

# USNDP Fiscal Year 2002 Final Report



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## **I. Introduction**

This year-end report summarizes the work of the U.S. Nuclear Data Program (USNDP) for the period of October 1, 2001 through September 30, 2002 with respect to the work plan for FY2002 that was prepared in March 2001. The work plan and final report are prepared at the direction of the DOE Office of Science, Division of Nuclear Physics for the nuclear data program. For the first time, the support for the nuclear data activity from sources outside the nuclear data program has been completely described in the manning table and in appendix A. This leverage amounts to about 28 FTE, mostly at NNSA laboratories, to be compared with 25 FTE at USNDP funded by the DOE Office of Science, Division of Nuclear Physics nuclear data program. When tasks are jointly funded, then it becomes impossible to differentiate accomplishments funded by nuclear data program resources from those which were otherwise funded. As a consequence, some of the work reported was accomplished with nuclear data program support, leveraged by other funding sources.

This section of the report consists of activity summaries for the major components of the U.S. Nuclear Data Program. The next section of this report is an updated staff level assignment table that reflects the final distribution of effort among the tasks carried out during FY2002. This is followed by the work plan for FY2002, along with the mid-year revisions. The plan has been annotated with bullets giving the status of each commitment made by the program participants.

Total staff assigned to USNDP activities during the year was lower than anticipated by 1.95 FTE, a reduction of about 7%. Support staff effort has been reduced by 0.8 FTE at BNL due to an unexpected retirement. A reduction in scientific/professional staff of 1.85 FTE results from retirements without replacement at BNL, LBNL and TUNL. This reduction is partly compensated by the inclusion for the first time of the LANL experimental work resulting in a total FTE decrease at the scientific/professional level of 1.15 FTE.

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

## **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 fiscal year 2002 in conjunction with the members of the Coordinating Committee. In February 2002, Pavel Oblozinsky replaced Charles Dunford as head of the NNDC. The NNDC Head continues as chair of the program Coordinating Committee, which consists of the Principal Investigators from each of the participating groups, and chaired the annual meeting of the program held at Brookhaven National Laboratory in April 2002. NNDC continues to chair the Cross Section Evaluation Working Group, which produces the ENDF/B evaluated nuclear data library for applied nuclear technology use, and hosted its annual meeting which was held at BNL in November 2001.

Upon request of the DOE Office of Science, for the first time, in March 2002, the USNDP conducted the Budget Briefing. This allowed the USNDP, represented by P. Oblozinsky, M. Chadwick, C. Dunford, J. Kelley and E. Norman, to make its case for FY2004. A major concern is continuing staff reduction, in particular the loss of highly experienced evaluators, coupled with staff renewal and a flat budget.

At its April 2002 meeting, the USNDP Coordinating Committee decided to terminate the Dissemination Working Group. Staff members from the Los Alamos National Laboratory and Lawrence Berkeley National Laboratory now chair the remaining two working groups of the USNDP, which are responsible for coordinating the technical activities of the reaction and structure components of the program. The Working Group chairs organized the technical discussions held during the USNDP annual meeting.

The NNDC serves as the focal point for U.S. collaboration in international nuclear data activities. The head of the NNDC serves as the U.S. member of the IAEA's International Nuclear Data Committee. The committee meets biennially and serves as the oversight body for the IAEA's Nuclear Data Section. At its May 2002 meeting, Pavel Oblozinsky was chosen as deputy chairman. Two staff members from NNDC participated in the IAEA-sponsored Nuclear Reaction Data Center (NRDC) meeting in Vienna in May 2002. The NRDC coordinates the compilation of nuclear reaction data and the dissemination of nuclear data worldwide. Two NNDC staff served as consultants to the IAEA Nuclear Data Section during the past fiscal year. The latest in a series of major international nuclear data conferences, held every three to four years, occurred in October 2001, at Tsukuba, Japan. The U.S. played an important role in the organization of the conference, and USNDP participants presented a significant number of papers at the conference.

The Cross Section Evaluation Working Group (CSEWG), which is organized and chaired by NNDC, celebrated its 50<sup>th</sup> meeting and 35<sup>th</sup> anniversary in November 2001 with a symposium and banquet. CSEWG organizes the production of the ENDF/B evaluated nuclear data library, which is widely used in developing applied nuclear technologies, including nuclear reactors and national security. Several USNDP participants attended the May 2002 meeting of the NEA-sponsored Working Party on International Evaluation Cooperation (WPEC). The US has the lead responsibility for several projects sponsored by this group.

### **USNDP Databases**

The NNDC operates a Compaq Alpha 4100 computer, which archives and serves the nuclear data produced by the U.S. Nuclear Data Program and the data obtained by other national and international collaborations. This facility operates 24 hours a day, 7 days a week, to provide electronic access to the data. Two other servers, one new, are running with Linux operating systems. These Linux machines will become the data servers for future electronic access to the USNDP nuclear databases. Considerable effort was made to upgrade the facility's cybersecurity to comply with DOE guidelines.

The NNDC maintains seven nuclear physics databases for the USNDP. These databases have been updated continuously in FY2002 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. Retrievals from the network databases located at NNDC increased 9.4% as compared to the prior fiscal year.

The nuclear data base migration to a new generation of relational database software and technology (Sybase/Linux), continues on schedule. The work on the nuclear structure databases is being done at NNDC while the migration of the nuclear reaction databases is being done as a joint project between NNDC and the IAEA's Nuclear Data Section. The migration effort for the bibliographic database, NSR, and the experimental reaction database, CSISRS has been completed. Both are now undergoing extensive testing. Work has begun on the migration of the ENSDF/NuDat database (nuclear structure data) and the CINDA (nuclear reaction bibliography). New technologies are being investigated for the exchange of data.

### **Data 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. The Dissemination Working Group has been dissolved by the USNDP Coordinating Committee because there was little inter-laboratory work that required coordination. Improvements to the Web sites of the USNDP participants continue to be made.

In July 2002, the NNDC made its new NSR database, which uses Sybase relational database software, available on the Web using a Java Server Page (JSP) interface. LANL T16 has enhanced its nuclear data viewer to be able to plot cross section ratios and differences.

As part of an IAEA-sponsored Coordinated Research Project, LBNL has completed the development of a searchable database for capture gamma ray data.

At ORNL, a new program to convert RadWare-format schemes to ENSDF format has been written and tested. The text-to-ENSDF programs have been updated and tested. Because of the large variation in possible types of input data, this be done using real data sets. New routines to improve the automatic graphical layout of the RadWare schemes converted from ENSDF and from text tables are currently under development.

TUNL has completed the redesign of its Web site. HTML and PDF documents have been completed for "Energy Levels" publications for the years 1979-present.



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

The main activity during the past year has been the evaluation of nuclear structure and decay data for entire mass chains or for individual nuclides and the entry of these results into the Evaluated Nuclear Structure Data File (ENSDF). These include a number of priority nuclides, and most evaluations will ultimately be published in the journal *Nuclear Data Sheets*. In addition, the currency of evaluated superdeformed-band data in ENSDF has been maintained, and data in many recent publications have been compiled and incorporated into the XUNDL file.

#### **Evaluations for ENSDF**

The USNDP nuclear structure and decay data evaluation groups have submitted 13 mass-chain and 47 nuclide evaluations (approximately 188 nuclides altogether, 36 of them priority nuclides) for inclusion in the ENSDF database. The evaluators have also reviewed 13 mass chain evaluations, and additional prepublication checks have been done at NNDC for all published evaluations. Superdeformed-band data for 6 nuclides have been updated, thereby maintaining currency of such data in ENSDF, and a revised version of the *Table of Superdeformed Nuclear Bands and Fission Isomers* has been prepared for publication in *Nuclear Data Sheets*. Twelve issues of the journal *Nuclear Data Sheets* were published by Elsevier; these issues contained 16 mass chains, 29 nuclides, and the annual references update.

#### **Compilations for XUNDL**

The XUNDL file contains experimental unevaluated data sets compiled primarily from recent papers. The McMaster group has submitted 159 new and 31 updated data sets, which are mostly, but not exclusively, for high-spin data. These data have been entered into XUNDL at BNL. New software to translate tabular text files to ENSDF format has been developed at McMaster to make the compilation process more efficient.

#### **Horizontal Evaluations**

The international Decay Data Evaluation Project (DDEP), which includes non-ENSDF evaluators from France, Germany, Russia, Spain, and the United Kingdom, prepares evaluations for radionuclide decays of importance in applied research. LBNL coordinates this project. New evaluations have been completed for 6 nuclides by ANL, LBNL and the Idaho group, and these have been submitted to the DDEP project for review. Ultimately, these will be made available to ENSDF evaluators for incorporation into ENSDF.

#### **Nuclear Science Reference File**

The keyworded references included in the NSR file have been expanded by 3240, including those prepared by foreign collaborators. These new keyword abstracts were prepared primarily by the NNDC staff that regularly reviews more than 75 refereed journals, along with laboratory reports and conference proceedings.

## **Other Items**

The Nuclear Wallet Cards have been updated on a continuing basis by BNL. Recently, the data in the January 2000 file for this publication were adopted as a standard by the DOE Office of Security, Nuclear Materials Management and Safeguards System.

The final draft of a neutron-capture gamma-ray database containing evaluated data for use in prompt-gamma activation analysis was completed; this work is part of an IAEA Coordinated Research Project in which LBNL plays a leadership role.

## 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 makes important contributions to nuclear reaction model code development and improvement of reaction cross section standards.

### Reaction Data Highlights

The NNDC has compiled 153 neutron and charged-particle data sets for the experimental nuclear reaction database, CSISRS. Under the sponsorship of the NEA Working Party on International Evaluation Cooperation (WPEC), the NNDC is leading an effort to review available neutron evaluations for fission product nuclei. The evaluation of neutron resonance parameters across the periodic table continues.

