



Annual Report for FY2006

Work Plan for FY2008

Prepared by:

Pavel Oblozinsky

National Nuclear Data Center

Brookhaven National Laboratory

February 2006

With contributions from:

Coral Baglin, LBNL

Allan D. Carlson, NIST

Toshihiko Kawano, LANL

John Kelley, TUNL

Filip G. Kondev, ANL

Dennis McNabb, LLNL

Balraj Singh, McMaster U.

Michael Smith, ORNL

www.nndc.bnl.gov/usndp

Table of Contents

| | <u>Page</u> |
|---|-------------|
| USNDP Annual Report for FY2006 | |
| Summary of the U.S. Nuclear Data Program Activity for 2006 (Report FY06) | |
| I. Introduction..... | 1 |
| II. Network Coordination and Data Dissemination..... | 4 |
| III. Nuclear Structure and Decay Data..... | 6 |
| IV. Nuclear Reaction Data..... | 8 |
| V. Accomplishments..... | 10 |
| | |
| USNDP Staffing Table FY2006..... | 13 |
| | |
| Detailed Status of the Work Plan (Report FY06) | |
| I. NNDC Facility Operation..... | 15 |
| II. Coordination..... | 16 |
| III. Nuclear Physics Databases..... | 21 |
| IV. Information Dissemination..... | 25 |
| V. Nuclear Structure Physics..... | 29 |
| VI. Nuclear Reaction Physics..... | 37 |
| | |
| Appendix A: Nuclear Data Activities funded from Sources outside USNDP..... | 51 |
| Appendix B: USNDP Organization..... | 54 |
| | |
| USNDP Work Plan for FY2008 | |
| | |
| Introduction (Work Plan FY08)..... | 57 |
| Work Plan Tasks and Planned Activities (Work Plan FY08)..... | 61 |
| I. NNDC Facility Operation..... | 61 |
| II. Coordination..... | 62 |
| III. Nuclear Physics Databases..... | 65 |
| IV. Information Dissemination..... | 68 |
| V. Nuclear Structure Physics..... | 71 |
| VI. Nuclear Reaction Physics..... | 76 |
| | |
| USNDP Staffing Table FY2008..... | 85 |
| | |
| Appendix C: Acronyms in the US Nuclear Data Program..... | 87 |

USNDP Annual Report for FY2006

Summary of the U.S. Nuclear Data Program Activity for 2006

I. Introduction (Report FY06)

The USNDP Annual Report for FY2006 summarizes the work of the U.S. Nuclear Data Program (USNDP) for the period of October 1, 2005 through September 30, 2006 with respect to the work plan for FY2006 that was prepared in February 2005. The work plan and final report are prepared at the direction of the DOE Office of Science, Office of Nuclear Physics for the nuclear data program. The support for the nuclear data activity from sources outside the nuclear data program is described in the staffing table and in Appendix A. This leverage amounts to about 25.7 FTE scientific, mostly at NNSA laboratories, to be compared with 18.15 FTE scientific (permanent + temporary) at USNDP laboratories funded by the DOE Office of Science, Office of Nuclear Physics nuclear data program. When tasks are jointly funded, then it is very difficult to differentiate accomplishments funded by nuclear data program resources from those that were otherwise funded. As a consequence, some of the work reported in the present report was accomplished with nuclear data program support, leveraged by other funding sources.

The present section of the report consists of activity summaries for the major components of the U.S. Nuclear Data Program. This is followed by an updated staff level assignment table that reflects the final distribution of effort among the tasks carried out during FY2006. The next section of this report contains the work plan for FY2006. The plan has been annotated with bullets giving the status of each commitment made by the program participants.

Total staff assigned to USNDP activities during the year was 23.65 FTE, lower by 0.48 FTE compared to FY2005. This decrease reflects the loss of 1.0 FTE scientific permanent at the NNDC (C. Dunford) that was partly offset by a new 0.7 scientific temporary staff for ENSDF, and the losses at other laboratories in nuclear reaction and astrophysics activities.

Fiscal year 2006 is the 8th year during which the Nuclear Data Program has operated under a work plan developed by the program participants. As the following sections illustrate, the nuclear data program is successfully carrying out important work in direct support of DOE missions. The work balances the ongoing collecting, analyzing, and archiving of nuclear physics information critical to basic nuclear research and to the development and improvement of nuclear technologies with the electronic distribution of this information to users in a timely and convenient manner.

The program metrics requested by DOE are included below. Table 1 summarizes the USNDP metrics for the years that such metrics were reported. Table 2 shows the breakdown of the metrics for this fiscal year by laboratory and compares them with the previous fiscal year. The tables are followed by a description of the meaning of each metrics.

Table 1. Summary of the USNDP metrics in FY01- FY06, for definitions see next page.

| Fiscal Year | USNDP Funding | Change | Compilations | Evaluations | Dissemination (in thousands) | Reports | Papers | Invited Talks |
|--------------------|----------------------|---------------|---------------------|--------------------|-------------------------------------|----------------|---------------|----------------------|
| 2001 | | | 7,139 | 334 | 667 | 21 | 25 | 22 |
| 2002 | \$4,890k | | 6,159 | 300 | 799 | 23 | 40 | 22 |
| 2003 | \$4,932k | +0.9% | 4,975 | 260 | 966 | 27 | 40 | 23 |
| 2004 | \$5,015k | +1.7% | 6,241 | 276 | 1,212 | 35 | 36 | 43 |
| 2005 | \$5,437k | +8.4% | 6,623 | 422 | 1,642 | 74 | 59 | 42 |
| 2006 | \$5,099k | -6.6% | 4,936 | 318 | 1,863 | 47 | 60 | 48 |

Table 1 shows that the FY06 budget decreased by a considerable –6.6% compared to previous fiscal year, quite a jump down compared to a solid raise of +8.4% one year earlier. The USNDP metrics decreased in two important categories, compilations and evaluations, while the dissemination continued to grow. The metrics can be understood as follows:

1. **Compilations.** A considerable decrease is observed, due to three reasons. First, there was some drop in published papers. Second, three major European journals in the bibliography database NSR were compiled by the IAEA Vienna. Third, CSISRS compilation went back to normal after unusually high activity in 2005 when a lot of older papers were compiled.
2. **Evaluations.** These include 208 nuclides evaluated for ENSDF, 104 reactions evaluated for ENDF and 6 other reactions evaluated for astrophysics. For more details see Table 2. The level reached in 2005 was exceptionally high for ENSDF due to the large number of super-heavy nuclides (63 nuclides, A = 266-294). Also reaction part is down compared to 2005, when large number of evaluations was contributed by LLNL. These two contributions alone made almost 100 evaluations in 2005.
3. **Dissemination.** There is an overall increase by 13%, indicating some slowing-down compared to previous years. Data retrievals from the USNDP databases offered by the NNDC continued to increase sharply, largely thanks to ENSDF data retrieved via the popular NuDat interface.
4. **Reports.** Decrease in reports should be explained by exceptionally high level reached in 2005 due to the Proceedings of the major nuclear data conference, Santa Fe'2004.
5. **Papers.** The number of papers published in refereed journals remained about the same as in FY 2005.
6. **Invited Talks.** These are somewhat up compared to FY 2005.

Table 2. USNDP metrics in FY2006, numbers for FY2005 are shown for comparison.

| Lab | Compilations | | Evaluations | | Dissemination ³ | | Reports | | Papers | | Invited Talks | |
|-------------------------|--------------|------|-------------|------|----------------------------|------|---------|------|--------|------|---------------|------|
| | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 |
| BNL ¹ | 6306 | 4528 | 175 | 150 | 778 | 1089 | 37 | 10 | 9 | 14 | 9 | 12 |
| LANL | - | - | 40 | 35 | 312 | 188 | 6 | 1 | 15 | 12 | 10 | 7 |
| LBNL | - | - | 68 | 43 | 376 | 376 | 1 | 4 | 8 | 5 | 8 | 6 |
| ORNL | - | - | 8 | 11 | 113 | 134 | 10 | 16 | 4 | 4 | 4 | 10 |
| ANL | - | - | 11 | 12 | 10 | 11 | 8 | 6 | 11 | 11 | 6 | 7 |
| LLNL | - | - | 37 | 3 | 6 | 13 | 4 | 6 | 5 | 6 | 5 | 6 |
| University ² | 317 | 408 | 83 | 64 | 47 | 52 | 8 | 4 | 7 | 8 | - | - |
| Total | 6623 | 4936 | 422 | 318 | 1642 | 1863 | 74 | 47 | 59 | 60 | 42 | 48 |

1) BNL evaluations in 2006 consist of 84 nuclides for ENSDF and 66 reactions for ENDF.

2) TUNL, NIST, McMaster. One half of McMaster funding comes from Canada. Evaluations in 2006 include 58 nuclides for ENSDF and 6 reactions for astrophysics.

3) Data retrievals in thousands. LBNL scaled in accord with retrievals/hits ratio observed at BNL.

Definitions

- *Compilations*: The sum of the new entries added to the USNDP bibliographic (NSR - papers) and experimental databases (CSISRS - reactions, XUNDL – structure data sets).
- *Evaluations*: The sum of new evaluations submitted or accepted for inclusion in the USNDP evaluated nuclear databases. Structure – number of evaluated nuclei (ENSDF), reactions – number of evaluated reactions (ENDF).
- *Dissemination*: The number of electronic data retrievals made from USNDP maintained web sites. Data retrieval is defined as a request for data from any of the databases that receives a result. Total pages, gifs, etc., accessed is not tallied.
- *Reports*: The number of technical documents (includes conference proceedings) or papers other than journal publications and invited talks. No administrative documents such as meeting minutes are reported.
- *Papers*: The number of articles published in refereed journals.
- *Invited talks*: The number of presentations given at the invitation of the organizers of a conference, symposium, workshop, training course, etc.

II. Network Coordination and Data Dissemination (Report FY06)

The National Nuclear Data Center (NNDC) continues to serve as the core facility of the U.S. Nuclear Data Program (USNDP). It has the main responsibility for national and international coordination, database maintenance, and data dissemination. However many of the other program participants are also involved in the coordination and dissemination activities.

National and International Coordination

The NNDC, while serving as the secretariat for the program, has prepared the program work plan for FY2007 in conjunction with the members of the Coordinating Committee. The NNDC Head serves as chair of the USNDP Coordinating Committee, which consists of the Principal Investigators from each of the participating groups, and he chairs the annual meeting of the program held at Brookhaven National Laboratory. LANL chairs the Nuclear Reaction Data Working Group, and LBNL the Nuclear Structure Working Group. ORNL chairs the Astrophysics Task Force, LANL the Nuclear Data for/from RIA Task Force, and LLNL chairs the Homeland Security Task Force.

In February 2006, the DOE Office of Nuclear Physics conducted its annual Budget Briefing. Pavel Oblozinsky, Coral Baglin and Toshihiko Kawano represented the USNDP and made the case for the FY2008 funding.

The NNDC serves as the focal point for U.S. collaboration in international nuclear data activities. Two USNDP evaluators from NNDC, two from LBNL and one from ANL served as lecturers at an IAEA-sponsored "Workshop on Nuclear Structure and Decay Data: Theory and Evaluation" in Trieste in February 2006.

NNDC continues to chair the Cross Section Evaluation Working Group, which produces the ENDF/B evaluated nuclear data library for nuclear science and applied nuclear technology use. The NNDC hosted the CSEWG annual meeting in November 2005. The major topic of the meeting was the release of the ENDF/B-VII.0 library scheduled for December 2006.

Several USNDP participants attended the April 2006 meeting of the NEA-sponsored Working Party on International Evaluation Cooperation (WPEC) in Paris, France. The US has the lead responsibility for several projects sponsored by this activity.

USNDP Databases

The NNDC operates five Dell servers running Linux operating systems to support its compilation, evaluation, database maintenance, and information dissemination functions. These computers archive and serve the nuclear data produced by the U.S. Nuclear Data Program and the data obtained by other national and international collaborations. This facility operates 24 hours a day, 7 days a week, to provide electronic access to the data.

The NNDC maintains seven nuclear physics databases for the USNDP. These databases have been updated continuously in FY2006 with new and revised information from efforts of the NNDC, the USNDP and international collaborators. Distributions of all or parts of these databases have been made to national and international collaborators as scheduled.

Data Dissemination

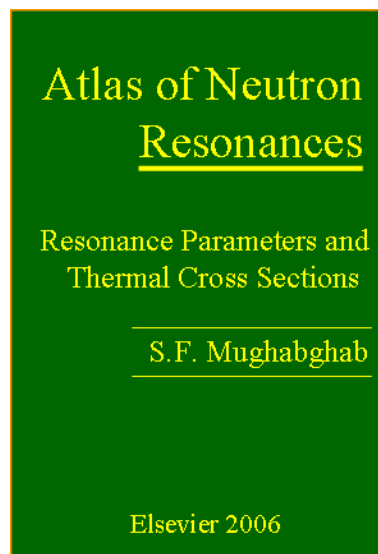
In FY2006, retrievals from the USNDP databases as offered by the NNDC web service, www.nndc.bnl.gov, increased by 41% in comparison to the previous year. In FY2006 it reached more than 1 million retrievals. This continuing sharp increase exceeds usual expectations. It is driven by exceptional success of the NuDat interface that serves the nuclear structure and decay data, and also by the new Chart of Nuclides introduced in 2006.

The **Computational Infrastructure for Nuclear Astrophysics**, online at ORNL's nuclear astrophysics data web site at nucastrodata.org, has been significantly expanded and improved in FY06. New features include updated reaction rate libraries, improved computational methods of generating reaction rates from cross sections, quick listing of all distinct versions of the rate of a particular reaction, improved element synthesis calculations with multiple spatial zones, improved rendering and export of simulation output, and quicker comparisons of simulation with different nuclear physics input.

The **Nuclear and Atomic Data System (NADS)** at LLNL allows for interactive viewing, modifying, plotting and saving reaction data, nuclear.llnl.gov/CNP/nads/NADSApplet.html. In FY06, the NADS system was updated to include the ENDF/B-VII.0, JEFF-3.1, JENDL-3.3, CENDL-2.1, BROND-2.2, IAEA Photonuclear and CENDL-3 Fission Product libraries. The dissemination statistics reporting was also dramatically improved.

Publications

Atlas of Neutron Resonances, a seminal book of 1,372 pages by the NNDC guest scientist Said Mughabghab was published by Elsevier in April 2006. It contains evaluated neutron data for $Z = 1 - 100$ nuclei (473 isotopes, 353 with resolved neutron resonances) and represents one of the most comprehensive low-energy neutron data resources. This wealth of available information is of considerable importance for applied technologies. In addition, the book contains uncertainties on thermal values and resonance parameters, representing an invaluable resource for the future work on cross-section covariance data.



III. Nuclear Structure and Decay Data (Report FY06)

The Working Group's principal focus during the year has once again been on the evaluation of nuclear structure and decay data, whether for entire mass chains or for individual nuclides, and the entry of these results into the Evaluated Nuclear Structure Data File (ENSDF). These included a number of priority nuclides, and most evaluations will also appear as publications in *Nuclear Data Sheets* or *Nuclear Physics A*. In addition, the currency of evaluated super-deformed band data in ENSDF has been maintained, NuDat and Nuclear Wallet Cards files have been updated, and the Nuclear Science Reference and XUNDL databases have been extended. Frequently accessed websites maintained at several data centers continue to disseminate these data in various user-friendly forms.

Evaluations for ENSDF

A total of 296 nuclide evaluations (71 of them for priority nuclides) were submitted during FY2006 for inclusion in the ENSDF database. Evaluators in the US and in Canada (which draws 50% of its support from the US Data Program) provided 208 of these. Several of the evaluations were performed in collaboration with new non-US evaluators, recruited as part of recent international structure-evaluator training efforts and mentored by experienced USNDP evaluators. The USNDP evaluators have also reviewed 17 mass chain evaluations, and additional prepublication checks have been done at NNDC for all published evaluations. Super-deformed band data for 6 nuclides have been updated in ENSDF. The eleven issues of the journal *Nuclear Data Sheets* (published by Elsevier) that were devoted to nuclear structure and decay data contained 20 individual mass chain evaluations plus a single paper covering all 63 nuclides from $A=266-294$; these publications also included work by evaluators from Argentina, Brazil, China, France, India who receive funding from outside of the US DOE Data Program.

Compilations for XUNDL

The XUNDL file contains experimental unevaluated data sets compiled primarily from recent papers. The McMaster group submitted 380 new and 28 updated data sets during FY06, and these were incorporated into XUNDL by BNL. Once again, private communications obtained from authors concerning some of the data entered into XUNDL during the year have been collected and forwarded to NNDC so that ENSDF evaluators also can also benefit from the information they contain.

USNDP Contribution to Decay Data Evaluation Project DDEP

The international DDEP collaboration includes USNDP evaluators as well as non-ENSDF evaluators from France, Germany, Russia, Spain, and the United Kingdom. It prepares evaluations for radionuclide decays of importance in applied research and LBNL continues to coordinate this project and provide general editorial oversight without cost to the US data program. During FY2006, one radionuclide evaluation was completed, two evaluations were reviewed, and lectures were presented at a training workshop for DDEP evaluators by other USNDP participants in this program.

USNDP Evaluator Participation in IAEA CRPs

Two USNDP nuclear structure evaluators are participating in IAEA Coordinated Research Projects (CRP) presently underway. One is titled “Updated Decay Data Library for Actinides”, a timely topic in the era of GNEP, and it involves both data evaluations and measurements which will ultimately benefit the ENSDF database. The other is titled “Reference Database for Neutron Activation Analysis”; its purpose is to provide evaluated k_0 /cross section data for use by the neutron activation community and those data will ultimately benefit the existing database (EGAF) which contains evaluated discrete-line photon data from thermal neutron capture.

Nuclear Science References

The nuclear science references included in the NSR file have been expanded by 3,993 papers during FY2006, and keyword abstracts were provided for 3,093 of these. This vital bibliographic database now contains approximately 187,000 citations. The work is performed primarily by the NNDC staff members, who regularly scan the majority of the journals that are monitored, along with laboratory reports and conference proceedings. However, several foreign collaborators also contribute to this work and the IAEA provided ~15% of the keywords in FY2006. Since the “Recent References” issue of the *Nuclear Data Sheets* has been discontinued, that material is now being made available on the web in similar format.

Internal Conversion Coefficient Calculations

The software package completed by a US-Australian-Russian collaboration last year is now in routine use by ENSDF evaluators and an interactive web page enables the scientific community at large to access internal conversion coefficient values interpolated from relativistic Dirac-Fock calculations that take the electron hole into account *via* the frozen-orbitals approximation.

Evaluator Recruitment and Training

In further response to the problem of a diminishing and graying nuclear structure data evaluation workforce worldwide, the IAEA held another two-week long evaluator training workshop at the ICTP in Trieste in February 2006. Four experienced USNDP evaluators lectured on ENSDF-related topics and oversaw lab sessions at this workshop, and another lectured on experimental techniques. 21 participants from 15 countries attended the workshop and, of these, one has already coauthored a mass chain evaluation. Evaluators at BNL, ANL and McMaster have also served as mentors for several non-US evaluators who recently began evaluation work.

ENSDF Contribution to ENDF/B-VII.0 Decay Data Library

In FY2006, the new decay data sublibrary was produced for the ENDF/B-VII.0 library. It contains 3,838 materials and is mostly derived from the ENSDF database and the 2005 edition of the Nuclear Wallet Cards. This work represents the major extension and update of the ENDF/B decay sublibrary after more than 30 years.

IV. Nuclear Reaction Data (Report FY06)

The nuclear reaction data effort focuses on evaluation of nuclear reaction data and the related measurement and compilation activities. The USNDP also makes important contributions to nuclear reaction model code development and improvement of reaction cross-section standards.

Reaction Data Highlights

The NNDC has compiled 171 papers (52 neutron, 112 charged-particle and 7 photonuclear papers with 535 reactions) for the experimental nuclear reaction database, CSISRS. Work at NNDC continued on creation of the international fission product library of neutron cross sections by assembling the final library with 219 materials. The Cross Section Evaluation Working Group (CSEWG), which is partly supported by this program, has made decisive progress towards the release of the next version of the US evaluated nuclear data library, ENDF/B-VII.0.

Evaluations of 104 neutron-induced reactions were produced for the new ENDF/B-VII.0 library. LANL completed evaluations of neutron reactions with minor actinides, including ^{234}U and ^{237}Np that are required by many nuclear applications, especially for the transmutation technology. In addition, numerous delicate updates for actinides were made by LANL, new evaluations mostly for fission products were completed by BNL and partly also by LLNL, and new covariance data for 12 materials were produced by BNL in collaboration with LANL.

The activity to supply nuclear data for Homeland Security continues in the framework of the Task Force that holds a special session during each annual USNDP meeting. LANL produced a new set of delayed neutron spectra based on the microscopic/macrosopic nuclear structure theory and the Hauser-Feshbach statistical model calculations. LLNL provided β -delayed photons from ^{235}U and ^{239}Pu fission. Both sets are important for detecting fissile materials.

The unique measurement (LANSCE) and analysis (T-16) capability at LANL were combined to produce new nuclear reaction data on ^{150}Sm and ^{237}Np . The GEANIE facility was used to measure $^{150}\text{Sm}(n, \gamma)$. These data were interpreted by using a modern quantum-mechanical model for pre-equilibrium processes. Fission and capture for ^{237}Np was measured at LANSCE. The fission cross sections were used to validate resonance parameters, and the resonance parameters of ^{237}Np were updated. The capture data were analyzed with the Hauser-Feshbach statistical model combined with the direct reaction theory.

Model Code Highlights

Several new features were added to the nuclear reaction calculation code EMPIRE. The prompt fission neutron spectra are calculated using the Los Alamos model. The DWBA calculations of direct reactions are now possible also for odd nuclei. A dispersive optical potential can be used with the ECIS code in the EMPIRE code system. The MSD model was extended to deformed nuclei. It was shown that missing strength in the continuum inelastic scattering cross section on ^{232}Th is filled-up with this modeling.

The TUNL program on pre-equilibrium phenomenology made several improvements in the exciton model code PRECO. The code manual was completed despite of the budget limitations. Effect of coupling between the single-particle state density and the averaged matrix element was investigated. The underestimation of the particle emission in the high-energy region could be explained by a collective mechanism.

