



## Annual Report for FY2009

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# Table of Contents

## Summary of U.S. Nuclear Data Program activities for FY2009

I. Introduction

II. Network Coordination and Data Dissemination

III. Nuclear Structure and Decay Data

IV. Nuclear Reaction Data

V. Accomplishments

USNDP Staffing table FY2009

## Detailed status of the work plan for FY2009

I. NNDC Facility Operation

II. Coordination

III. Nuclear Physics Databases

IV. Information Dissemination

V. Nuclear Structure Physics

VI. Nuclear Reaction Physics



## I. Introduction

The USNDP Annual Report for FY2009 summarizes the work of the U.S. Nuclear Data Program (USNDP) for the period of October 1, 2008 through September 30, 2009 with respect to the work plan for FY2009 that was prepared in February 2007. The work plan and final report for the US nuclear data program are prepared for the DOE Office of Science, Office of Nuclear Physics. 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 FTE scientific, mostly at NNSA laboratories, to be compared with 20 FTE scientific (permanent + temporary) at USNDP laboratories funded by the DOE Office of Science, Office of Nuclear Physics. Since it is often difficult to separate accomplishments funded by various sources, some of the work reported in the present report was accomplished with nuclear data program support leveraged by other funding.

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 FY2009. Then, we proceed with the detailed status of work done in FY2009.

Total staff assigned to USNDP activities during the year represented 25.65 FTE. In recent years there has been continuing loss of permanent scientific staff in the USNDP activities. This **loss has intensified in FY2009** with the permanent scientific staff dropping down to 12.55 FTE from 14.9 in FY2008. This decline has been partly counterbalanced by increase of the temporary scientific staff.

Fiscal year 2009 was the 11<sup>th</sup> year in which the Nuclear Data Program has operated under a work plan developed by the program participants. The program continued to carry out important work in support of the DOE mission. 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 easily accessible manner.

Tab. 1 summarizes the USNDP metrics for the last ten fiscal years. Tab. 2 shows the breakdown of the metrics by laboratory for the reported fiscal year and comparison with the previous fiscal year. The tables are followed by a definition of each metric.

Tab. 1 shows that the FY2009 budget increased by 5%. Thus the cumulative increase in the last two fiscal years was comparable to the cumulative result for the two preceding years in which substantial drop by 6.6% in FY2006 was later compensated by a solid 14.6% increase in FY2008. On the average, during last three years there has been a constant increase of the budget on the level compensating for inflation. The metrics show that most indicators were stable except modest increase in dissemination and striking fall in the number of reports.

**Table 1:** Summary of the USNDP metrics in FY2001- FY2009, the definitions of the various terms follow the table.

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
2007	\$5,841K	+14.6%	5,355	366	2,239	40	56	51
2008	\$5,967K	+2.2%	5,104	385	2,996	48	72	68
2009	\$6,267K*	+5.0%	4,047	400	3,294	26	61	56

\*: USNDP funding in FY2009 does not include \$584k allocated to MicroXact and \$213k of FY2010 appropriated to BNL in September 2009.

In particular:

- 1. Compilations.** Compilations efforts, including NSR, CSISRS and XUNDL databases, remain on the similar level, a decrease in BNL's number of NSR compilations is due to staff change and training, it is expected that BNL's output in FY2010 will match traditional values. The coverage of the major journals was complete but there has been some delay in the compilation of conference proceedings in NSR.
- 2. Evaluations.** There is a modest 3% increase in the evaluations, compared to FY2008. We note that the top performance in evaluations, reached in FY05, was exceptional due to preparation of the ENDF/B-VII.0 library and evaluation of large number of super-heavy nuclides (63 nuclides, A = 266-294) for ENSDF.
- 3. Dissemination.** This indicator continues to increase also at slower pace of about 10%. In FY2009 USNDP reached 3.3 million (3,294,000) data retrievals. At BNL, the most popular product continues to be NuDat that contributes almost 60% of data retrievals.
- 4. Reports.** Number of published reports, which has been approximately constant over the last three years, suffered a sharp drop: nearly by a factor of 2.
- 5. Papers.** Number of papers published in the refereed journals remained high, close to the record level of FY2008.
- 6. Invited Talks.** The number of invited talks decreased slightly compared to the FY2008 but remains the second best result ever.

These results must be considered satisfactory taking into account that the performance, essentially equivalent to the previous year, has been achieved in spite of the loss of more than two permanent scientific FTE. Increased workload resulted in the decrease of the number of published reports, which is the most immediate indicator (papers take longer to be published).

**Table 2:** USNDP metrics in FY2009, numbers for FY2008 are shown for comparison.

Laboratory	Compilations		Evaluations		Dissemination (in thousands)		Reports		Papers		Invited Talks	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
ANL	22	39	6	13	15	20	3	3	16	19	10	9
BNL <sup>1</sup>	4,592	2,500	150	151	1,961	2,325	12	4	21	8	17	6
LANL	-	-	60	45	384	300	3	3	14	13	11	14
LBNL	-	-	52	81	315	306	8	8	7	7	10	7
LLNL	-	-	6	5	7	8	10	2	4	3	8	4
ORNL	-	-	11	15	264	285	7	0	4	6	10	13
Universities <sup>2</sup>	490	1,508	100	90	50	50	5	6	6	5	2	3
<b>Total</b>	<b>5,104</b>	<b>4,047</b>	<b>385</b>	<b>400</b>	<b>2,996</b>	<b>3,294</b>	<b>48</b>	<b>26</b>	<b>72</b>	<b>61</b>	<b>68</b>	<b>56</b>

<sup>1</sup>: BNL compilations for FY2009 consist of 1,715 NSR papers and 785 CSISRS reactions. BNL evaluations for FY2009 consist of 106 nuclides for ENSDF and 45 reactions for ENDF.

<sup>2</sup>: Universities compilations for FY2009 consist of 1,000 NSR papers (McMaster), 447 XUNDL datasets (McMaster), 27 Atomic mass articles (McMaster) and 34 XUNDL datasets (TUNL). Universities evaluations for FY2009 consist of 88 ENSDF evaluations (McMaster) and 2 astrophysical reaction rates datasets (McMaster).

#### 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/covariances (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 papers in 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 explicit invitation of the organizers of a conference, symposium, workshop, training course, etc.

## II. Network Coordination and Data Dissemination

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 FY2009 in conjunction with the members of the Coordinating Committee. The NNDC Head serves as a chair of the USNDP Coordinating Committee, which consists of the Principal Investigators from each of the participating groups, and chairs the annual meeting of the program held at the Brookhaven National Laboratory. LANL chairs the Nuclear Reaction Data Working Group, and LBNL the Nuclear Structure Working Group. ORNL chairs the Astrophysics Task Force and LLNL chairs the Homeland Security Task Force.

In February 2009 the DOE Office of Nuclear Physics conducted its annual Budget Briefing. Pavel Oblozinsky, Coral Baglin, Toshihiko Kawano as well as F. Kondev, E. Chen and M. Herman represented the USNDP and made the case for the FY2011 funding.

The NNDC serves as the focal point for U.S. collaboration in international nuclear data activities. This collaboration continued both in nuclear structure and decay data (Network of Nuclear Structure and Decay Data Evaluators, NSDD) and reaction data (NEA Working Party on International Nuclear Data Evaluation, WPEC, and Network of Nuclear Reaction Data Centers, NRDC).

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 2008. The major topic of the meeting was the performance of the ENDF/B-VII.0 library and outlining plans for the next ENDF/B-VII.1 release.

In June 2009 the NNDC organized the Summer Nuclear Data Week consisting of the mini-CSEWG meeting, covariance workshop, meeting of the NEA-sponsored Working Party on International Evaluation Cooperation (WPEC) and three WPEC subgroups meetings.

## **USNDP Databases**

The NNDC operates five Dell servers running Linux operating system 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. In FY09 the NNDC has been constrained to migrate its services from the commercial Sybase to the open-source MySQL relational database. In spite of this unplanned transition NNDC web system continued to operate without interruptions and provided stable service to US nuclear data users.

The NNDC maintains seven nuclear physics databases for the USNDP. These databases have been updated continuously in FY2009 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 FY2009, retrievals from the USNDP databases as offered by the USNDP laboratories reached 3.3 million data retrievals (3,294,000). Use of USNDP services continues to grow, although the in FY09 this growth was slower (10%) than in FY08.

## **Major Publications**

The USNDP continues to publish monthly the refereed journal Nuclear Data Sheets. 11 issues were devoted to nuclear structure data and one issue to nuclear reaction data. In recent four years, citation of the of NDS has increased considerably reaching impact factor of 3.4 (see Accomplishments).

## **III. Nuclear Structure and Decay Data**

The Working Group's priorities emphasize the evaluation of nuclear structure and decay data, either for entire mass chains or for individual nuclides, and the entry of these results into the Evaluated Nuclear Structure Data File (ENSDF). ENSDF is of particular importance because it provides the source information for various other databases and applications such as NuDat, Nuclear Wallet Cards and MIRD as well as contributing much valuable structure and decay data information needed for ENDF/B.VII. Most ENSDF evaluations will also appear as peer-reviewed publications in either Nuclear Data Sheets or Nuclear Physics A. In addition, working group members periodically participate in international collaborations or coordinated research projects designed to provide nuclear data tailored to meet the specialized needs of various research and user communities. Frequently-accessed web sites maintained at several data centers continue to disseminate nuclear structure and decay data in a variety of user-friendly forms.

## **Evaluations for ENSDF**

A total of 286 nuclide evaluations were submitted for inclusion in the ENSDF database in FY2009. USNDP nuclear structure and decay data evaluation groups in the US and Canada were involved in 213 (or 75%) of these (~15% fewer than in FY2008). The latter nuclides also included contributions from new evaluators in Europe, Turkey, Ukraine and India who were being mentored by experienced evaluators from ANL, BNL and McMaster University. USNDP evaluators also provided peer review for 15 mass-chain evaluations, and NNDC performed additional checks prior to publication. Manpower for the US-Canada ENSDF evaluation effort remained essentially the same as for the previous FY (~7.0 FTE) and about 40% of that effort came from evaluators in temporary positions. The eleven issues of the journal Nuclear Data Sheets (published by Elsevier) that were devoted to nuclear structure and decay data contained 17 individual mass chain evaluations (208 nuclides); those publications also included work by evaluators from Argentina, France, India, Kuwait and Russia.

## **XUNDL and Atomic Mass Compilations**

The XUNDL database facilitates prompt access to unevaluated structure information from the most recently published research papers. The McMaster group prepared 390 new and 35 updated data sets for the XUNDL database during FY2009, and ANL, TUNL, IFJ-PAN (Krakow), India and the University of Jordan contributed an additional 39, 37, 14, 1 and 5 datasets, respectively; all of these were incorporated into the database by BNL. Atomic mass measurement papers published in 2008 and 2009 have been compiled at McMaster and are now posted on [www.nuclearmasses.org](http://www.nuclearmasses.org) at ORNL.