A new evaluation of the neutron cross sections for  $^{239}\text{Pu}$  has been completed and submitted for ENDF/B-VII by LANL. The evaluation includes updated data for the (n,2n) reaction which was highlighted in the 2002 NSAC Long Range Plan. Extensive improvements have been made to the evaluation of prompt neutron fission spectra for both  $^{235}\text{U}$  and  $^{238}\text{U}$ , the former as part of a WPEC sponsored international project. LANL has submitted a suite of 140 evaluations of photonuclear reactions for ENDF/B-VII. The evaluations were selected from those produced during an IAEA project in which LANL participated.

Analysis of experimental measurements is being used to improve nuclear model code predictions. GEANIE (n,x $\gamma$ ) data for  $^{196}\text{Pt}$  are being analyzed by a collaboration of LANL, LANSCE/WNR and LLNL researchers. Data been obtained on Y, Nb and  $^{92,94,96}\text{Mo}$  and are being analyzed. Preequilibrium components in  $^{58,60}\text{Ni}(n,x\alpha)$  and  $^{59}\text{Co}(n,x\gamma)$  have been quantified.

ANL is participating in a three-year project lead by IRRM, Geel to measure activation cross sections. The measurements have been completed. The results are being used to study the sensitivity of level density parameters to the measured data.

### Model Code Highlights

LANL continues to improve the McGNASH nuclear reaction code. A new hybrid Monte-Carlo preequilibrium module is being tested by both LANL and BNL. A LANL staff member is participating in the WPEC project to develop standard calculation modules for nuclear model codes.

LANL has made enhancements to our CEM and LAQGSM intra-nuclear cascade simulation codes by developing a new fission model that results in much more accurate spallation and fission fragment yields, important in ISOL and target fragmentation RIA design. Many benchmark comparisons against recent GSI data demonstrate the improvement.

BNL continues to collaborate with the IAEA on the improvement and validation of the nuclear reaction code EMPIRE. In April 2002, version 2-17 of the code was released.

TUNL is investigating complex particle reaction channels. New results on isospin conservation have been obtained, and work on surface effects in neutron-induced reactions has been completed.

### **Nuclear Standards Highlights**

Nearly all nuclear reaction data measurements are made relative to some reaction standard such as the hydrogen elastic cross section. Maintaining accurate current values for the standard cross sections is the objective of this task. The IAEA Nuclear Data Section has initiated a Coordinated Research Project in support of this activity. Staff members from NIST and LANL helped organize the second meeting of the project, for which they served as chair and secretary, respectively.

Data from more than 80 experiments have been reviewed for use in the new standards evaluation. A measurement of the np scattering cross section at 10 MeV has been published, and a new measurement of that cross section at 15 MeV has been recommended. LANL led an effort to compare the results of the three primary R-Matrix codes for the calculation of  $n + {}^6\text{Li}$  cross sections.

## V. Nuclear Astrophysics Data Task Force

A number of efforts within the U.S. Nuclear Data Program (USNDP) either directly or indirectly help improve our understanding of a wide range of exciting astrophysical phenomena such as stellar explosions, the interior of our sun, Red Giant stars, and the early Universe. This work includes evaluations of particular nuclear reactions or the properties of certain nuclei, development of nuclear models to calculate unmeasured properties, data dissemination in formats requested by astrophysicists as well as in standard NNDC formats, and assistance in the design of next-generation experimental facilities. The work done by members of the Nuclear Astrophysics Data Task Force spans the activities done within the USNDP Nuclear Reaction and Nuclear Structure Working Groups.

### Nuclear Reaction Data

At ANL, work was almost completed on evaluations of the  $^{31}\text{P}(p,\gamma)^{32}\text{S}$  and  $^{31}\text{P}(p,\alpha)^{28}\text{Si}$  reactions in collaboration with Hiram College. Considerable effort was devoted to the issue of handling the very large uncertainties often encountered in nuclear astrophysics reaction data sets; this was done in collaboration with Hiram College and in consultation with ORNL. A collaboration led by ORNL is utilizing this new large-uncertainty formalism in simulations of the synthesis of nuclei in nova explosions.

At BNL, a project to compile and evaluate alpha-induced nuclear reaction cross sections has begun, focusing on nuclei up to  $Z = 32$  and alpha particles with energies up to about 20 MeV. A number of these reactions are of interest in astrophysics. Preliminary results were obtained for reactions on  $^{40}\text{Ca}$  and  $^{44}\text{Ti}$ . An extension of this project, in collaboration with scientists from the Former Soviet Union (Russian Federal Nuclear Center), has just been funded by the CRDF. The NNDC also compiled 160 charged-particle cross section data sets, some of which are important for astrophysics, for entry into CSISRS.

At LANL, the n-p capture reaction – crucial for the early Universe – is being investigated with R-matrix theory. Good fits have been obtained for N-N scattering as well as for capture and photodisintegration data. Other reactions important for the Big Bang have been evaluated:  $d(d,n)$ ,  $d(d,p)$ ,  $^3\text{He}(d,p)$ ,  $^7\text{Li}(p,\alpha)$ , and  $^7\text{Be}(n,p)$ . Work is continuing on predictions of the  $^7\text{Be}(p,\gamma)^8\text{B}$  cross section, which contributes the largest nuclear physics uncertainty to the neutrino oscillation “solutions” of the Solar Neutrino Problem. Calculations have also been made for the TUNL Energy Levels of Light Nuclei ( $A=5-7$ ) evaluation. The effects of electron screening potentials are being explored, and preliminary screened reaction rates were produced for some of the hydrogen-isotope reactions. R-matrix calculations are being performed on ORNL measurements of the  $^{17}\text{F}(p,p)$ ,  $^{17}\text{F}(p,p')$ , and  $^{17}\text{F}(p,\alpha)^{14}\text{O}$  reactions to determine an improved stellar  $^{14}\text{O}(\alpha,p)^{17}\text{F}$  reaction rate. LANL is also collaborating with ANL and ORNL on the design for the radioactive beam production target at the Rare Isotope Accelerator (RIA). Because of the importance of radioactive beams to studies of the cosmos, this work is of vital importance for astrophysics. In addition, work on developing intranuclear cascade models to optimize radionuclide production, using new GSI data to guide and test theory development, is underway.

At ORNL, evaluations of the  $^{18}\text{F}(p,\gamma)$  and  $^{18}\text{F}(p,\alpha)$  reactions, important for understanding stellar explosions, and  $^{17}\text{O}(p,\gamma)$  and  $^{17}\text{O}(p,\alpha)$  reactions, important for understanding the evolution of Red Giant Stars, are nearing completion. The reactions on  $^{18}\text{F}$  are incorporating the latest exciting new experimental results with  $^{18}\text{F}$  beams from ORNL's Holifield Radioactive Ion Beam Facility, as well as new Thomas-Ehrman level shift calculations and an improved non-resonant reaction rate calculation. The new reaction rates will be put into formats requested by astrophysicists and distributed over the WWW. Also in progress is a project examining evaluated cross sections for the 19 reactions important for the Solar Neutrino Problem. These cross sections are being converted into reaction rates, parameterized, and compared to analytical approximations (e.g., the NACRE collection of rates). ORNL is also leading a novel effort to gauge the influence of nuclear reaction rate uncertainties (such as those determined from detailed cross section evaluations) on nucleosynthesis predictions in novae. Additionally, the level structures in Ar and S isotopes for hydrogen burning on Cl and P, respectively, have been assessed for studies of stellar explosions.

### **Nuclear Structure Data**

TUNL completed A = 8 and 9 evaluations. An evaluation of A = 10 is in progress. The evaluation "Energy Levels of Light Nuclei: A=5-7" has been published in Nuclear Physics A. These evaluations will be added to their extremely valuable collection of online evaluations, submitted to ENSDF, and published. This work is important to astrophysics research because many reactions induced on light ions are dominated by individual resonances detailed in these evaluations.

### **Dissemination**

At TUNL, work has continued on disseminating important evaluations of nuclei with mass  $A \leq 20$ . This includes level schemes, tables, and PDF and HTML versions of complete evaluations. At LBNL, a link to a partial update of the REACLIB collection of reaction rates for astrophysics was made on their Nuclear Astrophysics Data WWW site. ORNL has updated reaction rate information on their Nuclear Astrophysics Data WWW site.

**Final USNDP Manning Table for October 2001 through September 2002**

	ANL	BNL Sci/Pro	BNL Support	Idaho	L/ANL	LBNL	LLNL
<b>I. NNDC Facility Operation</b>	<b>0.00</b>	<b>1.20</b>	<b>1.25</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
Management		0.40					
Secretarial/Administrative Support			1.00				
Library			0.25				
Computer Operation		0.80					
<b>II. Coordination</b>	<b>0.00</b>	<b>0.50</b>	<b>0.00</b>	<b>0.05</b>	<b>0.40</b>	<b>0.10</b>	<b>0.00</b>
National Coordination		0.30		0.05	0.2	0.1	
International Coordination		0.20			0.2		
<b>III. Nuclear Physics Databases</b>	<b>0.00</b>	<b>3.70</b>	<b>1.05</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
Nuclear Science References (NSR)		0.15	0.75				
Experimental Nuclear Structure Data (XUNDL)		0.05					
Evaluated Nuclear Structure Data (ENSDF)		0.45	0.30				
Numerical Nuclear Data (NuDat)		0.05					
Reaction Data Bibliography (CINDA)		0.05					
Experimental Reaction Data (CSIRS)		0.05					
Evaluated Nuclear Data File (ENDF)		0.20					
Database Software Maintenance		0.55					
Future Database Systems		2.15					
<b>IV. Information Dissemination</b>	<b>0.00</b>	<b>0.80</b>	<b>0.50</b>	<b>0.00</b>	<b>0.10</b>	<b>0.30</b>	<b>0.00</b>
Maintenance of Remote Access to USNDP Data	0.00	0.40		0.00	0.00	0.00	0.00
Telnet Service		0.05					
WWW Service		0.35					
Customer Services		0.15	0.45				
Web Site Maintenance		0.15	0.05		0.10	0.30	
APS Link to NNDC Experimental databases		0.10					

