluations bringing the total to 442. China was a first-time contributor in this 2006 edition.
  - Continued to increase the number and variety of criticality alarm benchmarks.
  - Included a new volume entitled *Fundamental Physics Measurements* in the 2006 edition. In this volume benchmark specifications for fundamental physics measurements, relevant to nuclear criticality safety and nuclear data applications, are provided.
  - Included VNIITF Russian Ti-reflected benchmarks.
- Represented the United States at the annual ICSBEP meeting was held in Rio de Janeiro, Brazil in May 2006. Representatives from nine of the eighteen participating countries participated.
- Coordinated arrangements for conducting continued critical experiments (Vanadium) in Russia and held preliminary discussions to facilitate cooperation with the French Critical Experiments Facility held in France.

The ICSBEP Handbook continues to be a valuable resource to criticality safety engineers, worldwide. Approximately 500 copies of the Handbook have already been distributed since the release in mid September 2006. Many benchmarks also support the NCSP's Nuclear Data and Analytical Methods Development tasks.

2.b Analytical Methods Development and Code Support

- Converted VIM to FORTRAN 90.
- Completed the Phase I final report of the OECD/NEA Expert Group on source convergence.
- Completed the VIM2KENO translator code.
- Produced VIM libraries based on ENDF/B-VII nuclear data.
- Presented four-week long, hands-on workshops on the use of SCALE/KENO and SCALE/TSUNAMI in performing criticality safety analyses.
- Released MCNP version 5.1.40 to RSICC in December 2006. This release included several new features requested by the criticality community, such as source entropy, neutron fission multiplicity distributions, lethargy plots, and a stochastic geometry capability.
- Presented two-week long classes on the effective use of MCNP5 for criticality safety. In addition, several general MCNP training classes and workshops were presented. Such training classes continue to be well attended by criticality safety professionals.
- Incorporated the ERRORJ module into a version of NJOY. This is important in order for NJOY to be able to process the complete suite of covariance formats allowed by ENDF format. In addition, several NJOY updates were made to enable

processing of ENDF/B-VII beta evaluations. NJOY continues to be a critical nuclear data processing code for criticality applications.

- Consolidated the MCNP criticality test suite (validation and verification) and is part of the MCNP5 version 1.50 to be released shortly to RSICC. This attention to V&V to help support user installation of MCNP has been requested by criticality users.
- Added a new S(α, β) thermal scattering treatment to both MCNP5 and MCNP6. The new method uses a continuous treatment of secondary energy/angle so that nonphysical effects of discrete angles on thermal spectra are eliminated. Other features of interest that have been included in developmental versions of MCNP include the ability to create problem-specific cross-section libraries at the temperature of interest and Wielandt acceleration of k-effective calculations. The latter is a new method that appears to be very promising in improving source Convergence.
- Released by RSICC SCALE 5.1 software and documentation. Key enhancements that benefit criticality safety community include:
    - ENDF/B-VI based problem-independent multigroup cross-section libraries.
    - ENDF/B-VI based continuous energy cross-section library (for improved resonance processing in producing problem-dependent multigroup libraries).
    - Covarience libraries for use in uncertainty analysis (includes available ENDF/B-V and ENDF/B-VI data and optional augmentation with low-fidelity data based on integral measurements).
    - Extension of TSUNAMI sensitivity/uncertainty (S/U) software to enable use of ENDF/B-VI and ENDF/B-VII data.
    - Improved TSUNAMI to automatically correct for the absence of data in ENDF and low-fidelity covariance files.
    - Covariance data plotting added to Javapeno data visualization tool.
    - Improved robustness in KENO-VI geometry package.
    - HTML output provided for KENO-V and TSUNAMI.
    - New depletion sequences using KENO-V and KENO-VI.
    - Updated SMORES sequence for 1-D material optimization.
    - Expanded GeeWiz graphical user interface to allow input for SMORES and depletion sequences.
- Generated and tested for application with Continuous-Energy (CD-) KENO an ENDF/B-VI based point-wise continuous energy cross-section library.
- Successfully used an advanced version of the AMPX software system capable of processing ENDF/B-VI and –VII data to create SCALE 5.1 libraries.
- Released from RSICC the PUFF-IV package for processing ENDF/B covariance data files. This tool is needed to prepare covariance data libraries.
- Prepared TSUNAMI sensivity files for an extensive set of benchmarks including low- and high-enriched U-235 systems, plutonium solutions, bare plutonium metal systems, mixed uranium-plutonium oxide (MOX) systems, and U-233 systems. These files were used in S/U analyses to support key DOE applications of interest:
    - Design and evaluation of low-moderated MOX experiments financed by NA-26 and performed in Russia.