## **Compilation of Directly-Measured J Values**

The cutoff date for literature included in the most recent compilation of such data is 1974. The McMaster group has prepared a new compilation of such data, adding the many subsequent measurements, and this is being prepared for publication.

## **NuDat Enhancements**

NuDat continues to be an especially popular structure and decay data resource for nuclear scientists in national labs, research organizations and universities, and in FY2009 there were 1.3M retrievals from the database. There are now 21 options according to which 2-D color-coded nuclear charts can be colored, there are additional zooming possibilities, a wide-screen option and mouse-over effects on level and decay schemes have been added, and a gamma coincidence table for decay data has been included in response to a request from DoE (Nevada). Also, during the year, the database was migrated to four new powerful servers.

## **Nuclear Science References Database (NSR)**

This bibliographic nuclear science database, of vital importance to data evaluators and the nuclear science community alike, expanded by 2715 references (1588 keyworded) during FY2009 and now contains at least 197,195 citations. Oversight of this database became the responsibility of B. Pritychenko at NNDC in June 2009 and, since then, new features and improvements have been added to the database interface, and the database has been migrated from Sybase to MySQL. In addition to the keywording performed at NNDC, articles from three major European journals are keyworded by collaborators at the IAEA, a McMaster pilot program begun with undergraduate students to keyword Phys. Rev. C papers has continued, and keywording assistance for conference papers and laboratory reports is being provided by a former physics journal editor in Bratislava, all with NNDC oversight.

## **Inclusion of Resonance Reaction Data in ENSDF**

In response to a request from the astrophysics community, a committee was appointed during the 2008 Working Group meeting to consult with interested parties and prepare revised guidelines for more comprehensive inclusion of particle-unbound level information in ENSDF. The committee presented a draft document to the NSDD meeting in Vienna in March 2009 and has since incorporated any modifications arising from that meeting.

## **Structure Data Evaluator Recruitment and Training Efforts**

Several USNDP structure data evaluators contributed significantly this year to two new efforts to bolster the severely eroded contribution to ENSDF from Europe. Three participated in a November 2008 meeting convened by IAEA which included interested European groups and the chair of NuPNET, and led to the drafting (and subsequent signature) of a Memorandum of Understanding for the European community, along with a decision to hold an evaluator training workshop in Bucharest in April 2009 for 11 prospective structure data evaluators from Europe and Turkey. The seven mentors chosen from attendees of the NSDD meeting one week earlier included five USNDP evaluators and, with overall coordination by B. Singh (McMaster), the workshop participants evaluated the A=84 mass chain which was published in the November 2009 issue of Nuclear Data Sheets.

## **Other Activities:**

- USNDP Contribution to Decay Data Evaluation Project (DDEP): This international collaboration includes several USNDP evaluators as well as non-ENSDF evaluators from France, Germany, Romania, Russia, South Korea, 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.
- USNDP Evaluator Participation in IAEA CRPs: A USNDP nuclear structure evaluator is a participant in each of two IAEA Coordinated Research Projects (CRP) which run from 2005-2009; both projects held their 3rd Research Coordination Meetings in FY2009. Those projects are the "Updated Decay Data Library for Actinides", and the "Reference Database for Neutron Activation Analysis".
- Outreach: A talk on USNDP evaluated structure and decay data offerings was prepared by F.G. Kondev on behalf of all active evaluators from the Structure Working Group for presentation at the joint APS-DNP and Japan Physical Society meeting in Hawaii in October 2009.

## **IV. Nuclear Reaction Data**

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**

In FY2009 total of 785 CSISRS/EXFOR entries from 127 relevant articles, published mainly in regular journals and conference proceedings, were compiled by the NNDC. From this number, 45 entries contain nuclear data on neutron induced reaction, 76 entries contain data on charged particle reactions and 6 entries contain data on photonuclear reactions. Most important source of information is Physical Review C. About 60% of the entries are compilations of papers published in 2009, approximately one fifth of entries are compilations of papers published before 2006. The NNDC maintains ENDF/B-VII.0 library and collects all the deficiencies reported. In addition, it maintains ENDF/A database as repository of new evaluations that represent candidates for inclusion in the ENDF/B-VII.1 version of the library scheduled for release by the end of 2011. These data will be transferred to the complex management system GForge that has been recently installed at the NNDC.

BNL, LANL, ORNL, and ANL have a cooperative project on the covariance data evaluation for a large number of nuclei in the evaluated nuclear data files, primarily for the criticality safety study, but also important for many nuclear energy applications. We have continued to produce numerous new covariance data estimates including light elements, structural materials, fission products, and actinides. These activities aim at matching quality assurance standards set for the ENDF/B-VII.1 database, the next release of the general purpose file, which should include covariance data for ~100 materials needed for AFCI applications.

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. The support of the Homeland Security concentrate on preventing smuggling of nuclear materials by developing appropriate detection techniques and on developing methods for attribution. Detection strategies include active interrogation (correlated neutron and  $\gamma$  emission from neutron induced fission, thermal neutrons giving unique primary  $\gamma$ -cascades, nuclear resonance fluorescence (NRF) and photofission). Passive detection is relying on environment to provide probe, e.g., cosmic rays (mainly  $\mu$ 's) and

neutrinos. Some of these techniques, especially those based on photon probes, require specific nuclear data such as spins, parities and cross-sections for NRF states and neutron anisotropy, fission transition states and branching ratios for photofission. Ensuring technical manpower base (at least at universities) is still a work in progress. Manpower at universities is solidifying, but growth will be difficult.

LANSCe produced new experimental data of prompt fission neutron spectra for  $^{239}\text{Pu}$  and  $^{232}\text{Th}$ , with the FIGARO (now called  $\chi$ -v) detector. The fission spectra previously taken for  $^{239}\text{Pu}$  and  $^{235}\text{U}$  were compared with the Madland-Nix model calculation. For neutron capture measurement with DANCE, data analysis is in progress for  $^{89}\text{Y}$ , Gd and Mo isotopes,  $^{63}\text{Ni}$ , and  $^{238}\text{U}$ . Analysis of capture to fission ratio for  $^{239}\text{Pu}$ ,  $^{233,235}\text{U}$ ,  $^{242\text{m},243}\text{Am}$  is also in progress. The fission cross section measurements were performed for  $^{239,242}\text{Pu}$  and  $^{243}\text{Am}$  in the 0.2 eV to 200 MeV energy range. Neutron-induced  $\gamma$ -ray production cross sections for several detector materials were measured with GEANIE for background in  $0\nu\beta\beta$  decay experiments.

### **Model Code Highlights**

Several new features were added to the nuclear reaction calculation code EMPIRE. A new version of EMPIRE can handle six ejectiles including deuteron, triton, helium-3, and arbitrary light ions. Capabilities of ENDF-6 formatting use of combinatorial level density in RIPL-3, and the resonance uncertainty evaluations were improved significantly. A ZVView covariance plotting capability was also implemented. Several tasks will be undertaken at BNL before EMPIRE-3.0 release, such as easier installation and user-friendlier GUI.

New implementation of the Hauser-Feshbach model based on the Monte Carlo technique sheds more light on nuclear reaction mechanisms by looking into  $\gamma$ -ray spectroscopy and particle correlations. Two model codes are under development at LANL, CGM and CoH. A new Hauser-Feshbach statistical model code CoH ver.3 calculates particle emission spectra by the Monte Carlo method. A new Monte Carlo Hauser-Feshbach  $\gamma$ -ray cascading code CGM is utilized, not only for nuclear data evaluations, but also  $\beta$ -delayed neutron and  $\gamma$  calculations. Similarly, LLNL applies the DICEBOX code to model capture  $\gamma$ -ray cascade using the Monte Carlo method. The  $\gamma$ -ray cascading simulation in CGM and DICEBOX is strongly influenced by the nuclear structure data, and therefore the evaluated nuclear structure data will be more important.

LANL and LLNL continue developing prompt fission neutron spectrum modeling codes for better prediction and uncertainty quantification of evaluated spectra. Since experimental data are often insufficient for comprehensive understanding of the fission process, LLNL looked into other physical parameters such as TKE, asymptotic level density, relative excitation of the light and heavy fragments, and tuned them to reduce uncertainties. Covariances were obtained from the model calculations. The obtained neutron spectra for  $^{239}\text{Pu}$  were about 8% lower than the ENDF evaluation in the low energy region. LANL estimated the uncertainties in the ENDF evaluations based on the available experimental data, together with considering model uncertainties.

A transition of SAMMY from its recently retired author to an apprentice is in progress. A SAMMY-related paper on unexpected consequences of using data-covariance matrix in resonance parameter fitting has been submitted to the ORNL internal review process. A need for Doppler broadened scattering kernel in the SAMMY multiple scattering module has been recognized, and an implementation path is being devised.

### **Nuclear Standards Highlights**

A comprehensive paper has been written for publication in Nuclear Data Sheets. This work documents the activities that led to the international evaluation of the neutron cross section standards.

A journal publication of the measurements of the H(n,n)H angular distribution at the neutron incident energy of 14.9 MeV is completed. In order to make measurements at smaller scattering angles an experiment has been designed. The NIST collaborative work on the measurement of the spin-dependent portion of the n- $^3\text{He}$  coherent scattering length using a polarized neutron beam and a polarized  $^3\text{He}$  target has been published. Measurements of the  $^6\text{Li}(n,t)$  cross section is underway, and the same experimental setup will be used for the  $^{10}\text{B}(n,\alpha)$  cross section.

### **Nuclear Astrophysics Highlights**

Work continued on the evaluation of several nuclear reactions important for astrophysics modeling at ORNL [ $^{26}\text{Al}+p$  and  $^{26}\text{Al}+d$  to determine  $^{26}\text{Al}(p,\gamma)$  rate] and at McMaster [ $^{32}\text{S}(p,t)$ ,  $^{29}\text{P}(p,\gamma)$ ,  $^{27}\text{Si}+p$ ,  $^{25}\text{Al}+p$ ]. LANL continued developing in the nuclear mass model by studying an impact of spin-orbit parameters. A new model to calculate nuclear reactions on the excited nucleus was developed at LANL, which enables us to calculate stellar enhancement factors. UNC and ANL studied a thermal equilibrium of  $^{176}\text{Lu}$  via  $K$ -mixing, and found that the half-life of  $^{176}\text{Lu}$  ground state can be different in astrophysical environments.