At LANL, several new modules were developed for the reaction code McGNASH, including the optical model and the direct/semi-direct (DSD) capture using the Skyrme-Hartree-Fock-BCS mode. The calculated neutron-capture cross-sections for ^{208}Pb and ^{238}U show a good agreement with the experimental data. The new fission module and the width fluctuation modules are underway. The CVS repository for the McGNASH code was set up and made available to internal test users.

Nuclear Standards Highlights

NIST has led an international nuclear reaction standards evaluation project that was carried out under the auspices of an IAEA Coordinated Research Project, the NEA Working Party on International Evaluation Cooperation and the CSEWG. Most of the evaluations were produced through R-matrix calculations combined with experimental data and using the GMA code to provide the final results. Within this effort, LANL provided a set of R-matrix evaluations for the $^6\text{Li}(n,t)$, $^{10}\text{B}(n,\alpha)$ and $^{10}\text{B}(n,\alpha_1\gamma)$ standards. Independently of this project, LANL did an R-matrix evaluation of the H(n,n) standard. As a result of these efforts, the standards have been provided to the ENDF/B-VII.0 library. For the first time, the ENDF/B-VII.0 standards sublibrary was created that contains the cross sections and also the covariances for most of the standards.

Additional R-matrix work is planned at LANL on the $^3\text{He}(n,p)$ and H(n,n) standards. New measurements for several standards, including H(n,n), $^6\text{Li}(n,t)$, $^{10}\text{B}(n,\alpha)$, $^{10}\text{B}(n,\alpha_1\gamma)$ and $^{238}\text{U}(n,f)$ are being made that will be useful for future standards evaluations. An IAEA data development project on maintenance of the standards should allow continuous improvements to the standards.

Nuclear Astrophysics Highlights

Work continued on the evaluation of several nuclear reactions important for astrophysics modeling at ORNL [$^{18}\text{F}(p,\alpha)$, $^{17}\text{O}(p,\alpha)$, $^{17}\text{O}(p,\gamma)$, $^{18}\text{F}(p,\gamma)$, $^{25}\text{Al}(p,\gamma)$, $^7\text{Be}(p,\gamma)$, $^{33,34}\text{Cl}(p,\gamma)$, and $^{30}\text{P}(p,\gamma)$], at LANL [$^{12}\text{C}(\alpha,\gamma)$], and at McMaster [$^{25}\text{Al}(p,\gamma)$, $^{13}\text{N}(p,\gamma)$].

Fission barrier calculation was improved at LANL, including an axial asymmetry. The potential energy of deformed nuclei is calculated with the microscopic/macrosopic model, and the single-particle energies are calculated. The results were published in Phys. Rev. Let. in 2006. The fission barrier data will be used for fission cross-section calculations for many actinides.

LANL produced new calculations of neutron radiative capture cross sections on tin isotopes, based on the direct/semi-direct theory, and showed the importance of the DSD process for the double-magic nuclei. It was also pointed out that nuclear structure information is crucial for cross section calculations on nuclei off stability.

V. Accomplishments (Report FY06)

This new chapter was prepared for the first time, in response to a new requirement by DOE-SC, Office of Nuclear Physics. Following this request, in this chapter we summarize our most significant accomplishments in FY2006/FY2007 (anticipated). Each accomplishment is described on one page, with one-half of text and another one-half of graphics.

In the present document we report two accomplishments.

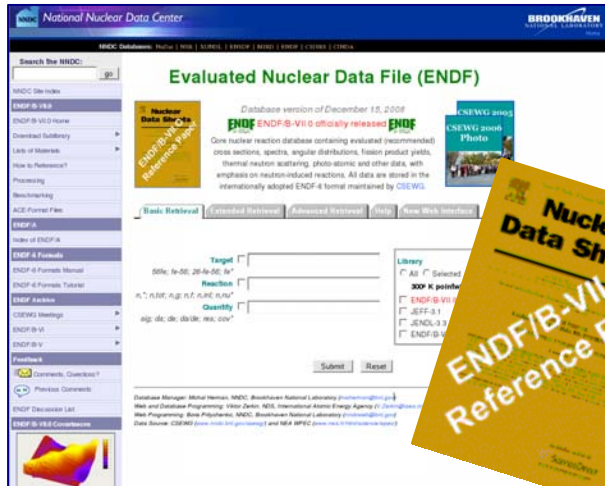
The first accomplishment is the release of the new evaluated nuclear data library ENDF/B-VII.0 for nuclear science and technology. This is the common result of considerable importance achieved together by the Cross Section Evaluation Working Group (CSEWG) and USNDP. Although the CSEWG contribution to the final product was dominant, USNDP made significant contributions that are highlighted in the following page.

The second accomplishment reported here is 1 million retrievals from the USNDP databases served by the NNDC. This achievement reflects the collective work of USNDP in maintaining and improving the databases and the work of the NNDC in maintaining and improving the web service.

Two other potential accomplishments were suggested. One suggestion aimed to address a positive trend in the ENSDF evaluation manpower on both the national and international level (revival of the ENSDF evaluation manpower). The other suggestion focused on the USNDP leadership in international nuclear data collaborations. These suggestions would need more thought and more detailed justification, and therefore they are not included in the present document.

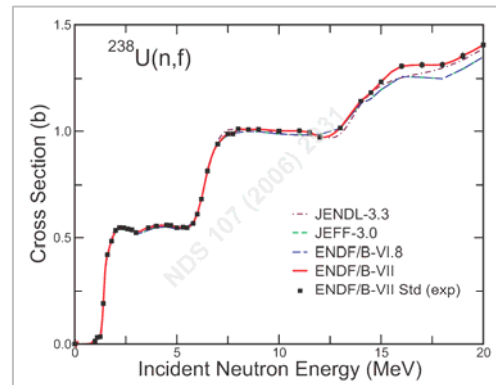
Release of the ENDF/B-VII.0 library (The first major release since 1990)

In December 2006, the NNDC released the next generation evaluated nuclear data library for nuclear science and technology, ENDF/B-VII.0 - the major US library dedicated to nuclear reactions. This remarkable event coincides with the renewed interest in the nuclear energy option (AFC, GNEP, Gen-IV). The ENDF/B-VII.0 has been developed by CSEWG with a significant contribution from the **USNDP** laboratories (LANL, BNL, NIST, LLNL).

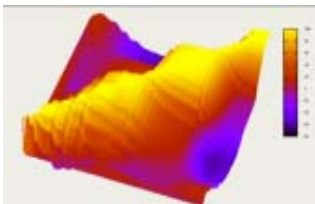


The principal advances over the previous ENDF/B-VI library:

1. New cross sections for U, Pu, Th, Np and Am, with improved performance in benchmark tests (**USNDP**)

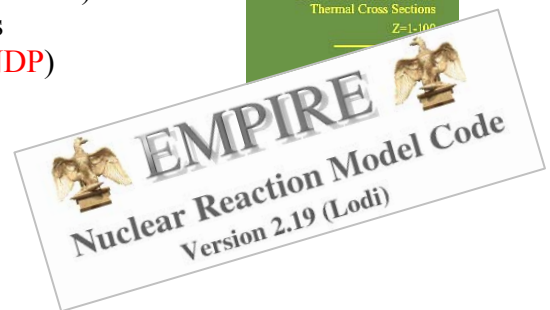
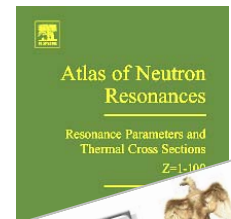


2. More precise standard cross sections for neutron reactions on H, ^6Li , ^{10}B , Au and for $^{235,238}\text{U}$ fission (**USNDP**)
3. Improved thermal neutron scattering
4. Large suite of photonuclear reactions
5. Extensive set of neutron cross sections on fission products (**USNDP**, 70 BNL evaluations with EMPIRE-Atlas method)
6. Many new light nucleus neutron and proton reactions
7. Post-fission beta-delayed photon decay spectra (**USNDP**)
8. New radioactive decay data (**USNDP**)



9. New methods for uncertainties and covariances (**USNDP**)

10. New actinide fission energy deposition.

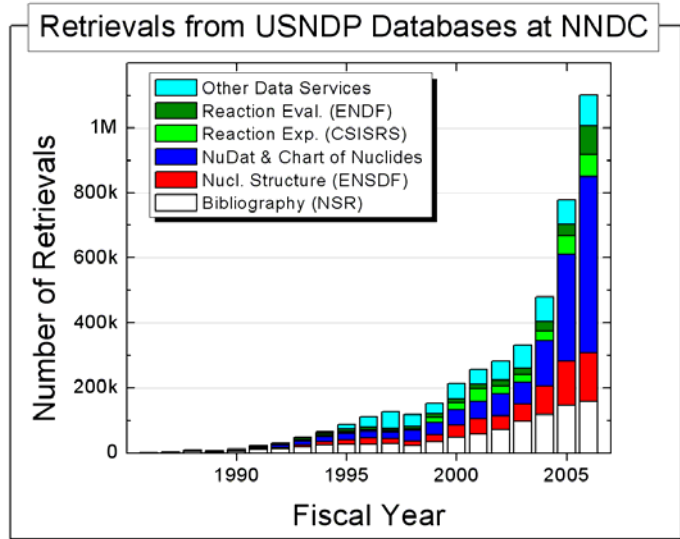


Validation carried out in US and Europe (hundreds of integral experiments) proved absolute superiority of the ENDF/B-VII.0 over earlier libraries.

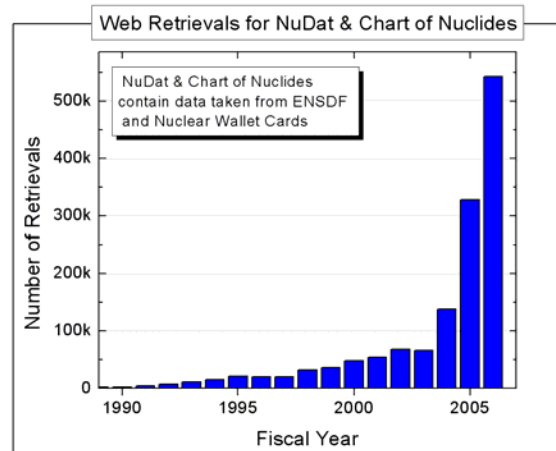
Extensive paper, already known as the “big paper”, on ENDF/B-VII.0 appeared in the special issue of Nuclear Data Sheets in December 2006.

1 Million retrievals from the USNDP databases served by the NNDC

In FY2006, the NNDC web service reached an important **milestone**: 1 million data retrievals from the **US Nuclear Data Program** databases. This accomplishment is the result of several factors: Continuing effort of the USNDP in updating and maintaining the databases; extensive NNDC database migration project that culminated by introducing the new web service in April 2004; unprecedented success of the new NuDat interface that offers nuclear structure and decay data; continuing improvement of the NNDC service.



NuDat is a derived database largely based on the Evaluated Nuclear Structure Data File, ENSDF, and to less extent on the Nuclear Wallet Cards. The related **NuDat2** web interface offers data in easily understandable and convenient ways, with appeal to both the scientific and applied communities. For less sophisticated users, the Chart of Nuclides was posted on the web in 2006. Thanks to this, the growth kept momentum and the combined product delivered 540,000 retrievals in 2006, more than the entire NNDC web service in 2004.



Geographical distribution of the NNDC data retrievals shows that the users are primarily from the US/Canada and Europe. The US demand is coming mostly from the US Government organizations (national laboratories - LANL, ORNL, LLNL, LBNL, ANL) and the Universities (Yale, Texas A&M, Duke, Michigan and Florida State Universities), with a notable demand from the industry, military and others.

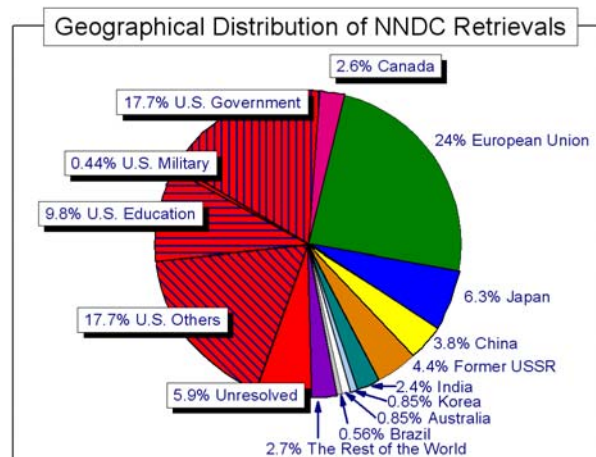


Table 3. USNDP Staffing Table for FY2006

Note: BNL and ORNL include subcontracted part-time ENSDF evaluators (scientific temporary staff).

| | ANL | BNL | | | LANL | LBNL | LLNL | Mc Master | NIST | ORNL | TUNL | Program Total | | | | |
|--|-------------|-------------|-------------|-----------------|-------------|-------------|-------------|--------------|-------------|-------------|-------------|---------------|-------------|-----------------|--------------|-------------|
| | | Sci Perm | Sci Temp | Tech & Admin | | | | | | | | Sci Perm | Sci Temp | Tech & Admin | Grad Stud | Total |
| I. NNDC Facility Operation | 0.00 | 0.35 | 0.00 | 1.65 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.35 | 0.00 | 1.65 | 0.00 | 2.00 |
| Management | | 0.35 | | | | | | | | | | 0.35 | | | | 0.35 |
| Secretarial/Administrative Support | | | | 0.55 | | | | | | | | | | 0.55 | | 0.55 |
| Library | | | | 0.25 | | | | | | | | | | 0.25 | | 0.25 |
| Computer Operation | | | | 0.85 | | | | | | | | | | 0.85 | | 0.85 |
| | | | | | | | | | | | | | | | | |
| II. Coordination | 0.10 | 0.65 | 0.00 | 0.00 | 0.40 | 0.30 | 0.05 | 0.00 | 0.00 | 0.05 | 0.00 | 1.55 | 0.00 | 0.00 | 0.00 | 1.55 |
| National Coordination | | 0.35 | | | 0.10 | 0.30 | 0.05 | | | 0.05 | | 0.85 | | | | 0.85 |
| International Coordination | 0.10 | 0.30 | | | 0.30 | | | | | | | 0.70 | | | | 0.70 |
| | | | | | | | | | | | | | | | | |
| III. Nuclear Physics Databases | 0.00 | 1.05 | 0.00 | 1.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.05 | 0.00 | 1.50 | 0.00 | 2.55 |
| Nuclear Science References (NSR) | | 0.10 | | 0.70 | | | | | | | | 0.10 | | 0.70 | | 0.80 |
| Exper. Nucl. Structure Data (XUNDL) | | 0.05 | | | | | | | | | | 0.05 | | | | 0.05 |
| Evaluated Nucl. Structure Data (ENSDF) | | 0.20 | | 0.65 | | | | | | | | 0.20 | | 0.65 | | 0.85 |
| Numerical Nuclear Data (NuDat) | | 0.10 | | | | | | | | | | 0.10 | | | | 0.10 |
| Reaction Data Bibliography (CINDA) | | 0.05 | | | | | | | | | | 0.05 | | | | 0.05 |
| Experimental Reaction Data (CSISRS) | | 0.05 | | | | | | | | | | 0.05 | | | | 0.05 |
| Evaluated Nuclear Data File (ENDF) | | 0.40 | | | | | | | | | | 0.40 | | | | 0.40 |
| Database Software Maintenance | | | | 0.15 | | | | | | | | | | 0.15 | | 0.15 |
| Future Database Systems (Migration) | | 0.10 | | | | | | | | | | 0.10 | | | | 0.10 |
| | | | | | | | | | | | | | | | | |
| IV. Information Dissemination | 0.00 | 0.90 | 0.00 | 0.25 | 0.10 | 0.15 | 0.00 | 0.00 | 0.00 | 1.50 | 0.60 | 1.25 | 0.00 | 1.85 | | 3.10 |
| Nuclear Data Sheets | | 0.10 | | 0.15 | | | | | | | | 0.10 | | 0.15 | | 0.25 |
| Customer Services | | 0.05 | | 0.10 | | | | | | | | 0.05 | | 0.10 | | 0.15 |
| Web Site Maintenance & Development | | 0.75 | | | 0.10 | 0.15 | | | | 1.50 | 0.60 | 1.10 | | 1.60 | | 2.70 |

| | ANL | BNL | | | LANL | LBNL | LLNL | Mc Master | NIST | ORNL | TUNL | Program Total | | | | |
|---|-------------|-------------|-------------|-----------------|--------------|-------------|-------------|--------------|-------------|-------------|-------------|------------------|-------------|-----------------|--------------|--------------|
| | | Sci Perm | Sci Temp | Tech & Admin | | | | | | | | Sci Perm | Sci Temp | Tech & Admin | Grad Stud | Total |
| V. Nuclear Structure Physics | 0.62 | 2.70 | 1.30 | 0.00 | 0.10 | 2.30 | 0.20 | 0.50 | 0.00 | 0.40 | 0.90 | 5.57 | 3.85 | 0.00 | 0.00 | 9.42 |
| NSR Abstract Preparation | | 0.60 | | | | | | | | | | 0.60 | | | | 0.60 |
| Compilation of Exper. Structure Data | | | | | | | | 0.15 | | | | 0.15 | | | | 0.15 |
| Evaluations for ENSDF | 0.47 | 1.75 | 1.30 | | | 2.00 | | 0.33 | | 0.40 | 0.45 | 3.25 | 3.85 | | | 6.10 |
| Ground and Metastable State Properties | | 0.15 | | | | | | | | | | 0.15 | | | | 0.15 |
| Radioactive Decay Data Evaluation | 0.15 | 0.05 | | | | | | 0.02 | | | | 0.22 | | | | 0.22 |
| Thermal Capture Gamma Data Eval. | | | | | | 0.30 | 0.20 | | | | | 0.50 | | | | 0.50 |
| Light Mass Eval. for Nuclear Physics A. | | | | | | | | | | | 0.45 | 0.45 | | | | 0.45 |
| Nuclear Structure Data Measurement | | | | | 0.10 | | | | | | | 0.10 | | | | 0.10 |
| ENSDF Evaluation Support Codes | | 0.15 | | | | | | | | | | 0.15 | | | | 0.15 |
| | | | | | | | | | | | | | | | | |
| VI. Nuclear Reaction Physics | 0.05 | 1.85 | 0.0 | 0.00 | 1.20 | 0.55 | 0.20 | 0.38 | 0.20 | 0.60 | 0.00 | 4.53 | 0.00 | 0.00 | 0.50 | 5.03 |
| Experimental Data Compilation | | 0.50 | | | | | | | | | | 0.50 | | | | 0.50 |
| <i>Neutron Data</i> | | 0.15 | | | | | | | | | | 0.15 | | | | 0.15 |
| <i>Charged Particle Data</i> | | 0.30 | | | | | | | | | | 0.30 | | | | 0.30 |
| <i>Photonuclear Data</i> | | 0.05 | | | | | | | | | | 0.05 | | | | 0.05 |
| EXFOR Manuals | | 0.05 | | | | | | | | | | 0.05 | | | | 0.05 |
| ENDF Manuals and Documentation | | 0.10 | | | | | | | | | | 0.10 | | | | 0.10 |
| ENDF Evaluations | | 0.90 | | | 0.10 | | 0.20 | | | | | 1.20 | | | | 1.20 |
| Nuclear Reaction Standards | | | | | 0.10 | | | | 0.20 | | | 0.30 | | | | 0.30 |
| Nuclear Model Development | | 0.20 | | | 0.30 | | | | | | | 0.50 | | | | 0.50 |
| Nuclear Reaction Data Measurements | | 0.10 | | | 0.30 | 0.55 | | | | | | 0.95 | | | | 0.95 |
| Astrophysics Nuclear Data Needs | 0.05 | | | | 0.40 | | | 0.38 | | 0.60 | | 0.93 | | | 0.50 | 1.43 |
| Reaction Data for RIA Target Design | | | | | 0.00 | | | | | | | 0.00 | | | | 0.00 |
| | | | | | | | | | | | | | | | | |
| DOE-SC Nuclear Data Funded Staff | 0.77 | 7.50 | 1.30 | 3.40 | 1.80 | 3.30 | 0.45 | 0.88 | 0.20 | 2.55 | 1.50 | 14.30 | 3.85 | 5.00 | 0.50 | 23.65 |
| Staff Supported by Other Funding | 0.00 | 0.50 | 0.00 | 0.20 | 14.40 | 0.00 | 7.50 | 0.50 | 2.80 | 0.00 | 0.00 | 25.70 | 0.00 | 0.20 | 0.00 | 25.90 |
| TOTAL STAFF | 0.77 | 8.00 | 1.30 | 3.60 | 16.20 | 3.30 | 7.95 | 1.38 | 3.00 | 2.55 | 1.50 | 40.00 | 3.85 | 5.20 | 0.50 | 49.55 |

Detailed Status of the Work Plan (Report FY06)

I. NNDC Facility Operation (Report FY06)

A. Management

This task includes planning, budgeting, personnel, interaction with BNL management, and interaction with funding authorities.

B. Library

NNDC maintains an archival collection of low- and intermediate-energy nuclear physics publications. This library of journals, reports and other documents supports the NNDC compilation activities and the U.S. nuclear reaction and nuclear structure data evaluation effort as well as international nuclear structure evaluations.

C. Computer Operation

The NNDC operates several Dell servers running Red Hat Linux in support of its compilation, evaluation, database maintenance, and information dissemination functions. In addition, each staff member has a PC that supports an interface to these Linux servers and supports administrative functions such as word processing and email. This task includes software and hardware upgrades, machine operations and internal user support for both the Linux and Windows platforms.

BNL Planned Activities:

- Scan and remediate regularly vulnerabilities on NNDC servers and clients to ensure compliance with DOE cyber security requirements.
- Purchase and install a new and powerful EMPIRE server for faster processing of ENDF/B-VII data files.
- Port EMPIRE codes and scripts from Linux to Windows platform.
- Develop an automatic failover system for the NNDC Web server.
- Make operational replication of nuclear database updates from NNDC to NDS/IAEA.

Status:

- Cyber security vulnerabilities were regularly addressed and successfully resolved.
- Powerful Dell server for EMPIRE was purchased, all ENDF/B-VII files were successfully processed.
- Porting of EMPIRE on Windows platform was not pursued due to the need to prepare another testing version of the ENDF/B-VII library.
- An automatic failover system for NNDC Web server was developed.
- An automatic replication from NNDC to NDS/IAEA was not implemented - priority was given to urgent tasks related to processing and testing of the ENDF/B-VII.0 library.