**Final USNDP Manning Table for October 2001 through September 2002**

	McMaster	NIST	ORNL	TUNL	Program Total
			Sci/Pro		Sci/Pro Support
<b>I. NNDC Facility Operation</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>1.20</b>
Management					0.40
Secretarial/Administrative Support					1.00
Library					0.25
Computer Operation					0.80
<b>II. Coordination</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.05</b>	<b>1.10</b>
National Coordination					0.65
International Coordination				0.05	0.45
<b>III. Nuclear Physics Databases</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>3.70</b>
Nuclear Science References (NSR)					0.15
Experimental Nuclear Structure Data (XUNDL)					0.05
Evaluated Nuclear Structure Data (ENSDF)					0.45
Numerical Nuclear Data (NuDat)					0.05
Reaction Data Bibliography (CINDA)					0.05
Experimental Reaction Data (CSIRS)					0.05
Evaluated Nuclear Data File (ENDF)					0.20
Database Software Maintenance					0.55
Future Database Systems					2.15
<b>IV. Information Dissemination</b>	<b>0.00</b>	<b>0.00</b>	<b>0.05</b>	<b>1.50</b>	<b>2.75</b>
Maintenance of Remote Access to USNDP Data	0.00	0.00	0.00	0.00	0.40
Telnet Service					0.05
WWW Service					0.35
Customer Services					0.15
Web Site Maintenance			0.05	1.50	2.10
APS Link to NNDC Experimental databases					0.10



### Final USNDP Manning Table for October 2001 through September 2002

	ANL	BNL	Idaho	LANL	LBNL	LLNL
		Sci/Pro				
		Support				
<b>V. Nuclear Structure Physics</b>	<b>0.50</b>	<b>2.20</b>	<b>0.40</b>	<b>0.10</b>	<b>2.35</b>	<b>0.00</b>
NSR Abstract Preparation		0.55				
Compilation of Experimental Structure Data						
Evaluation of data for ENSDF	0.50	1.50	0.40	0.00	2.35	0.00
Masses and Nuclides	0.45	1.40	0.35		1.65	
Ground and Metastable State Properties		0.10				
Radioactive Decay Data Evaluation	0.05		0.05		0.20	
Thermal Capture Gamma Data Evaluation					0.50	
Nuclear Structure Data Measurement				0.10		
ENSDF Physics and Checking Codes		0.15				
<b>VI. Nuclear Reaction Physics</b>	<b>0.40</b>	<b>1.55</b>	<b>0.00</b>	<b>1.60</b>	<b>0.00</b>	<b>0.40</b>
Experimental Data Compilation	0.00	0.55	0.00	0.00	0.00	0.00
Neutron Data		0.05				
Charged Particle Data		0.45				
EXFOR Manuals		0.05				
Evaluation of Fission Product Nuclides		0.60				
ENDF Manuals and Documentation		0.05				
ENDF Evaluations				0.10		0.20
Nuclear Reaction Standards				0.10		
Nuclear Model Development	0.15			0.65		0.20
Evaluation of Data Needed for Astrophysics	0.25	0.35		0.25		
Nuclear Reaction Data Measurements				0.30		
Reaction Data for RIA Target Design				0.20		
<b>DOE/Science Nuclear Data Funded Staff</b>	<b>0.90</b>	<b>9.95</b>	<b>0.45</b>	<b>2.20</b>	<b>2.75</b>	<b>0.40</b>
<b>Staff Supported by Other Funding</b>	<b>0.80</b>	<b>0.05</b>	<b>0.20</b>	<b>14.40</b>	<b>0.50</b>	<b>7.50</b>
<b>TOTAL STAFF</b>	<b>1.70</b>	<b>10.00</b>	<b>0.65</b>	<b>16.60</b>	<b>3.25</b>	<b>7.90</b>

**Final USNDP Manning Table for October 2001 through September 2002**

	McMaster	NIST	ORNL	TUNL	Program Total
					Sci/Pro Support
<b>V. Nuclear Structure Physics</b>	<b>0.50</b>	<b>0.00</b>	<b>0.65</b>	<b>1.40</b>	<b>8.10</b>
NSR Abstract Preparation					0.55
Compilation of Experimental Structure Data	0.10		0.05		0.15
Evaluation of data for ENSDF	0.40	0.00	0.60	1.40	7.15
Masses and Nuclides	0.40		0.60	1.40	6.25
Ground and Metastable State Properties					0.10
Radioactive Decay Data Evaluation					0.30
Thermal Capture Gamma Data Evaluation					0.50
Nuclear Structure Data Measurement					0.10
ENSDF Physics and Checking Codes					0.15
<b>VI. Nuclear Reaction Physics</b>	<b>0.00</b>	<b>0.60</b>	<b>0.45</b>	<b>0.40</b>	<b>5.40</b>
Experimental Data Compilation	0.00	0.00	0.00	0.00	0.55
Neutron Data					0.05
Charged Particle Data					0.45
EXFOR Manuals					0.05
Evaluation of Fission Product Nuclides					0.60
ENDF Manuals and Documentation					0.05
ENDF Evaluations					0.30
Nuclear Reaction Standards		0.60			0.70
Nuclear Model Development				0.40	1.40
Evaluation of Data Needed for Astrophysics			0.45		1.30
Nuclear Reaction Data Measurements					0.30
Reaction Data for RIA Target Design					0.20
<b>DOE/Science nuclear data program Funded Staff</b>	<b>0.50</b>	<b>0.60</b>	<b>1.15</b>	<b>3.35</b>	<b>22.25</b>
<b>Staff Supported by Other Funding</b>	<b>0.50</b>	<b>4.20</b>	<b>0.00</b>	<b>0.00</b>	<b>28.15</b>
<b>TOTAL STAFF</b>	<b>1.00</b>	<b>4.80</b>	<b>1.15</b>	<b>3.35</b>	<b>50.40</b>
					<b>3.00</b>

## Detailed Status of Work Plan

### I. NNDC Facility Operation

#### A. Management

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

P. Oblozinsky succeeded C. Dunford as head of NNDC in February 2002.

#### 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 data evaluation and international nuclear structure evaluation.

#### C. Computer Operation

The NNDC operates a Compaq Alpha 4100 server using the OpenVMS operating system to support our compilation, evaluation, database maintenance, and information dissemination functions. In addition to the primary production server, the NNDC operates Linux servers and MS Windows servers in support of its database migration project. Task includes software upgrades, hardware and software procurements, machine operations and internal user support.

#### **BNL Deliverables:**

Keep downtime to less than 3%.

#### **Status:**

- The Alpha 4100 server maintained high availability and performed well. We will continue our database maintenance and data dissemination from our Alpha server in the near future.
- Considerable effort was devoted to upgrading cyber-security to comply with DOE guidelines.
- We started operating Sybase database server and Apache Web server with Tomcat Java servlet/JSP application server on Linux machines as part of the database migration effort. Various databases and Web sites are being developed on these servers.

## II. Coordination

### A. National Coordination

**BNL** - Chair USNDP Coordinating Committee, Chair Cross Section Evaluation Working Group, USNDP specific tasks.

#### **BNL Deliverables:**

Prepare FY2003 work plan for USNDP in time for spring 2002 FWP submittals.  
Chair USNDP Meeting in April 2002.

Organize and chair CSEWG Meeting at BNL, November 2001.

Maintain USNDP Web-site.

#### **Status:**

- The final report for the US Nuclear Data Program for FY 2001 was completed in December 2001.
- The USNDP FY2003 Work Plan was completed in February 2002 in time for the March budget review.
- P.Oblozinsky organized and chaired the April 10-12, 2002 USNDP Meeting
- P.Oblozinsky organized and chaired the November 2001 CSEWG Meeting.
- C.Dunford organized a symposium in honor of the 35<sup>th</sup> anniversary of the founding of CSEWG.
- The USNDP and CSEWG Web sites were maintained and updated.

**Idaho** -- Chair U.S. Nuclear Data Program's Nuclear Structure Working Group, and help coordinate nuclear structure data work at different labs to advance USNDP goals.

#### **Idaho Deliverables:**

Organize and chair Nuclear Structure Working Group meeting at USNDP meeting in 2002.

#### **Status:**

- Working Group meeting was organized and chaired.

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

#### **LANL Deliverables:**

Organize and chair CSEWG Evaluation Committee meeting at BNL, November 2001.

Organize and chair Nuclear Reaction Working Group meeting at USNDP meeting in 2002.

**Status:**

- Both actions completed.

**LBL** -- Chair U.S. Nuclear Data Program's Data Dissemination Working Group, and help coordinate data dissemination work at different labs to advance USNDP goals. Also included here are the Isotopes project management responsibilities of interacting with LBNL management and the DOE program manager.

**LBL Deliverables:**

Organize and chair Data Dissemination Working Group meeting at USNDP meeting, April 2002.

**Status:**

- Organized and chaired Data Dissemination Working Group meeting at USNDP meeting, April 2002. Meeting decided to disband this working group.
- C. Baglin assumed chairmanship of USNDP's Nuclear Structure Working Group following April 2002 meeting.

**B. International Coordination**

**BNL** -- Member of Nuclear Reaction Data Center Network, Member Nuclear Structure and Decay Data Network, U.S. Member of the International Nuclear Data Committee (INDC), member of NEA Working Party on Evaluation Cooperation, participation in IAEA sponsored activities such as Advisory Group Meetings and Coordinated Research Projects.

**BNL Deliverables:**

Participate in technical meeting of NRDC in Paris in 2002.

Participate in NEA Working Party on Evaluation Cooperation in 2002.

Provide a lecturer for the "mini" Structure Workshop in Vienna in 2002.

**Status:**

- P. Oblozinsky attended the INDC meeting in May 2002. He was elected deputy chair of the INDC
- P. Oblozinsky and V. McLane attended the NRDC meeting in May 2002. The international nuclear reaction data compilation effort (EXFOR) was reviewed, and more flexible and efficient organization was adopted.
- P. Oblozinsky attended the NEA WPEC meeting in May 2002. During the year, P. Oblozinsky acted as chair of the Subgroup 21 to review neutron cross-section evaluations for the bulk of fission products.