Progress was made at ORNL on developing computational infrastructure for nuclear astrophysics; new reaction rate calculator, element synthesis animator, new profiles of X-ray bursts, and tools for sensitivity studies. BNL generated Maxwellian averaged cross sections (MACS) from the evaluated nuclear data libraries, and compared with the existing MACS database.

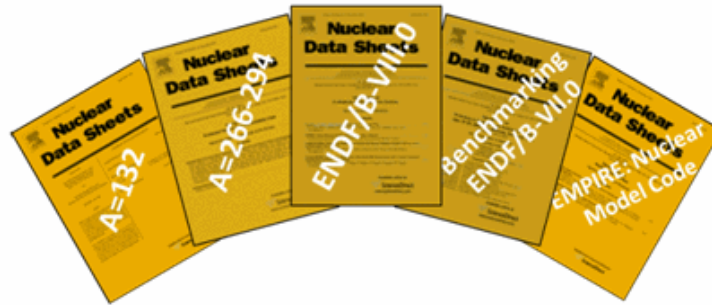
## **V. Accomplishments**

This year we bring to the attention solidification of the Nuclear Data Sheet as a major journal providing nuclear data and successful development of the experimental and theoretical methods for determining fission neutron spectra and their uncertainties.

**Nuclear Data Sheets**

Nuclear Data Sheets is a journal devoted to compilation and evaluation of experimental and theoretical results in nuclear physics. The journal started in February 1966 as Nuclear Data, Section B. In January of 1969 its name changed to Nuclear Data Sheets, Section B, and eventually to Nuclear Data Sheets in July of 1971. J. Tuli from National Nuclear Data Center, serves as the editor of the journal.

Traditionally, Nuclear Data Sheets has published evaluated nuclear structure and decay data. Since 2006, however, the journal has extended its scope by devoting one issue, generally the December issue, to nuclear reaction data. The journal is available both in print as well online. The popularity of the journal has risen during recent years as shown by the impact factors values of 0.953 in 2006, 1.362 in 2007 and 3.404 in 2008. The 2008 impact factor value is even higher than the corresponding one for Nuclear Physics A!



The five most cited papers are listed below in chronological order:

2005	Nuclear Data Sheets for A = 132, Volume 104, p497 (2005), Khazov Yu., Rodionov A.A., Sakharov S., Singh B., cited <b>11</b> times in Scopus
2005	Nuclear Data Sheets for A = 266-294, Volume 106, p251 (2005), Gupta M., Burrows T.W., cited <b>16</b> times in Scopus
2006	ENDF/B-VII.0: Next Generation Evaluated Nuclear Data Library for Nuclear Science and Technology" Volume 107, p2931 (2006), Chadwick, M.B. , Oblozinský, P. , Herman, M. et al., cited <b>193</b> times in Scopus
2006	Benchmarking ENDF/B-VII.0", Volume 107, p3061 (2006), van der Marck, S.C., cited <b>10</b> times in Scopus
2007	EMPIRE: Nuclear Reaction Model Code System for Data Evaluation", Volume 108, p2655 (2007), Herman, M. , Capote, R., Carlson, B.V. et al., cited <b>43</b> times in Scopus

**Fission spectra**

Large sensitivity of many nuclear systems to fission neutron spectra makes their uncertainties important for development of the new generation of nuclear reactors and for national security. To meet needs for high-quality prompt fission neutron spectrum data, USNDP undertook experimental and theoretical efforts to improve the fission spectrum data. Two peer-reviewed papers are under preparation at LANL.

The prompt fission neutron spectra from <sup>235</sup>U and <sup>239</sup>Pu were measured with the FIGARO neutron detector array with the double time-of-flight technique at LANSCE, and model parameters along with their uncertainties were estimated. The new experimental data support evaluated prompt fission neutron spectra available in ENDF/B-VII.0.

In parallel to the experimental program, a theoretical effort was undertaken to estimate uncertainties on the evaluated fission spectra in ENDF/B-VII.0. A new Monte Carlo method to calculate spectrum error propagation in the neutron transport simulations has been developed.

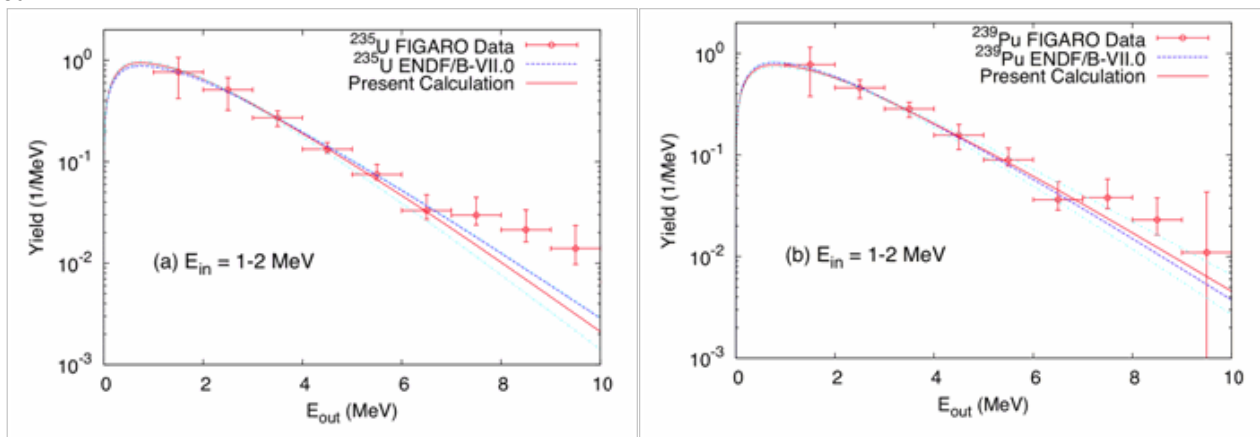


Figure 1 (a)(b). Prompt fission neutron spectra for <sup>235</sup>U and <sup>239</sup>Pu, averaged over 1-MeV incident and outgoing neutron energy intervals. The dot-dashed curves show the estimated 1-σ error band. Data analysis preliminary.



Three major results should be noted: (1) the ENDF/B-VII.0 fission spectra at fast neutron energies are supported by the FIGARO experiments within experimental uncertainties, (2) the uncertainties of the ENDF/B-VII.0 evaluations are derived, and (3) for the first time the Monte Carlo method has been applied to propagate fission spectrum uncertainties in neutron transport simulations.

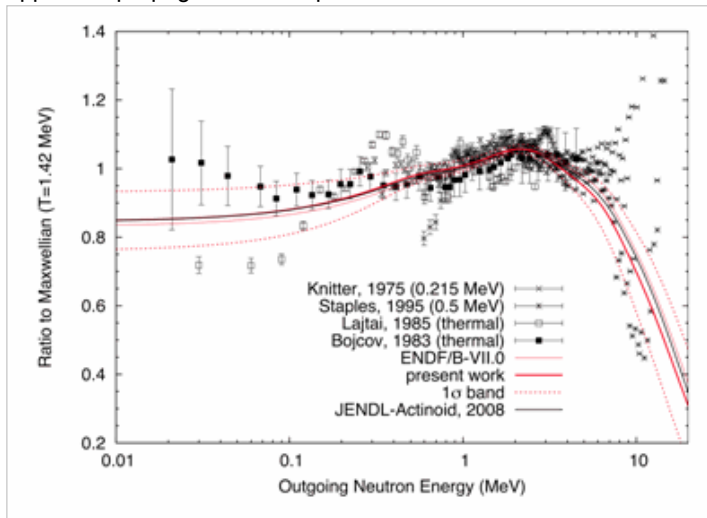


Figure 2. Uncertainty estimated for  $^{239}\text{Pu}$  fission neutron spectrum at neutron incident energy of 500 keV. The  $1\text{-}\sigma$  error band is shown by the dotted lines. Data analysis preliminary.

# USNDP Staffing table FY2009

	ANL		BNL			LANL		LBNL	LLNL	MCMMASTER		NIST		ORNL				TUNL			Sum
	PhD P	PhD T	PhD P	PhD T	T/A	PhD P	PhD T	PhD P	PhD P	PhD P	PhD T	PhD P	GS	PhD P	PhD T	T/A	GS	PhD P	PhD T	T/A	
<b>I. NNDC Facility Operation</b>	0.00	0.00	0.85	0.00	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
Management			0.85																		0.85
Secretarial Admin.Support					0.75																0.75
Library																					0.00
Computer Operations					0.40																0.40
<b>II. Coordination</b>	0.05	0.00	0.40	0.00	0.00	0.40	0.00	0.20	0.01	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	1.11
National Coordination			0.30			0.10		0.10	0.01					0.05							0.56
International Coordination	0.05		0.10			0.30		0.10													0.55
<b>III. Nuclear Physics Databases</b>	0.00	0.00	1.35	0.50	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.90
Nucl. Science References, NSR			0.15		0.75																0.90
Exper. Nucl. Structure Data, XUNDL			0.05																		0.05
Eval. Nucl. Structure Data, ENSDF			0.20																		0.20
Numerical Nucl. Data, NuDat			0.30																		0.30
Reaction Data Bibliography, CINDA																					0.00
Experimental Reaction Data, CSISRS																					0.00
Evaluated Nuclear Data File, ENDF			0.10	0.40																	0.50
Database Software Maintenance			0.30	0.10	0.30																0.70
Future Database System Develop.			0.25																		0.25
<b>IV. Information Dissemination</b>	0.00	0.00	0.70	0.05	1.30	0.05	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.15	0.00	1.00	1.00	0.00	0.00	0.60	4.95
Nuclear Data Sheets			0.35	0.05	0.90																1.30
Customer Services			0.15		0.40																0.55
Web Development & Maintenance			0.20			0.05		0.10						0.15		1.00	1.00			0.60	3.10
	ANL		BNL			LANL		LBNL	LLNL	MCMMASTER		NIST		ORNL				TUNL			
	PhD P	PhD T	PhD P	PhD T	T/A	PhD P	PhD T	PhD P	PhD P	PhD P	PhD T	PhD P	GS	PhD P	PhD T	T/A	GS	PhD P	PhD T	T/A	Sum
<b>V. Nuclear Structure Physics</b>	0.70	0.30	1.89	2.25	0.20	0.10	0.00	1.50	0.00	0.60	0.80	0.00	0.00	0.15	0.15	0.00	0.00	0.85	0.60	0.15	10.24
NSR Abstract Preparation			0.79	0.20	0.20					0.10											1.29
Compilation of Exper. Structure Data	0.05									0.20								0.10			0.35
Eval. of Masses & Nuclides for ENSDF	0.45	0.30	0.95	2.05				1.00		0.30	0.80			0.15	0.15			0.33	0.25	0.15	6.88
Ground & Metastable State Properties			0.10																		0.10
Radioactive Decay Data Evaluation	0.10																				0.10
Thermal Capture Gamma Data Eval.								0.30													0.30
Light Mass Eval. for Nucl. Physics A						0.10												0.42	0.35		0.87
Nuclear Structure Data Measurement	0.10							0.20													0.30