- Additionally, an 11-CPU cluster was acquired, installed and used for ENDF/B-VII.0 phase 1 testing using NJOY and MCNP codes. In the future it will be used for the generating and processing of covariance data.

II. Coordination (Report FY06)

A. National Coordination

ANL -- Chair the Measurement and Basic Physics Committee of the Cross Section Evaluation Working Group.

ANL Planned Activities:

Organize and chair the CSEWG Measurement and Basic Physics Committee.

Status:

- ANL organized and chaired the Measurement and Basic Physics Committee at the November 2005 CSEWG Meeting

BNL -- Chair USNDP Coordinating Committee, chair Cross Section Evaluation Working Group, develop USNDP work plan, and maintain its web site.

BNL Planned Activities:

Prepare FY2007 work plan for USNDP in time for spring 2006 FWP submittals.

Organize and chair CSEWG Meeting at BNL in November 2005.

Organize and chair USNDP Meeting at BNL in November 2005.

Edit and publish summary reports of the CSEWG and USNDP meetings.

Maintain CSEWG and USNDP web sites.

Status:

- FY2007 work plan for USNDP was prepared in February 2006.
- CSEWG Meeting was held at BNL in November 2005.
- USNDP Meeting was held adjacent to CSEWG Meeting in November 2005.
- Summary report of CSEWG-USNDP 2005 meeting was published in January 2006.
- CSEWG and USNDP web sites were regularly maintained.
- Additionally, a short CSEWG meeting to discuss validation of preliminary releases of the ENDF/B-VII library took place in June 2006 at BNL.

LANL -- Chair U.S. Nuclear Data Program's Nuclear Reaction Working Group and help coordinate nuclear reaction data work at different labs to advance USNDP; chair Evaluation Committee of the Cross Section Evaluation Working Group.

LANL Planned Activities:

- Organize and chair CSEWG Evaluation Committee meeting at BNL, November 2005.
- Organize and chair Nuclear Reaction Working Group meeting at USNDP meeting in November 2005.
- Help to organize and assist to lead the CSEWG Homeland Security Task Force, and interact with LANL NA22 representative to provide feedback on user needs.

Status:

- Organized and chaired the Evaluation Committee at the November 2005 CSEWG meeting.
- Organized and chaired Nuclear Reaction Working Group meeting at USNDP meeting in November 2005.
- Homeland Security and Astrophysics data needs were investigated.

LBNL -- Serve as a member of the USNDP Coordinating Committee and chair the USNDP Nuclear Structure and Decay Data Working Group in addition to overseeing, coordinating, and directing the work of members of the Isotopes Project. The latter effort includes working with LBNL management, with other members of the USNDP, and with the program officers of the DOE.

LBNL Planned Activities:

- Organize and chair Nuclear Structure and Decay Data Working Group meeting at USNDP meeting, November 2005.

Status:

- Served on USNDP Coordinating Committee.
- Organized and chaired USNDP Nuclear Structure and Decay Data Working Group meeting in November 2005.

LLNL -- Chair the Task Force on Nuclear Data Needs for Homeland Security and serve on the Cross Section Evaluation Working Group and USNDP executive committees.

LLNL Planned Activities:

- Attend the annual CSEWG meeting in November 2005
- Provide Task Force on Nuclear Data Needs for Homeland Security report for CSEWG.

Status:

- Two LLNL participants attended the FY06 CSEWG meeting
- LLNL prepared the final Task Force on Nuclear Data Needs for Homeland Security report for CSEWG

ORNL -- Chair the Astrophysics Task Force and help facilitate and coordinate nuclear astrophysics data work at different labs to advance USNDP goals; provide leadership in planning future activities in nuclear data for nuclear astrophysics

ORNL Planned Activities:

Summarize USNDP efforts in nuclear data for nuclear astrophysics at USNDP Meeting in November 2005.

Communicate current efforts and future plans with researchers in nuclear astrophysics data.

Discuss future plans in nuclear astrophysics data with USNDP/NNDC and DOE.

Status:

- USNDP efforts in nuclear data for nuclear astrophysics summarized in an oral presentation and a written report for USNDP meeting in November 2005.
- Represented nuclear astrophysics data efforts of USNDP members at Workshop on Nuclear Astrophysics Data in Basel, Switzerland in June, 2006, and gave invited presentation on status and future of international nuclear astrophysics data efforts.
- Represented nuclear astrophysics data efforts of USNDP members at meeting of Ad-Hoc Working Group in Nuclear Astrophysics Data at Nuclei in the Cosmos IX symposium in Geneva, Switzerland in June, 2006.
- Explored prospects for joint research / data projects in nuclear astrophysics involving multiple USNDP sites.

B. International Coordination

ANL – Represent ANL in the International Nuclear Structure and Decay Data Network that is under auspices of IAEA. Participate in IAEA-sponsored coordinated research programs and training workshops. Represent U.S. measurements interest in the NEA Working Party on International Evaluation Cooperation

ANL Planned Activities:

Participate in IAEA-sponsored CRP on “Updated Data Library for Actinides”

Participate in NEA WPEC annual meeting

Status:

- ANL staff participated in the IAEA-CRP on “Updated Decay Data Library for Actinides” and chaired the first CRP meeting.
- Two lectures were prepared and presented at the IAEA/ICTP organized workshop “Nuclear Structure and Decay Data: Theory and Evaluation”, held in Trieste, Italy, February-March 2006.

- ANL hosted and mentored a scientist from University of Sofia NSDD data group (Dr. S. Lalkovski, currently at University of Brighton, UK) as a nuclear structure data evaluator.
- ANL staff attended the 2006 WPEC meeting (the trip was sponsored by the ANL Criticality Safety Program).

BNL -- Represent the United States in IAEA-sponsored Nuclear Reaction Data Center Network (NRDC) and Nuclear Structure and Decay Data Network (NSDD). The NNDC center head is the U.S. member and vice-chair of the IAEA International Nuclear Data Committee and the lead US member of the NEA Working Party on International Evaluation Cooperation in his position as chair of CSEWG. BNL frequently participates in IAEA sponsored activities such as Workshops, Technical Meetings and Coordinated Research Projects.

BNL Planned Activities:

- Participate in IAEA-sponsored NRDC meeting in 2006.
- Participate in NEA WPEC annual meeting in 2006.
- Organize and lecture at IAEA-sponsored training workshop for new structure evaluators in 2006.
- Provide lecturer for the IAEA nuclear reactions training workshop in 2006.
- Participate in IAEA CRP meeting on Reference Input Parameter Library RIPL-3.

Status:

- One NNDC staff member participated in the Nuclear Reaction Data Center meeting in September 2006.
- The NNDC head led the US team at the NEA Working Party on International Evaluation Cooperation (WPEC) meeting at Paris, France in May 2006. He presented a talk on the status of the ENDF/B library.
- NNDC provided director and 2 lecturers (6 lectures) for NSDD Workshop at Trieste in February-March 2006.
- The IAEA nuclear reaction training course, anticipated to be hold in Trieste in 2006, was cancelled.
- NNDC hosted three nuclear structure evaluation trainees, two from India (G. Mukherjee, S. Basu) and one from Argentina (D. Abriola).
- The NNDC staff member participated at the RIPL-3 meeting in December 2006.
- Two staff members of the NNDC participated in the INDC meeting in June 2006, to provide input and advice to the IAEA Nuclear Data Program.

LANL -- Participate in and chair international nuclear reaction data collaborations. This insures that the U.S. benefits from breakthroughs around the world, and plays a leadership role in new developments. LANL staff members chair NEA/WPEC committees in covariance data, and international model code development cooperation. LANL will host visits by foreign scientists with international reputations to benefit from the exchange of information and ideas.

LANL Planned Activities:

Participate in NEA WPEC May 2006 meeting.

Participate in relevant IAEA meetings.

Make latest version of NJOY data processing code available to the international community.

Status:

- LANL staff members participated in WPEC meeting in Paris, France in May 2006. Organized a WPEC Subgroup 24 meeting at LANL.
- Upgrades to NJOY were released to the international NJOY data processing community.
- Collaborate with JAEA researchers to upgrade a covariance processing module, ERRORJ, as a part of the NJOY code system.
- Hosted key researchers from JAEA, Japan and NRG Petten, The Netherlands.

LBNL – Participate in IAEA-sponsored training workshops and coordinated research programs on nuclear structure and decay data.

LBNL Planned Activities:

Provide lecturer(s) for structure and decay data evaluator-training Workshop if one is scheduled during FY06.

Status:

- Provided one lecturer (4 lectures, 10 lab. sessions) for the two-week IAEA/ICTP (Trieste) “Workshop on Nuclear Structure and Decay Data: Theory and Evaluation” in February/March 2006.
- Began participation in a new IAEA/CRP titled “Reference Database for Neutron Activation Analysis” (see section V. F).

McMaster – Continue participation in new evaluators training program.

McMaster Deliverable:

Collaborate with new evaluators for ENSDF work.

Status:

- One evaluator from St. Petersburg, Russia spent about 3 weeks at McMaster in June 2006 for collaborative work on ENSDF evaluation of A=135. This mass chain has been submitted. The collaborative work with the team of new evaluators in India was completed in 2006 with the joint publication of A=165 and 218 mass chains.

III. Nuclear Physics Databases (Report FY06)

A. Nuclear Science References (NSR)

The NNDC is responsible for NSR, the bibliographic database for nuclear physics research. This task includes quality control, file update and maintenance, and file distribution to collaborators. Updates are done on a continuing basis. The preparation of NSR entries is given under Nuclear Structure Physics.

BNL Planned Activities:

Database distributed to collaborators monthly.

Status:

- NSR files were distributed monthly.

B. Experimental Nuclear Structure Data (XUNDL)

The NNDC is responsible for maintaining and providing access to the XUNDL database. This database contains compilations (in ENSDF format) of recently published or completed level-structure data. While the emphasis remains on recent high-spin publications, many low-spin studies are also included. The compilation work is mainly carried out at McMaster University. The McMaster group also coordinates this work with that of other centers. The NNDC updates the database as new/revised data sets are received from McMaster.

BNL Planned Activities:

Update database as new data sets are received from McMaster University.

Status:

- Database updated as required, 380 new and 28 updated files were included.

C. Evaluated Nuclear Structure Data File (ENSDF)

The NNDC is responsible for the ENSDF database that contains evaluated experimental nuclear structure and decay data. The NNDC is responsible for maintaining the database and organizing the quality control (review) of evaluations submitted for inclusion. This task includes database updates and distribution to collaborators. Updates are done upon completion of reviews. Corrections are implemented on a continuing basis.

BNL Planned Activities:

Database distributed to collaborators twice a year.

Status:

- 24 mass-chains, 15 nuclides, and 6 data sets were received, processed and added to ENSDF in FY2006. Processing includes file checking, review and post-review checking.

- The ENSDF database was distributed in October 2005 and March 2006.

D. Numerical Nuclear Data File (NuDat)

The NNDC is responsible for NuDat, an all numeric database of nuclear data including level and γ -ray properties extracted from ENSDF, ground and metastable state properties (Wallet Cards), atomic and nuclear radiations derived from ENSDF, and thermal neutron cross sections and resonance integrals.

BNL Planned Activities:

Distribute NuDat database to the IAEA every time there is an upgrade, about 10 times a year.

Status:

- The NuDat database was distributed in October 2005 and March 2006.

E. Neutron Reaction Data Bibliography (CINDA)

The NNDC is responsible for the CINDA database that contains references to nuclear reaction data in the published and unpublished literature. Its contents are produced cooperatively by the four international neutron data centers, with updates exchanged in an agreed computer format. The data are organized by data measured, not by reference. The database serves as an index to the neutron data contained in the experimental database, CSISRS. The database is updated as transmissions from the data centers are received and checked.

BNL Planned Activities:

Update CINDA database with reference from cooperating centers (500 expected).

Status:

- The database serves as an index to the reaction data (neutrons, charged-particle and photonuclear), updates are automatically created from CSISRS. The database was updated regularly via own entries to CSISRS as well as the cooperating centers.

F. Experimental Reaction Data File (CSISRS)

The NNDC is responsible for maintaining the CSISRS database. This database contains experimentally measured nuclear reaction data covering the low- and intermediate-energy regions. Many groups worldwide compile and exchange experimental data in an agreed format, EXFOR. The effort described here includes the quality control, file update and data exchange activities. The database is updated as transmissions from the compiling centers are received and checked. The compilation activity is given under Nuclear Reaction Physics.

BNL Planned Activities:

Update CSISRS with EXFOR with compilation from cooperating centers (500 expected).

Status:

- The CSISRS database was continuously updated using input from the cooperating data centers (650 compilations).

G. Evaluated Nuclear Data File (ENDF)

The NNDC is responsible for ENDF, a database of evaluated nuclear data required for many nuclear applications. The work is organized under the Cross Section Evaluation Working Group (CSEWG), coordinated by the NNDC. The ENDF file contains complete descriptions of nuclear reactions of neutrons with many nuclides and elements for energies up to 20 MeV and radiations from radioactive decay. A number of evaluations for energies up to 150 MeV and for incident charged particles and photons are also included. The data are stored in the ENDF format developed at NNDC about 35 years ago and adopted as an international standard. In addition to the U.S. library, ENDF/B, the database contains evaluated data libraries from the European Union, Japan, Russia, and China. This activity includes the processing and quality control for the U.S. ENDF/B library, the distribution of this database in the United States and the exchange of libraries internationally. A new version of the library, ENDF/B-VII.0, will be assembled, tested and made available to users through a Web interface linked to the relational database.

BNL Planned Activities:

Maintain ENDF discussion list to facilitate validation of ENDF/B-VII.

Complete phase 1 testing of ENDF/B-VII.

Complete assembly and release of ENDF/B-VII library in the first quarter of FY2006.

Status:

- ENDF discussion list, endf@lists.bnl.gov, was regularly maintained.
- Complete phase 1 testing of the ENDF/B-VII library was performed. This was done for beta 1 (October 2005) and beta2 (April 2006) testing versions of the library.
- ENDF/B-VII beta3 version was assembled and prepared for release and testing. It contains a complete set of sub-libraries, including a neutron sub-library with 393 evaluations and a photonuclear sub-library with 163 evaluations. The official release of ENDF/B-VII.0 was postponed due to further testing by CSEWG.

H. Database Software Maintenance

This activity includes software bug fixes and enhancements for the six nuclear physics databases maintained by NNDC.

BNL Planned Activities:

Re-write the selector generation program for NSR.

Status:

- The selector generation program was rewritten, and it is currently under beta testing.

I. Database Systems Development

The multi-year effort to migrate the USNDP databases to a LINUX/SYBASE environment was completed in FY2004. Afterwards, several follow-up tasks should be performed. In addition, new developments should be started.

A new Web interface, complementary, to the existing one, should be developed to facilitate the retrieval of experimental data in CSISRS by non-ENDF users, such as nuclear astrophysics. This interface should focus on the relevant experimental data, such as a full reference to the publication, a comprehensive reaction description and the experimental data. The existing interface, giving access to the complete compilation (with more details than the reference, reaction and data) will be retained and will still be accessible to users who need it.

BNL Planned Activities:

Development of journal tracking database in support of NSR compilation

Begin development of java-based publication codes for ENSDF.

Develop new CSISRS web interface for non-ENDF users.

Investigate java-based stand-alone versions of some databases and products.

Investigate XML formats for data exchange.

Status:

- CSISRS web interface was modified to better serve non-ENDF users.
- Development of new java-based ENDF interface (Sigma) has begun.
- The other tasks were not pursued due to the loss of funding (1 FTE was lost in FY2006).

IV. Information Dissemination (Report FY06)

The goal of the dissemination activities of the USNDP is to provide scientists and engineers with nuclear data from the USNDP-maintained nuclear databases in a variety of user-friendly formats and media.

A. Web Site Maintenance

The NNDC provides electronic access to the nuclear physics databases that it maintains on behalf of the USNDP as well as access to other nuclear physics information through its web site. The NNDC web services are powered by four 2.8 GHz dual-processor Dell servers running on the Linux operating system and using the Apache Tomcat and Sybase server software. This solution was made public in April 2004 and has proven to be secure, fast and have minimum downtime. Most of the databases were redeveloped to take advantage of the new hardware possibilities as well as new programming technologies, such as the use of the Java and Java scripts languages. This upgrade significantly increases reliability of the system. The NNDC also maintains the Atomic Mass Data Center Web site. Other USNDP members also offer information through their Web sites. These services require resources to maintain currency and improve performance.

ANL Planned Activities:

- Maintain electronic access to the ANL Nuclear Data Measurements (ANL/NDM) report series web site.
- Maintain and upgrade Experimental Resources for Nuclear Data web site.
- Maintain and upgrade the ANL Nuclear Data Information web site.

Status:

- The three web sites were maintained and periodically upgraded.

BNL Planned Activities:

- Improve NSR and ENSDF Web interfaces.
- Maintain Web interface to the ENDF database.
- Develop new Web interfaces for Atomic Masses and B(E2).
- Replace Perl-based programs with a Java version.
- Improve reliability and cyber security of its Web services by installing the latest version of the Apache/Tomcat servers and mod-jk2 connector software for a new dual Web server program.
- Maintain currency of the CSEWG, USNDP and the NNDC Web sites.

Status:

- The NSR and ENSDF Web interfaces were updated.
- Web interface for the ENDF database was maintained and improved by adding extensive Help pages.
- Web interface for B(E2) was developed.
- Perl-based programs were largely replaced with Java programs.

- Reliability and cyber security of the NNDC Web service was improved by adding a new public server.
- The currency of the CSEWG, USNDP and the NNDC Web site was maintained.
- Several new products were developed, such as the Chart of Nuclides, web interfaces for BRICC, update of thermal neutron capture gammas, BE(2) and double beta decay databases.

LANL Planned Activities:

Include access to new reaction and structure data evaluations supported by DOE/Nuclear Physics, via the T-16 web site.

Provide actinide ENDF/B-VII data via LANL web site for criticality data testing.

Status:

- The latest LANL evaluations were made available via our web site. This has been particularly important for the integral data testing community that is validating the preliminary ENDF/B-VII evaluations.

LBNL Planned Activities:

Maintain and update Active Server Pages enabling interactive searches of nuclear structure data, radioactive-decay data, neutron-capture γ -ray data, x-ray data, atomic-mass data and Nuclear Science References as needed. Maintain web pages for fission data, nuclear systematics and nuclear science education.

Support the Isotope Explorer 2 and 3 software previously developed by LBNL.

Status:

- Maintained and updated existing web pages as needed and supported Isotope Explorer 2 and 3 and NSR search software.

LLNL Planned Activities:

Maintain LLNL Nuclear Data and Atomic Data Viewer.

Extend the Nuclear and Atomic Data Viewer to handle other data formats (especially Monte Carlo data).

Maintain and upgrade LLNL Computational Nuclear Physics web pages.

Status:

- Nuclear and Atomic Data System was maintained.
- Computational Nuclear Physics web pages were maintained.
- New evaluated nuclear data libraries added to the Nuclear and Atomic Data System.
- Nuclear and Atomic Data System dissemination statistics reporting dramatically improved.

ORNL Planned Activities:

Development and maintenance of our Web/FTP site providing the RadWare interface to ENSDF and XUNDL data sets will be terminated.

Development and maintenance of our online software suite to convert nuclear data to astrophysical reaction rates and plot, manipulate, and share results online.

Regularly update nuastrodata.org html web pages.

Status:

- The website radware.phy.ornl.gov has been maintained by uploading the latest versions of ENSDF and converting the files to RADWARE format.
- The **Computational Infrastructure for Nuclear Astrophysics**, online at **nuastrodata.org**, has been significantly expanded and improved in FY06. This tool enables users to upload cross sections, perform simple data evaluation tasks, convert cross sections into reaction rates, and use these rates in element synthesis calculations. New features FY06 include updated reaction rate libraries, improved computational methods of generating reaction rates from cross sections, quick listing of all distinct versions of the rate of a particular reaction, improved element synthesis calculations with multiple spatial zones, improved rendering and export of simulation output, and quicker comparisons of simulation with different nuclear physics input.

TUNL Planned Activities:

Continue to improve the TUNL website and provide access to new information on $A = 3 - 20$ nuclei.

Continue to prepare new PDF and HTML documents of the most recent TUNL reviews.

Continue to provide PDF and HTML documents for FAS reviews for the $A = 3 - 20$ series.

Continue to provide General Tables to accompany the most recent TUNL reviews of the $A = 3 - 20$ series.

Continue to provide Energy Level Diagrams (in GIF, PDF and EPS/PS formats) to accompany the PDF and HTML documents for the most recent TUNL reviews and preliminary reports, and for the earlier FAS reviews.

Status:

- PDF and HTML files are online for *Fay Ajzenberg-Selove and TUNL reviews* for 1966-present, and 1959 ($A = 5 - 17$). This year we added $A = 10$ (1966La04) and $A = 11 - 17$ (1959Aj76).
- Energy Level Diagrams are online for *Fay Ajzenberg-Selove and TUNL reviews* for 1959-present. This year we added $A = 11 - 20$ (1959Aj76).
- An effort to provide compiled and evaluated information on Thermal Neutron Capture data for $A = 2 - 20$ nuclei is essentially completed.

- New work has begun on a collection of compiled and evaluated information on beta-decay for A=3-20 nuclei.

B. Customer Services

This task accounts for the non-electronic services which the USNDP renders to customers. At the scientific staff level, this means direct assistance to users needing advice from nuclear data experts or advice on solving complex queries *via* electronic access to the database. The NNDC staff allocation at the support level is for maintaining a help desk and for administrative/clerical support of its customer services.

BNL Planned Activities:

Effort is required to maintain help desk and provide technical support to users as necessary.

Status:

- The NNDC staff responded to user inquiries by phone, email or via web. Comments/questions option was introduced and maintained for CSISRS and ENDF interfaces and also for the NNDC web service.

C. Publications

The USNDP provides some paper publications as well as electronic access to the nuclear physics databases that it maintains. This includes the Nuclear Data Sheets published by Elsevier and various versions of the Nuclear Wallet Cards.

BNL Planned Activities:

Prepare twelve issues of Nuclear Data Sheets for publication
Investigate a publication of adopted levels and gammas of all nuclides in ENSDF in electronic form (Web and CD-ROM).

Status:

- Twelve issues of Nuclear Data Sheets were published.
- The project to publish all adopted levels and gammas in ENSDF has been discontinued.

V. Nuclear Structure Physics (Report FY06)

A. NSR Abstract Preparation

The literature search and preparation of KEYWORD abstracts for publications included in NSR require scientific expertise.