- The Workshop on Nuclear Structure Evaluation is scheduled for FY2003 in Vienna, November 18-22, 2002.
- P. Oblozinsky was selected to be one of the summary speakers at the international nuclear data conference (ND2001) in Tsukuba, Japan. Two Staff members attended and presented a total of 8 papers.
- Several NNDC staff members served on advisory committees for ND2001.

**Idaho** -- Chair USNDP Nuclear Structure Working Group and interact with international Nuclear Structure and Decay Data network on behalf of USNDP on technical matters.

**Status:**

- There were no international meetings held in FY2002.

**LANL** -- Participate in, and chair, international nuclear reaction data collaborations. This insures that the U.S. benefits from breakthroughs around the world, and plays a leadership role in new developments. LANL staff members chair NEA committees in fission spectra, and international model code development cooperation; and chair IAEA coordinated research programs on photonuclear reactions, and on reference input model parameters. LANL will host the next International Conference on Nuclear Data for Science and Technology in Santa Fe in 2004. LANL will host visits by foreign scientists with international reputations to benefit from the exchange of information and ideas.

**LANL Deliverables:**

- Participate in NEA Working Party on Evaluation Cooperation meeting in 2002.
- Begin to organize the next International Conference on Nuclear Data for Science and Technology
- Make latest version of NJOY data processing code available to the international community.
- Provide a lecturer on nuclear data processing with NJOY for the IAEA/ICTP Trieste Lectures in March 2002.
- Host a couple of international visitors to collaborate on the evaluation of nuclear data.
- Assist in the organization of the 2002 international nuclear data conference in Japan.

**Status:**

- Chadwick participated in NEA Working Party on Evaluation Cooperation meeting in Geel and presented a talk.
- The organization of the next International Conference on Nuclear Data for Science and Technology is well underway. Advisory committees have been formed. The conference will be held in the Eldorado hotel in Santa Fe. About 400 participants are expected.
- NJOY version 99.67 was released in Feb 2002. A newer version was distributed to the European JEF community that incorporated a patch for 8 delayed neutron groups, which they need.

- MacFarlane gave a lecture on nuclear data processing with NJOY for the IAEA/ICTP Trieste Lectures in March 2002.
- LANL hosted Prof K.L. Kratz (Mainz) and 2 students to work on astrophysical data evaluation, and M. Blann to work on nuclear reaction model development.
- Several T-16 staff served on advisory committees for international nuclear data conference held in Tsukuba, Japan in October 2001.
- Haight acted as advisor to the US Member of the International Nuclear Data Committee (INDC).

**LBL** -- Chair the international Decay Data Evaluation Project.

**Status:**

- Browne coordinated the Decay Data Evaluation Project (DDEP) international collaboration.

### 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. Entry preparation not included. Updates are done on a continuing basis.

**BNL Deliverables:**

Database distributed to collaborators monthly.

**Status:**

- NSR distributions were made on a monthly basis.

#### B. Experimental Nuclear Structure Data File (XUNDL)

The NNDC is responsible for XUNDL, the database of unevaluated experimental nuclear structure data. Recent additions contain mostly "high-spin" data sets. NNDC responsibility is limited to maintaining the database and access to it. Data set compilation is coordinated through McMaster University.

**BNL Deliverables:**

Database updates to be done as data sets are received.

**Status:**

- Database updated as datasets received from McMaster.

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

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

**BNL Deliverables:**

Database distributed to collaborators twice a year.

**Status:**

- ENSDF was distributed in February and August, 2002.



#### D. Numerical Nuclear Data File (NuDat)

The NNDC is responsible for NuDat, an all numeric database of nuclear data including level and  $\gamma$ -ray properties extracted from ENSDF, ground and metastable state properties (Wallet Cards), atomic and nuclear radiations derived from ENSDF and thermal neutron cross sections and resonance integrals. The database is also available in a PC version. It is updated twice a year.

**BNL Deliverables:**

Database distributed to collaborators twice a year.

**Status:**

- NuDat was distributed in February and August, 2002.

#### E. Neutron Reaction Data Bibliography (CINDA)

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

**BNL Deliverables:**

CINDA exchange files from cooperating centers will be added to the database (20 expected).

**Status:**

- 16 CINDA exchange files were received from cooperating centers and added to the database.
- 7 new CINDA exchanges were created at NNDC and sent to cooperating centers.

#### F. Experimental Reaction Data File (CSISRS)

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

**BNL Deliverables:**

Update CSISRS with EXFOR exchange tapes from cooperating centers (18 expected).

**Status:**

- 15 EXFOR exchange tapes were created and sent to the cooperating data centers.
- 13 EXFOR exchange tapes were received from cooperating centers and added to the CSISRS library.

**G. Evaluated Nuclear Data File (ENDF)**

The NNDC is responsible for ENDF, a database of evaluated nuclear data required for many nuclear applications. The 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 are also included. The data are stored in the ENDF format developed at NNDC about 35 years ago. This format has been adopted as an international standard. In addition to the U.S. library, ENDF/B, the database contains evaluated data libraries from Western Europe, 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. There will be no more releases of ENDF/B-VI before ENDF/B-VII is ready.

**BNL Deliverables:**

Create a site from which new evaluations can be obtained before formal release of ENDF/B-VII.

**Status:**

- This site was created and a mechanism for linking to new evaluations was put in place.

**H. Database Software Maintenance**

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

**I. Future Database Systems**

In FY2001, a project to migrate the NNDC databases to a modern relational database system was initiated. Detailed plans for accomplishing this migration have been developed in the migration started. As part of this task, legacy support software must be migrated and dissemination software modernized. We intend to accomplish this migration without interrupting our present electronic data access. It is expected that the task will be completed in FY2004, depending on the level of support available.

**BNL Deliverables:**

Complete migration of NSR database.

Develop new ENSDF database and software.

Complete test database for bibliographic, experimental and evaluated reaction data and supporting maintenance software.

**Status:**

- NSR database migration has been completed. Database entry and publication software written in Fortran were modified to interface to the new relational database. Programming has started on new Java-based data entry software.
- A “Top-level” ENSDF has been created and populated. Many features of the NuDat system have been included. A Web interface is under development.
- A new relational database for experimental reaction data has been developed as a joint project with the IAEA and is now undergoing testing. The new experimental bibliographic database has been designed. It is now in the early stages of testing. Work on the migration of the ENDF database will not begin until FY2003.
- XML is being investigated as a medium for data exchange and database loading.

## 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. Maintenance of Remote Access to USNDP Databases

The NNDC provides electronic access to the nuclear physics databases that it maintains. This access is supported in two forms, remote login (TELNET) and *via* the Web.

#### **BNL Deliverables:**

No enhancements are planned for the remote login (TELNET) access software. Migrate Web interfaces for NSR and ENSDF to new relational databases.

#### **Status:**

- A Sybase/JSP interface to NSR relational database was made available on the Web in June 2002.
- Standard interface project was discontinued due to lack of resources.

### 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.

### C. Web Site Maintenance

USNDP members who offer information through a Web site require resources to maintain currency and improve performance. All sites will coordinate their effort and implement a "USNDP approved site" program with an appropriate identifier.

#### **ANL Deliverables:**

Continue to maintain and add content to Web sites of interest to USNDP.

#### **Status:**

- Provided access to 154 ANL/NDM reports dealing with various Nuclear Data issues.
- Provided information on experimental resources available in the United States for nuclear data measurements.
- Provided information on activities of the Argonne Nuclear Data Program.

**BNL Deliverables:**

Effort required for keeping the USNDP, CSEWG, NSDD Network, and NNDC Web sites current.

**Status:**

- NNDC, USNDP and CSWEG Web sites have been updated.
- A new international NSDD Network Web site has been created.
- Proceedings of 2001 Evaluators' Workshop was added to the NNDC site.
- Added *Proton Emitters, Super Deformed Bands, and History of the Origin of the Chemical Elements and Their Discoverers* to the NNDC Web site.
- Added the nuclear reaction model code, EMPIRE II, to the NNDC Nuclear Model Codes site.
- Added the proceedings of the CSEWG 35<sup>th</sup> Anniversary Symposium to CSEWG Web site.

**LANL Deliverables:**

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

Add access to ENDF/B-VI, Release 8, when available.

Continue coordination of T-16 site with other USNDP sites.

**Status:**

- Access to ENDF/B-VI, Release 8, JENDL3.3 and the new ENDF atomic data files is now available from the T-16 site.
- The nuclear data viewer has been modernized to use PHP language and the capability to do difference and ratio plots for cross section data has been added. We have installed a new Web server with two high-speed processors and lots of disc space.
- We have maintained our links to other USNDP Web sites and have added "gold star" approvals.

**LBNL Deliverables:**

Complete Website for compiled capture gamma data as part of IAEA Coordinated Research Program for Prompt Capture Gamma-Ray Analysis.

Maintain currency of data on LBNL Web site.

**Status:**

- Completed IAEA Capture Gamma CRP dissemination software, but Website has been delayed until completion of CRP (Spring 2003).
- Maintained/updated ENSDF and NSR data on the LBNL Website.
- Remedied Isotope Explorer 3 server problems arising from computer upgrades.

**TUNL Deliverables:**

Provide a new Website design and layout for our Website

Provide PDF documents of most recent reviews for  $A = 5, 6, 7$  (2002 publication), and preliminary versions of  $A = 8-9$ .

Scan in Energy Levels Diagrams from the older FAS publications that correspond to the PDF and HTML documents we post online.

Provide Reference Update lists for  $A = 16$ , and update the lists for  $A = 5, 6, 7$  to correspond to the 2002 publication.

Prepare "Energy Levels" publications from 1981, 1982, 1984, 1985, and 1986 in PDF format.

Continue the development of PalmOS applications and databases and add them to the TUNL site.