ENSDF Evaluation Support Codes			0.05																		0.05
VI. Nuclear Reaction Physics	0.05	0.00	0.10	2.50	0.20	1.35	0.10	0.20	0.20	0.00	0.20	0.20	0.50	0.35	0.00	0.00	1.00	0.00	0.00	0.00	6.95
Experimental Data Compilation				0.40																	0.40
ENDF Manuals and Documentation				0.15																	0.15
ENDF Evaluations				1.35	0.20	0.25			0.20												2.00
Nuclear Reaction Standards						0.10						0.20	0.50								0.80
Nuclear Model Development				0.60		0.40	0.10														1.10
Nucl. Reaction Data Measurements						0.30		0.20													0.50
Astrophysics Nucl. Data	0.05		0.10			0.30					0.20			0.35			1.00				2.00
DOE-SC Nucl. Data Funded Staff	0.80	0.30	5.29	5.30	3.90	1.90	0.10	2.00	0.21	0.60	1.00	0.20	0.50	0.70	0.15	1.00	2.00	0.85	0.60	0.75	28.15
Staff Supported by Other Funds	0.20	0.40	0.90	0.00	0.00	12.00	0.00	0.50	7.90	0.40	0.00	2.80	0.00	0.35	0.00	0.50	1.00	0.00	0.00	0.00	26.95
<b>TOTAL STAFF</b>	<b>1.00</b>	<b>0.70</b>	<b>6.19</b>	<b>5.30</b>	<b>3.90</b>	<b>13.90</b>	<b>0.10</b>	<b>2.50</b>	<b>8.11</b>	<b>1.00</b>	<b>1.00</b>	<b>3.00</b>	<b>0.50</b>	<b>1.05</b>	<b>0.15</b>	<b>1.50</b>	<b>3.00</b>	<b>0.85</b>	<b>0.60</b>	<b>0.75</b>	<b>55.10</b>

PhD P: PhD Permanent,  
 PhD T: PhD Temporary,  
 T/A: Technical and administrative,  
 GS: Graduate student.

# Detailed Status of the Work Plan Fiscal Year 2009 Report

## I. NNDC Facility Operation

### 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 evaluation effort.

### C. Computer Operation

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	Status
Scan and remediate regularly vulnerabilities on NNDC servers and clients to ensure compliance with DOE cyber security requirements	Almost 3,000 cyber security vulnerabilities detected on the new servers powering NNDC's Web services were promptly remediated. This significantly contributed to BNL passing the annual DOE Safety and Security Audit with an overall rating of 'Satisfactory', the highest rating in 2009.
Provide computer support to the NNDC staff and its visitors as necessary.	All NNDC desktop computers were upgraded from single-CPU machines to more powerful dual-/quad-core workstations. Further, two network printers were replaced with faster and higher resolution units thereby enhancing NNDC's printing capabilities. Finally, two scientific staff members were provided with more powerful laptop computers to boost their mobile computing capabilities.
Upgrade aging NNDC computer system, including database servers and web servers by purchasing and installing new servers.	Two quad-core Web servers and two quad-core database servers were purchased and made operational thereby increasing almost fourfold the computing power available for web users. In addition, the new servers will enhance the reliability and availability of NNDC's Web services.
<b>Unplanned activity:</b> Migration of NNDC databases from Sybase to MySQL due to the exorbitant increase of licensing fees by Sybase.	All major nuclear physics databases were successfully migrated from Sybase, a commercial database software, to MySQL, an open-source database software from Sun Microsystems. This migration is foreseen to significantly reduce licensing and support costs, in addition to improved performance and quality of technical support.

## II. Coordination

### A. National Coordination

National coordination is required for activities under the US Nuclear Data Program as well as Cross Section Evaluation Working Group. This is mostly performed by the National Nuclear Data Center, with contributions from other laboratories (USNDP Working Groups and Task Forces as well as CSWEG Committees).

ANL: Chair the Covariance Committee the Cross Section Evaluation Working Group.

ANL Planned Activities	Status
Organize and chair the CSEWG Covariance Committee.	ANL staff organized and chaired the CSEWG Covariance Committee

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

BNL planned activities	Status
Prepare FY2010 work plan for USNDP in time for spring 2009 FWP submittals.	FY2010 work plan for USNDP was prepared in February 2009.
Organize and chair CSEWG Meeting at BNL in November 2008.	CSEWG Meeting was held at BNL in November 2008.
Organize and chair USNDP Meeting at BNL in November 2008.	USNDP Meeting was held adjacent to CSEWG Meeting in November 2008.
Edit and publish summary reports of the CSEWG and USNDP meetings.	Summary report of CSEWG-USNDP 2008 meeting was published on-line in December 2008. USNDP Annual Report for FY 2008 was published on-line in February 2009.
Maintain CSEWG and USNDP websites	CSEWG and USNDP web sites were regularly maintained.

LANL planned activities	Status
Organize and chair CSEWG Evaluation Committee meeting at BNL, November 2008.	Organized and chaired Evaluation Committee meeting at the November 2008 CSEWG meeting.
Organize and chair Nuclear Reaction Working Group meeting at USNDP meeting in November 2008, and help coordinate Homeland Security, Astrophysics, and RIA Task Forces.	Organized and chaired Nuclear Reaction Working Group meeting at the November 2008 USNDP meeting, and help coordinate Homeland Security and Astrophysics Task Forces. The RIA Task Force has been closed.

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	Status
Organize and chair Nuclear Structure and Decay Data Working Group meeting at USNDP meeting, November 2008	Task completed by C.M. Baglin.

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

LLNL planned activities	Status
Organize and chair the CSEWG Task Force on Nuclear Data Needs for Homeland Security.	Organized and chaired the CSEWG Task Force on Nuclear Data Needs for Homeland Security at the November 2008 meeting.

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	Status
Summarize USNDP efforts in nuclear data for nuclear astrophysics at USNDP Meeting in November 2008.	USNDP efforts in nuclear data for nuclear astrophysics summarized in an oral presentation at the USNDP meeting in November 2008
Communicate current efforts and future plans with researchers in nuclear astrophysics data.	Current efforts and future work in nuclear astrophysics data were presented in invited presentations at CIAE [CHINA], NN2009 [CHINA], NAO [TOKYO], Univ. of Tokyo [Tokyo], and JAEA [JAPAN].
Represent USNDP nuclear astrophysics efforts at international collaboration meetings on nuclear astrophysics data.	Recent efforts of USNDP labs in nuclear astrophysics data were discussed in an invited presentation at the "Workshop on nuclear data and its application to nuclear astrophysics" at RIKEN in April 2009. Current efforts and future work in nuclear astrophysics data were also presented in invited presentations at CIAE [CHINA], NN2009 [CHINA], NAO [TOKYO], Univ. of Tokyo [Tokyo], and JAEA [JAPAN].
Initiate collaborative research projects to raise the visibility of nuclear data projects directed at astrophysics applications.	Suggestions for collaborative work between USNDP labs and nuclear data centers in Japan, were discussed in an invited presentation at the "Workshop on nuclear data and its application

	to nuclear astrophysics" at RIKEN in April 2009; several possible collaborative projects between USNDP labs were discussed in FY2009 including horizontal decay data evaluations and nuclear mass evaluations.
Discuss future plans in nuclear astrophysics data with DOE, with USNDP/NNDC, and with other agencies.	Future plans of USNDP labs in nuclear astrophysics data, and suggestions for future collaborative work, were discussed in an invited presentation at the "Workshop on nuclear data and its application to nuclear astrophysics" at RIKEN in April 2009

## 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	Status
Participate in IAEA CRP on "Updated Data Library for Actinides".	ANL staff participated in the activities of the IAEA CRP on "Updated Data Library for Actinides".
Participate in the 2009 NSDD meeting.	ANL staff participated in the activities of the 2009 NSDD meeting
Provide a lecturer at the IAEA/ICTP organized nuclear structure data workshop, if one is scheduled.	ANL staff participated as a lecturer in the activities of the IAEA/EU organized 2009 Bucharest training workshop

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 sponsored activities such as Workshops and Technical Meetings.

BNL planned activities	Status
Participate in the IAEA-sponsored NRDC meeting in 2009.	The two NNDC EXFOR compilers attended the meeting.
Participate in NEA WPEC annual meeting in 2009.	The NNDC has organized the WPEC meeting at Port Jefferson, NY in June 2009. Five NNDC staff members participated in the meeting.
Serve as coordinator of the WPEC Subgroup 24 on fast neutron cross-section covariances.	The WPEC SG24 has concluded its activities, reported the results to the WPEC meeting, and has been formally closed.
Provide lecturer to the IAEA/ICTP workshop on nuclear reaction data (if organized).	The workshop has been organized but, this time, it was TALYS code rather than EMPIRE oriented, therefore participation of the NNDC lecturer was not needed.
Participate in the IAEA-sponsored NSDD meeting in 2009.	Three NSDD staff members attended NSDD meeting in Vienna. One NSDD member co-chaired the meeting and co-authored the minutes.
Conduct and lecture at the IAEA-sponsored workshop at Bucharest in 2009	NSDD staff members organized, lectured, and mentored at the workshop.

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	Status
Participate in NEA-WPEC 2009 meeting	Due to some conflicts with other meetings, nobody from LANL participated in the WPEC meeting in 2009. However, we have communicated with the group members on topics discussed under the WPEC coordination.
Participate in relevant IAEA CRP meetings (FENDL and minor actinide data).	Three LANL participants participated in the IAEA meetings.
Participate and give invited talks at the 16th Pacific Basin Nuclear Conference (16PBNC) - Pacific Partnership toward a Sustainable Nuclear Future - October 13-18, 2008 in Aomori, Japan.	A LANL scientist gave an invited talk on the US nuclear data measurement activities at the 16PBNC in Aomori, Japan.
Make latest version of NJOY data processing code available to the international community.	Upgrades to NJOY were released to international NJOY nuclear data processing community.

Host a couple of international visitors to LANL to collaborate on the evaluation of reaction data.	Hosted key researchers from Kinki University (Japan), Kyushu University (Japan), IRRM (Belgium), and JINR (Russia).
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LBL: Participate in IAEA-sponsored training workshops, planning meetings and coordinated research programs on nuclear structure and decay data.

LBL planned activities	Status
Conclude participation in IAEA CRP on "Reference Database for Neutron Activation Analysis" (CRP ends in November 2009).	Last meeting of IAEA CRP completed and final report is under preparation by the IAEA.
Participate in NSDD meeting at IAEA in 2009.	Participated in NSDD Meeting in Vienna.