    - Investigate potential application to operations related to disposal of U-233 in ORNL's 3019 Building.
    - Obtain improved estimate of bias and uncertainty for bare plutonium metal spheres using generalized linear least squares methodologies to account for differential and integral uncertainties.
    - Assess bias and uncertainties of weapons-grade and reactor-grade plutonium solutions under broad range of moderator conditions.
- Developed a "straw-man" mathematical model for establishing safe-margins-of-subcriticality for criticality-safety computational-acceptance criteria. Abstract of work has been submitted for the ICNC 2007.
- Developed two alternative theoretical approaches that would enable computation of adjoint solutions (for sensitivity analysis) in continuous-energy Monte Carlo codes.
- Prepared an approach for performing maximum k-eff searches based on geometry optimization.
- Made 725 responses to SCALE users who requested technical assistance via e-mail and the SCALE website.
- RSICC continued to provide the criticality safety community with code and data packages essential to criticality safety analyses while adhering to DOE requirements for software distribution and export control.
- Developed a COG website and made it publicly available at: http://cog.llnl.gov.
- Developed at LLNL cog2vim translator code and provided to ANL.
- Developed a LLNL-led code intercomparison study that identified the need for improved S(α, β) treatments.
- Identified additional study deficiencies in the ENDF-6 File 7 format description and implementation in NCSP codes that have subsequently been corrected.
- Completed preliminary ENDF/B-VII data testing for U-233 using COG.

These accomplishments demonstrate that independent, state-of-the-art computational analysis tools and processed nuclear cross-section data are maintained and enhanced by a repository of experts who provide assistance to the user community. New code versions are being made available to the criticality safety community. R&D activities continue towards use advanced computational approaches (e.g., sensitivity and uncertainty analyses) to assure an improved understanding of (or improved estimate of) computational bias and uncertainties and to guide design and selection of critical experiments.

2.c Nuclear Data

- Released ENDF/B-VII to RSICC. The principal advances over the previous ENDF/B-VI library are the following:
    - New cross sections for U, Pu, Th, Np, and Am actinide isotopes, with improved performance in integral validation criticality and neutron transmission benchmark tests.
    - More precise standard cross sections for neutron reactions on H, ^{6}Li, ^{10}B, Au and for ^{235,238}U fission, developed by a collaboration with the IAEA and the OECD/NEA Working Party on Evaluation Cooperation (WPEC).
    - Improved thermal neutron scattering data.