BNL will be working with the IAEA in Vienna to include them in the keywording effort. Eventually they will take over responsibility for several European journals (Nuclear Physics A, European Journal A, and Physics Letters B; approx. 20-25% of keywording effort).

BNL Planned Activities:

- Prepare entries for 4,100 new references with keyword abstracts for 3,100.
- Train IAEA Nuclear Data Section staff in NSR keywording.
- Transfer keywording of the European Journals (Nuclear Physics A, European Journal A, and Physics Letters B) to IAEA Nuclear Data Section.

Status:

- About 80 refereed journals were scanned regularly and a number of conference proceedings were scanned as they were published. 3,993 entries were added to the NSR database including 3,093 with keywords.
- The IAEA Nuclear Data Section staff member (M. Kellet) was trained in NSR keywording.
- Transfer keywording of the three European Journals to IAEA Nuclear Data Section was successfully completed.

B. Compilation of Experimental Structure Data

This activity involves compilation of recently published or completed experimental nuclear structure data (primarily high-spin) for inclusion in XUNDL.

BNL Planned Activities:

- Compile BE(2) experimental data

Status:

- 28 new entries for 27 different nuclides were added to the BE(2) database

McMaster Planned Activities:

- Compile data sets (in ENSDF format) for current publications with emphasis on high-spin physics, but many low-spin and decay data publications will also be compiled.
- Review compiled data sets submitted by other data centers prior to inclusion in the XUNDL database.
- Communicate with the authors of the original papers for data-related problems and to request additional details of unpublished data. On an annual basis

send a copy of all such private communications to NNDC for archival and distribution purposes.

Train a new undergraduate student in early 2006 for XUNDL compilation work.

Status:

- 380 new data sets from current journal publications in experimental nuclear structure (high-spin and low-spin) were compiled and sent to NNDC. Another 28 data sets were updated based on new papers from the same groups or authors as in data sets from earlier papers.
- No compiled data sets received this year from other data centers.
- Throughout the year there was active communication with the original authors of the papers to resolve data-related problems and to obtain additional details of data that are useful to include in XUNDL and/or ENSDF databases. Copies of these communications (about 40 in all) were sent to NNDC in September 2006 in print form and as a computer file for archival purpose and for potential use in ENSDF evaluations.
- A new undergraduate student Maxim Mitchell was trained in early 2006 to work during the year on XUNDL compilations. He will be working until April 2007.

C. Data Evaluation for ENSDF

The USNDP evaluates nuclide and mass chain nuclear structure and decay data for inclusion in the ENSDF database. This effort now includes the A=21-44 mass region previously evaluated by the Utrecht group; LBNL is responsible for A=21-30, Canada for A=31-44.

ANL Planned Activities:

1.5 equivalent mass chains will be evaluated and published.
At least one mass chain will be reviewed.

Status:

- One mass chain (A=200) and one nuclide were evaluated and data were submitted to NNDC for further processing and reviews.
- A=201 mass chain was revised significantly following recommendations made by the reviewer and it was published in Nuclear Data Sheets.

BNL Planned Activities:

Four and one-half equivalent mass chains will be evaluated.
At least 5 mass chains will be reviewed (including 1 mass chain by Idaho).

Status: (Includes three subcontracted part-time evaluators, one was foreseen in FY06 Workplan, two others were added later: C. Reich – Idaho, N. Nica - Texas A&M and E. Browne – LBNL)

- 8 mass chains were evaluated and submitted:
 - A = 47 (12 nuclides by Burrows)
 - A = 48 (14 nuclides resubmitted by Burrows)
 - A = 94 (14 nuclides by Abriola & Sonzogni)
 - A = 140 (16 nuclides by Nica)
 - A = 234 (10 nuclides by Browne & Tuli)
 - A = 236 (9 nuclides by Browne & Tuli)
 - A = 251 (collaboration, 5 nuclides by Tuli)
 - A = 253 (collaboration, 5 nuclides by Tuli)
- 5 mass chains and super-heavies were published in Nuclear Data Sheets:
 - A = 48 (Burrows)
 - A = 94 (Abriola & Sonzogni)
 - A = 236 (Browne & Tuli)
 - A = 251, 253 (Tuli & collaborators)
 - A = 266-294 (Gupta and Burrows)
- 13 mass chains were reviewed:
 - A = 52, 64, 94 (Reich)
 - A = 74 (Winchell)
 - A = 131 (Burrows)
 - A = 101, 109, 112, 213, 216, 218, 232, 233 (Tuli).

LBNL Planned Activities:

Hire one post doc for training as an evaluator.

Evaluate 5 mass chain equivalents, including a minimum of two from the actinide region and one from the A=24-30 region.

Review mass-chain evaluations, as requested.

Participate in training and/or mentoring of new structure evaluators, as needed.

Status:

- Existing post doc position was extended through FY06.
- Evaluations for A=23, 184, 213, 216, ¹⁷³Pt, ¹⁸⁷Po, ¹⁹²At (43 nuclides, including 13 priority nuclides) were submitted.
- Reviewed two mass chain evaluations (A=51, 48).

McMaster Planned Activities:

1.5 equivalent mass chains (including the A=31-44 region) will be evaluated.

Mass chains will be reviewed as requested.

Update superdeformed-band data in ENSDF for new publications. All nuclides will be covered that do not require extensive updating and reevaluation for data sets involving low-spin or non-SD structures.

Some collaboration with a new center/evaluator as part of training.

Status:

- Four full-length mass chains ($A=38, 64, 100, 135$) and 6 individual nuclides were evaluated and sent to NNDC for inclusion in ENSDF and publication in Nuclear Data Sheets. $A=135$ was done in collaboration with group in Russia, also as part of the training and mentoring process.
- $A=122$ mass chain from the Japanese data center and ^{241}Pu decay data evaluation (for DDEP) from a Russian center were reviewed.
- Six nuclides were updated for new super-deformed band data and revised data sets were sent to BNL for inclusion in ENSDF. We are current on the coverage of known superdeformed structures (SD bands) in the ENSDF database.
- One evaluator from St. Petersburg, Russia spent about 3 weeks at McMaster for collaborative work on ENSDF evaluation of $A=135$. This mass chain has been submitted. The collaborative work with the team of new evaluators in India was completed in 2006 with the joint publication of $A=165$ and 218 mass chains.

ORNL Planned Activities:

Complete evaluation of structure information for nuclei with $A=241, 208$ and 245.

Start evaluation of $A=248$ and 246 nuclei.

Train one evaluator

Status:

- $A=241$ evaluation is complete and published
- $A=245$ evaluation will be completed in June 2007
- $A=208$ evaluation was submitted in early FY07
- $A=201$ evaluation was reviewed
- $A=58$ evaluation started
- Murray Martin has continued his training of post-doc Caroline Nesaraja in A-chain evaluations.

TUNL Planned Activities:

Prepare the ENSDF files for $A = 11-12$ nuclei corresponding with the *Nuclear Physics A* publication.

Begin preparation of the ENSDF file for $A = 13$ nuclei corresponding to the *Nuclear Physics A* publication.

Status:

- The data file for $A = 9$ was accepted in ENSDF in February 2006; the file for $A = 10$ is essentially complete (99%).
- Preliminary work on $A = 11, 12$ ENSDF files is underway.
- TUNL's new post-doc is beginning to evaluate $A=13$ nuclei and will prepare the ENSDF file.

D. Ground and Metastable State Properties

This is the evaluation of data for the Nuclear Wallet Cards.

BNL Planned Activities:

NNDC will update the Nuclear Wallet Cards file.

Status:

- The file was updated twice during 2006.

E. Radioactive Decay Data Evaluation

Decay data for nuclides of importance for metrology are evaluated in an international collaboration. When complete, these evaluations are entered into the ENSDF format and made available to ENSDF evaluators. In the United States, LBNL coordinates this project at no cost to the US Nuclear Data Program.

ANL Planned Activities:

Evaluate decay data for one radionuclide.

Review decay data evaluation for one radionuclide.

Status:

- One nuclide (^{204}Tl) was evaluated
- One nuclide (^{239}Pu) was reviewed.
- Series of decay data measurements were carried out at ANL as a part of the commitment to the IAEA-CRP on “Updated Decay Data Library for Actinides”. Data were collected for $^{243-246}\text{Cm}$, ^{240}Pu and ^{237}Np and some of the results were published. Evaluations of ^{246}Cm and ^{206}Hg were initiated.

LBNL Planned Activities:

Coordinate and plan activities of this international collaboration.

Review the evaluations of about five radionuclides.

Submit decay datasets for two radionuclides.

Status:

- Coordination and planning of the activities of this collaboration continued but no longer received financial support at LBNL.

F. Thermal Capture Gamma Data Evaluation

The EGAF (Evaluated Gamma-ray Activation File) database, disseminated by the IAEA, provides discrete-line γ -ray information from thermal (n,γ) reactions, tailored to suit the needs of the neutron activation analysis community. Statistical-model calculations can generate quasi-continuum photon cascade data to complement these experimental discrete-line data. Together, these data provide a valuable resource required for updating the ENDF database. The EGAF database also requires ongoing maintenance and development to make it more useful to the applied communities it serves.

LBNL Planned Activities:

Maintain and develop EGAF database (i) by adding any new (n,γ) data that become available from the Budapest reactor or elsewhere, along with any total radiative-capture cross-sections derived from them, (ii) by revising (in collaboration with IAEA) neutron-capture decay data in EGAF in order to serve the neutron activation analysis community better, and (iii) by extending EGAF (in collaboration with IAEA and LLNL) to include available neutron-reaction γ -ray data measured at reactor-neutron energies. Continue collaboration with LLNL to perform statistical-model calculations of quasi-continuum γ -ray cascade information. This also includes (i) supervision of an doctoral student who will generate several new, complete ENDF-format capture γ -ray datasets for use with MCNP and other transport-code calculations and (ii) development of a utility code for the analysis of statistical γ -ray feedings for (n,γ) , β decay, and other reaction-gamma datasets to assist evaluators in the assignment of level $J\pi$ values and the normalization of decay data when the decay scheme is incomplete.

Status:

- The development of the utility code for the analysis of statistical γ -ray feedings for (n,γ) datasets was completed last FY. It has yet to be extended for use with other types of datasets or made available to ENSDF evaluators.
- The results of the previous year's statistical analysis of (n,γ) E=thermal cross sections for Pd isotopes is being prepared for publication (in collaboration with LLNL).
- The development of the utility code for the analysis of statistical γ -ray feedings for (n,γ) datasets was completed last FY. It has yet to be extended for use with other types of datasets or made available to ENSDF evaluators.
- Commenced participation in an IAEA/CRP on *Reference Database for Neutron Activation Analysis*; the objective of this project is to provide a recommended set of evaluated k_0 /cross section data for use by this applied community. This project will ultimately provide information relevant to item (ii) of the first deliverable above.

G. Evaluation of Light Nuclei for *Nuclear Physics A*.

TUNL evaluates additional data not included in ENSDF for publication in *Nuclear Physics A* and on its web site

TUNL Planned Activities:

Distribute preliminary review of $A = 12$ nuclides for comments.

Prepare "*Energy Levels of Light Nuclei, A = 11 - 12*" for publication in *Nuclear Physics A*.

Publish evaluation of $A = 3$ nuclides in *Nuclear Physics A*.

Begin evaluation of $A = 13$ nuclei and prepare preliminary report to be distributed for comment.

Status:

- Evaluation of $A = 12$ nuclei is underway
- Evaluation of $A = 11$ nuclides is 95% complete; preprints for $A=11$ and 12 will be released simultaneously.
- Continuing to prepare evaluation of $A = 3$ nuclides.
- The new TUNL post-doc has begun an evaluation of $A=13$ nuclides.

H. Nuclear Structure Data Measurement

LANL/LANSCE maintains a small program to measure nuclear decay information.

LANL Planned Activities:

Examine prompt gamma-ray emission data from neutron reactions on ^{130}Te and ^{100}Mo to search for previously unobserved transitions in these and other, nearby residual nuclei.

Interact with mass chain evaluators on the nuclear structure of these nuclei.

Status:

- Data have been taken for both ^{130}Te and ^{100}Mo .
- Isomer states of $^{203,205}\text{Tl}$, and high-spin states of ^{135}Xe were studied.
- The experimental results on gold were accepted by Phys. Rev. C for publication.
- Interaction with the evaluators for these nuclei continues.

I. ENSDF Physics and Checking Codes

The NNDC maintains ENSDF checking and physics programs on behalf of the national and international evaluator networks. Only maintenance and upgrades for format changes are planned.

BNL Planned Activities:

Maintenance and upgrades for format changes as required.

Upgrade RADLST to properly treat higher-order (≥ 3) unique forbidden β^\pm transitions. Upgrade LOGFT to use the Schönfield electron-capture probabilities.

Development of ENSDF editor as well as Java versions of LOGFT, BRICC, ALPHAD and FMTCHK.

Status:

- Procedure changes have been documented in the evaluating policy files
- RADLST and LOGFT were not updated. Work on these updates has been discontinued.
- Version 2.0a of BRICC was released.
- Upgrades to COMTRANS, ENSDF, FMTCK, PANDORA, GTOL and RULER were performed.
- The ENSDF editor was made available and Java wrappers were written on legacy FORTRAN codes.

VI. Nuclear Reaction Physics (Report FY06)

A. Experimental Data Compilation

The NNDC, as part of a larger international cooperation, has responsibility for compiling experimental nuclear reaction data that have been produced in the U.S. and Canada.

Incident neutron reactions have been well covered historically. NNDC thus concentrates on new measurements only.

Since incident charged particle data have not been completely compiled in the past, NNDC is compiling new charged-particle measurements. In addition, because of emerging needs such as astrophysics, the NNDC is compiling older data. Hence, there is a larger staff commitment to compiling this type of data.

NNDC is responsible for maintaining the manuals describing the EXFOR format and the methods for compiling different kinds of data.

ANL should prepare EXFOR files for experimental neutron activation data measured in collaboration with IRMM.

ANL Planned Activities:

Submit EXFOR files to the NEA Data Bank for those original data sets provided to ANL by IRMM for processing.

Status:

- This activity was completed.

BNL Planned Activities:

Compile data from 200 charged particle and neutron reaction publications.

Status:

- Experimental cross-section data from 171 republications were compiled (112 charged-particle, 52 neutron and 7 photonuclear). This translates into 535 compiled individual reactions.
- NNDC responsibility for maintaining EXFOR manuals was taken over by the Nuclear Data Section, IAEA Vienna.

B. ENDF Evaluations

Evaluated nuclear reaction data, for applications and for basic science needs, are stored in the ENDF database, which is maintained by BNL. As chair of the CSEWG evaluation committee, LANL staff works with BNL to insure quality control, particularly for new evaluations. New evaluations funded primarily from other sources are prepared for archival in the ENDF library. BNL, LANL, LLNL and ORNL provided neutron, proton and photonuclear reaction data evaluations for ENDF/B-VII released in FY2006. LLNL develops a computer code that

translates LLNL evaluations in the internal ENDL format into ENDF-6 formatted data so that LLNL evaluations can flow back into the nuclear data community.

ANL Planned Activities:

No work planned for FY2006.

BNL Planned Activities:

Respond to user needs for evaluated nuclear reaction data.

Collect and address users' feedback related to the ENDF library.

Work with LANL to complete upgraded evaluations for ENDF/B-VII, to be released in December 2005.

Develop methodology for providing covariance data, in the fast neutron region, to the next release of ENDF.

Status:

- The NNDC responded to user needs for evaluated neutron reaction data by leading the development of the International Evaluated Fission Product Library.
- Users' feedback on the ENDF library was collected and addressed via Web sites for beta1, beta2 and beta3 testing versions of ENDF/B-VII.0.
- NNDC worked closely with LANL, all evaluations were upgraded as necessary and included into the testing versions of ENDF/B-VII. The final release was postponed by 1 year, to December 2006.
- The covariance methodology was developed and sample cases for 12 materials were produced and included into the ENDF/B-VII.0 library.
- Atlas of Neutron Resonances, a seminal book of 1,372 pages by S. Mughabghab, NNDC was published by Elsevier in April 2006.
- A new decay data sub-library, covering 3,838 materials was produced as a part of ENDF/B-VII.0.

LANL Planned Activities: (work mostly supported from other sources)

Fix formatting issues reported by BNL, and submit the final version of LANL ENDF evaluations, for U, Pu, Am, Np isotopes that perform well in criticality benchmarks.

Provide upgraded ENDF evaluated data files for charged-particle reactions having $A \leq 10$, including covariance data.

Include covariance data for important actinides (this is supported by many projects including AFCI, criticality safety, and also a WPEC collaboration).

Work with BNL to complete upgraded evaluations for new version of ENDF, ENDF/B-VII, for release at the end of CY 2005.

Provide criticality data testing of the actinide evaluations in fast, intermediate, and thermal assemblies for validation of the new ENDF/B-VII evaluations.

Status:

- Formatting issues reported were fixed, and the final version of LANL ENDF evaluations for U, Pu, Np, Am isotopes were submitted for ENDF/B-VII.
- The final version of LANL charged-particle reaction data were submitted for ENDF/B-VII. The final covariance data are still under development.
- Covariance data for important actinides, including ^{235}U , ^{238}U , and ^{239}Pu in the fast neutron region were produced. Those data were processed with NJOY/ERRORJ to generate group-structure covariance data for AFCI, criticality safety, and WPEC collaborations.
- Worked with BNL on the new version of ENDF, ENDF/B-VII.0 that was released in December 2006.
- Criticality benchmark tests for ENDF/B-VII were provided, and this information was used to validate the new ENDF evaluations.

LLNL Planned Activities: (work mostly supported from other sources)

Develop `endl2endf` code to translate data in the internal LLNL format to the international standard ENDF-6 format.

Release the `fete` (from ENDF to ENDL) translation code.

Submit new improved evaluations for neutron induced reactions on nuclei in the A=43-56, 74-83, and 123-158 mass regions.

Review state of actinide evaluations and make improvements based on study of systematics in this mass range for DNEA program.

Status:

- The `fete` code was released under the Gnu Public License and is available at <http://nuclear.llnl.gov/CNP/fete>.
- The `endl2endf` code is being developed and already has enabled a large number of LLNL evaluations to be submitted to the ENDF community.
- A large suite of partial evaluations (489) was included into ENDF/A library.
- The $^{74,75}\text{As}$ evaluations were finalized and included in ENDF/B-VII.0.
- Pu evaluation work has been delayed due to a shortage of manpower at LLNL.
- Post-fission β -delayed γ data have been added to ENDF/B-VII.0 for ^{239}Pu and ^{235}U evaluations.

LLNL - The Institute of Isotope and Surface Chemistry, Budapest has recently undertaken an extensive set of elemental measurements of capture gamma-ray energies and intensities as part of an IAEA CRP on "Development of a Database for Prompt Gamma-ray Neutron Activation Analysis (PGAA)," led by LBNL. The evaluated tables of prompt and delayed gamma-ray yields developed by this activity, called the Evaluated Gamma-ray Activation File (EGAF), are a significant improvement over previous work. LBNL and LLNL will collaborate to develop a set of ENDF files to be used to update the capture gamma-ray production information in the ENDF/B database. The availability of these data in coupled neutron-photon transport codes is

very important to several national security programs. This project is leveraged by funding from those programs.

LLNL Planned Activities:

Provide peer review of the EGAF database.

Simulate the gamma-ray cascade from resonance capture in order to add information on the quasi-continuum of gamma rays for $A > 40$ nuclei where level spacings become comparable to detector resolution. This information is usually not available experimentally because the targets used were not typically mono-isotopic.

Extend the data files up to approximately $E_n = 100$ keV based on the results of the simulations.

Produce ENDF files with the discrete and quasi-continuum gamma-ray spectra.

Status:

- Files with the quasi-continuum gamma-ray spectra are being developed.
- Paper validating results using Pd has been written and will soon be submitted.

C. ENDF Manuals and Documentation

NNDC is responsible for maintaining the format and procedures manual for the ENDF system. We also produce the documentation supporting the contents of the ENDF/B library.

BNL Planned Activities:

Maintain ENDF-6 format manual that is available on the Web. This format is used for the ENDF/B-VII release.

Status:

- ENDF-6 format manual has been updated in accordance with the decisions of CSEWG. Three testing versions of ENDF/B-VII were prepared in this format.

D. Nuclear Reaction Standards

Nearly all nuclear reaction data measurements are made relative to some reaction standard such as the hydrogen elastic cross section. Maintaining accurate current values for the standard cross sections is the objective of this task that can be accomplished only through international cooperation. A new international evaluation of the neutron cross-section standards was initiated to provide the improved standards that are needed. This evaluation, which was completed this year, has been largely performed by an IAEA Coordinated Research Project (CRP) with support, largely experimental in nature, through the Working Party on International Evaluation Cooperation (WPEC) of the Nuclear Energy Agency and the CSEWG.

ANL Planned Activities:

No work planned for FY2006.

LANL Planned Activities:

Participate in the international effort to reevaluate the light-element standard cross sections with LANL leadership for H, Li, and investigate the nature of output covariance data from R-matrix analyses of systems containing the light-element standard cross sections.

Incorporate the fission cross section standards (^{235}U , ^{239}Pu) into the new ENDF evaluations, and perform validation tests with integral measurements.

Status:

- Covariance data evaluation continues. This is a joint effort between the theory and experimental groups. Possible systematic errors in the experimental data reported in the past were identified.
- Fission cross sections reported as a ratio to the standards were modified by using the recent standards evaluation. Those results were included in the ENDF/B-VII evaluations.
- Light element standard cross sections were finalized, and many of those were submitted as the ENDF/B-VII standards.

NIST Planned Activities:

Complete the work through the CRP providing the remaining standards and uncertainties for the ENDF/B-VII library.

Coordinate the nuclear data standards activity of the NEA Working Party on International Evaluation Cooperation) and chair the IAEA CRP on the Improvement of the Standard Cross Sections.

Participate in the IAEA data development project on maintenance of the neutron cross section standards.

Complete the work through the CRP of the understanding of the covariances/variances obtained from the standards evaluation.

Finish the documentation of the standards evaluation process.

Begin the documentation of changes to EXFOR files based on the corrections obtained from the files of Poenitz and new information obtained from the CRP investigations.

Continue to recommend new measurements and perform examinations of the data from them for use in future evaluations of the standards.

Continue the collaboration with Ohio University and LANL on the measurement of hydrogen elastic scattering angular distributions.