McMaster: Continue participation in new evaluators training program.

McMasters planned activities	Status
Participate in the policy matters related to the NSDD network.	Participated in two activities: 1. Guidelines for RUL for M1 transitions 2. Guidelines for inclusion of charged-particle and resonance data in ENSDF
Participate in training/mentoring of new ENSDF evaluators through collaborative work, as needed and as the opportunity arises	Training and mentoring of 5 new evaluators through their visits to McMaster and e-mail comm. Co-ordinated ENSDF workshop at Bucharest in April 2009

TUNL: Represent TUNL at IAEA-sponsored at Nuclear Structure and Decay Data network (NSDD).

TUNL planned activities	Status
Participate in the policy matters related to the NSDD network.	Continuing
Participate in NSDD/IAEA meetings	Continuing

### III. Nuclear Physics Databases

#### 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	Status
Database distributed to collaborators monthly.	Completed, updates were distributed to NDS,IAEA and LBNL.

#### 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	Status
Update database as input is received from McMaster.	Updates done as received, about once a week. Database distributed twice during the FY.

#### C. Evaluated Nuclear Structure Data File (ENSDF)

The NNDC is responsible for ENSDF, a database of evaluated experimental nuclear structure and decay data. The NNDC is responsible for format and content checking, preparation of manuscript, and 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	Status
Database distributed to collaborators twice a year.	Completed
Process evaluations received from NSDD evaluators.	Completed

## 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  $\gamma$ -ray 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 Nuclides and interactive level schemes.

BNL planned activities	Status
Update NuDat database as necessary, about 10 times a year.	NuDat was updated regularly. In addition, the database was migrated into MySQL installed in more powerful servers.

## 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 in

BNL planned activities	Status
Contribute to CINDA by compiling experimental cross-section data to the CSISRS database (150 compiled papers expected).	Recently, all reaction data compiled by the NNDC and introduced into the CSISRS database are automatically included in CINDA.

## 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	Status
Update CSISRS with EXFOR compilations from cooperating centers (500 entries expected). The NNDC compilation work can be found under Nuclear Reaction Physics, chapter V of the present document.	The CSISRS database was regularly updated.

## 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, are assembled, tested and made available to users through the ENDF/A web interface.

BNL planned activities	Status
Effort needed to maintain Linux/Sybase database system.	ENDF migration from Sybase to MySQL database software was completed in July 2009. However, ENDF still runs on the internal Sybase server but is no longer updated.
Maintain and improve Sigma database and web interface for users without specialized knowledge of ENDF-6 format. (See also information dissemination, chapter IV).	Sigma was migrated to MySQL, ROSFOND was added as well as selected ENDF/A evaluations.

## H. Database Software Maintenance

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



BNL planned activities	Status
Fix bugs and develop enhancements for the six nuclear physics databases maintained by NNDC.	Completed.

## I. Database Systems Development

The multi-year effort to migrate the USNDP databases to a LINUX/SYBASE environment was completed in FY2004. After wards, several follow-up tasks needed to 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	Status
Effort needed to maintain Linux/Sybase database system.	Completed.
Maintain and improve Sigma database and web interface for users without specialized knowledge of ENDF-6 format. (See also information dissemination, chapter IV).	Completed. See sections III.g and and IV.a.

## IV. Information Dissemination

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 proved 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	Status
Maintain and upgrade the ANL/NDM report series web site.	The web site was maintained and periodically upgraded
Maintain and upgrade Experimental Resources for Nuclear Data web site.	The web site was maintained and periodically upgraded
Maintain and upgrade ANL Nuclear Data Information web site.	The web site was maintained and periodically upgraded

BNL Planned Activities	Status
Improve NSR and ENSDF web interfaces.	NSR Web interface was substantially improved.
Maintain web interface to the ENDF database.	ENDF Web interface was improved.
Improve Sigma web interface by adding new and extended features following user's requests.	Sigma 3.0 and 3.1 versions were released, which include ROSFOND library, fission yields, pre-calculated integral quantities, and improved zooming.
Maintain web interface for double-beta decay.	Completed.
Improve reliability and cyber security of its web services by installing the latest version of Apache/Tomcat servers and mod-jk connector software for a new dual web server system.	Completed, NNDC has installed latest versions of Tomcat 5.5 and Apache 2 servers and improved web pages.
Maintain currency of the CSEWG, USNDP and the NNDC web sites.	Completed.
Explore possibility for a nuclear astrophysics webpage in collaboration with JINA.	NNDC has created Nuclear Rates webpage that is referenced by JINA.

LANL Planned Activities	Status
Provide actinide ENDF/B-VII data via LANL web site for criticality data testing, together with other LANL evaluations (e.g., light nucleus reactions).	The latest LANL evaluations were made available via our web server, together with the BNL/NNDC archive, to the integral data testing community that is validating the preliminary ENDF/B-VII.1 evaluations.
LLNL Planned Activities	Status
Maintain LLNL's Nuclear and Atomic Data Viewer.	LLNL's Nuclear and Atomic Data Viewer maintained.
Extend the Nuclear and Atomic Data Viewer as per user requests.	Nuclear and Atomic Data Viewer not extended.
Maintain and upgrade LLNL's Computational Nuclear Physics web pages.	Website maintained. Added to website were self-contained physics simulations that can be interfaced to any parent transport code, such as MCNP, MCNPX, Geant4, and COG. The simulations are 1) Fission: Simulates discrete neutron and gamma-ray emission from the fission of heavy nuclei, this includes spontaneous, neutron-induced, or photon-induced fission; 2) RadSrc: Calculates intrinsic gamma-ray spectrum from the nuclear decay of a mixture of radioisotopes; 3) CRY: Generates correlated cosmic-ray particle showers at one of three elevations (sea level, 2100m, and 11300m) for use as input to transport and detector simulation codes. (funded from other sources)
LBNL planned activities	Status
Update Isotopes Project existing web pages.	Updates completed. No further development done.
ORNL Planned Activities	Status
Continued development and maintenance of our online software suite to convert nuclear data to astrophysical reaction rates and plot, manipulate, and share results online; this activity is at risk of termination.	The Computational Infrastructure for Nuclear Astrophysics, online at nucastrodata.org, is serving as the software backbone for data processing and dissemination of a new international collaboration in nuclear astrophysics data. New workflow management tools have been developed for this effort and are now ready for use. These tools have utilization in the nuclear data community beyond research in nuclear astrophysics. New features this year include a new reaction rate calculator (in progress), a simplified interface for element synthesis animator, six new profiles of X-ray bursts available for simulations, and simplification of tools for sensitivity studies (in progress).
TUNL Planned Activities	Status
Continue to improve the TUNL website and provide access to new information on A = 3 - 20 nuclei.	Continuing.
Continue to prepare new PDF and HTML documents of the most recent TUNL reviews.	The preliminary draft of the A=3 review will be added to the TUNL web page in early 2010, and the link will be updated to the final draft after the manuscript is submitted to Nuclear Physics A for publication.
Continue to provide PDF and HTML documents for FAS reviews for the A = 3 - 20 series.	PDF and HTML files are online for Fay Ajzenberg-Selove and TUNL reviews for 1959-present. We continue to correct typographical errors found in the text of the original publications, and we continue to update references to the NSR keynumbers.
Continue to provide General Tables to accompany the most recent TUNL reviews of the A = 3 - 20 series.	This activity is not continuing. The NNDC/NSR search abilities are more than adequate for users to find references of interest.
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.	Energy Level Diagrams are online for Fay Ajzenberg-Selove and TUNL reviews for 1959-present.
Develop web page to provide compiled and evaluated data on particle decay of unstable ground states.	The interface is present on the TUNL pages, and the pages are updated at least once a year.

## 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	Status
Provide technical support to users as necessary.	All reasonable user queries were addressed and adequate support was provided.
Maintain Comments/Questions option for all reaction databases, for the NNDC web service and for Nuclear Wallet Cards.	Completed.

## 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	Status
Prepare twelve issues of Nuclear Data Sheets for publication.	Completed
Prepare special issue of Nuclear Data Sheets on neutron reaction data.	The December 2008 special issue was published which included the articles submitted to the Covariance workshop in Port Jefferson.

## V. Nuclear Structure Physics

### A. NSR Abstract Preparation

The literature search and preparation of KEYWORD abstracts for publications included in NSR require scientific expertise. BNL continues to have the overall responsibility for this database. The IAEA is expected to provide more than 20% of the keywords. Similar contributions from other external collaborators are expected. These will be checked and edited by BNL as necessary before being added to the database.

BNL Planned Activities	Status
Prepare entries for about 3,800 new references, and keyword abstracts for 2,500 of them.	A total of 2,715 new entries were added; 1,518 keyworded.
Check and edit approximately 700 key-worded abstracts for three European journals prepared at the IAEA Nuclear Data Section.	439 entries from NDS,IAEA were checked.
Check and edit key-worded abstracts from other collaborators as applicable and necessary.	1,000 entries from McMaster University and 224 entries from Slovak Academy of Sciences were checked.

McMaster Planned Activities	Status
NSR keywording for PR-C	1000 articles were keyworded during 2008-2009

### B. Compilation of Experimental Structure Data

This activity involves compilation of recently published or completed experimental nuclear structure data for inclusion in XUNDL. The compilation is done by McMaster, while the NNDC is maintaining the database. In FY09, ANL plans to start contributing to compilation effort.

ANL Planned Activities	Status
Compile and review datasets for recently published experimental nuclear structure data for inclusion in the XUNDL database.	39 data sets were compiled from articles published in the journals Phys. Lett. B and J. Phys. G. Data were coded into ENSDF format and submitted to McMaster University for review and subsequent inclusion in the XUNDL database. Interacted with the leading authors on several occasions to collect additional data and to resolve ambiguities.

BNL Planned Activities	Status
Compile new BE(2) experimental data.	Continued activity, 15 nuclei.
Compile new $2\beta$ -decay experimental data.	Continued activity, 19 nuclei, 83 decay modes.