**Status:**

- Created new Website layout and design.
- Completed PDF documents with hyperlinks for:  $A = 5, 6$  and  $7$  (2002 publication) and  $A = 8$  (preprint version, February 2002).
- HTML and PDF documents have been completed for all nuclides and "Energy Levels" publications for the years 1979-present (with the exception of  $A = 18-20$  (1983) to be completed soon).
- Update Lists for  $A = 16$  have been completed. Update Lists for  $A = 5, 6, 7$  have been updated to correspond to the 2002 publication of  $A = 5, 6, 7$ .
- General Tables [that correspond to the publication and/or preprint versions] have been completed for  $A = 8$ . General Tables for  $A = 5, 6, 7$  have been updated.
- Scanned versions of earlier FAS Energy Level Diagrams have been posted online [in GIF, PDF and PS formats] for  $A = 5-10$  (1979),  $A = 11-12$  (1980),  $A = 13-15$  (1981) and  $A = 16-17$  (1982).

**D. APS Link to NNDC Experimental Databases**

Presently NNDC provides a link from our bibliographic databases to paper abstracts for journals which support this access. For those with subscriptions, the user can then access the complete paper. In cooperation with APS (Ridge), we will provide the ability to go from the Phys. Rev. C abstract/article to the NNDC database (CSISRS or XUNDL) where data mentioned in the publication will be archived.

**BNL Deliverables:**

System will be in operation.

**Status:**

- Effort on hold due to insufficient available resources.

## V. Nuclear Structure Physics

### A. NSR Abstract Preparation

The literature search and preparation of KEYWORD abstracts for publications included in NSR require scientific expertise. NNDC staff creates most of the entries with some help from Russia and Japan.

#### **BNL Deliverables:**

Keyword abstracts for 3200 references will be prepared in FY2002.

#### **Status:**

- Keyword abstracts were prepared for 3240 references in FY2002.

### B. Compilation of Experimental Structure Data

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

#### **McMaster Deliverables:**

Compile data sets (in ENSDF format) of current publications, primarily in high-spin physics.

Compile older high-spin publications needed for outdated ENSDF evaluations on a time available basis.

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

#### **Status:**

- A total of 159 new datasets were prepared and included in the XUNDL database. In addition 31 datasets were updated to include new papers and revised information. Two datasets contributed by other data centers were checked and edited at McMaster. While most of the datasets were prepared from current papers, some were selected for mass chains that are quite outdated in ENSDF.
- This year several decay and other low-spin papers were also compiled.
- There were frequent communications with the original authors to resolve data-related inconsistencies and to obtain additional details of data from their experiments. Each dataset was processed through ENSDF analysis codes such as GTOL, and FORMAT checking codes. (It should be pointed out that the datasets in XUNDL should not be viewed simply as “data-entry”, even though these are marked as “unevaluated”).
- This year we have also developed new software for translation of tabular text files to ENSDF format. Many additional spectroscopic quantities have been incorporated in this code. The new code, when fully implemented, is expected to result in an improved procedure for automatic translation of data tables to ENSDF format.

**ORNL Deliverables:**

Improve software for converting tabular/graphic published level-scheme data in journals as well as unpublished data supplied by researchers to Radware database, into ENSDF format. Examples used in the development of these procedures will be submitted to BNL as XUNDL data sets.

**Status:**

- A new program to convert Radware-format schemes to ENSDF format has been written and tested.
- The text-to-ENSDF programs have been updated and tested; the large variation in possible types of input data requires that this be done using real data sets.
- New routines to improve the automatic graphical layout of the RadWare schemes converted from ENSDF and from text tables are currently under development.

**C. Data Evaluation**

The USNDP evaluates nuclide and mass chain nuclear structure and decay data for inclusion in the ENSDF database. ANL has added a skilled nuclear structure physicist to its staff in order to participate in the nuclear structure data evaluation activity. TUNL has expressed interest in taking responsibility for  $A=21-30$ . This would complement the agreement from Canada to assume responsibility for  $A=31-44$  and thereby cover the region formerly evaluated by the Utrecht group.

**ANL Deliverables:**

This is a new activity.  
One mass chain will be evaluated.  
One mass chain will be reviewed.

**Status:**

- Evaluation of one full-length mass chain ( $A=177$ , 13 nuclides) was completed and submitted to NNDC for inclusion in ENSDF and publication in *Nuclear Data Sheets*
- Reviewed one mass chain ( $A=170$ ).

**BNL Deliverables:**

Three and one-half equivalent mass chains will be evaluated.  
At least four mass chains will be reviewed.  
Hire a post doc for training as an evaluator.



**Status:**

- Evaluations for mass-chains A=68, 82, 138 and for nuclides  $^{49}\text{Mn}$ ,  $^{50}\text{Fe}$ ,  $^{140}\text{Xe}$ ,  $^{140}\text{Dy}$ ,  $^{142}\text{Ho}$ ,  $^{145}\text{Sm}$ ,  $^{132}\text{In}$  and  $^{134}\text{In}$  were completed.
- Four mass-chains were reviewed.
- No funds were made available to hire additional staff.

**Idaho Deliverables:**

Complete evaluation of A=156.

Begin evaluation of A=155 and 159

Two mass chains will be reviewed.

**Status:**

- The evaluation of A=87 was completed and published.
- Good progress was made on the A=156 evaluation. However, due to the large volume of new data to be evaluated and problems associated with getting unpublished important data from experimenters around the world, this project was not completed. Completion is expected early in the next fiscal year.
- Reviews were carried out for mass chains A=82, 87, 138, and 143.
- A majority of the evaluation for A=159 has been carried out.

**LBNL Deliverables:**

Four equivalent mass chains will be evaluated.

Mass chains will be reviewed as requested.

**Status:**

- Evaluated four mass chains (A=179, 186, 210, 239) comprised of a total of 43 nuclides.
- Evaluated remaining 7 nuclides for A=189.
- Evaluated two nuclides ( $^{183}\text{Tl}$ ,  $^{187}\text{Bi}$ ).
- Responsibility for A=21 to 30 has been assigned to LBNL.

**McMaster Deliverables:**

1.5 equivalent mass chains (including some in the A=31-44 region) will be evaluated. Evaluations for A=40, 165 and 190 are planned.

Mass chains will be reviewed as requested.

Update superdeformed-band data in ENSDF. All nuclides will be covered that do not require a complete reevaluation.

**Status:**

- A=98 and A=190 full evaluations were submitted for ENSDF and Nuclear Data Sheets. A=165 and A=40 are in progress.

- Six nuclides were revised for new superdeformed-band data, and included in ENSDF.
- The evaluation for a total of 30 nuclides were updated and included in ENSDF.
- The 1996 edition of the *Table of Superdeformed Bands and Fission Isomers* was revised to include all such data up to September 2002. The software to generate tables and drawings had to be developed at McMaster, since the software used for the 1996 version was no longer available. The final version is scheduled to be published in the October 2002 issue of the NDS.
- Review work: A=198 (partial review), A=126.

**ORNL Deliverables:**

Evaluation of A=242 and 244 on temporary reassignment from Kurchatov will be completed.

Work will continue on A=208 and A=238.

Mass chains will be reviewed as requested.

**Status:**

- A=242 and 244 evaluations have been completed: the A=242 evaluation is published in *Nuclear Data Sheet* 96,177 (2002); the A=244 evaluation is in review.
- A=238 is completed and published in *Nuclear Data Sheets* 97, 129 (2002); work on the A=208 evaluation is continuing.
- A=235 and A=239 evaluations are reviewed.

**TUNL Deliverables:**

Evaluate mass 10 and distribute for comment.

Begin preparing the publication for A = 8, 9 and 10 for submission to *Nuclear Physics A*.

Submit ENSDF files for A=5, 6, and 7.

**Status:**

- Completed and mailed the preprint version of A = 8 for review (February 2002).
- Expect to finish review of A = 10 and mail preprint by year's end.
- Published A = 5, 6, 7 in *Nuclear Physics A* 708 (2002) 3.
- Plan to submit ENSDF files for A = 5, 6, 7 by Fall 2002.

#### D. Ground and Metastable State Properties

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

##### **BNL Deliverables:**

NNDC will include the data revisions in the NuDat databases.

##### **Status:**

- The Nuclear Wallet Cards has been kept current. The updates have been included in the NuDat database.
- The Nuclear Wallet Cards have been adopted as a standard by the DOE Office of Nuclear Material Management Security and Safeguards.

#### E. Radioactive Decay Data Evaluation

Decay data for nuclides of importance for applied research are evaluated in an international collaboration. When complete, these evaluations are entered into the ENSDF format and merged into the ENSDF database. In the United States, LBNL coordinates this project.

##### **ANL Deliverables:**

Decay data for one nuclide will be evaluated.

##### **Status:**

- Evaluation of decay data for one nuclide ( $^{177}\text{Lu}$ ) was completed and submitted to the Chairman of DDEP.

##### **LBNL Deliverables:**

Decay data for one nuclide will be evaluated.

Coordinate activity of international collaboration.

Review evaluations of 12 nuclides.

##### **Status:**

- Edited DDEP collaboration material.
- Evaluated one decay ( $^{227}\text{Th}$ ).
- Reviewed 13 decay evaluations ( $^{228}\text{Th}$ ,  $^{224}\text{Ra}$ ,  $^{220}\text{Rn}$ ,  $^{216}\text{Po}$ ,  $^{212}\text{Po}$ ,  $^{212}\text{Bi}$ ,  $^{212}\text{Pb}$ ,  $^{208}\text{Tl}$ ,  $^{131}\text{I}$ ,  $^{131\text{m}}\text{Xe}$ ,  $^{110}\text{Ag}$ ,  $^{110\text{m}}\text{Ag}$ ,  $^{11}\text{C}$ ).

##### **Idaho Deliverables:**

Decay data for 5 nuclides will be evaluated.

##### **Status:**

- The decay data were evaluated for  $^{24}\text{Na}$ ,  $^{64}\text{Cu}$ ,  $^{110}\text{Ag}$ , and  $^{110\text{m}}\text{Ag}$  as well as the gamma-ray data of  $^{226}\text{Ra}$  and its daughters.

- Several decay data evaluations from the other groups were reviewed.