Status:

- The work through the CRP was completed which led to the remaining standards and uncertainties being provided for the ENDF/B-VII library.
- The nuclear data standards activity of the NEA Working Party on International Evaluation Cooperation was coordinated. This activity (Subgroup 7) was completed and a final report was written.

- The IAEA CRP on the Improvement of the Standard Cross Sections was chaired during this year. The IAEA data development project on maintenance of the neutron cross section standards was used for the work associated with the documentation and publishing of the CRP evaluation of the standards.
- The work through the CRP on the understanding of the covariances/variances obtained from the standards evaluation was completed. The covariance data were provided for the ENDF/B-VII library.
- The documentation of the standards evaluation process was done through an NEA Subgroup report, the contribution to the special issue of Nuclear Data Sheets on the ENDF/B-VII evaluation and a nearly completed IAEA comprehensive report on the CRP evaluation process.
- The documentation of changes to EXFOR files based on the corrections obtained from the files of Poenitz and new information obtained from the CRP investigations has begun. Most of that data have been obtained in boxes from Idaho National Laboratory.
- We continue to recommend new measurements and perform examinations of the data from them for use in future evaluations of the standards. It is important to maintain this effort in preparation for the next standards evaluation. The hydrogen data from Indiana University has now been published and appears to resolve the problem in the 100-200 MeV energy region. New boron measurements are underway by Hamsch *et al.*, Giorganis *et al.* and Zhang *et al.* Measurements are underway also for lithium by Dewey *et al.*, Zhang *et al.* and Devlin *et al.* The preliminary $^{238}\text{U}(n,f)/^{235}\text{U}(n,f)$ measurements at n_TOF have led to new interest in the correct values of these ratios.
- Final data are being obtained for the hydrogen elastic scattering angular distribution at about 15 MeV neutron energy in a collaboration with Ohio University and LANL.

E. Nuclear Model Development

This task covers activities such as development and validation of nuclear reaction models used for prediction of nuclear reaction cross sections. The TUNL preequilibrium code will be incorporated into the LANL code. Measurements made by ANL and LANL along with other measurements made with DOE low-energy physics funds will play a crucial role in the validation of the models in these computer codes.

ANL – Continue an ongoing collaboration with IRMM to utilize experimental neutron activation data for gaining an improved understanding of nuclear model parameters.

ANL Planned Activities:

Assist IRMM in preparing publications to document completed work.

Status:

- This activity was completed.

BNL – We are active in nuclear reaction model development focusing on the BNL code EMPIRE. The work in this fiscal year will concentrate on further extensions and improvements of its capabilities, including a new version of the level densities with appropriate parameterization. The work on validation of the code will be actively pursued, in particular in relation to emerging requirements for homeland security applications. Close collaboration with LANL will continue focusing on validation of the fission models in EMPIRE and GNASH. Major effort will be dedicated to the development of capabilities for estimating covariance data for fast-neutron reaction cross sections.

In response to the needs of many user groups (such as Gen-IV reactors, criticality safety, Advanced Fuel Cycle Initiative), BNL will collaborate with LANL and ANL on a methodology for nuclear data covariances. To this end, a covariance module in EMPIRE for fast neutron energies should be developed and tested.

BNL Planned Activities:

Release new version of the code EMPIRE with above-mentioned improvements.

Develop the first version of covariance module in EMPIRE for fast neutrons.

Status:

- The EMPIRE-2.19 version (originally released in March 2005) was continuously updated in the CVS repository, though no official new release was made. The improvements include
 - Improved multi-modal fission with multi-humped barriers
 - Further improvement in the treatment of exclusive spectra
 - Calculations of prompt fission neutron spectrum including post-fission neutrons
 - Calculation of average number of neutrons per fission (ν -bar)
 - DWBA calculations on odd targets
 - Extension of MSD model to deformed nuclei
- The first version of the covariance module in EMPIRE for fast neutrons was developed in collaboration with LANL using their Bayesian code KALMAN.
- A study was completed, and published, to predict neutron induced fission cross sections on a set of Am isotopes. The aim was to provide independent information to T-16 group at LANL to validate their predictions by GNASH code.

LANL – Nuclear reaction theory calculations have played a crucial role in the evaluation of nuclear data, and will continue to play an important part in future evaluations due to the decrease in operating experimental facilities throughout the world. The LANL GNASH code has proved to be an important tool, and we will continue development of a new version of this code, McGNASH, to provide a state-of-the-art capability to predict reaction cross sections. This also involves a close collaboration with experimentalists at LANSCE to interpret new measurements using the GEANIE gamma-ray detector, as well as (n, charged-particle) data. These data will result in advances in our understanding of nuclear reaction mechanisms, and improvements in

our modeling codes. Also, largely under DOE/DP support, we will continue modernization of our R-matrix EDA code (used for light nucleus calculations and data evaluations) and explore implementation of exact particle-exchange formalism.

LANL Planned Activities:

Calculate and interpret gamma-ray reactions measured with GEANIE at LANSCE. A current area of research is understanding pre-equilibrium spin transfer physics, by studying residual nucleus gamma-ray decay cross sections as a “spin window”. We will complete the analysis of $n+^{90}\text{Zr}$ data by using quantum mechanical pre-equilibrium process, and the same procedure will be applied to ^{48}Ti data.

Collaborate with LANSCE experimentalists on the interpretation of new FIGARO measurements of prompt neutron spectra.

Perform radiative capture calculations in support of new DANCE detector capture measurements (depends on what data are first reported by DANCE experimentalists).

Obtain information on nuclear level densities on more fission product nuclei through $(n,x\gamma)$ and (n,n') reactions to extend our present measurements on ^{130}Te and ^{99}Tc .

Measure the fission neutron spectrum and $\bar{\nu}$ from neutron-induced fission of actinides with the FIGARO array for neutron energies from 1 to 100 MeV. The data will test the Los Alamos Model of neutron emission in fission.

Measure neutron-capture cross sections on radioactive nuclei at DANCE with the goal of deriving nuclear level densities for nuclei off stability from neutron capture resonances.

Develop a Monte Carlo method to calculate the fission neutron spectrum, taking account of sequential neutron evaporation from fission fragments. The calculation will be compared with the Los Alamos model that is widely used for the prompt fission neutron spectrum evaluations.

Status:

- The calculation and interpretation of the $^{48}\text{Ti}(n,n')$ reaction have been completed. A quantum mechanical calculation for the pre-equilibrium process improved an agreement with the GEANIE data. A Phys. Rev. C paper was prepared.
- Radiative capture calculations were performed for ^{234}U and ^{237}Np in the unresolved resonance region, and compared with DANCE experimental data.
- We have developed a new technique to calculate the radiative capture cross sections for deformed nuclei. The Hauser-Feshbach model was combined with the coupled-channels theory. The results were presented at the international conference in Cadarache/France.
- Hartree-Fock-BCS model was applied to calculate a direct/semidirect process, and the capture cross sections on nuclei off-stability were calculated.

TUNL – Ongoing work involves the development of preequilibrium nuclear reaction models, as well as the improvement and benchmarking the computer code PRECO. Specific tasks to be undertaken are difficult to predict because this is basic research, where the amount of effort required and the direction that will result is unknown ahead of time. Current plans involve completing preparations for a new release of PRECO, and extending model verification—and, where necessary, modification—as well as code benchmarking for (N,N) reactions to higher incident energies. This involves studying the incident energy dependence of the matrix elements for the residual interactions causing nuclear energy equilibration. Other tasks may be substituted based on emerging developments and user input.

TUNL Planned Activities:

New release of PRECO and its users manual.

An expanded dataset of spectra for (N,N) reactions at incident energies of 40 to 100 MeV.

Possible revisions to the models and/or global input set and thus to the code.

Status:

- DOE funding for this activity was discontinued.

F. Nuclear Reaction Data Measurements

The measurement of nuclear data is essential to provide data, which either cannot be calculated or cannot be calculated with sufficient accuracy for user applications. This activity is also essential to support and verify nuclear model development and application.

BNL – We are responsible for compilation of nuclear reaction data within the USNDP. It is very important for compilers to maintain an active contact with data producers so that they have up-to-date knowledge of measurement procedures and techniques including their advantages and drawbacks along with understanding of data uncertainties. This goal can be best achieved by taking part in nuclear data measurements. BNL will do so by devoting a relatively small effort, 0.1 FTE, to collaboration primarily with the LANSCE data measurement program at LANL.

BNL Planned Activities:

Participate in (n,n'γ) and fission neutron spectrum measurements at FIGARO at LANSCE.

Participate in the Lead-Slowing Down Spectrometer measurements on ultra-small targets, such as ^{235m}U(n,f), at LANSCE.

Participate in measurements of fission yields from U and Pu isotopes with a mass spectrometer at ILL, France.

Status:

- The NNDC staff member participated in the (n,n'γ) and fission neutron spectrum measurements at FIGARO at LANSCE.
- The NNDC staff member also participated in the Lead-Slowing Down Spectrometer measurement of ^{235m}U(n,f) at LANSCE.
- Our participation in measurements at ILL, France was cancelled.

LANL -- Nuclear data for fission products are important for a number of applications. This task is related to the evaluation activity described in Section VI.B.

LANL Planned Activities:

Measure and analyze prompt neutron emission following interactions of fast neutrons fission products such as strontium and barium isotopes. These measurements are gated on gamma rays from (n,n' γ) reactions.

Measure the fission neutron spectrum and $\bar{\nu}$ from neutron-induced fission of ^{239}Pu with the FIGARO array for neutron energies from 1 to 100 MeV. Collaborators include scientists from CEA (France).

Measure prompt gamma rays from neutron interactions with stable fission product nuclei, e.g. ^{124}Sn , with the goal of deducing partial reaction cross sections.

Measure the neutron capture cross section of $^{240,242}\text{Pu}$ at DANCE for neutron energies less than 200 keV.

Measure neutron capture cross section at DANCE on at least one radioactive isotope of importance to nuclear astrophysics.

Status:

- Strontium and barium isotopes samples were prepared. Measurements have not started yet.
- Data for ^{239}Pu fission neutron spectrum and average number of prompt neutrons have been taken at FIGARO, and analysis is in progress.
- Data have been taken in the GEANIE facility on ^{124}Sn , $^{203,205}\text{Tl}$ and ^{136}Xe , and analysis is in progress.
- Data for the neutron capture cross section of ^{237}Np , ^{240}Pu , ^{242}Pu ^{152}Eu have been completed at DANCE. Analysis of Pu data has begun.
- Data for the neutron fission cross-section of ^{237}Np have been finalized, and the data covariances were obtained.

LLNL Deliverables (funded with non-USNDP funds):

Neutron induced reaction measurements on one or more isomer targets.

Perform surrogate (n,n'), (n,2n), (n, γ) and (n,f) measurements on several nuclei with programmatic and/or astrophysical importance.

Status:

- Produced ^{237}U (n,f), (n,2n) and (n, γ) measurement using surrogate technique. Results published in Phys. Rev. C.

LBNL – In FY06, the support for ongoing nuclear data-related experimental activities provided for many years from DOE Low Energy Nuclear Physics funds was no longer available and it was drawn instead from Data Program funds. Such activities include measurements such as (α,γ) reaction cross

sections of interest in astrophysics, thermal-neutron cross sections using isotopically-enriched light nuclide targets, and cross sections of relevance to advanced fuel cycle data needs deduced using the surrogate-reaction technique.

Status:

- In collaboration with the Chemical Research Centre, Budapest, Hungary, thermal (n, γ) cross sections were measured for ${}^6,7\text{Li}$, ${}^{10,11}\text{B}$, ${}^{13}\text{C}$ and ${}^{15}\text{N}$.
- Measurements of the low-energy (α,γ) reaction cross section for ${}^{197}\text{Au}$ and (α,γ) reaction thick-target yields for ${}^{64}\text{Zn}$ and ${}^{63}\text{Cu}$ were completed and the publication of the results was submitted to Phys. Rev. C.
- Analysis of ${}^{238}\text{U}({}^3\text{He},\text{tf})$ experimental data available from an earlier 88" Cyclotron run performed by an LBNL, LLNL and Richmond University collaboration was started. This reaction is a surrogate for the ${}^{237}\text{Np}(\text{n},\text{f})$ reaction and the objective of this work is to benchmark the charge-exchange surrogate reaction at the LBNL experimental setup to enable its future use as a surrogate for (n,f) reactions of relevance to Advanced Fuel Cycle data needs. (${}^3\text{He},\text{tf}$) reactions on relatively stable even-Z targets can lead to important odd-Z fissioning systems.
- Participation in an IAEA-CRP on *New Applications of Prompt Gamma-ray Neutron Activation Analysis* was completed and contributions provided for the final report on that project.

G. Evaluation of Data Needed for Astrophysics

The objective of this activity is to support the nuclear data needs of the increasingly sophisticated simulations of astrophysical phenomena. The Astrophysics Task Force of the USNDP, presently chaired by ORNL, serves to improve communication and coordination of nuclear data evaluation activities relevant for studies in astrophysics.

ANL Planned Activities:

No activities planned for FY2006.

Status:

- Structure of states above the long-lived isomer in ${}^{186}\text{Re}$ that are of relevance to the ${}^{187}\text{Re}/{}^{187}\text{Os}$ cosmo-chronometer were studied using the ${}^{186}\text{W}(\text{d},2\text{n})$ reaction. Evaluations were initiated of the production (and destruction) cross-section of this isomeric state.

BNL Planned Activities:

No activity planned for FY2006.

LANL -- Participate in the USNDP effort to develop high-quality data for astrophysics calculations of nucleosynthesis. Make new calculated and evaluated results available to the wider astrophysics research community *via* the USNDP Astrophysics Task Force.

LANL Planned Activities:

Continue N-N analysis to energies above 50 MeV and provide evaluated n-p capture cross sections, rates, and covariance data.

Complete the re-analysis of $^{10}\text{B}+n$ reaction, using a re-constructed set of experimental data including covariance.

Complete neutron-rich fission barrier calculations, using new and improved multidimensional macro-micro fission model.

Improve neutron capture models to provide capture cross sections for nucleosynthesis network calculations.

Status:

- Extension of the N-N analysis up to 200 MeV was not completed, but covariance data were investigated.
- R-matrix analysis for $^{10}\text{B}+n$ has been completed.
- Axial-asymmetry shape-degree of freedom was included in the macroscopic-microscopic code.
- Fission potential energy surfaces for 5254 nuclei for more than 5 million shapes for each nucleus were calculated. Barrier heights were extracted, to be used in studies of the end of r-process, by use of water immersion techniques.
- A new neutron capture model was developed, which employs the microscopic nuclear structure model. This was applied to calculate neutron capture cross sections for tin isotopes.

McMaster University – Evaluate hydrogen and helium capture reactions on unstable proton-rich nuclei that are important for energy generation and element synthesis in stellar explosions, with a focus on reactions to be studied at radioactive beam facilities (e.g., TRIUMF-ISAC).

McMaster Planned Activities:

Evaluate the reaction rates of radiative proton capture on ^{26g}Al and ^{26m}Al .

Continue evaluations of rates of proton capture on ^{21}Na , ^{25}Al , ^{13}N , and the $^{18}\text{Ne}(\alpha,p)^{21}\text{Na}$ reaction, as experiments progress.

Status:

- Both the $^{26g}\text{Al}(p,\gamma)^{27}\text{Si}$ and the $^{40}\text{Ca}(\alpha,\gamma)^{44}\text{Ti}$ reaction rates are up to date as of June 2006. (The latter represents a change from the original goal of evaluating the $^{26m}\text{Al}(p,\gamma)^{27}\text{Si}$ reaction rate, since TRIUMF-ISAC has been unable to deliver ^{26m}Al beams. Meanwhile, the $^{40}\text{Ca}(\alpha,\gamma)^{44}\text{Ti}$ experiment is near completion and comprises the Ph.D. thesis of a McMaster student.) All published data on the other reactions listed above have been compiled and evaluated. The corresponding reaction rates have been calculated, and when suitable the computational software suite for nuclear astrophysics

(www.nucastro.org), created by ORNL, has been successfully used in fitting the rates.

ORNL – Evaluate capture reactions on radioactive proton-rich nuclei that are important for element synthesis and energy generation in stellar explosions.

ORNL Planned Activities:

Complete evaluations of proton capture on ^{18}F .

Continue assessments of capture reactions on p-rich unstable nuclides.

Develop software suite to determine astrophysical reaction rates from cross sections, S-factors, and nuclear structure data.

Status:

- The evaluations of $^{18}\text{F}(p,\alpha)^{15}\text{O}$ and $^{18}\text{F}(p,\gamma)^{19}\text{Ne}$ reactions were updated a final time to include latest information from a new FY06 measurement of $^{18}\text{F}(p,\alpha)$ at high energies. A paper on the latest measurements with the data evaluation has been published and was part of a completed Ph.D. thesis for a graduate student. A paper for the evaluations of the $^{18}\text{F}+p$ reactions has been submitted to PRC; a second paper describing the astrophysical implications of the new rate is in progress; numerous presentations and conference proceedings discussed this work, including the APS meetings and 9 invited international presentations.
- Two new ORNL measurements of $^{17}\text{O}+p$ reactions have the highest precision measurement of the energy of a new resonance that dominates the rates at temperatures of nova burning, as well as an excellent measurement of the resonance strength. The new measurement was combined with others in an evaluation, and a paper on this work has been submitted for publication and will be part of a Ph.D. thesis for a graduate student.
- Over forty ^{31}S levels in the $^{30}\text{P}(p,\gamma)^{31}\text{S}$ reaction relevant for novae have been investigated using data from a recent ORNL measurement of $^{32}\text{S}(p,d)^{31}\text{S}$ and an evaluation of all available information. A new reaction rate has been determined, and the astrophysical implications have been investigated. The work has been submitted for publication, and was part of a successful Ph.D. dissertation.
- Analyses of levels in ^6Be and ^8B have been made, relevant for thermonuclear burning in the Sun. These analyses are part of two different Ph.D. theses.

H. Reaction Data for RIA Target Design

Rare Isotope Accelerator facility design needs high-quality nuclear reaction data for target design. LANL will collaborate in order to provide key reaction cross-sections using theory calculations and measurements to evaluate the data.

LANL Planned Activities:

We aim to maintain important collaboration connecting with RIA community because of its importance in nuclear science, but effort is limited because of budget restrictions. However, we will continue to maintain a presence in the RIA planning community via participation in RIA meetings and workshops.

Status:

- Neutron capture calculations and fission barriers were done for some astrophysical important nuclides.

Appendix A

Nuclear Data Activities Funded from Sources Outside the Nuclear Data Program (Report FY06)

BNL – Additional support for the nuclear data work at the National Nuclear Data Center comes from two sources:

1. Elsevier supports the production of computer-generated photo-ready copy of manuscripts for the Nuclear Data Sheets.
2. DOE Nuclear Criticality Safety program, funded by DOE NNSA, supports the NNDC consultant services and its data development work on improved fission product evaluations.

LANL – Most of the nuclear data work is supported from funds other than the nuclear data program. The effort is in support of the ENDF-related work of nuclear model development, nuclear reaction evaluation and ENDF processing.

1. Nuclear weapons (ASCI program). This work supports the development of more accurate ENDF cross section databases for actinide fission fuels, light-nucleus thermonuclear fuels, and for reactions on important materials used for diagnostics (radiochemical reactions). Nuclear model code development, for both statistical and preequilibrium models, and for light R-matrix codes, is supported by this program, as is the development of the NJOY data processing code for providing data usable by Monte Carlo and deterministic transport codes in applications. The funding also supports physics research developments in nuclear reaction and structure theory (with a recent emphasis on nuclei and isomers away from stability), and fission theory. Data testing using integral benchmarks such as fast critical assemblies is used to validate the ENDF data.
2. AFCI (Advanced Fuel Cycle Initiative). This supports the development of improved nuclear data important for transmutation in the fast neutron energy region, as well as high-energy spallation models important for describing processes in the spallation target. Recent focuses have been improved ENDF data on minor actinides (ATW fuel), and lead and bismuth (target/coolant), as well as better intra-nuclear cascade codes for modeling neutron production and radionuclide production in the spallation target. This program also supports experimental nuclear reaction measurements at LANSCE for both fission and capture cross sections.
3. Nuclear criticality safety. This funding supports improved nuclear data important in criticality safety studies, such as uranium isotopes, as well as data on chlorine, aluminum,

etc. Data testing using critical assemblies and NJOY processing code development is also funded by the program

4. LANL LDRD. There are 3 LANL LDRD projects that support nuclear reaction data measurements.

LBNL – Members of the Isotopes Project have always been encouraged to spend a portion of their time working on experiments in the area of low energy nuclear physics. Post-doctoral associate spend 50% of their time working on experiments, primarily at LBNL facilities such as the 88” cyclotron, others a maximum of 20%. Measurements of (α,γ) reaction cross sections at low energies, of the half-life of ^{108m}Ag , and of total (n,γ) cross sections are ongoing. Plans also include PGAA elemental analyses in collaboration with researchers at the Budapest reactor, neutron activation analysis experiments using the 10^{10} n/s LBNL D+D neutron generator and participation in an IAEA inter-laboratory comparison of the PGAA analysis of cement standards using the LBNL neutron generator. Other plans will depend on the interests of new staff.

- The DOE low-energy nuclear physics funds that have supported these activities in the past were not available in FY06. See LBNL entry under “F. Nuclear Reaction Data Measurements” for accomplishments of the above type.
- The surrogate-reaction technique has the potential to provide valuable information about cross sections of relevance to advanced fuel cycle data needs. Such work is a current research priority for LBNL/LLNL/University of Richmond collaboration. DOE Low-Energy Nuclear Physics support was provided in FY06 for the preparation of a successful LBNL LDRD proposal that will enable the continuation of such measurements in FY07.

LLNL – NNSA supports most of the LLNL nuclear data activities. Slightly more than half of the support goes to nuclear data evaluation, nuclear data processing and nuclear data validation. The rest of the support is used for nuclear theory and modeling development.

McMaster – The nuclear data effort receives 0.5 FTE support from the Canadian research agency to evaluate A-chains/nuclides for ENSDF and to train/supervise summer students for compilation of experimental nuclear structure data for XUNDL

NIST – A variety of sources support nuclear data activities:

1. The Nuclear Data Verification and Standardization program has funding through the Commerce Department (NIST). This provides about half of the total support for the program.
2. NIST provides 1 FTE for interferometry work, which has yielded coherent scattering lengths (which provide scattering data) needed for neutron cross-section evaluations.