Maintain, update and distribute XUNDL.	Completed
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McMaster Planned Activities	Status
Compile data sets (in ENSDF format) for current experimental nuclear structure publication. The websites of prominent journals in nuclear physics will be scanned regularly for new papers.	447 datasets were compiled at McMaster for XUNDL, including 19 with other centers outside US and 35 updated for new papers. 27 atomic mass papers were compiled.
Review compiled data sets submitted by other data centers prior to inclusion in the XUNDL database.	76 datasets received from other US centers were reviewed and edited if needed.
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.	This process continued throughout 2008-2009 and several e-mail communications resulted in clarification of data and additional data received.
Train a new undergraduate student in early 2009 for XUNDL compilation work.	One student Babak Karamy was trained in 2009

TUNL Planned Activities	Status
Compile XUNDL data for A=2-20	Compiled 34 files from April-September

### 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 nuclide or a group of related nuclei to deduce recommended values from the measured data and prepare a file in ENSDF format that is the basis for publications in "Nuclear Data Sheets" and is 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	Status
1 equivalent mass chain will be evaluated and published.	Evaluation of all nuclides within A=204 mass chain was completed and submitted to NNDC for review; evaluation of A=177 and 209 mass chains is continuing
1 mass chain will be reviewed.	Review of A=133 mass chain that was submitted by the St. Petersburg NSDD center was completed
Collaborate with scientists from other NSDD data centers on evaluation projects.	Collaborations with evaluators from NSDD centers in Australia, China, India, Jordan, Bulgaria, and U.K. are continuing. Work on the horizontal evaluation on K-isomers is continuing in collaboration with scientists from Australia.

BNL Planned Activities	Status
At least 6 equivalent mass chains will be evaluated.	Completed and submitted 11 mass chains (4 NNDC, 7 Collaboration).
At least 6 mass chains will be reviewed.	Reviewed 11 mass chains.
Continue mentoring new ENSDF evaluators.	Continued mentoring.

LBNL Planned Activities	Status
Evaluate the equivalent of at least 3 mass chains, including a minimum of one from the A=21-30 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).	Published A=25, 81, 119, 145, 179, 229 and isotopes <sup>30</sup> Si, <sup>30</sup> Al, <sup>30</sup> F, <sup>29</sup> Al, <sup>29</sup> Mg, <sup>29</sup> F, <sup>28</sup> Mg, <sup>28</sup> Na, <sup>28</sup> F, <sup>27</sup> Na, <sup>27</sup> Ne, <sup>27</sup> F, <sup>26</sup> Ne, <sup>26</sup> F, <sup>25</sup> Ne.
Review mass-chain evaluations, as requested.	2 reviews completed

McMaster Planned Activities	Status
3.5 equivalent mass chains (including the A=31-44 region and the data for new nuclides as mentioned below) will be evaluated.	A=32, 34, 50, 71, 77, 84, 163 were submitted in 2009; A=34, 77 and 163 were shared with other US evaluators.
Mass chains will be reviewed as requested.	A=102 was reviewed
Update ENSDF for the identification of new nuclides and for the first publications on the findings of the excited states of nuclides.	37 nuclides were updated in ENSDF in this category

Collaboration with a new center/evaluator as part of mentoring process, as needed.	Collaboration with five new evaluators; and several at Bucharest ENSDF workshop in April 2009
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ORNL Planned Activities	Status
Complete evaluation of structure information for one nucleus in A=241-249 region.	In consultation with NNDC, evaluations of A=152 and A=69 are in progress; A = 58 was revised based on review comments. A = 58 has 12 nuclides, 537 references, and is a 284 page evaluation.
Review one mass chain evaluation.	A=121 was reviewed.

TUNL Planned Activities	Status
Prepare the ENSDF files corresponding to new publications in the "Energy Levels of Light Nuclei" series.	We are now updating the ENSDF files in tandem with the Nuclear Physics A articles in order to provide a clear description of the data sources and procedure for deducing best values. Previously, we prepared the ENSDF files after the Nuclear Physics publication. In some cases a closer look into much earlier work was included in the ENSDF reviews which led to discrepancies in the Nuclear Physics reviews and the ENSDF evaluations. Our present philosophy is to re-evaluate all available data, and to prepare the reviews/evaluations simultaneously, so that the best values can be included in each.

## D. Ground and Metastable State Properties

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

BNL Planned Activities	Status
Update database as new information becomes available.	Continued updating Nuclear Wallet Cards file.

## 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, included 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	Status
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.	Evaluations of 243,245Cm nuclides are continuing
Reviews of selected nuclides will be carried out, if requested.	

McMaster Planned Activities	Status
Evaluate or review decay datasets for one or two radionuclides.	none in 2008-2009

## F. Neutron-Induced $\gamma$ -Ray Data Evaluation

The EGAF (Evaluated Gamma-ray Activation File) database, disseminated by the IAEA and maintained by LBNL, currently provides discrete-line prompt  $\gamma$ -ray information from thermal (n, $\gamma$ ) 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 could constitute a valuable resource required for updating the ENDF database. Additionally, delayed photon data need to be added to EGAF. The k<sub>0</sub>-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<sub>0</sub> values then need to be integrated into EGAF and, ultimately, made available to ENSDF evaluators.

LBNL Planned Activities	Status
Continue the following activities outlined in the FY07 Work Plan with a view to maintaining and developing the EGAF database: <ul style="list-style-type: none"> <li>Continue collaboration with LLNL to perform statistical-model calculations of quasi-continuum <math>\gamma</math>-ray cascade information and</li> </ul>	DICEBOX statistical model code installed at LBNL. Evaluation of tungsten, gadolinium, and potassium isotopes in progress. Updating of EGAF database is in progress.

<p>generate ENDF-format capture <math>\gamma</math>-ray datasets for use with MCNP and other transport-code calculations.</p> <ul style="list-style-type: none"> <li>■ Add to EGAF the neutron-activation file produced in the course of participating in the IAEA CRP on "Reference Database for Neutron Activation Analysis" (November FY2008 completion date for CRP).</li> <li>■ Add any new thermal (n,<math>\gamma</math>) data that become available, along with any total radiative-capture cross-sections derived from them.</li> </ul>	
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LLNL Planned Activities	Status
<b>Unplanned activity</b> (funded from other sources): Evaluation of EGAF data in collaboration with LBNL	Developed tools to automate the evaluation of LBNL EGAF capture gamma-ray data. Data evaluated using DICEBOX statistical Monte-Carlo simulations, with automation of building input files from RIPL data and viewing results of simulation versus EGAF data. Building of ENDF files from results of DICEBOX simulation near completion.

### 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	Status
Continue to evaluate A=3 Nuclei.	The internal manuscript for the A=3 evaluation is complete. We plan to distribute the document for external review in early 2010, and we plan to submit the manuscript for publication in the spring of 2010.
Continue to evaluate A=11, 12 and 13 nuclei.	The manuscript "Energy Levels of Light Nuclei: A=11" will be complete in early spring 2010. The review of A=13 nuclei will be complete soon after that. Evaluation of A=12 nuclides continues. These reviews will be published separately.

### 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. Maintain important collaborative connections with RIA and GRETINA research communities, because of their vital importance to the nuclear science in US.

ANL Planned Activities	Status
Complete decay data measurements on $^{245}\text{Cm}$ as a part of the ANL commitment to the IAEA-CRP on "Updated Decay Data Library for Actinides".	New decay data measurements of $^{233}\text{Pa}$ , $^{243}\text{Am}$ , $^{243}\text{Cm}$ and $^{249}\text{Cf}$ were completed and data analysis is continuing
Participate in the development of the Argonne Total Absorption Gamma-ray Spectrometer at the CARIBU facility and the corresponding data infrastructure analysis, compilation and evaluation of decay data for neutron-rich fission products.	Participated in activities aimed at developing of ATAGS and the corresponding infrastructure at ANL for analysis, compilation and evaluation of decay data for neutron-rich fission products. Hosted and mentored a student from ANSTO/ANU Australia who worked on the project at no cost to ANL NDP. Participated in collaborative nuclear structure and decay data activities at the Argonne ATLAS facility with notable contributions to studies of K-isomers in heavy nuclei near A=250 and in deformed nuclei in the A~180 region. This work complements the evaluation activities of K-isomers that are carried out by the ANL nuclear data staff. Maintained important collaborative connections with FRIB and GRETINA research communities, because of their vital importance to nuclear science in US

LANL: LANL/LANSCE continues to maintain a small program to measure nuclear decay data information.

LANL Planned Activities	Status
Examine prompt gamma-ray emission data and gamma-gamma coincidence data from neutron reactions on $^{56}\text{Fe}$ to search for previously unobserved transitions in this nuclide.	Experiment conducted and analyzed both for single and for gamma-gamma coincident transitions. Transitions from a state in $^{56}\text{Fe}$ at 3076 keV were looked for but not found. If they exist (expected 2229 and/or 991 keV transitions), they are below the detection limit at GEANIE.
Interact with mass chain evaluators on the nuclear structure of these nuclei.	Interaction with the evaluators for these nuclei continues.

LBNL – 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.

LBNL Planned Activities	Status
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. Continue cross section measurements with neutron beams at the Budapest Reactor.	Continuing

## 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	Status
Maintain and upgrade ENSDF checking and physics programs for format changes as required.	Continued maintenance of ENSDF analysis codes.

## VI. Nuclear Reaction Physics

### 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	Status
Compile experimental data from 150 charged particle and neutron reaction publications.	127 papers with experimental reaction data compiled into EXFOR, which corresponds to 875 reaction compilations.

### 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 FY2007. 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.

BNL Planned Activities	Status
Respond to user needs for evaluated nuclear reaction data.	Aid was provided to users who requested assistance with retrieving nuclear reaction data.
Collect and address users' feedback related to the ENDF library.	GForge, a commercial collaboration software system, was installed and tested. In the near future, GForge will serve as the platform on which ENDF deficiencies are posted; their designated evaluators perform updates; and the nuclear data community monitors their statuses.

Work with LANL on upgraded evaluations for future release of the ENDF/B library (version VII.1).	New and upgraded LANL evaluations were collected in ENDF/A and recently migrated to the GForge collaboration system. Feedback was provided to LANL on performance of the NOY code in processing covariance data.
Improve methodology for providing covariance data, in the fast neutron energy region, to the next release of ENDF.	Tendency of the statistical methods to provide too optimistic error estimates has been addressed. Several reasons have been identified and their effects are being tested.

LANL Planned Activities	Status
Upgrade the LANL ENDF evaluations for actinides that perform well in criticality benchmarks, considering new LANSCE experimental data.	$^{236}\text{U}$ and $^{241}\text{Am}$ capture and fission data were upgraded. A new evaluation for $^{240}\text{Pu}$ that considers new LANSCE fission cross section data was made, which includes the covariance data.
Provide upgraded ENDF evaluated data files for light elements, including covariance data. An improved treatment of three-body breakup channels will be incorporated into the EDA code in order to better describe data for (n,xn) reaction on $^9\text{Be}$ .	A new $^9\text{Be}$ evaluation that includes new RPI experimental data was made. New evaluations for $^3\text{H}$ , $^6\text{Li}$ , and $^{16}\text{O}$ have been made.
Continue to study a problem on oxygen, which is reported by criticality benchmarks.	Several new evaluations have been made for oxygen. One that performs the criticality benchmarks best will be determined.
Re-evaluate V data, for which problems in the criticality benchmarks are reported.	The V data evaluation has postponed to FY2010, however, we have performed a preliminary statistical model calculation. Instead, we have completed new As evaluations.
Submit the covariance data for light elements (this is supported by many projects including AFCI, criticality safety, and also a WPEC collaboration).	The covariance data for the light element have not been submitted. We will make them available once new R-matrix evaluations are completed.
Provide new delayed gamma-ray data.	A new Monte Carlo code for calculating the delayed gamma-ray data was given to our internal users for testing.