#### F. Thermal Capture Gamma Data Evaluation

This work is being performed by LBNL as part of an IAEA Coordinated Research Project entitled, "Prompt Gamma Activation Analysis." The specific task assigned to LBNL is to evaluate thermal and cold (n, $\gamma$ ) data sets for stable nuclei. The results of this evaluation will be placed into a database.

##### **LBNL Deliverables:**

This database will be completed.

##### **Status:**

- Completed draft of final capture-gamma database (database cannot be released until conclusion of IAEA CRP in Spring 2003).

#### G. Nuclear Structure Data Measurement

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

##### **LANL Deliverables:**

Examine the prompt gamma-ray emission data on  $^{59}\text{Co}$  to search for previously unobserved transitions.

Interact with the A=59 mass chain evaluator (C. Baglin) on the structure of these nuclei.

##### **Status:**

- All of the identified transitions from (n,n') excitation of  $^{59}\text{Co}$ , which we observed with the continuous-in-energy neutron source at LANSCE, are consistent with known transitions.

#### H. ENSDF Physics and Checking Codes

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

##### **BNL Deliverables:**

Upgrade RadList and LOGFT to properly treat 2<sup>nd</sup>-order non-unique forbidden  $\beta^\pm$  transitions.

Begin to implement the “Evaluator’s Corner” that will allow ENSDF evaluators remote interactive access to the latest versions of the ENSDF physics and checking codes *via* the Web.

**Status:**

- LOGFT upgraded to handle 3<sup>rd</sup> and higher order unique forbidden  $\beta^\pm$  transitions; still needs extensive testing.
- No work done on the “Evaluator’s Corner”. The codes HSICC and LOGFT have been made accessible through Nuclear Physics Computational Tools site.

## 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 only.

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

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

#### **BNL Deliverables:**

Compile data from 100 charged-particle and neutron reaction publications.

#### **Status:**

- Data from 153 charged-particle and neutron reaction experiments were compiled.

### B. ENDF Manuals and Documentation

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

#### **BNL Deliverables:**

The ENDF summary documentation will be updated for release 8 of ENDF/B-VI and placed on the Web.

#### **Status:**

- The ENDF summary documentation was updated for release 8 of ENDF/B-VI.

### C. 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, and LLNL will provide neutron, proton and photonuclear reaction data evaluations for ENDF/B-VII.

**BNL Deliverables:**

Review and recommend the best available fission product neutron reaction evaluations for ENDF/B-VII.

**Status:**

- Review of the bulk of fission product neutron reaction evaluations was initiated under the WPEC SG21 international project. Reviews and recommendations for 18 materials were completed as an international effort of 10 reviewers representing US, Japan, Russia and China evaluation projects. The work currently continues on another 100 fission products.
- Evaluation of neutron cross sections for 19 fission products in the fast energy region was completed in collaboration with KAERI. For 3 materials ( $^{99}\text{Tc}$ ,  $^{153}\text{Eu}$ ,  $^{157}\text{Gd}$ ) complete files were prepared by BNL by merging the thermal and resonance region with the fast energy region. After final checking, these files will be submitted to ENDF/B-VII.

**LANL Deliverables:**

Lead planning effort for ENDF/B-VII.

Submit improved neutron and photonuclear evaluations for  $^{235,238}\text{U}$  and  $^{239}\text{Pu}$  to be included in ENDF/B-VII.

**Status:**

- The planning was initiated by the Evaluation Committee (chaired by LANL) at the 2001 CSEWG meeting. ENDF/B-VII will be a major focus of effort at the 2002 CSEWG meeting.
- The new  $^{239}\text{Pu}$  evaluation was sent to BNL for ENDF/B-VII. It includes the (n,2n) cross section that was highlighted in the recent 2002 NSAC Long Range Plan.
- The prompt fission neutron spectrum matrix for the n +  $^{238}\text{U}$  system has been calculated using the Los Alamos model. The uranium isotope evaluations include many improvements for capture, inelastic, and (n,xn) reactions.
- We have submitted a suite of over 140 ENDF evaluations of photonuclear reactions for ENDF/B-VII, based on the IAEA project (led by LANL and BNL). The evaluations adopted from Russia (actinides) were modified by so they are consistent with ENDF rules and useable in transport calculations. These also have application in Homeland Security for the detection of special nuclear materials, esp.  $^{235}\text{U}$ .
- The final report of Subgroup 9: Prompt Fission Neutron Spectra (chaired by LANL) is being written. WPEC Subgroup 9 reviewed the matrix for the n +  $^{235}\text{U}$  system. The final report recommends that a new high-quality

measurement of the differential thermal spectrum be performed, because of the large disagreements among existing measurements and integral measurements.

**LLNL Deliverables:**

Prepare evaluations for Eu, Sm, Cr, and Ti isotopes.

Review evaluations submitted for inclusion in ENDF/B as requested.

**Status:**

- Evaluations done for Br, Kr, and Se. Distribution in ENDF/B format delayed as we prepare codes to automate translation into ENDF/B format.

D. Nuclear Reaction Standards

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

**LANL Deliverables:**

Organize and participate in the effort to evaluate the light-element standard cross sections.

**Status:**

- Led the effort to compare the three primary R-matrix codes, EDA, RAC, and SAMMY, in a test problem involving  $n+{}^6\text{Li}$  data
- Attended and recorded minutes from the second Research Coordination Meeting (RCM) organized by the IAEA on the Improvement of the Standard Cross Sections for the Light Elements.

**NIST Deliverables:**

Coordinate the international standards activity.

Determine the methodology for producing the new standards evaluation.

Review existing experimental data and recommend new measurements as needed.

Collaborate with Ohio University and LANL in the measurement of hydrogen elastic angular distributions; continue diagnostic work on the 15 MeV measurements.



**Status:**

- Coordinated the standards subgroup of the WPEC.
- Held a special session at the ND2001 international conference (Oct 10, 2001) to review the progress being made on the experimental and evaluation efforts for the standards evaluation.
- Assisted in establishing the IAEA CRP, which was initiated early this calendar year. This group will have the major responsibility for the international evaluation of the standards and an improved understanding of their uncertainties.
- Worked with IAEA on the agenda and chaired the first RCM of the CRP.
- More than 80 experiments are being or have been reviewed for use in the standards evaluation.
- The np scattering measurements at 10 MeV neutron energy were published in Phys. Rev.
- Work continues on the design of the experiment at a neutron energy of 15 MeV. Source considerations are a major concern. A “dry run” is planned for February 2003.

**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. 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 code development work will be coordinated with the proposed LLNL work. The collaboration will include intercomparison of results, validation of model with experimental data and development of new physics modules. The TUNL pre-equilibrium code will be incorporated into the LANL code. Measurements made by ANL, LANL, and other measurements made with DOE low-energy physics funds (e.g., Grimes, Becker and others) will play a crucial role in the validation of the models in these computer codes.

Neutron-induced reactions provide insights into nuclear level densities. With the continuous-in-energy neutron source at LANSCE/WNR, we investigate the effect of nuclear level densities in three ways by measuring: (1) particle emission spectra (both light charged particles and neutrons); (2) excitation functions of cross sections as a function of incident neutron energy; (3) prompt gamma rays that indicate the angular momentum distribution of states populated in compound nuclear reactions.

**ANL** -- Work on a journal article that will report results from measurements performed during 1999-2001 will be completed. A detailed nuclear model parameter sensitivity study will be performed for calculations relevant to these and earlier data acquired from a collaborative program with IRMM, Geel, Belgium. This program also involves contributions from theoretical physicists in Romania and Hungary.

**ANL Deliverables:**

A journal article will be submitted.

Completed evaluations in ENDF format.

Experimentally validated nuclear model parameters submitted to IAEA Reference Input Parameter Library (RIPL).

**Status:**

- Results from measurements performed during 1999-2001 were reported at the International workshop on “Fast Neutron Physics”, September 5-7, 2002, Dresden, Germany. Preparation of a journal article has been delayed by the IRMM/ANL collaboration until further data analysis is completed.
- Some horizontal evaluations have been prepared by the IRMM/ANL collaboration but these have not been submitted to the data centers.
- A preliminary report on the nuclear model parameters for some reactions has been submitted to the IAEA Nuclear Data Section by the IRMM/ANL collaboration.
- Participated in an extensive series of neutron spectrum measurements at Ohio University (in collaboration with scientists from IRMM, Geel, Belgium). The analysis of these data is continuing.

**BNL** – BNL collaborates with other laboratories by developing calculational modules for nuclear model code improvements. This activity was not in the original work plan.

**Status:**

- In collaboration with the IAEA, further validation of and improvements to the nuclear reaction code Empire were performed. An improved version, Empire-2.17, was prepared and released in February 2002.
- In collaboration with LANL the validation of the pre-equilibrium code HMS, based on the hybrid model Monte Carlo approach, was initiated. The code was incorporated as a module into Empire-2.17, and compilation of suitable (N,xN) data was performed.

**LANL** -- The LANL GNASH code has proved to be an important tool in nuclear data evaluation, and we will develop a new version of this code to provide a state-of-the-art capability to predict reaction cross sections. This task also involves a close collaboration with experimentalists at LANSCE to interpret new measurements using the GEANIE  $\gamma$ -ray detector, as well as (n,charged-particle) data, resulting in advances in our understanding of nuclear reaction mechanisms, as well as improvements in our modeling codes. In addition, we will continue to modernize the EDA R-matrix code used for light nucleus data evaluation.

**LANL Deliverables:**

Continue development of McGNASH, our improved version of the GNASH Hauser-Feshbach code, using Fortran90 and modern coding practices, with numerous improved physics packages, particularly: level densities, preequilibrium reactions,

transmission coefficients, and  $\gamma$ -ray strength functions. Include a Monte-Carlo option. (Note that this is highly leveraged with support from DOE/DP). Collaborate with LLNL and with the NEA WPEC on code validation.