3. NSF provided 1 FTE for a graduate student to work on the interferometry experiments cited above.
4. NIST provided 1 FTE (75% experimental, 25% evaluation) for nuclear structure and decay data work. Much of this work also has applications in radioactivity standards and radiopharmaceutical studies.

ORNL – The nuclear data work is partly funded by the DOE-SC Low Energy Nuclear Physics program.

TUNL – The nuclear data work is partly funded by the DOE-SC Low Energy Nuclear Physics program through a TUNL/NCSU grant.

Appendix B

USNDP Organization (Report FY06)

Coordinating Committee (chair P. Oblozinsky, BNL)

Working Groups

- Nuclear Structure and Decay Data (chair C. Baglin, LBNL)
- Nuclear Reaction Data (chair T. Kawano, LANL)

Task Forces

- Nuclear Data for Astrophysics (chair M. Smith, ORNL)
- Nuclear Data for/from Rare Isotope Accelerators (chair T. Kawano, LANL)
- Nuclear Data for Homeland Security (chair D. McNabb, LLNL)

USNDP Work Plan for FY2008

This page was intentionally left blank.

Introduction (Work Plan FY08)

The work plan described in this document has been developed to cover work to be done by the United States Nuclear Data Program (USNDP) during fiscal year 2008 that begins on October 1, 2007. Previously, 8 work plans have been prepared for the data program covering fiscal years 2000 - 2007. This plan has been prepared in consultation with the members of the Coordinating Committee who represent the organizations participating in the program. Each Coordinating Committee member prepared a draft plan for his or her organization. Each contribution was integrated into a unified work plan. The draft plan was then circulated to the Coordinating Committee for comments and corrections before the final document was submitted to the Department of Energy.

As was the case in the work plan for FY2007, the tasks proposed by the various organizations were reviewed internally according to the following criteria which were developed considering the mission and goals outlined in past review panel reports and oversight committee discussions, and in consultation with the DOE program manager.

1. A task should meet one of the three program priorities:
 - a) Maintenance & update of information in the USNDP nuclear physics databases
 - b) Improvement in dissemination of the information contained in those databases to the user community;
 - c) Modernization of data evaluation software used by the program participants.
2. A task should be useful to at least one major user community.
3. A task should not duplicate effort within or outside the program.

The plan is divided into six major components. Specific tasks have been assigned to one of these components. They are as follows:

- I. NNDC Facility Operation
- II. Coordination
- III. Nuclear Physics Databases
- IV. Information Dissemination
- V. Nuclear Structure Physics
- VI. Nuclear Reaction Physics

The following section details the proposed work plan for FY2008, defining tasks, organizational responsibilities, and planned activities. It is envisioned that this document will serve as the basis for a performance review at the end of fiscal year 2008. Incorporated in the NNDC plan are three subcontracted part-time evaluators (E. Browne – LBNL, N. Nica – Texas A&M and C. Reich – Idaho).

The major challenge for the USNDP is the volatile funding situation. In FY06, the program lost a considerable portion, -6.6%, of the funding. At the moment of writing the present report, the FY07 funding for the US Nuclear Data Program was not yet known

The impact on the program is discussed below. The Workplan for FY2008 was prepared under the assumption that the President's Budget will be approved for both FY07 and FY08. This would imply modest 3.1% growth in FY08.

Table 5 summarizes the US Nuclear Data Program budget and metrics for previous years and provides projections for the current year FY2007 and for FY2008.

Table 5. US Nuclear Data Program metrics for FY 2001 – 2008, for definitions see p.3.

| Fiscal Year | USNDP Funding | Compilations | Evaluations | Dissemination (in thousands) | Reports | Papers | Invited Talks |
|--------------------|----------------------|---------------------|--------------------|-------------------------------------|----------------|---------------|----------------------|
| 2001 | | 7,139 | 334 | 667 | 21 | 25 | 22 |
| 2002 | \$4,890k | 6,159 | 300 | 799 | 23 | 40 | 22 |
| 2003 | \$4,932k | 4,975 | 260 | 966 | 27 | 40 | 23 |
| 2004 | \$5,015k | 6,241 | 276 | 1,212 | 35 | 36 | 43 |
| 2005 | \$5,437k | 6,623 | 422 | 1,642 | 72 | 59 | 42 |
| 2006 | \$5,099k | 4,936 | 318 | 1,863 | 47 | 60 | 48 |
| 2007* | \$6,901k | 4,825 | 339 | 2,183 | 63 | 47 | 52 |
| 2008** | \$7,114k | 4,835 | 340 | 2,458 | 63 | 47 | 52 |

*) President's Budget; includes \$1mil for AFC activities – not part of the projected metrics

***) President's Budget; includes \$1mil for AFC activities – not part of the projected metrics

AFC Activities. An important comment should be made on the Advanced Fuel Cycle activities. In response to the renewed interest in nuclear energy applications the President's Budget for both FY07 and FY08 includes \$1mil for AFC activities. These funds are subject to solicitation, opened also to laboratories outside the existing US Nuclear Data Program. The proposals are currently under review, therefore, the AFC funds are merely shown in the table, but they are not projected in the expected metrics for FY07 and for FY08. Likewise, with the exception of LBNL, AFC activities are not explicitly mentioned in the Workplan for FY08.

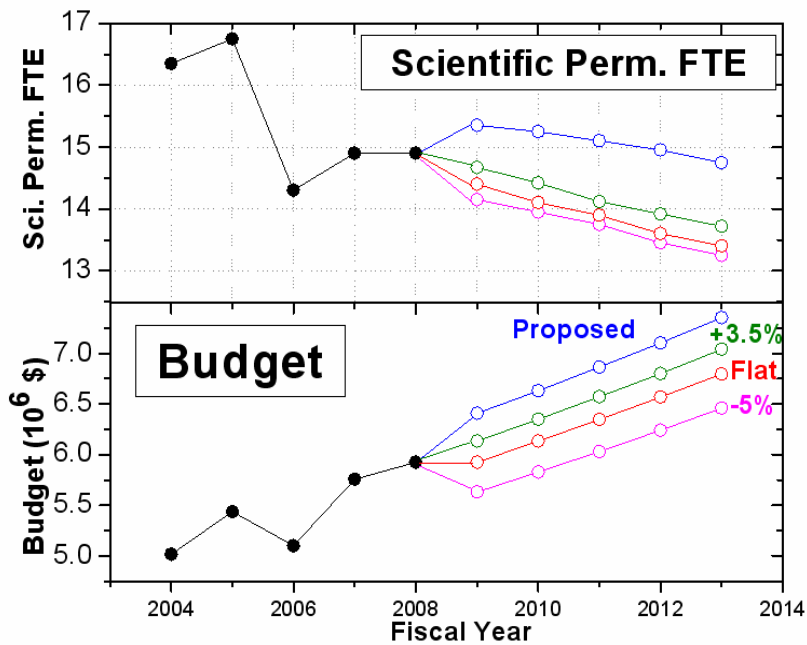
Table 6. USNDP scientific permanent effort: Projected levels in FY08 are compared with FY06.

| Activity | 2006 | 2008 | Comment |
|-----------------------------|--------------|--------------|--|
| I. NNDC Operation | 0.35 | 0.35 | Stable effort |
| II. Coordination | 1.55 | 1.33 | Some decrease |
| III. Databases | 1.05 | 1.05 | Stable effort |
| IV. Dissemination | 1.25 | 1.23 | Total effort increased from 3.10 to 4.68 FTE |
| V. Nuclear Structure | 5.57 | 6.49 | Scientific temporary decreased from 3.85 to 3.41 FTE |
| VI. Nuclear Reactions | 4.53 | 4.45 | Scientific temporary increased from 0.00 to 1.50 FTE |
| Total FTE scientific | 14.30 | 14.90 | Overall increase by ~ 4% |

Detailed FY2008 projection of staffing levels is given at the end of the present document. Here, we focus on the scientific effort, representing its most important aspect. Projected scientific permanent staffing levels in FY2008 are summarized in Table 6 where comparison with final FY2006 is made.

The DOE-SC supported scientific permanent effort is expected to increase by ~0.6 FTE or ~4% in FY08. This is due to a FTE increase in ANL (supporting a full FTE in 2008) and LBNL, where a post-doc in 2006 was converted to staff member in 2007. The number of post-docs in nuclear reactions will also increase, from none in 2006 to 1.50 FTE in 2008.

In FY06, the US Nuclear Data Program lost 6.6% of the funding, which as can be seen in the plot on the right, impacted the total number of scientific permanent FTE. It is expected that budget increases in FY07, FY08 and beyond (tentative projections for FY09-FY13 under different budget scenarios) would not be able to recover the FY06 loss. Continuing gradual reduction in the scientific permanent staffing level will have negative impact on the program, though this would be somewhat offset by more staff in the scientific temporary category. Individual laboratories foresee the following impact:



- **BNL.** The NNDC lost 1 FTE scientific permanent in FY06. This had negative impact on the maintenance of ENDF checking codes and ENDF-6 formats manual; slowed down the USNDP reporting; required adjustment in NSR bibliography compilation (offset by shifting compilation of 3 major European journals to the IAEA). The funding for FY07 is not yet clear, making it difficult to maintain the ongoing and to plan the future effort. The President's Budget for FY08 does not allow recovery of the FY06 losses.
- **ANL.** The proposed FY08 budget would allow maintain 1 FTE permanent staff effort at ANL, including a part-time post-doc.
- **LANL.** Due to budget cut in FY06, the LANL nuclear data group was not able to hire new Post-Docs. Without a new generation of staff for nuclear data measurements and evaluations the nuclear data activities will slow-down, representing a long-standing problem for the USNDP. The USNDP funding for FY07 and the President's Budget for FY08 would help to maintain LANL scientific activities as well as other DOE programs that require high quality nuclear data.
- **LBNL.** In FY07, ~0.5 FTE of ENSDF evaluation effort is being funded by LBNL from sources outside of the Data Program. The proposed FY08 budget for LBNL

further exacerbates this problem and it is liable to result in a loss of this ENSDF evaluation effort. In addition to the reduction of evaluation productivity, this could adversely affect the longer-term viability of the group.

- **McMaster.** McMaster University lost 0.5 FTE of DOE supported activity on June 30, 2006, implying discontinuation of nuclear astrophysics data evaluation effort at McMaster. McMaster applied for grant in December 2006 for 3-year period from July 2007 to June 2010 which includes astrophysics effort on a somewhat reduced level of 0.3 FTE, the structure component is increased to 0.6 FTE. We are waiting for the results of this grant proposal. Thus there is possibility of renewing the astrophysics evaluation effort at McMaster.
- **NIST.** The NIST Neutron Cross Section Standards effort would have to be discontinued if DOE funding is stopped. Maintaining this work is important for future standards evaluations that are the basis for cross section libraries. NIST resources that provide leverage to the DOE funding for this work are contingent on DOE support.
- **ORNL.** Due to budget cuts, the ORNL Nuclear Data Project has already lost 3 part-time participants (a consultant, a research staff member, and a graduate student) in the Nuclear Data project in FY06, and has already lost one additional part time participant (a research staff member) and 2 full time participants (a graduate student, a programmer) in FY07. Further development of the interface of ENSDF to RADWARE has already been terminated; the nuclear astrophysics online computational suite is at risk of being taken offline in FY07; and reaction evaluations for astrophysics have been reduced.
- **TUNL.** The nuclear modeling effort (0.4FTE) at TUNL lost the funding in FY06. Expected recovery of the funding in FY07 and FY08, still below the FY 2005 level, would allow increase in the ENSDF evaluation effort.

Work Plan Tasks and Planned Activities (Work Plan FY08)

I. NNDC Facility Operation (Work Plan FY08)

A. Management

This task includes planning, budgeting, personnel, interaction with BNL management, and interaction with funding authorities.

B. Library

NNDC maintains an archival collection of low- and intermediate-energy nuclear physics publications. This library supports the NNDC compilation activities and the U.S. nuclear reaction and nuclear structure data evaluation and international nuclear structure data evaluation effort.

C. Computer Operations

The NNDC operates several servers running Red Hat Enterprise Linux in support of their compilation, evaluation, database maintenance, and information dissemination functions. In addition, each staff member has a PC that supports an interface to these Linux servers and supports administrative functions such as word processing and email. Furthermore, MS Windows servers provide centralized backup, printing and file serving for the PCs. This task includes software upgrades, hardware and software procurements, machine operations and internal user support for both the Linux and Windows platforms.

BNL Planned Activities:

- Scan and remediate regularly vulnerabilities on NNDC servers and clients to ensure compliance with DOE cyber security requirements
- Provide computer support to the NNDC staff and its visitors as necessary.
- Move the secondary database server powering up the NNDC web site to ITD central computing facility to enhance services reliability.
- Improve the NNDC computer room and its operating environment by upgrading air conditioning system.

II. Coordination (Work Plan FY08)

A. National Coordination

ANL -- Chair the Measurement and Basic Physics Committee of the Cross Section Evaluation Working Group.

ANL Planned Activities:

Organize and chair the CSEWG Measurement and Basic Physics Committee.

BNL -- Chair USNDP Coordinating Committee, chair Cross Section Evaluation Working Group, develop USNDP work plan, and maintain its USNDP website.

BNL Planned Activities:

Prepare FY2009 work plan for USNDP in time for spring 2008 FWP submittals.

Organize and chair CSEWG Meeting at BNL in November 2007.

Organize and chair USNDP Meeting at BNL in November 2007.

Edit and publish summary reports of the CSEWG and USNDP meetings.

Edit and publish USNDP Annual Report for FY2007.

Maintain CSEWG and USNDP websites.

LANL -- Chair U.S. Nuclear Data Program's Nuclear Reaction Working Group and help coordinate nuclear reaction data work at different labs to advance USNDP; chair Evaluation Committee of the Cross Section Evaluation Working Group.

LANL Planned Activities:

Organize and chair CSEWG Evaluation Committee meeting at BNL, November 2007.

Organize and chair Nuclear Reaction Working Group meeting at USNDP meeting in November 2007, and help coordinate Homeland Security, Astrophysics, and RIA Task Forces.

LBNL -- Serve as a member of the USNDP Coordinating Committee and chair the USNDP Nuclear Structure and Decay Data Working Group in addition to overseeing, coordinating, and directing the work of members of the Isotopes Project. The latter effort includes working with LBNL management, with other members of the USNDP, and with the program officers of the DOE.

LBNL Planned Activities:

Organize and chair Nuclear Structure and Decay Data Working Group meeting at USNDP meeting, November 2007.

Serve on USNDP Coordinating Committee.

LLNL -- Chair the Task Force on Nuclear Data Needs for Homeland Security of the Cross Section Evaluation Working Group.

LLNL Planned Activities:

Organize and chair the CSEWG Task Force on Nuclear Data Needs for Homeland Security.

ORNL -- Chair the Astrophysics Task Force, and help facilitate and coordinate nuclear astrophysics data work at different labs to advance USNDP goals; provide leadership in planning future activities in nuclear data for nuclear astrophysics

ORNL Planned Activities:

Summarize USNDP efforts in nuclear data for nuclear astrophysics at USNDP Meeting in November 2007

Communicate current efforts and future plans with researchers in nuclear astrophysics data.

Represent USNDP nuclear astrophysics efforts at international collaboration meetings on nuclear astrophysics data.

Initiate collaborative research projects to raise the visibility of nuclear data projects directed at astrophysics applications

Discuss future plans in nuclear astrophysics data with DOE, with USNDP/NNDC, and with other agencies.

B. International Coordination

ANL - Represent the ANL in IAEA-sponsored Nuclear Structure and Decay Data Network (NSDD) and Decay Data Evaluation Project. Participate in IAEA-sponsored coordinated research programs (CRP) and training workshops.

ANL Planned Activities:

Participate in IAEA CRP on “Updated Data Library for Actinides”.

BNL -- Represent the United States in IAEA-sponsored Nuclear Reaction Data Center Network (NRDC) and Nuclear Structure and Decay Data Network (NSDD). The NNDC center head is the U.S. member and vice-chair of the IAEA’s International Nuclear Data Committee (INDC), the lead US member of the NEA Working Party on International Evaluation Cooperation (WPEC) in his position as chair of CSEWG. Many of the NNDC staff participates in IAEA/ICTP-sponsored activities such as Workshops and Technical Meetings.

BNL Planned Activities:

Participate in the IAEA-sponsored NRDC meeting in 2008.

Participate in NEA WPEC annual meeting in 2008.

Serve as coordinator of the WPEC Subgroup 24 on fast neutron cross-section covariances.

Provide lecturer to the IAEA/ICTP workshop on nuclear reaction data (if organized).

LANL -- Participate in and chair international nuclear reaction data collaborations. This insures that the U.S. benefits from breakthroughs around the world, and plays a leadership role in new developments. LANL staff members participate in NEA/WPEC committees on covariance data and international model code development cooperation. LANL will host visits by foreign scientists with international reputations to benefit from the exchange of information and ideas.

LANL Planned Activities:

Participate in the International Program Committee to plan the next International nuclear data conference (ND2007), to be held in Nice, France, April 23-26, 2007.

Participate in NEA-WPEC 2007 meeting.

Participate in relevant IAEA CRP meetings (RIPL-3).

Make latest version of NJOY data processing code available to the international community.

Host a couple of international visitors to LANL to collaborate on the evaluation of reaction data.

LBNL – Participate in IAEA-sponsored training workshops, planning meetings and coordinated research programs on nuclear structure and decay data.

LBNL Planned Activities:

Continue participation in IAEA CRP on “Reference Database for Neutron Activation Analysis”

Participate in IAEA/ICTP nuclear structure and decay data evaluation training workshop if one is scheduled during FY08.

McMaster Planned Activities:

Participate in the discussions of spin-parity assignment rules and other policy matters related to the NSDD network.

Participate in training/mentoring of new ENSDF evaluators through collaborative work, as needed and as the opportunity arises.

III. Nuclear Physics Databases (Work Plan FY08)

A. Nuclear Science References (NSR)

The NNDC is responsible for NSR, the bibliographic database for nuclear physics research. This task includes quality control, file update and maintenance, and file distribution to collaborators. Updates are done on a continuing basis. The preparation of NSR entries is given under Nuclear Structure Physics.

BNL Planned Activities:

Database distributed to collaborators monthly.

B. Experimental Nuclear Structure Data (XUNDL)

The NNDC is responsible for maintaining and providing access to the XUNDL database. This database contains compilations (in ENSDF format) of recently published or completed level-structure data for high-spin and low-spin physics. The compilation work is mainly carried out at McMaster University. The McMaster group also coordinates this work with that of other centers. The NNDC updates the database as new/revised data sets are received from McMaster.

BNL Planned Activities:

Update database as input is received from McMaster.

C. Evaluated Nuclear Structure Data File (ENSDF)

The NNDC is responsible for the ENSDF, a database of evaluated experimental nuclear structure and decay data. The NNDC is responsible for format and content checking, preparation of manuscript, and the quality control (review) of evaluations submitted for inclusion. The NNDC maintains the database, which includes database updates and distribution to collaborators. Corrections are implemented on a continuing basis.

BNL Planned Activities:

Database distributed to collaborators twice a year.
Process evaluations received from NSDD evaluators.

D. Numerical Nuclear Data File (NuDat)

The NNDC is responsible for NuDat, which consists of a database and a suite of codes that access it, allowing web users to search for level and γ -rays properties extracted from ENSDF, ground and meta-stable state properties (Wallet Cards), atomic and nuclear radiations derived from ENSDF, and thermal neutron cross sections and resonance integrals. Additionally, NuDat contains an interactive Chart of Nuclei and interactive level schemes.

BNL Planned Activities:

Update NuDat database as necessary, about 10 times a year.

E. Neutron Reaction Data Bibliography (CINDA)

The NNDC continues to contribute to the CINDA database that contains references to nuclear reaction data in the published and unpublished literature. Since 2004, CINDA also contains bibliography information on charged-particle and photonuclear reactions. The database serves as an index to the data contained in the experimental database, CSISRS. The database is maintained by the Nuclear Data Section, IAEA Vienna.

BNL Planned Activities:

Contribute to CINDA by compiling experimental cross-section data to the CSISRS database (200 compiled papers expected).

F. Experimental Reaction Data File (CSISRS)

The NNDC is responsible for maintaining the CSISRS database at BNL. This database contains experimental nuclear reaction data for incident energies below 1 GeV, including neutron-induced reactions and reactions with incident charged particles of mass $A \leq 12$. Many groups worldwide compile experimental data and send it to the central database in Vienna in the EXFOR format. Then, each is responsible to update its own database. The effort described here includes quality control, file update and data transfer activities. The NNDC database is updated, as compilations are exchanged and checked from the compiling centers. The compilation activity is given under Nuclear Reaction Physics.

BNL Planned Activities:

Update CSISRS with EXFOR compilations from cooperating centers (500 expected).

G. Evaluated Nuclear Data File (ENDF)

The NNDC is responsible for ENDF, a database of evaluated nuclear data required for many nuclear applications. The work is organized under the Cross Section Evaluation Working Group (CSEWG), coordinated by the NNDC. The ENDF file contains complete descriptions of nuclear reactions of neutrons with many nuclides and elements for energies up to 20 MeV and radiations from radioactive decay. A number of evaluations for energies up to 150 MeV and for incident charged particles and photons are also included. The data are stored in the ENDF format developed at NNDC about 35 years ago, and adopted as an international standard. In addition to the U.S. library, ENDF/B, the database contains evaluated data libraries from the European Union, Japan, Russia, and China. This activity includes the processing and quality control for the U.S. ENDF/B library, the distribution of this database in the United States and the exchange of libraries internationally.

New evaluations for the next release of the library, ENDF/B-VII.1, will be assembled, tested and made available to users through a preliminary ENDF/A web interface.

BNL Planned Activities:

- Maintain ENDF discussion list to facilitate validation of new ENDF/B-VII.0 library.
- Collect and maintain new evaluations submitted for future release of the ENDF/B-VII library.
- Perform phase I testing of all new evaluations for the ENDF/B-VII.1 library.

H. Database Software Maintenance

This activity includes software bug fixes and enhancements for the six nuclear physics databases maintained by NNDC.

BNL Planned Activities:

- Re-write the selector generation program for NSR.

I. Database Systems Development

The multi-year effort to migrate the USNDP databases to a LINUX/SYBASE environment was completed in FY2004. Afterwards, several follow-up tasks should be performed.