LLNL Planned Activities	Status
Perform new evaluations as per LLNL customer requests and submit these and other LLNL generated evaluations into ENDF.	Automated procedure to make LLNL evaluations in ENDF format simultaneously along with LLNL's format, and produce ENDF evaluations directly from results of Hauser-Feshbach code TALYS. Evaluations resubmitted to ENDF/A: $^{240}\text{Am}$ . Evaluations completed during FY09 to be submitted to ENDF/A: $^{27}\text{Al}$ , $^{36}\text{Ar}$ , $^{57}\text{Fe}$ , $^{59}\text{Co}$ , $^{74,75}\text{As}$ , $^{78}\text{Kr}$ , $^{123,124}\text{Xe}$ , $^{180,181}\text{Ta}$ , $^{185,187}\text{Re}$ , $^{204,206,207,208}\text{Pb}$ , $^{239}\text{U}$ .
<b>Unplanned activity:</b> Energy dependent Q-values	MT=458 files re-generated for all actinides in ENDF/B-VII.0, with energy dependent Q-values from fission.

## 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	Status
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 library.	The ENDF-6 format manual has been kept up to date with the format changes endorsed by CSEWG and has been posted on the NNDC web site. In the near future, GForge will serve as the platform on which the ENDF-6 Formats Manual is posted; updates are loaded; and through which subscribed members of the nuclear data community are alerted (through e-mail) on the latest updates.

## D. Nuclear Reaction Standards

Nearly all neutron cross section measurements are made relative to a neutron cross section 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 most efficiently accomplished through international cooperation. A new international evaluation of the neutron cross-section standards, which was initiated by the CSEWG, was recently completed. The work was performed largely by an IAEA Coordinated Research Project (CRP) with support from the NEA Working Party on International Evaluation Cooperation (WPEC) of the Nuclear Energy Agency and the CSEWG. It is important to improve the standards database and procedures for evaluations in preparation for new evaluations of the standards.



LANL Planned Activities	Status
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.	Participated in the international effort to reevaluate the standards. The new evaluation for Li has been performed with the R-matrix analysis, and the data will be made available through the new ENDF release.
Incorporate the cross section standards into the new ENDF evaluations, and perform validation tests with integral measurements.	The new $^{240}\text{Pu}$ fission cross section evaluation was based on the $^{235}\text{U}$ fission cross section standards. The benchmark testing is underway.
Measure cross sections for the standards reaction $^6\text{Li}(n,\alpha)$ from 5 to 10 MeV to provide improved data for R-matrix analysis.	Differential data taken and used in R-Matrix analysis to improve cross section used as a standard. The differential data were sent to NNDC for inclusion in CSISRS/EXFOR data base.
Study covariance data evaluation for the standards in a different technique when the R-matrix analysis gives extremely small uncertainties.	We have investigated a general problem in covariance evaluation with the least-squares data fitting method, and recalled the PPP problem.
Complete report on H(n,p) angular distribution standards measurements at 15 MeV with Ohio University and NIST.	Draft manuscript for submittal to Physical Review C is close to approval by all authors.

NIST Planned Activities	Status
Continue work on the IAEA data development project on maintenance of the neutron cross section standards. Attend the IAEA Consultants' Meeting on this project and provide results on the updating of the standards database and its impact on the standards.	Attended the IAEA data development project on maintenance of the neutron cross section standards and gave a report on experimental work done since the completion of the standards evaluation. An assessment of the impact of these data was presented.
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.	Additional documentation work on the Poenitz files containing corrections to original experimental data was done.
Continue to recommend and encourage new measurements and perform examinations of the data from them for use in future evaluations of the standards.	New measurements were recommended and encouraged in a continuing effort to improve the database for use in future evaluations of the standards.
Begin an experiment using neutron detection (instead of proton detection) to measure the H(n,n) angular distribution in collaboration with Ohio University and LANL. Investigate use of a time projection chamber for angular distribution measurements.	Diagnostic work and initial preliminary data were obtained on an experiment using neutron detection (instead of proton detection) to measure the H(n,n) angular distribution in collaboration with Ohio University and LANL. Studies were started to investigate the use of a time projection chamber for angular distribution measurements.
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.	Samples were monitored and possible new samples were investigated for the National Repository for Fissionable Isotope Mass Standards. The samples in this facility are available for loan in physics experiments.
Complete a calibration of NBS-I, the U.S. national primary standard neutron source.	A preliminary calibration of NBS-I, the U.S. national primary standard neutron source was made relative to nu-bar of $^{252}\text{Cf}$ .
Complete a measurement of the $^6\text{Li}(n,t)$ standard cross section at ~ 4 meV neutron energy using an improved fluence determination based on $\alpha$ - $\gamma$ coincidences with the $^{10}\text{B}(n,\alpha_1\gamma)$ reaction.	Preliminary results have been obtained for the $^6\text{Li}(n,t)$ standard cross section at ~ 4 meV neutron energy using an improved fluence determination based on $\alpha$ - $\gamma$ coincidences with the $^{10}\text{B}(n,\alpha_1\gamma)$ reaction.
Complete efforts to improve the $^3\text{He}(n,p)$ standard cross section by making measurements of the spin-dependent n- $^3\text{He}$ coherent scattering length.	The spin-dependent n- $^3\text{He}$ coherent scattering length measurement has been completed This data will lead to improvements in the $^3\text{He}(n,p)$ standard cross section through R-matrix analyses.

## 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

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 extended and tested.

BNL Planned Activities	Status
Release new version of the code EMPIRE with above-mentioned improvements.	EMPIRE is under continued development and the current version is available on-line through the cvs revision system.
Develop the improved version of the covariance module in EMPIRE for fast neutrons.	The resonance module of EMPIRE has been extended by inclusion of long range correlations among resonance parameters. An alternative method, also based on the Atlas of Neutron Resonance, is being developed.
Implement and test the new resonance module allowing to generate covariances utilizing information from Atlas of Neutron Resonances.	The new module has been implemented and tested. It has been found that strong correlations between gamma-widths are needed to prevent rapid decrease of the uncertainties at high energy end of the resonance range. Similar approach, however, does not yield improvement in the case of elastic scattering uncertainties.

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, and FIGARO detectors for neutron emission 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	Status
Perform neutron inelastic scattering and fission-neutron spectrum measurements with the FIGARO array. Correlate $^{56}\text{Fe}(n,xy)$ data from GEANIE with $^{56}\text{Fe}(n,xn)$ data from FIGARO.	Data taken both at GEANIE and at FIGARO. Analysis is underway.
Complete analysis of measurement of the fission-neutron spectrum for fission induced by neutrons of 1 to 200 MeV on $^{235}\text{U}$ and $^{239}\text{Pu}$ . The shape of the major part of the emission spectrum between 1 and 8 MeV will be determined in this experiment, performed in collaboration with CEA researchers, and will be compared with the Los Alamos model prediction. The modeling includes the Monte Carlo prompt neutron emission technique and the microscopic quantum mechanical preequilibrium calculations.	Data analysis completed. The fission spectrum shapes under the neutron incident energy of 8MeV were compared with the Los Alamos model calculations. For the Monte Carlo prompt neutron calculation, we have developed a code to generate the neutron and $\gamma$ -ray emission spectra based on the Hauser-Feshbach theory. The microscopic quantum mechanical pre-equilibrium still underway.
Perform radiative capture calculations on Eu isotopes in support of DANCE detector capture measurements, and provide the Maxwellian averaged cross section to s-process study.	The code is ready, but still need to finalize the experimental data.
Perform radiative capture calculations for fission products, in collaboration with CEA (France).	A suite of capture calculations on fission products was performed in collaboration with CEA. The results were submitted to a peer-review journal.
Develop a code to calculate the delayed gamma spectrum from fission products, using the Monte Carlo technique for the Hauser-Feshbach statistical decay.	The delayed neutron and gamma spectrum calculation code, CGM ver.3.0, was written. However, the code runs in a deterministic mode for now.
Develop a theory and method to calculate compound reactions when strongly coupled-channels exist. This is crucial to study reaction cross sections for actinides.	The coupled-channels Hauser-Feshbach theory was developed. This model allows us to calculate nuclear reactions on the excited states. A Phys. Rev. C paper was published.
Modern nuclear structure models, such as Hartree-Fock, will be applied to calculate nuclear reaction cross sections to reduce phenomenological model parameters.	The Hartree-Fock model was utilized to calculate neutron inelastic scattering and proton capture processes.
Study $^{238}\text{U}$ and $^{232}\text{Th}$ neutron inelastic scattering at low-excitation energies where theoretical calculation underestimates experimental data.	Several possibilities, such as energy resolution in experiments, collective enhancement in the level densities, have been investigated. However the problem still persists.

LLNL Activities	Status
<b>Unplanned activity</b> (funded from other sources): Event by event fission modeling	The event-by-event fission simulation code FREYA was used to produce a new evaluation of the $^{239}\text{Pu}$ fission spectrum up to 5.5 MeV incident neutron energies. Two papers in Physical Review C. The first describes the benefits of FREYA's event-by-event approach which, since it conserves mass number, charge, energy and 3-momentum at each step, makes it possible to keep track of all relevant correlations. Some of the results for differential observables and a description of the relevant correlations are given. The second describes the procedure used to determine the fission neutron spectrum.
<b>Unplanned activity</b> (funded from other sources): Reaction theory for surrogate reactions	Evaluation of Weisskopf-Ewing and ratio approximations in surrogate reactions. Begun determination of partial fusion in (d,p) reactions. This is needed to determine neutron escape (breakup) in competition with absorption (compound nucleus production). First method used an orthonormal expansion, but found inadequate for this non-Hermitian problem. Second method begun using source terms/Greens functions, to be continued in FY10.