    - An extensive set of neutron cross sections on fission products developed through a WPEC collaboration.
    - A large suite of photonuclear reactions.
    - Extension of many neutron- and proton-induced evaluations up to 150 MeV.
    - Many new light nucleus neutron and proton reactions.
    - Post-fission beta-delayed photon decay spectra.
    - New radioactive decay data.
    - New methods for uncertainties and covariances, together with covariance evaluations for some sample cases.
    - New actinide fission energy disposition.
- Extensive testing and validation work using the ENDF/B-VII data with radiation transport codes to model measured critical assemblies demonstrate:
    - The long-standing underprediction of low-enriched uranium thermal assemblies is removed.
    - The ^{238}U and ^{208}Pb reflector biases in fast systems are largely removed.
    - The good agreement of ENDF/B-VI. Release 8 good agreement for simulations of thermal high-enriched uranium assemblies is preserved;
    - The underprediction of fast criticality of ^{233,235}U and ^{239}Pu assemblies is removed.
    - The intermediate spectrum critical assemblies are predicted more accurately.
- Increasing requests of the criticality safety community to demonstrate scientific uncertainties in calculated quantities (such as k-eff) associated with nuclear data. The AROBCAD system is designed to assist in this work. AROBCAD analyses are critically dependent on quality covariance data, which are now available for U-235, U-238, and Pu-239 as a result of this work.
- Completed the F19 evaluation data measurement at LANSCE/WNR.
- Completed the preliminary Mn55, K39, and K41 resonance evaluations.
- Distributed revised SAMMY manual and code package through RSICC. SAMMY is a key nuclear modeling tool which uses resonance region nuclear data measurements to produce cross-section evaluations with covariance data. Release of the SAMMY code package will be crucial for providing new cross-section evaluations with covariance data in the resonance region.
- Developed, coded, and tested the improved Cauchy principle value method. It can now produce probability tables analytically (without noise) at any temperature.
- Conducted Phase I reviews for all available ENF/B-VII covariance files.
- Completed substantial development of a substantial code system EMPIRE-KALMAN. The code has been used to generate covariance data for Gd isotopes that were included in ENDF/B-VII. EMPIRE-KALMAN is being developed to support current and future covariance needs. For example, it will be relied upon heavily for the FY2007 work toward creation of a complete, low-fidelity covariance data set.

Overall, the nuclear measurements, nuclear modeling, and evaluation accomplishments enable the NCSP to respond to emerging nuclear data needs in the field. Moreover, these R&D efforts serve to maintain highly technical scientific capabilities (*capability maintenance*) and support criticality safety analysis efforts for improving operational efficiencies (*operational cost/efficiency risk*). Completion of the nuclear data evaluations provides improved cross-section and covariance data for nuclides identified as being of high-importance for nuclear criticality safety analyses.

2.d Differential Measurements

- Successfully operated ORELA for ~180 hours since April 2006.
- Fixed the intermittent vacuum problem in Section 4 of the accelerator.
- Replaced one thyratron and repaired several electrical problems.
- Completed the K41 capture measurement.

Restoration of the ORELA operation for performing nuclear data measurements is a significant accomplishment that will enable the NCSP to respond to current and emerging nuclear data needs for criticality safety applications.

2.e Integral Experiments

- Received approval for the SNR startup of DAF nuclear materials handling.
- Conducted CEF/DAF nuclear measurements successfully on nuclear material outside shipping containers (precursor to establishing subcritical measurements).
- Began groundwork and coordination to permit CEF experimenters to participate in criticals in France, Russia, and Sandia.
- Issued the CEF/TA-18 Staffing Transition Plan by LANL.

2.f Information Preservation and Dissemination

- Completed a beta version of software (CritView) to facilitate searching and displaying the ARH600 data.
- Entered all 2006 ANS papers into a searchable database bringing the total to over 500 in the Hanford NCSP database.
- Installed a new Dell server and upgraded the operating system to Red Hat Linux for the LLNL NCSP website.
- Upgraded the LLNL NCSP database with an additional 3,640 entries.
- Upgraded the search engine (searching by value index, document date, OSTI document number, and category) for both LLNL Bibliographic and Hanford NCTSP databases.
- Began editing of ORNL Heritage videotapes.

2.g Training and Qualification

- Reestablished the hands-on criticality safety engineer training and qualification course at LLNL.
- Held six courses in CY2006 and over 50 students have gone through the courses.
- Met requirements of DOE-STD-1135 for the hands-on criticality safety course.
- Developed a web-based online registration form which is available at: http://ncsp.llnl.gov/HS3201/registration.html.

- Developed potential options for development of a criticality safety training simulator.
- Completed the second of two-hand calculation NCSET modules and submitted for final review and posting on the LLNL NCSP website.