Calculate and interpret  $\gamma$ -ray reactions measured with GEANIE at LANSCE, including  $n+^{196}\text{Pt}$  reactions producing far-from-stability products, and reactions in competition with fission of  $^{235,238}\text{U}$ .

Complete analysis of LANSCE data for neutron interactions with  $^{59}\text{Co}$  and  $^{58,60}\text{Ni}$  including both charged-particle emission and prompt gamma-ray production with the goal of testing nuclear level density theories.

Obtain information on nuclear level densities near  $A=90$  through  $(n,n'\gamma)$  reactions.

Further the investigation of the predicted isospin effect for isotopes near the  $N=Z$  line through  $(n,\alpha)$  reactions by completing the data analysis for sulfur and calcium targets (the latter with Ohio University).

Obtain nuclear level densities near  $A=90$  through analysis of  $(n,\text{charged particle})$  data taken on Y, Nb and  $^{92,94,96}\text{Mo}$ . Charged particles observed are protons, deuterons and alpha particles.

Analyze data to investigate the effect of pre-equilibrium reactions both on  $(n,\text{charged particle})$  and  $(n,x\gamma)$  reactions.

**Status:**

- This year we have incorporated in McGNASH, a link to our pre-equilibrium DDHMS code (currently being tested), and completed our width-fluctuation module. We are also testing against similar use of DDHMS in BNL's Empire code.
- A LANL staff member is playing a lead role in the development of nuclear reaction code modules for the NEA WPEC Subgroup A project.
- The results of the calculation and interpretation of  $\gamma$ -ray reactions measured with GEANIE at LANSCE, including  $n+^{196}\text{Pt}$  reactions producing far-from-stability products, and reactions in competition with fission of  $^{235,238}\text{U}$  have been published in *Physical Review* and *Journal of Nuclear Science and Technology*.
- Analysis of LANSCE data for neutron interactions with  $^{59}\text{Co}$  and  $^{58,60}\text{Ni}$  was completed
- Data on  $(n,n'\gamma)$  reactions on molybdenum isotopes to obtain nuclear level density information have been taken.
- Work investigating the predicted isospin effect for isotopes near the  $N=Z$  line through  $(n,\alpha)$  reactions has been delayed as the Ohio post doc took another job.
- Data have been obtained on Y, Nb and  $^{92,94,96}\text{Mo}$  and are being analyzed. This task is somewhat delayed due to effort required to establish the FIGARO array of gamma and neutron detectors to enable measurements of the complementary neutron emission spectra. This array is now in production operation.
- Pre-equilibrium components in  $^{58,60}\text{Ni}(n,x\alpha)$  and  $^{59}\text{Co}(n,x\gamma)$  have been quantified.

**LLNL** --We are developing a suite of reaction modeling codes that will be suitable for investigating processes involving reactions on unstable targets, such as encountered in astrophysics, radioactive ion beam physics, and other applications. A new Hauser-Feshbach code using object-oriented programming techniques is being developed. These techniques eliminate the need for fixed dimensions within the program and will facilitate incorporation of special features, such as isospin conservation and nonstandard forms for level densities. The code is being written in ANSI/ISO standard C++.

**LLNL Deliverables:**

First version of program will be available for testing.

**TUNL** – The ongoing development of pre-equilibrium nuclear reaction models involves the improvement and benchmarking of the computer code PRECO. New work will focus on continuing revisions to the description of reactions with incident and/or emitted complex particles. In addition, new (n,xp) data at 50-60 MeV will be studied to resolve an open question on the amount of surface localization of the initial interaction for incident neutrons.

**TUNL Deliverables:**

Submit a brief journal article on the work on neutron-induced reactions.

Submit a journal article on complex particle reaction channels.

**Status:**

- Work on complex particle reactions is nearing completion, but took longer and involved more effort than expected.
- The first draft of a paper on this work is also nearing completion.
- Work on surface effects in neutron-induced reactions is complete, with results tentatively included in the paper on complex particle channels.
- New results on isospin conservation were obtained and are to be written up for publication.

F. Evaluation of Data Needed for Astrophysics

The objective of this activity is to support the nuclear data needs of the increasingly sophisticated nuclear astrophysics universe modeling. The Astrophysics Task Force of the USNDP, presently chaired by a staff member from ORNL, plans, initiates and implements cooperative nuclear data evaluation activities which involve the nuclear data and the nuclear astrophysics communities.

**ANL** – The compilation of charged-particle data of the type (p, $\alpha$ ) and (p, $\gamma$ ) for mass A = 30-50 nuclides will continue. The focus during this period will be on the stable isotopes of sulfur. Work will begin on the evaluation of data for these reactions. The objective is the

preparation of evaluated data files that can be used for computation of astrophysical nuclear reaction rates.

**ANL Deliverables:**

Compilations of (p, $\alpha$ ) data for  $^{32}\text{S}$  and of (p, $\alpha$ ) and (p, $\gamma$ ) data for the minor sulfur isotopes,  $^{33,34,36}\text{S}$ .

**Status:**

- The long-ongoing project of compiling and evaluating (p, $\alpha$ ) and (p, $\gamma$ ) data for  $^{31}\text{P}$  (in collaboration with Hiram College) is near completion. A technical ANL/NDM report on this work is currently at final stages of preparation.
- Work has begun on compilations of (p, $\alpha$ ) and (p, $\gamma$ ) data for the sulfur isotopes, but it was set aside temporarily due to the retirement of the investigator involved in this work. It will be resumed, however, under the provision of the USNDP Work Plan for FY2003.
- A detailed study of statistical methods for handling large errors and severe conditions was completed. The results were published in *Nuclear Instruments and Methods*. Collaborative work with scientists from ORNL is continuing.

**BNL** – In support of the nuclear data needs of the increasingly sophisticated nuclear data needs for astrophysics, NNDC has initiated a project to compile and evaluate alpha-induced nuclear reaction cross sections for astrophysics. The work will focus on nuclei  $8 < Z < 32$  and alpha particles with the incident energy below 20 MeV. These reactions, important in the helium burning stage of stars, novae, and supernovae events, include ( $\alpha,\alpha$ ), ( $\alpha,n$ ), ( $\alpha,p$ ) and ( $\alpha,\gamma$ ) reaction channels. Of particular interest are reactions leading to production and destruction of  $^{44}\text{Ti}$ . Based upon thorough compilation of data including reactions and structural information, critical analysis of the data will be done, and related cross sections and reaction rates will be evaluated.

**BNL Deliverables:**

Complete evaluation of  $\alpha$  reactions below 20 MeV leading to production and destruction of  $^{44}\text{Ti}$ .

**Status:**

- Tentative results on alpha reactions leading to production and destruction of  $^{44}\text{Ti}$  were obtained. This initial work was almost halted because of the lack of funding.
- The project, prepared as a collaborative effort of the nuclear data group in VNIIEF Sarov (Russia), BNL and ORNL, applied for funding at the CRDF Cooperative Grants Program that supports conversion of the

Russian weapon laboratories. The project has now been approved and the work will resume as soon as all paperwork is completed.

**LANL --** Participate in 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 Dissemination Working Group.

**LANL Deliverables:**

Predict fission-barriers for neutron-rich heavy nuclei for r-process nucleosynthesis using recent advances in Moller-Nix theory.

Extend n-p capture analysis to higher energies and provide evaluated data.

Continue evaluation of other processes important in Big-Bang nucleosynthesis.

Complete analysis to predict the  ${}^7\text{Be}(p,\gamma){}^8\text{B}$  cross section, for the solar neutrino problem.

Continue to contribute to the TUNL Energy Levels of Light Nuclei (A=5-10) effort.

Study effects of electronic screening on Maxwellian rates under astrophysical conditions.

Provide data for light radioactive targets beginning with  ${}^{17}\text{F}+p$

**Status:**

- We have used our calculated 5-dimensional fission barriers, and calculated ground-state quantities that enter mass calculations and determined new model parameters from adjustments to measured ground-state masses and to measured fission barrier heights. Initial studies with the enhanced model are promising. The stage is now set for extensive calculations of fission barriers in high-dimensional spaces for large regions of nuclei, both neutron-rich and proton-rich nuclei from lighter nuclei to very heavy systems.
- Developed a new representation of  $\gamma$ -ray channels in R-matrix theory that led to an improved fit to the n-p capture data at energies up to 50 MeV.
- Continued an analysis of reactions in the  ${}^8\text{Be}$  system that includes the “Big-Bang”  ${}^7\text{Li}$ -abundance reactions  ${}^7\text{Li}(p,\alpha){}^4\text{He}$ ,  ${}^7\text{Li}(p,n){}^7\text{Be}$ , and  ${}^7\text{Be}(n,p){}^7\text{Li}$ .
- Submitted the final draft of the Energy Levels of Light Nuclei (A=5-7) to Nuclear Physics.
- Studied the effects of electronic screening on Maxwellian rates under astrophysical conditions.
- Obtained new rates for the  ${}^{14}\text{O}(\alpha,p){}^{17}\text{F}$  reaction that are a factor of 3-65 higher than the previous values by analyzing  ${}^{17}\text{F}(p,p)$ ,  ${}^{17}\text{F}(p,p')$ , and  ${}^{17}\text{F}(p,\alpha)$  measurements from the HRIBF at Oak Ridge.

**ORNL** -- Evaluate capture reactions on radioactive proton-rich nuclei which are important for element synthesis and energy generation in stellar explosions. Evaluate capture reactions important for understanding Red Giant Stars. Evaluate reactions important for nuclear burning in the interior of the sun.

**ORNL Deliverables:**

Work will continue on the evaluation of reaction data for  $^{33}\text{Cl}$ ,  $^{25}\text{Al}$ , and  $^{26}\text{Si}$ .