A new web interface, complementary to the existing one, should be developed to facilitate the retrieval of experimental data in CSISRS by non-ENDF users, such as nuclear astrophysics. This interface should focus on the relevant experimental data, such as a full reference to the publication, a comprehensive reaction description and the experimental data. The existing interface, giving access to the complete compilation (with more details than the reference, reaction and data) will be retained and will still be accessible to users who need it. Also, a new ENDF interface should be developed for users who do not possess specialized knowledge of ENDF-6 format.

BNL Planned Activities:

- Continue development of journal tracking database in support of NSR compilation.
- Maintain new CSISRS web interface for users without specialized knowledge of ENDF.
- Maintain and improve Sigma web interface for users without specialized knowledge of ENDF format.

IV. Information Dissemination (Work Plan FY08)

The goal of the dissemination activities of the USNDP is to provide scientists and engineers with nuclear data from the USNDP-maintained nuclear databases in a variety of user-friendly formats and media.

A. Web Site Maintenance

The NNDC provides electronic access to the nuclear physics databases that it maintains on behalf of the USNDP as well as access to other nuclear physics information through its web site. The NNDC web services are powered by four 2.8 GHz dual-processor Dell servers running on the Linux operating system and using the Apache Tomcat and Sybase server software. This solution was made public in April 2004 and has proven to be secure, fast and to have minimum downtime. Most of the databases were redeveloped to take advantage of the new hardware possibilities as well as new programming technologies, such as the use of the Java and Java scripts languages. In FY 2005 this system was upgraded from a single web server to dual web server system. This upgrade significantly increases reliability of the system. The NNDC also maintains the Atomic Mass Data Center website. Other USNDP members also offer nuclear physics information through their websites. These services require resources to maintain currency and improve performance.

ANL Planned Activities:

- Maintain and upgrade the ANL/NDM report series web site.
- Maintain and upgrade Experimental Resources for Nuclear Data web site.
- Maintain and upgrade ANL Nuclear Data Information web site.

BNL Planned Activities:

- Improve NSR and ENSDF web interfaces.
- Maintain web interface to the ENDF database.
- Improve web interface for double-beta decay.
- Improve reliability and cyber security of its web services by installing the latest version of Apache/Tomcat servers and mod-jk2 connector software for a new dual web server system.
- Maintain currency of the CSEWG, USNDP and the NNDC web sites.
- Investigate Google search to support compilation of NSR.
- Explore possibility for a nuclear astrophysics webpage in collaboration with JINA.

LANL Planned Activities:

- Include access to new reaction and structure data evaluations, supported by DOE/Nuclear Physics, via the T-16 web site.
- Provide actinide ENDF/B-VII data via LANL web site for criticality data testing, together with other LANL evaluations (e.g., light nucleus reactions).

LBLN Planned Activities:

Maintain existing web pages and support the Isotope Explorer 2 and 3 software previously developed by LBNL.

LLNL Planned Activities:

Maintain LLNL's Nuclear and Atomic Data Viewer.

Add search capability to the Nuclear and Atomic Data Viewer.

Extend the Nuclear and Atomic Data Viewer as per user requests.

Maintain and upgrade LLNL's Computational Nuclear Physics web pages.

ORNL Planned Activities:

Development and maintenance of our online software suite to convert nuclear data to astrophysical reaction rates and plot, manipulate, and share results online is at severe risk of termination

Efforts to regularly update nucastrodata.org html web pages is at risk of termination

TUNL Planned Activities:

Continue to improve the TUNL website and provide access to new information on $A = 3 - 20$ nuclei.

Continue to prepare new PDF and HTML documents of the most recent TUNL reviews.

Continue to provide PDF and HTML documents for FAS reviews for the $A = 3 - 20$ series;

Continue to provide General Tables to accompany the most recent TUNL reviews of the $A = 3 - 20$ series;

Continue to provide Energy Level Diagrams (in GIF, PDF and EPS/PS formats) to accompany the PDF and HTML documents for the most recent TUNL reviews and preliminary reports, and for the earlier FAS reviews.

B. Customer Services

This task accounts for the non-electronic services which the USNDP renders to customers. At the scientific staff level, this means direct assistance to users needing advice from nuclear data experts or advice on solving complex queries *via* electronic access to the database. The NNDC staff allocation at the support level is for maintaining a "help desk" and for administrative/clerical support of its customer services.

This task accounts for the non-electronic services which the USNDP renders to customers. At the scientific staff level, this means direct assistance to users needing advice from nuclear data experts or advice on solving complex queries *via* electronic access to the database. The NNDC staff allocation at the support level is for maintaining a help desk and for administrative/clerical support of its customer services.

BNL Planned Activities:

Effort required to provide technical support to users as necessary.

Extend Comments/Questions option for all reaction databases.

C. Publications

The USNDP provides some paper publications as well as electronic access to the nuclear physics databases that it maintains. This includes the Nuclear Data Sheets published by Elsevier and various versions of the Nuclear Wallet Cards.

BNL Planned Activities:

Prepare twelve issues of Nuclear Data Sheets for publication

Investigate a publication of adopted levels and gammas of all nuclides in ENSDF in electronic form (web and CD-ROM).

V. Nuclear Structure Physics (Work Plan FY08)

A. NSR Abstract Preparation

The literature search and preparation of KEYWORD abstracts for publications included in NSR require scientific expertise.

BNL continues to have an overall responsibility for this database. The IAEA is expected to provide approximately 30% of the keywords. These will be checked and edited by BNL as necessary before being added to the database.

BNL Planned Activities:

Prepare entries for 4,000 new references, and keyword abstracts for 2,500 of them.

Check and edit approximately 1,000 key-worded abstracts (Nucl. Phys. A, Eur. Phys. J. A, and Phys. Lett. B) prepared at the IAEA Nuclear Data Section.

B. Compilation of Experimental Structure Data

This activity involves compilation of recently published or completed experimental nuclear structure data for inclusion in XUNDL.

BNL Planned Activities:

Compile BE(2) experimental data.

Compile $\beta\beta$ -decay experimental data.

McMaster Planned Activities:

Compile data sets (in ENSDF format) for current experimental nuclear structure publications on high-spin and low-spin physics. Prominent journals in Nuclear Physics will be scanned regularly for new papers.

Review compiled data sets submitted by other data centers prior to inclusion in the XUNDL database.

Communicate with the authors of the original papers for data-related problems and to request additional details of unpublished data. On a timely basis send a copy of all such private communications to NNDC for archival and distribution purposes.

Train a new undergraduate student in early 2008 for XUNDL compilation work.

C. Data Evaluation for ENSDF

The USNDP evaluates nuclear structure and decay data for inclusion in the ENSDF database. This effort includes the critical analysis of all available experimental nuclear structure and radioactive decay data for a nucleus or group of related nuclei to deduce recommended values from the measured data and prepare a file in ENSDF format that will be the basis for a publication in “*Nuclear Data Sheets*” and will be used to update the contents of the USNDP nuclear structure and decay database, ENSDF. The US effort is supplemented by foreign contributions prepared under the auspices of the IAEA-sponsored international Nuclear Structure and Decay Data network.

ANL Planned Activities:

- 2 equivalent mass chains will be evaluated and published.
- At least two mass chains will be reviewed.
- Collaborate with scientists from new NSDD data centers on evaluation projects.
- Complete the horizontal evaluation on nuclear K-isomers and initiate drafting of a final publication.

BNL Planned Activities:

- At least 6 equivalent mass chains will be evaluated.
- At least 6 mass chains will be reviewed.
- Continue mentoring of new ENSDF evaluators.

LBNL Planned Activities:

- Evaluate the equivalent of at least 4 mass chains, including a minimum of one from the $A=26-30$ region. In the course of this, an attempt will be made to identify specific needs of the nuclear structure community and tailor some evaluation activities to meet those needs (*e.g.*, specific isotope evaluations in neutron-rich regions).
- Review mass-chain evaluations, as requested.

McMaster Planned Activities:

- 1.5 equivalent mass chains (including the $A=31-44$ region) will be evaluated.
- Mass chains will be reviewed as requested.
- Update ENSDF for the identification of new nuclides and for the first publications on the findings of the excited states of nuclides.
 - This activity will partially replace our updating of SD structures in nuclei where not much new data are now reported.
- Collaboration with a new center/evaluator as part of mentoring process, as needed

ORNL Planned Activities:

- Complete evaluation of structure information for nuclei with $A=245$ and 152 .
- Review one mass chain evaluation.

Continue evaluation of A=58 in collaboration with McMaster Univ.

TUNL Planned Activities:

Prepare the ENSDF files corresponding to new publications in the “Energy Levels of Light Nuclei” series.

D. Ground and Metastable State Properties

The NNDC maintains a database of nuclide properties for the Nuclear Wallet Cards.

BNL Planned Activities:

Update database as new information becomes available.

E. Radioactive Decay Data Evaluation

Decay data for nuclides of importance for metrology are evaluated in an international collaboration. When complete, these evaluations will be entered into the ENSDF format, merged into the ENSDF database and made available to ENSDF evaluators. In the United States, E. Browne (LBNL) coordinates this project at no cost to the US Nuclear Data Program.

ANL Planned Activities:

Evaluation of two radionuclides will be carried out as a part of the ANL contribution to the IAEA CRP on “Updated Decay Data Library for Actinides” and the DDEP collaboration.

Reviews of selected nuclides will be performed.

McMaster Planned Activities:

Evaluate or review decay datasets for one or two radionuclides.

F. Neutron-Induced γ -Ray Data Evaluation

The EGAF (Evaluated Gamma-ray Activation File) database, disseminated by the IAEA and maintained by LBNL, currently provides discrete-line prompt γ -ray information from thermal (n,γ) reactions in a format tailored to suit the needs of the neutron activation analysis community. However, it requires ongoing maintenance and development to make it more useful to the applied communities it serves. Statistical-model calculations can generate quasi-continuum photon cascade data to complement these experimental discrete-line data. Together, the experimental and calculated data will constitute a valuable resource required for updating the ENDF database. Additionally, delayed photon data need to be added to EGAF. The k_0 -value database currently used by the neutron activation analysis community needs to be assessed and compared with the corresponding decay information in ENSDF, and the resulting evaluated k_0 values then need to be integrated into EGAF and, ultimately, made available to ENSDF evaluators.

LBLN Planned Activities:

Continue the following activities outlined in the FY07 Work Plan with a view to maintaining and developing the EGAF database:

- (i) Continue collaboration with LLNL (see also Section VI. B, LLNL entry) to perform statistical-model calculations of quasi-continuum γ -ray cascade information; in FY07, these calculations will be extended to the heavier elements. This project also includes supervision of a doctoral student at LLNL who is generating ENDF-format capture γ -ray datasets for use with MCNP and other transport-code calculations.
- (ii) Add to EGAF the neutron-capture decay data produced in the course of participating in the IAEA CRP on “Reference Database for Neutron Activation Analysis” (FY09 completion date for CRP); in FY07, the initial evaluation of k_0 values will have been presented to the CRP.
- (iii) Add any new thermal (n,γ) data that become available, along with any total radiative-capture cross-sections derived from them.

G. Evaluation of Light Nuclei for *Nuclear Physics A*.

TUNL evaluates additional data not included in ENSDF for publication in *Nuclear Physics A* and on its web site

TUNL Planned Activities:

Prepare “*Energy Levels of Light Nuclei, A = 11 - 12*” manuscript for publication in *Nuclear Physics A*.

Evaluate nuclei in the $A = 13 - 15$ mass region in preparation for a future “*Energy Levels of Light Nuclei, A = 13 - 15*”.

H. Nuclear Structure Data Measurement

ANL - ANL will devote a relatively small effort (0.1 FTE) to participate through collaborative agreements in nuclear physics research activities related to nuclear data needs. The emphasis will be on data measurements aimed at providing answers to specific questions that arise from recent nuclear data evaluations and at improving the quality of existing databases in specific areas, such as (but not limited to) decay data of minor actinides and neutron-rich fission products

ANL Planned Activities:

Complete decay data measurements on ^{243}Cm , ^{233}Pa , ^{237}Np as a part of the ANL commitment to the IAEA-CRP on “Updated Decay Data Library for Actinides”

Participate in the development of the Argonne Total Absorption Spectrometer (ATAS) and the corresponding infrastructure at ANL for analysis, compilation and evaluation of decay data for neutron-rich fission products.

LANL/LANSCE maintains a small program to measure nuclear decay information.

LANL Planned Activities:

Examine prompt gamma-ray emission data from neutron reactions on Xe and Kr isotopes, and photo-induced reactions on ^{56}Fe to search for previously unobserved transitions in these and other, nearby residual nuclei.

Interact with mass chain evaluators on the nuclear structure of these nuclei.

LBL – to promote a closer working relationship with the nuclear structure community, LBNL will devote a small effort (~0.1 FTE) to participation in local nuclear structure experimental work.

LBL Planned Activities:

Participate in local nuclear structure experiments with an emphasis on topical issues and data needs such as AFC-related measurements or nuclear structure experiments on nuclei far from stability.

I. ENSDF Physics and Checking Codes

The NNDC maintains ENSDF checking and physics programs on behalf of the national and international evaluator networks

BNL Planned Activities:

Maintenance and upgrades for format changes as required.

Continuing development of ENSDF editor as well as Java versions of LOGFT, ALPHAD and FMTCHK.

VI. Nuclear Reaction Physics (Work Plan FY08)

A. Experimental Data Compilation

The NNDC, as part of a larger international cooperation, has responsibility for compiling experimental nuclear reaction data that have been produced in the U.S. and Canada.

Incident neutron reactions have been well covered historically. NNDC thus concentrates on new measurements, but continues compilations of earlier publications that have not been included in the CSISRS database.

Since incident charged particle data have not been completely compiled in the past, NNDC is compiling new charged-particle measurements. In addition, because of emerging needs such as astrophysics, the NNDC is compiling older data. Hence, there is a larger staff commitment to compiling this type of data.

BNL Planned Activities:

Compile experimental data from 200 charged particle and neutron reaction publications.

B. ENDF Evaluations

Evaluated nuclear reaction data, for applications and for basic science needs, are stored in the ENDF database, which is maintained by BNL. As chair of the CSEWG evaluation committee, LANL staff works with BNL to insure quality control, particularly for new evaluations. New evaluations funded primarily from other sources are prepared for archival in the ENDF library. BNL, LANL, LLNL and ORNL provided neutron, proton and photonuclear reaction data evaluations for ENDF/B-VII released in FY2006. LLNL develops a computer code that translates LLNL evaluations in the internal ENDL format into ENDFB-6 formatted data so that LLNL evaluations can flow back into the nuclear data community.

ANL Planned Activities:

No work planned for FY2008.

BNL Planned Activities:

Respond to user needs for evaluated nuclear reaction data.

Collect and address users' feedback related to the ENDF library.

Work with LANL on upgraded evaluations for future release of the ENDF/B library (version VII.1).

Improve methodology for providing covariance data, in the fast neutron energy region, to the next release of ENDF.

LANL Planned Activities: (work mostly supported from other sources)

Upgrade the LANL ENDF evaluations for U, Pu, Am, Np isotopes that perform well in criticality benchmarks, considering new LANSCE experimental data.

Provide upgraded ENDF evaluated data files for charged-particle reactions having $A \leq 10$, including covariance data. Continue to study a problem on oxygen, which is reported by criticality benchmarks.

Re-evaluate Ti data, for which problems in the criticality benchmarks are reported..

Submit the covariance data for several important actinides, as well as for light elements, in the fast energy region (this is supported by many projects including AFCI, criticality safety, and also a WPEC collaboration).

Provide new delayed neutron data that include neutron spectra, yields, and delayed gamma-ray data.

LBNL – LBNL has recently initiated a new program to use surrogate reactions to deduce reaction cross sections which are of importance to Advanced Fuel Cycle (AFC) programmatic needs (a national priority). This is collaboration between the nuclear structure and nuclear reaction groups at LBNL and outside groups at LLNL and the University of Richmond that is currently funded from outside of the DOE Data Program. The LBNL group will lead a series of benchmarking experiments to test the applicability and accuracy of these new techniques for deducing cross sections of importance to AFC and the s-process. It is anticipated that this activity will provide nuclear reaction data measurements of importance to the Data Program.

LBNL is collaborating with the Budapest Reactor Centre in the measurement, using isotopic-enriched targets, of selected thermal (n, γ) cross section data to supplement earlier elemental target measurements from which important information was either lacking (*e.g.*, data from low-abundance isotopes) or discrepant.

LBNL Planned Activities:

Continue to perform (n, γ) cross section measurements at thermal energies in collaboration with the Budapest Research Centre.

Complete measurements (begun in FY07) of (n, γ) cross sections using thermal and 2.5 MeV neutrons from the LBNL neutron generator (in collaboration with NRC Negev, Israel)

LLNL Planned Activities: (work mostly supported from other sources)

Perform new evaluations as per customer requests and submit these and other LLNL generated evaluations into ENDF.

Produce ENDF files with the discrete and quasi-continuum gamma-ray spectra in collaboration with LBNL using data in EGAF database.

Add capability to fete to translated ENDF covariance data and propagate these data into calculations of benchmark quantities using Monte-Carlo techniques.

Test LLNL translation and processing codes that use new structure rich nuclear data format. Extend format to include elements of ENDF evaluated data format.

C. ENDF Manuals and Documentation

The NNDC is responsible for maintaining the format and procedures manual for the ENDF system. We also produce the documentation supporting the contents of the ENDF/B library.

BNL Planned Activities:

Maintain ENDF-6 formats manual that is available on the web and prepare major update of the manual. This format is used for the ENDF/B-VII release.

D. Nuclear Reaction Standards

Nearly all nuclear reaction data measurements are made relative to some reaction standard such as the hydrogen elastic cross section. Maintaining accurate current values for the standard cross sections is the objective of this task, which can be accomplished only through international cooperation. A new international evaluation of the neutron cross section standards was done to provide the improved standards that are needed. This evaluation was largely performed by an IAEA Coordinated Research Project (CRP) with support, primarily experimental in nature, through the Working Party on International Evaluation Cooperation (WPEC) of the Nuclear Energy Agency and CSEWG.

ANL Planned Activities:

No work planned for FY2008.

LANL Planned Activities:

Participate in the international effort to reevaluate the light-element standard cross sections with LANL leadership for H, Li and B, and investigate the nature of output covariance data from R-matrix analyses of systems containing the light-element standard cross sections.

Incorporate the cross section standards into the new ENDF evaluations, and perform validation tests with integral measurements.

Measure cross sections for the standards reaction ${}^6\text{Li}(n,\alpha)$ from 1 to 5 MeV to provide improved data for R-matrix analysis.

Study covariance data evaluation for the standards in a different technique when the R-matrix analysis gives extremely small uncertainties.

NIST Planned Activities:

Participate in the IAEA data development project on maintenance of the neutron cross section standards so that standards will be available for future cross section libraries.

Finish detailed documentation for the standards evaluation process.
Continue the documentation of changes to EXFOR files based on the corrections obtained from the files of Poenitz and new information obtained from the CRP investigations.
Continue to recommend new measurements and perform examinations of the data from them for use in future evaluations of the standards. Encourage measurements by submitting standards for the WPEC High Priority Request List.
Submit for publication the collaborative measurements with Ohio University and LANL on the measurements of the hydrogen elastic scattering angular distributions. Consider additional standards work with the collaboration.
Continue to acquire and monitor samples in the National Repository for Fissionable Isotope Mass Standards. Also make these samples available for loan in physics experiments.
Continue work on a measurement of the ${}^6\text{Li}(n,t)$ standard cross section standard at ~ 4 MeV neutron energy using improved fluence determinations based on calorimetry, nu-bar of ${}^{252}\text{Cf}$ and α - γ coincidences with the ${}^{10}\text{B}(n,\alpha\gamma)$ reaction.
Continue efforts to improve the ${}^3\text{He}(n,p)$ standard cross section using spin-dependent n- ${}^3\text{He}$ coherent scattering length work.

E. Nuclear Model Development

This task covers activities such as development and validation of nuclear reaction models used for prediction of nuclear reaction cross sections. The two major codes are GNASH (LANL) and EMPIRE (BNL). Measurements made by ANL and LANL along with other measurements made with DOE low-energy physics funds will play a crucial role in the validation of the models in these computer codes. BNL and LANL will also participate in the IAEA Coordinated Research Project RIPL-3 to improve accuracy and reliability of input parameters used in nuclear reaction calculations

ANL Planned Activities:

No work planned for FY2008.

BNL – We are active in nuclear reaction model development focusing on the BNL code EMPIRE. The work in this fiscal year will concentrate on further extensions and improvements of its capabilities, including a new version of the level densities with appropriate parameterization. The work on validation of the code will be actively pursued, in particular in relation to emerging requirements of homeland security applications. Close collaboration with LANL will continue focusing on validation of the fission models in EMPIRE and GNASH. Major effort is dedicated to the development of capabilities for estimating covariance data for fast-neutron reaction cross sections.

In response to the needs from many user groups (such as Gen-IV reactors, criticality safety, Advanced Fuel Cycle Initiative), BNL will collaborate with LANL and ANL on a methodology for nuclear data covariances. To this end, a covariance module in EMPIRE for fast neutron energies should be developed and tested.

BNL Planned Activities:

- Release new version of the code EMPIRE with above-mentioned improvements.
- Develop the improved version of the covariance module in EMPIRE for fast neutrons.
- Implement and test the new resonance module allowing utilize information from Atlas of Neutron Resonances.

LANL – Nuclear reaction theory calculations have played a crucial role in the evaluation of nuclear data, and will continue to play an important part in future evaluations due to the decrease in operating experimental facilities throughout the world. The LANL GNASH code has proved to be an important tool, and we will continue development of a new version of this code, McGNASH, to provide a state-of-the-art capability to predict reaction cross sections. This also involves a close collaboration with experimentalists at LANSCE to interpret new measurements using the GEANIE and DANCE gamma-ray detectors, as well as (n,charged-particle) data. These data will result in advances in our understanding of nuclear reaction mechanisms, and improvements in our modeling codes. Also, largely under DOE/DP support, we will continue modernization of our R-matrix EDA code (used for light nucleus calculations and data evaluations) and explore implementation of exact particle-exchange formalism.