## 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.

LANL Planned Activities	Status
Measure and analyze prompt neutron emission following interactions of fast neutrons with fission products such as strontium. These measurements are gated on gamma rays from (n,n' $\gamma$ ) reactions.	Data taken on elemental barium and strontium. Analysis is underway.
Complete data analysis for gamma-ray output from neutron-induced fission of $^{235}\text{U}$ , $^{238}\text{U}$ , and $^{239}\text{Pu}$ for neutron energies from 1 to 100 MeV. Collaborators include scientists from CEA (France).	Neutron output has been reported in several conference proceedings. Gamma-ray data have been taken and analysis is beginning.
Design an experiment to measure that part of the fission neutron spectrum that lies below 1 MeV.	Done. Detectors of $^6\text{Li}$ -glass have been demonstrated to be suitable for this measurement, planned to begin in CY 2010.
Complete analysis of gamma-ray production for neutrons on fission products such as $^{136}\text{Xe}$ with the goal of deducing partial reaction cross sections.	Excitation functions have been measured for about 40 transitions. Absorption corrections are in progress to convert these excitation functions into cross sections.
Measure the neutron capture cross-section of $^{241}\text{Am}$ at DANCE for neutron energies less than 200 keV.	Measurement of $^{241}\text{Am}$ capture cross section completed. A Phys. Rev. C paper was published.
Measure the neutron capture and fission cross sections of $^{239}\text{Pu}$ at DANCE for energies less than 200 keV.	Partial data obtained. Completion of experiment expected in 2010. Sample preparation has delayed this project.
Measure the neutron capture cross-section at DANCE for at least one radioactive isotope of importance to nuclear astrophysics.	Measurements made of neutron capture on $^{63}\text{Ni}$ . Data are being analyzed as part of a PhD thesis research by a student at the University of Notre Dame.

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 is leading 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, $\gamma$ ) 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	Status
Continue to perform (n, $\gamma$ ) cross section measurements at thermal energies in collaboration with the Budapest Research Centre.	New measurements of $^6\text{Li}$ , $^7\text{Li}$ , $^{10}\text{B}$ , $^{11}\text{B}$ , $^{12}\text{C}$ , $^{13}\text{C}$ , $^{14}\text{N}$ , $^{15}\text{N}$ (n, $\gamma$ ) cross sections completed and in process of analysis. Research paper on $^{39,40,41}\text{K}$ (n, $\gamma$ ) cross sections in preparation for submission to Phys. Rev. C.

Lead series of surrogate-reaction benchmarking measurements at LBNL.	$^{237}\text{Np}(n,f)$ surrogate reaction data published in Nuclear Instruments and Methods Phys. Res. B
LLNL Planned Activities	Status
Neutron induced reaction measurements on one or more isomer targets.	Not done.
Perform surrogate $(n,n')$ , $(n,2n)$ , $(n,\gamma)$ and $(n, f)$ measurements on several nuclei with programmatic and/or astrophysical importance. (funded from other sources)	We have relocated our surrogate apparatus to a new experimental hall. We have augmented our capabilities by adding on a general purpose scattering chamber.
Perform neutron capture measurements with DANCE array at LANSCE in collaboration with LANL. (funded from other sources)	Failed attempt for the $(n,\gamma),(n,f)$ cross section measurement on $^{239}\text{Pu}$ using the DANCE array.
Perform fission cross-section measurements with the lead slowing down spectrometer at LANSCE in collaboration with LANL. (funded from other sources)	Fission neutron measurement for $^{235}\text{U}$ using the FIGARO array with the new LLNL designed fission counter (test run).

## 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	Status
Complete work on $^{186m}\text{Re}$ that is of relevance to the $^{187}\text{Re}/^{187}\text{Os}$ cosmo-chronometer, including measurements and modeling of the production and destruction cross-sections of the $^{186m}\text{Re}$ isomer (in collaboration with TUNL).	Studies of 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 are continuing. Studies of the role of K-mixing on the thermal equilibrium of $^{176}\text{Lu}$ have been completed in collaboration with scientists from the University of North Carolina at Chapel Hill and an article has been published in Physical Review C.
Evaluate weak interactions data for the needs of the nuclear astrophysics community	Evaluation of weak interactions data for the needs of the nuclear astrophysics community is continuing.

BNL Planned Activities	Status
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 (largely done by guest scientist not funded by USNDP).	Completed
USNDP support of this work will be limited to including the evaluations in appropriate databases and to providing data dissemination.	Nuclear Rates website for dissemination of Maxwellian-averaged cross sections and astrophysical reaction rates has been created.

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	Status
Continue N-N analysis to energies above 50 MeV and provide evaluated n-p capture cross-sections, rates, and covariance data.	Extension of N-N analysis was not completed.
Improve neutron capture models to provide neutron capture rates off-stability to s-process hydro-dynamics simulations.	A new Hartree-Fock BCS model calculation was performed for proton induced reactions on odd targets.
Provide neutron emission rates for the electron capture process in the astrophysical stellar environment.	The neutron emission rate database was provided for nucleosynthesis network calculations.

McMaster: The evaluation of nuclear astrophysics data is expected to complement the on-going experimental program of measurements of radiative capture cross sections and particle-transfer experiments using radioactive ion beam facilities at TRIUMF, NSCL, RIKEN and ANL.

McMaster Planned Activities	Status
Specific reactions planned for evaluation in FY09: $^{27}\text{Si}(p,d)$ $^{26}\text{Si}$ and $^{28}\text{Si}$ ( $^{12}\text{C},^6\text{He}$ ) $^{34}\text{Ar}$ .	$^{25}\text{Al}(p,\gamma)^{26}\text{Si}$ and $^{29}\text{P}(p,\gamma)^{30}\text{S}$ reactions were evaluated and submitted to nucastrodata.org library

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

stellar explosions.

ORNL Planned Activities	Status
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.	Assessments of levels in $^{27}\text{Si}$ are in progress as a result of ORNL measurements of $^{26}\text{Al}(p,p)$ and $^{26}\text{Al}(d,p)$ measurements; assessment of levels in $^{18}\text{Ne}$ is in progress as a result of ORNL measurement of $^{17}\text{F}(p,p')$ ; assessments of levels in $^{22}\text{Mg}$ were made as a result of ORNL measurement of $^{24}\text{Mg}(p,t)^{22}\text{Mg}$ .
Extract spectroscopic information (excitation energies, spectroscopic factors, spins, parities, ANCs) on nuclei near the $N=82$ closed shell – $^{131}\text{Sn}$ , $^{133}\text{Sn}$ , $^{135}\text{Te}$ - from transfer reaction measurements on radioactive Sn and Te nuclei. This information is important for modeling the r-process in supernovae.	Paper submitted to Nature on level structure of $^{133}\text{Sn}$ and magicity of $^{132}\text{Sn}$ ; level assessments in progress for $^{131}\text{Sn}$ and $^{135}\text{Te}$ .

## H. Reaction Data for FRIB Target Design

The Facility for Rare Isotope Beams 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	Status
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.	Very limited activities. Theoretical modeling for neutron radiative capture reaction was investigated in collaboration with LANSCE experimentalists in support of FRIB.

## Appendix A

### Nuclear Data Activities Funded from Sources outside the Nuclear Data Program (Report FY2009)

#### ANL

Additional support for the nuclear data work at Argonne comes from ANL LDRD project entitled "Development of Argonne Total Absorption Gamma-ray Spectrometer for Advanced Fuel Cycle Applications". This is a collaborative project with scientists from the ANL Physics Division that expired at the end of FY2009.

#### BNL

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

1. Elsevier supports the production of computer-generated photo-ready copy of manuscripts for the Nuclear Data Sheets.
2. The US Nuclear Criticality Safety Program (NCSP), funded by DOE NNSA, supports the NNDC services in maintaining NCSP data submitted to ENDF/B-VII library as well as data development work on estimates/evaluations of neutron cross section covariances for criticality safety applications.
3. The AFCI Data Adjustment project, funded by DOE-NE, supports the NNDC work on development of neutron cross section covariances for fast advanced burner reactors.
4. Two ANST grants from DOE support development of neutron cross section covariances for selected materials to be included in ENDF/B-VII.1.

#### 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. Advanced Simulation and Computing (ASC 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. Advanced Fuel Cycle (AFC). 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.
5. Nuclear Weapons supports LANSCE measurements of fission output (neutrons and gamma rays), neutron capture on actinides and radchem isotopes, and neutron reactions relevant to radchem.
6. SciDAC (Scientific Discovery through Advanced Computing). This funding supports advanced nuclear reaction modeling based on microscopic nuclear structure theory (universal nuclear energy density functional).

#### LBNL

LDRD funding for a project on the measurement of cross sections for advanced fuel cycles provided partial support for one of our structure evaluators, enabling retention of evaluation capability while addressing laboratory research priorities. Analysis of  $^{238}\text{U}(^3\text{He},\text{tf})$  cross section data measured in collaboration with LLNL and University of Richmond was completed, and LBNL provided the lead author on the resulting paper published in Nucl. Instrum. Meth. Phys. Res. B. This reaction serves as a surrogate for the  $^{237}\text{Np}(n,\text{f})$  reaction which is of relevance to Advanced Fuel Cycle data needs. The work benchmarked the experimental procedures at LBNL using a previously-measured reaction, with a view to employing the surrogate reaction technique to obtain vital (n,f) cross section data for cases where direct experimental measurements are not feasible. USDOE Low-energy Nuclear Physics funds provided about 0.3 FTE support for ENSDF mass chain evaluation already mentioned in this report. ARRA research stimulus funds received this year funded 0.2 FTE for ENSDF mass chain evaluation and capture gamma-ray library evaluations in collaboration with LLNL. The DICEBOX statistical

model code was installed at LBNL and A=30 mass chain completed.

### **LLNL**

NSA Defense Programs, the Department of Homeland Security, and branches of the Office of Science outside the USNDP support most of the nuclear efforts at LLNL. Funding from USNDP is used to coordinate these efforts and process data for use by the larger community. Much of the Livermore experimental work is made possible by beam time and collaborations at TUNL, TRIUMF, LBNL and LANSCE. Sponsorship for different nuclear efforts includes:

1. NNSA/DP/ASC funds data evaluation, validation and verification efforts, development of ab-initio structure and reaction methods and development of theory supporting the surrogate measurement campaign for unstable actinides.
2. NNSA/DP/SC funds experimental campaigns for unstable actinides, including development of the Time P rejection Chamber at LLNL for new <sup>239</sup>Pu fission cross section measurements.
3. NNSA/NA-22 and DHS fund experimental work on the structure of Pu and U, including the recent discovery of strong electromagnetic resonances in these nuclei and the development of methods of improved calculations of neutron-capture spectra.
4. DHS funds fission-multiplicity experiments and theory development.
5. Two separate SciDAC grants support (i) reaction theory development and (ii) nuclear astrophysics.
6. LDRD supports ab-initio reaction theory.

### **McMaster**

The nuclear data project at McMaster receives 0.4 FTE support from the Canadian research agency NSERC 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 standard cross section work using ~4 meV neutrons and also 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.