LANL Planned Activities:

- Calculate and interpret gamma-ray reactions measured with GEANIE at LANSCE. A FY08 area of research centers on neutron reactions on fission products including the noble gases, xenon and krypton.
- Collaborate with LANSCE experimentalists on the interpretation of new FIGARO measurements of neutron inelastic scattering.
- Perform radiative capture calculations on Gd and Eu isotopes in support of DANCE detector capture measurements, and provide the Maxwellian averaged cross section to s-process study.
- Perform radiative capture calculations for fission products, in collaboration with CEA (France).
- Perform neutron inelastic scattering and fission neutron spectrum measurements with the FIGARO array.
- Develop a code to calculate the delayed neutron spectrum including Los Alamos micro-macroscopic nuclear mass model, which allows beta-decay from isomer states
- Develop a theory and method to calculate compound reactions when a strongly coupled-channels exist. This is crucial to study reaction cross sections for actinides.
- Modern nuclear structure models, such as Hartree-Fock, will be applied to calculate nuclear reaction cross sections to reduce phenomenological model parameters.
- Study ^{238}U neutron inelastic scattering at low-excitation energies where theoretical calculation underestimates experimental data.

TUNL – Ongoing work involves the development of preequilibrium nuclear reaction models, as well as the improvement and benchmarking of the computer code PRECO. The unique strengths of this program are its ability to describe reactions with complex particles in the exit and/or entrance channel, and the comprehensive nature of the state densities, which contain the effects of shell structure, the pairing interaction and isospin conservation.

TUNL Planned Activities:

DOE funding for this activity has been discontinued.

G. Nuclear Reaction Data Measurements

The measurement of nuclear data is essential to provide data, which either cannot be calculated or cannot be calculated with sufficient accuracy for user applications. This activity is also essential to support and verify nuclear model development and application.

BNL – We are responsible for compilation of nuclear reaction data within the USNDP. It is very important for the compilers to maintain active contact with data producers so that they have up-to-date knowledge of measurement procedures and techniques, including their advantages and drawbacks, along with an understanding of data uncertainties. This goal can be best achieved by taking part in nuclear data measurements. BNL will do so by devoting a relatively small effort, 0.1 FTE, to collaboration primarily with the LANSCE data measurement program at LANL.

BNL Planned Activities:

Participate in (n,n' γ) and fission neutron spectrum measurements at FIGARO at LANSCE.

Participate in the Lead-Slowing Down Spectrometer measurements on ultra-small targets at LANSCE.

LANL Planned Activities:

Measure and analyze prompt neutron emission following interactions of fast neutrons with fission products such as strontium and barium isotopes. .

These measurements are gated on gamma rays from (n,n' γ) reactions.

Measure the gamma-ray output from neutron-induced fission of ^{235}U , ^{238}U , and ^{239}Pu for neutron energies from 1 to 100 MeV. Collaborators include scientists from CEA (France).

Complete analysis of gamma-ray production for neutrons on fission products ^{100}Mo and ^{130}Te with the goal of deducing partial reaction cross sections.

Complete measurement of gamma-ray production from neutrons on natural Pb and Te to provide data for background assessments in neutrino-less double beta-decay experiments (with University of South Dakota, LBNL, and LLNL).

Measure the neutron capture cross-section of $^{242\text{m}}\text{Am}$ at DANCE for neutron energies less than 200 keV.

Measure the neutron capture and fission cross sections of ^{243}Am and ^{239}Pu at DANCE for energies less than 200 keV.

Measure the neutron capture cross-section at DANCE for at least one radioactive isotope of importance to nuclear astrophysics.

LBNL – LBNL has recently initiated a new program to use surrogate reactions to deduce reaction cross sections which are of importance to Advanced Fuel Cycle (AFC) programmatic needs (a national priority). This is collaboration between the nuclear structure and nuclear reaction groups at LBNL and outside groups at LLNL and the University of Richmond that is currently funded from outside of the DOE Data Program. The LBNL group will lead a series of benchmarking experiments to test the applicability and accuracy of these new techniques for deducing cross sections of importance to AFC and the s-process. It is anticipated that this activity will provide nuclear reaction data measurements of importance to the Data Program.

LBNL is collaborating with the Budapest Reactor Centre in the measurement, using isotopically-enriched targets, of selected thermal (n, γ) cross section data to supplement earlier elemental target measurements from which important information was either lacking (*e.g.*, data from low-abundance isotopes) or discrepant.

LBNL Planned Activities:

Continue to perform (n, γ) cross section measurements at thermal energies in collaboration with the Budapest Research Centre.

Complete measurements (begun in FY07) of (n, γ) cross sections using thermal and 2.5 MeV neutrons from the LBNL neutron generator (in collaboration with NRC Negev, Israel)

LLNL Planned Activities (work completely supported from other sources):

Neutron induced reaction measurements on one or more isomer targets.

Perform surrogate (n,n'), (n,2n), (n, γ) and (n,f) measurements on several nuclei with programmatic and/or astrophysical importance.

Perform neutron capture measurements with DANCE array at LANSCE in collaboration with LANL.

Perform fission cross-section measurements with the lead slowing down spectrometer at LANSCE in collaboration with LANL.

H. Evaluation of Data Needed for Astrophysics

The objective of this activity is to support the nuclear data needs of the increasingly sophisticated simulations of astrophysical phenomena. The Astrophysics Task Force of the USNDP, presently chaired by ORNL, serves to improve communication and coordination of nuclear data evaluation activities relevant for studies in astrophysics.

ANL Planned Activities:

Complete work on ^{186m}Re that is of relevance to the $^{187}\text{Re}/^{187}\text{Os}$ cosmochronometer, including modeling of the production and destruction cross-sections of the ^{186m}Re isomer and the analysis of the $^{187}\text{Re}(n,2n)^{186m}\text{Re}$ data (in collaboration with TUNL)

Asses the nuclear structure and decay data needs for astrophysical modeling work in collaboration with scientists within USNDP Astrophysics Task Force and JINA

BNL Planned Activities (largely done by guest scientist not funded by USNDP):

Perform systematic evaluations of neutron capture cross sections in the energy region of interest for nuclear astrophysics (neutron unresolved resonance region). Produce Maxwellian averages of these data.

USNDP support to this work will be limited to including the evaluations in appropriate databases and to providing data dissemination.

Produce Maxwellian averages for neutron capture cross sections using the ENDF/B-VII.0 library.

LANL -- Participate in the USNDP effort to develop high-quality data for astrophysics calculations of nucleosynthesis. Make new calculated and evaluated results available to the wider astrophysics research community *via* the USNDP Astrophysics Task Force.

LANL Planned Activities:

Continue N-N analysis to energies above 50 MeV and provide evaluated n-p capture cross-sections, rates, and covariance data.

Complete neutron-rich fission barrier calculations, using new and improved multidimensional macro-micro fission model.

Improve neutron capture models to provide capture cross sections for nucleosynthesis network calculations.

Provide neutron capture cross sections on important s-process branching point nuclei.

Provide direct/semidirect capture cross sections on important r-process waiting point nuclei

McMaster -- Pending the approval of a submitted (in December 2006) DOE grant (for 2007-2010) proposal, the evaluation of nuclear astrophysics data is expected to complement the ongoing experimental program of direct measurements of radiative capture cross sections and particle-transfer experiments using radioactive ion beam facilities at TRIUMF, NSCL, RIKEN and ANL.

McMaster Planned Activities:

Specific reactions planned for evaluation in FY08: $^{19}\text{Ne}(p,\gamma)^{20}\text{Na}$ and $^{30}\text{S}(\alpha,p)^{33}\text{Cl}$.

ORNL -- Evaluate capture reactions on radioactive proton-rich nuclei which are important for element synthesis and energy generation in stellar explosions.

ORNL Planned Activities:

Complete evaluations of proton capture on ^{17}O and the $^{17}\text{O}(p,\alpha)^{14}\text{N}$ reaction for novae and red giant stars; this will form part of a Ph.D. thesis.

Continue assessments of capture reactions on p-rich unstable nuclides that are important for novae and X-ray bursts. The nuclei to be studied are those planned for measurements at ORNL's Holifield Radioactive Ion Beam Facility.

Extract spectroscopic information (excitation energies, spectroscopic factors, spins, parities, ANCs) on nuclei near the $N=82$ closed shell – ^{131}Sn , ^{133}Sn , ^{135}Te - from transfer reaction measurements on radioactive Sn and Te nuclei. This information is important for modeling the r-process in supernovae.

I. Reaction Data for RIA Target Design

Rare Isotope Accelerator facility design needs high-quality nuclear reaction data for target design. LANL will collaborate in order to provide key reaction cross-sections using theory calculations and measurements to evaluate the data.

LANL Planned Activities:

We aim to maintain important collaboration connections with the RIA community because of its importance in nuclear science, but effort is limited because of budget restrictions. However, we will continue to maintain a presence in the RIA planning community via participation in RIA meetings and workshops.

Table 7: USNDP Staffing Table in FY2008

Note: BNL includes subcontracted part-time ENSDF evaluators.

Sci Perm = scientific permanent staff, Sci Temp = scientific temporary, Tech & Admin = technical & administrative staff

| | ANL | BNL | | | LANL | LBNL | LLNL | Mc Master | NIST | ORNL | TUNL | Program Total | | | | |
|--|-------------|-------------|-------------|-----------------|-------------|-------------|-------------|--------------|-------------|-------------|-------------|------------------|-------------|-----------------|--------------|-------------|
| | | Sci Perm | Sci Temp | Tech & Admin | | | | | | | | Sci Perm | Sci Temp | Tech & Admin | Grad Stud | Total |
| I. NNDC Facility Operation | 0.00 | 0.35 | 0.00 | 1.65 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.35 | 0.00 | 1.65 | 0.00 | 2.00 |
| Management | | 0.35 | | | | | | | | | | 0.35 | | | | 0.35 |
| Secretarial/Administrative Support | | | | 0.55 | | | | | | | | | | 0.55 | | 0.55 |
| Library | | | | 0.25 | | | | | | | | | | 0.25 | | 0.25 |
| Computer Operations | | | | 0.85 | | | | | | | | | | 0.85 | | 0.85 |
| | | | | | | | | | | | | | | | | |
| II. Coordination | 0.03 | 0.65 | 0.00 | 0.00 | 0.40 | 0.20 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 1.33 | 0.00 | 0.00 | 0.00 | 1.33 |
| National Coordination | | 0.35 | | | 0.10 | 0.20 | | | | 0.05 | | 0.70 | | | | 0.70 |
| International Coordination | 0.03 | 0.30 | | | 0.30 | | | | | | | 0.63 | | | | 0.63 |
| | | | | | | | | | | | | | | | | |
| III. Nuclear Physics Databases | 0.00 | 1.05 | 0.00 | 1.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.05 | 0.00 | 1.50 | 0.00 | 2.55 |
| Nuclear Science References (NSR) | | 0.10 | | 0.70 | | | | | | | | 0.10 | | 0.70 | | 0.80 |
| Exper. Nucl. Structure Data (XUNDL) | | 0.05 | | | | | | | | | | 0.05 | | | | 0.05 |
| Evaluated Nucl. Structure Data (ENSDF) | | 0.20 | | 0.65 | | | | | | | | 0.20 | | 0.65 | | 0.85 |
| Numerical Nuclear Data (NuDat) | | 0.10 | | | | | | | | | | 0.10 | | | | 0.10 |
| Experimental Reaction Data (CSISRS) | | 0.10 | | | | | | | | | | 0.10 | | | | 0.10 |
| Evaluated Nuclear Data File (ENDF) | | 0.40 | | | | | | | | | | 0.40 | | | | 0.40 |
| Database Software Maintenance | | | | 0.15 | | | | | | | | | | 0.15 | | 0.15 |
| Database System Development | | 0.10 | | | | | | | | | | 0.10 | | | | 0.10 |
| | | | | | | | | | | | | | | | | |
| IV. Information Dissemination | 0.03 | 0.90 | 0.00 | 0.25 | 0.10 | 0.10 | 0.00 | 0.00 | 0.00 | 2.70 | 0.60 | 1.23 | 0.10 | 2.85 | 0.50 | 4.68 |
| Nuclear Data Sheets | | 0.10 | | 0.15 | | | | | | | | 0.10 | | 0.15 | | 0.25 |
| Customer Services | | 0.05 | | 0.10 | | | | | | | | 0.05 | | 0.10 | | 0.15 |
| Web Site Maintenance & Development | 0.03 | 0.75 | | | 0.10 | 0.10 | | | | 2.70 | 0.60 | 1.08 | 0.10 | 2.60 | 0.50 | 4.28 |

| | ANL | BNL | | | LANL | LBNL | LLNL | Mc Master | NIST | ORNL | TUNL | Program Total | | | | |
|---|-------------|-------------|-------------|---------------|--------------|-------------|-------------|--------------|-------------|-------------|-------------|------------------|-------------|---------------|--------------|--------------|
| | | Sci Perm | Sci Temp | Tech & Adm | | | | | | | | Sci Perm | Sci Temp | Tech & Adm | Grad Stud | Total |
| V. Nuclear Structure Physics | 1.30 | 2.70 | 1.30 | 0.00 | 0.10 | 2.00 | 0.00 | 0.60 | 0.00 | 0.50 | 1.40 | 6.49 | 3.41 | 0.00 | 0.00 | 9.90 |
| NSR Abstract Preparation | | 0.60 | | | | | | | | | | 0.60 | | | | 0.60 |
| Compilation of Exper. Structure Data | | | | | | | | 0.15 | | | | 0.15 | | | | 0.15 |
| Evaluations for ENSDF | 1.00 | 1.75 | 1.30 | | | 1.45 | | 0.43 | | 0.50 | 0.70 | 3.97 | 3.16 | | | 7.13 |
| Ground and Metastable State Properties | | 0.15 | | | | | | | | | | 0.15 | | | | 0.15 |
| Radioactive Decay Data Evaluation | 0.20 | 0.05 | | | | | | 0.02 | | | | 0.27 | | | | 0.27 |
| Thermal Capture Gamma Data Eval. | | | | | | 0.35 | | | | | | 0.35 | | | | 0.35 |
| Light Mass Eval. for Nuclear Physics A. | | | | | | | | | | | 0.70 | 0.45 | 0.25 | | | 0.70 |
| Nuclear Structure Data Measurement | 0.10 | | | | 0.10 | 0.20 | | | | | | 0.40 | | | | 0.40 |
| ENSDF Evaluation Support Codes | | 0.15 | | | | | | | | | | 0.15 | | | | 0.15 |
| | | | | | | | | | | | | | | | | |
| VI. Nuclear Reaction Physics | 0.10 | 1.85 | 0.80 | 0.00 | 1.50 | 0.10 | 0.30 | 0.30 | 0.20 | 0.00 | 0.00 | 4.45 | 1.50 | 0.00 | 1.00 | 6.95 |
| Experimental Data Compilation | | 0.50 | | | | | | | | | | 0.50 | | | | 0.50 |
| <i>Neutron Data</i> | | 0.15 | | | | | | | | | | 0.15 | | | | 0.15 |
| <i>Charged Particle Data</i> | | 0.30 | | | | | | | | | | 0.30 | | | | 0.30 |
| Photonuclear Data | | 0.05 | | | | | | | | | | 0.05 | | | | 0.05 |
| ENDF Manuals and Documentation | | 0.15 | | | | | | | | | | 0.15 | | | | 0.15 |
| ENDF Evaluations | | 0.90 | 0.80 | | 0.10 | | 0.30 | | | | | 1.30 | 0.80 | | | 2.10 |
| Nuclear Reaction Standards | | | | | 0.10 | | | | 0.20 | | | 0.30 | | | | 0.30 |
| Nuclear Model Development | | 0.20 | | | 0.60 | | | | | | 0.00 | 0.80 | | | | 0.80 |
| Nuclear Reaction Data Measurements | | 0.10 | | | 0.30 | 0.10 | | | | | | 0.50 | | | | 0.50 |
| Astrophysics Nuclear Data Needs | 0.10 | | | | 0.40 | | | 0.30 | | 1.80 | | 0.90 | 0.70 | | 1.00 | 2.60 |
| Reaction Data for RIA Target Design | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| DOE-SC Nuclear Data Funded Staff | 1.46 | 7.50 | 2.10 | 3.40 | 2.10 | 2.40 | 0.30 | 0.90 | 0.20 | 5.05 | 2.00 | 14.90 | 5.01 | 6.00 | 1.50 | 27.41 |
| Staff Supported by Other Funding | | 0.50 | 0.20 | 0.20 | 14.40 | 0.50 | 7.50 | 0.40 | 2.80 | | | 26.10 | 0.20 | 0.20 | 0.00 | 26.50 |
| TOTAL STAFF | 1.46 | 8.00 | 2.30 | 3.60 | 16.50 | 2.90 | 7.80 | 1.30 | 3.00 | 5.05 | 2.00 | 41.00 | 5.21 | 6.20 | 1.50 | 53.91 |

Appendix C

Acronyms in the Nuclear Data Program

National coordination: CSEWG, NNDC, USNDP
International coordination: CJD, IAEA, INDC, NEA, NSDD, NRDC, WPEC
Databases: CINDA, CSISRS, ENDF, ENSDF, NuDat, NSR, MIRD, Wallet Cards, XUNDL

CINDA – Computer Index to Nuclear (reaction) Data

Bibliography of publications in nuclear reaction physics, primarily for neutrons. Charged-particle and photonuclear added in 2005.

Emphasis on nuclear data measurements. Entries for each reaction reported in a paper.

Originated by Prof. Herbert Goldstein, Columbia University, in the early 1960's.

Input prepared by NNDC in collaboration with NEA Data Bank, Paris, IAEA Nuclear Data Section, Vienna, and Russian Nuclear Data Center (CJD), Obninsk, Russia.

Database maintained separately by each of the collaborating organizations.

Database heavily application oriented.

CSEWG – Cross Section Evaluation Working Group

US group, comprising about 20 organizations (national labs, academia, industry) and coordinated by NNDC, that produces the Evaluated Nuclear Data File (ENDF).

Complete evaluations of nuclear reaction and decay data using theory where necessary.

Largely used in nuclear technology applications such as power reactors and medicine, and in design of nuclear research facilities.

CSISRS – Cross Section Information, Storage and Retrieval System

Database of experimental neutron, charged particle and photo-nuclear reaction data.

Data compiled in an internationally adopted format, EXFOR, in use since 1969.

Data jointly compiled by the members of the NRDC network.

Database maintained separately by each of 4 core collaborating organizations (NNDC, NEA Data Bank, IAEA Nuclear Data Section and CJD).

Fairly complete for neutron reaction data.

ENDF – Evaluated Nuclear Data File

Database of evaluated nuclear reaction data, which is primarily used in nuclear applications.

Contains all of the world's evaluated nuclear reaction data files (see WPEC below).

Master source for the US file ENDF/B maintained by NNDC.

ENSDF – Evaluated Nuclear Structure Data File

Database of evaluated experimental nuclear structure and radioactive decay data.

Data evaluated by the members of the international NSDD network.

Theory **NOT** used to fill in gaps in experimental data.

Basis for the Nuclear Data Sheets publication.

Database maintained and distributed by the NNDC.

IAEA - International Atomic Energy Agency, Vienna, Austria

The IAEA Nuclear Data Section is one of 4 international core nuclear data centers for compilation, evaluation and dissemination.

Organizes the international Nuclear Structure and Decay Data (NSDD) network of nuclear structure evaluators.

Organizes the Nuclear Reaction Data Centers (NRDC) network of compilation and dissemination centers.

INDC – International Nuclear Data Committee

IAEA oversight committee for its nuclear data program which meets biennially.

US delegation of three is lead by NNDC head.

NEA - Nuclear Energy Agency, Paris, France

Membership restricted to OECD countries.

The NEA Data Bank is one of 4 international core nuclear data centers for compilation, evaluation and dissemination.

Organizes the Working Party on International Evaluation Cooperation (WPEC), a cooperative effort of the five organizations responsible for the world's major evaluated nuclear reaction data files (for applications).

NNDC – National Nuclear Data Center, Brookhaven National Laboratory, New York

The NNDC is the United States nuclear data center and one of 4 international core nuclear data centers for compilation, evaluation and dissemination.

Organizes the US nuclear data activities (see USNDP and CSEWG).

Focal point of US international nuclear data activities.

NSDD – Nuclear Structure and Decay Data network

IAEA sponsored network of physicists who evaluate nuclear structure and decay data for the ENSDF data file.

US is the leading partner in this effort.

NRDC – Nuclear Reaction Data Center network

IAEA sponsored network of nuclear reaction data compilers and nuclear data disseminating organizations.

Core consists of 4 neutron compilation and dissemination centers, NNDC, NEA Data Bank, IAEA Nuclear Data Section and CJD.

Complimented by specialized charged-particle and photo-nuclear data compilation centers.

NSR – Nuclear Science References

Bibliography for publications in low and intermediate energy nuclear physics.

Literature scanned. Keyword abstracts are prepared for appropriate papers.

Most effort at NNDC with help from Russia and Japan for native language publications.

Database maintained and distributed by NNDC.

The 2nd most popular database. Heavily used by basic research.

NuDat – Nuclear Data

Numerical, searchable database of nuclear structure, nuclear radiations and neutron cross sections.

Derived from the ENSDF database.

The most popular database. Useful for nuclear property searches

Database maintained and distributed by the NNDC.

MIRD – Medical Internal Radiation Dose tables

Radiation dose information useful to medical science

Originated at Oak Ridge Nuclear Data Project.

Derived from ENSDF.

USNDP – United States Nuclear Data Program

Coordinating organization for the nuclear data work funded by the DOE Office of Science, Office of Nuclear Physics.

Wallet Cards

Pocket-sized publication listing all known nuclides and their decay properties

Database maintained, published and distributed by the NNDC.

WPEC – Working Party on International Nuclear Data Evaluation Cooperation

Nuclear Energy Agency sponsored effort to improve nuclear reaction data files.

Use common format, ENDF, invented in the US in the 1960's

Members are the leaders of 5 major application-oriented evaluated nuclear reaction data libraries:

- USA ENDF/B US library generated by the CSEWG, maintained by NNDC.
- Europe JEFF European Union library maintained by NEA Data Bank, Paris for its OECD member states
- Japan JENDL Japanese library maintained at JAERI Nuclear Data Center, Tokai.
- Russia BROND Russian library maintained at CJD, Institute of Physics and Power Engineering, Obninsk
- China CENDL Chinese library maintained at the China Institute of Atomic Energy, Beijing.

XUNDL – Experimental Unevaluated Nuclear Data List

Database of experimental nuclear structure data

Presently contains mostly high-spin data from current experimental papers.

Data sets prepared/reviewed at McMaster University, Canada.

Database maintained and distributed by the NNDC.