**Status:**

- Continued evaluations of the  $^{18}\text{F}(p,\gamma)$  and  $^{18}\text{F}(p,\alpha)$  reactions, important for understanding stellar explosions. We are incorporating the latest new experimental results with  $^{18}\text{F}$  beams from ORNL's Holifield Radioactive Ion Beam Facility, as well as new Thomas-Ehrman level shift calculations and an improved non-resonant reaction rate calculation. The new reaction rates will be put into formats requested by astrophysicists and distributed over the Web. A previous draft of a paper and a Ph.D. thesis are being revised to take the latest experimental results into account.
- Continued evaluations of the  $^{17}\text{O}(p,\gamma)$  and  $^{17}\text{O}(p,\alpha)$  reactions, important for understanding the evolution of Red Giant Stars. We combined a new direct capture calculation with estimates of the resonant capture cross section. A paper is being drafted on this work.
- Continued evaluations of cross sections for the 19 reactions important for the Solar Neutrino Problem. These cross sections are being converted into reaction rates, parameterized, and compared to analytical approximations. We extended our analysis to include NACRE evaluations of these rates, made fits to NACRE rates in a standardized format needed by astrophysics modelers, and compared these rates to other evaluations. A paper on this work is being drafted.
- Led a novel effort to gauge the influence of nuclear reaction rate uncertainties (such as those determined from detailed cross section evaluations) on nucleosynthesis predictions in novae.
- Initiated assessments of the level structure of Ar isotopes for hydrogen burning on Cl, and on the S isotopes for hydrogen burning on P, for studies of nuclear burning in stellar explosions.

I. Nuclear Reaction Data Measurements

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

**LANL Deliverables:**

Complete the experiment and analysis of prompt gamma-ray emission following interactions of fast neutrons with  $^{99}\text{Tc}$ .

Consult with evaluators on neutron interactions with fission products.

**Status:**

- $^{99}\text{Tc}$  experiment completed. Data analysis delayed pending  $^{59}\text{Co}$  analysis and techniques developed for that.

J. Reaction Data for RIA Target Design

Rare Isotope Accelerator facility design needs high-quality nuclear reaction data for target design, and facility design. LANL works with ORNL and ANL researchers to provide key reaction cross-sections using theory calculations and measurements to evaluate the data.

**LANL Deliverables:**

Work closely with RIA community to determine nuclear data needs for RIA target design.

Develop and improve nuclear reaction models for predicting (p,xn) reactions, as well as spallation and fission in intranuclear cascade model codes.

Complete and publish isospin-dependent global relativistic Schrödinger optical model.

**Status:**

- We have hosted Jerry Nolen at LANL to discuss RIA needs, and presented LANL's RIA research to the RIA R&D committee in February, at LBL.
- We have made enhancements to our CEM and LAQGSM intra-nuclear cascade simulation codes by developing a new fission model that results in much more accurate spallation and fission fragment yields, important in ISOL and target fragmentation RIA design. Many benchmark comparisons against recent GSI data demonstrate the improvement.
- We are slowly converging on a relativistic Schrödinger global optical potential, for neutron and proton scattering by (approximately) spherical nuclei from mass 16 to 209, and for incident energies ranging from 20 MeV to 2000 MeV. A difficult aspect of this project has been the scarcity of relevant experimental data above 1000 MeV.



- Studied the effects of electronic screening on Maxwellian rates under astrophysical conditions.
- Obtained new rates for the  $^{14}\text{O}(\alpha,p)^{17}\text{F}$  reaction that are a factor of 3-65 higher than the previous values by analyzing  $^{17}\text{F}(p,p)$ ,  $^{17}\text{F}(p,p')$ , and  $^{17}\text{F}(p,\alpha)$  measurements from the HRIBF at Oak Ridge.

**ORNL** -- Evaluate capture reactions on radioactive proton-rich nuclei which are important for element synthesis and energy generation in stellar explosions. Evaluate capture reactions important for understanding Red Giant Stars. Evaluate reactions important for nuclear burning in the interior of the sun.

**ORNL Deliverables:**

Work will continue on the evaluation of reaction data for  $^{33}\text{Cl}$ ,  $^{25}\text{Al}$ , and  $^{26}\text{Si}$ .

**Status:**

- Continued evaluations of the  $^{18}\text{F}(p,\gamma)$  and  $^{18}\text{F}(p,\alpha)$  reactions, important for understanding stellar explosions. We are incorporating the latest new experimental results with  $^{18}\text{F}$  beams from ORNL's Holifield Radioactive Ion Beam Facility, as well as new Thomas-Ehrman level shift calculations and an improved non-resonant reaction rate calculation. The new reaction rates will be put into formats requested by astrophysicists and distributed over the Web. A previous draft of a paper and a Ph.D. thesis are being revised to take the latest experimental results into account.
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- Initiated assessments of the level structure of Ar isotopes for hydrogen burning on Cl, and on the S isotopes for hydrogen burning on P, for studies of nuclear burning in stellar explosions.

## I. Nuclear Reaction Data Measurements

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

### **LANL Deliverables:**

Complete the experiment and analysis of prompt gamma-ray emission following interactions of fast neutrons with  $^{99}\text{Tc}$ .

Consult with evaluators on neutron interactions with fission products.

### **Status:**

- $^{99}\text{Tc}$  experiment completed. Data analysis delayed pending  $^{59}\text{Co}$  analysis and techniques developed for that.

## J. Reaction Data for RIA Target Design

**LANL** -- Rare Isotope Accelerator facility design needs high-quality nuclear reaction data for target design, and facility design. LANL works with ORNL and ANL researchers to provide key reaction cross-sections using theory calculations and measurements to evaluate the data.

### **LANL Deliverables:**

Work closely with RIA community to determine nuclear data needs for RIA target design.

Develop and improve nuclear reaction models for predicting (p,xn) reactions, as well as spallation and fission in intranuclear cascade model codes.

Complete and publish isospin-dependent global relativistic Schrödinger optical model.

### **Status:**

- We have hosted Jerry Nolen at LANL to discuss RIA needs, and presented LANL's RIA research to the RIA R&D committee in February, at LBL.
- We have made enhancements to our CEM and LAQGSM intra-nuclear cascade simulation codes by developing a new fission model that results in much more accurate spallation and fission fragment yields, important in ISOL and target fragmentation RIA design. Many benchmark comparisons against recent GSI data demonstrate the improvement.
- We are slowly converging on a relativistic Schroedinger global optical potential, for neutron and proton scattering by (approximately) spherical nuclei from mass 16 to 209, and for incident energies ranging from 20 MeV to 2000 MeV. A difficult aspect of this project has been the scarcity of relevant experimental data above 1000 MeV.

## Appendix A.

### Nuclear Data Activities Funded from Sources Outside the DOE Division of Science, Nuclear Data Program

**ANL** -- There are two additional sources of funding that are being used to support the ANL nuclear data work during FY2002.

1. Funds from an Argonne LDRD (Laboratory Director's Research Discretionary fund) grant for the development of FIGARO (a concept for nuclear interrogation with gamma rays)
2. Development of photoneutron target for a project funded by the Advanced Accelerator Applications (AAA) program.

Note: Funding for these projects terminated during this period.

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

1. Academic Press supports the production of computer-generated photo-ready copy of manuscripts for the Nuclear Data Sheets.
2. Consultant services to the DOE Nuclear Criticality Safety program.

**Georgia Tech** – There are no additional sources of funding for nuclear data work in this group.

**Idaho** – The group has one subcontract with Idaho State University to compute efficiencies for Ge semiconductor gamma-ray detectors using Monte Carlo methods.

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

1. **Nuclear weapons (ASCI program)**. This work supports the development of more accurate ENDF cross section databases for actinide fission fuels, light-nucleus thermonuclear fuels, and for reactions important on materials used for diagnostics (radchem 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 away from stability and isomers), and fission theory. Data testing using integral benchmarks such as fast critical assemblies, are used to validate the ENDF data.

2. **AAA (Advanced Accelerator Applications, including transmutation of waste).** This supports the development of improved nuclear data important in the transmuter 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 intranuclear cascade codes for modeling neutron production and radionuclide production in the spallation target. This program also supports experimental nuclear reaction measurements at WNR.
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. **RIA R&D.** The RIA R&D program funds LANL participation in the national program at a modest level. The funding supports improved intranuclear cascade code development (CEM and LAQGSM) for modeling radionuclide production in both ISOL and target-fragmentation mechanisms, including validation and optimization through comparisons with recently-measured data at GSI and other facilities.
5. **LANL LDRD.** There are 3 LANL LDRD projects that support nuclear reaction data measurements.

**LBL** – Members of the Isotopes Project plan to perform nuclear physics experiments to address the nuclear data needs of nuclear astrophysics. We are planning to perform a series of ( $\alpha, \gamma$ ) cross section measurements on nuclides with  $A > 100$ . We also are planning to measure the half-life of the long-lived fission product,  $^{121m}\text{Sn}$ . Support for this activity comes from the low energy nuclear physics program.

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

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

**NIST** – A variety of sources support nuclear data activities.

1. The Nuclear Data Verification and Standardization program does have funding through the Commerce Department (NIST). The NIST support provides 44% of the total support for the program.
2. NIST provides 1 FTE for interferometry work which 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. DOE NE (Office of Nuclear Energy, Science and Technology) provided NERI funding of 0.75 FTE for iron transmission studies which will have an impact on evaluations of the iron cross sections.
5. 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 radio-pharmaceutical studies.

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

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

## **Appendix B.**

### **USNDP Organization**

Coordinating Committee (chair P. Oblozinsky, BNL)

#### Working Groups

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

#### Task Forces

- Nuclear Data for Astrophysics (chair M. Smith, ORNL)
- Nuclear Data for Rare Isotope Accelerators (chair M. Chadwick, LANL)
- Impact of Nuclear Data on Society (chair J. Kelley, TUNL)

## Appendix C.

### Acronyms in the Nuclear Data Program

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

#### CINDA – Computer Index to Nuclear Data

Bibliography for publications in nuclear reaction physics.  
Emphasis on nuclear data measurements. Entries for each reaction reported in a paper.  
Originated by Prof. Herbert Goldstein, Columbia University, in the early 1960's.  
Input prepared by NNDC in collaboration with NEA Data Bank, Paris, IAEA Nuclear Data Section, Vienna, and Russian Nuclear Data Center (CJD), Obninsk, Russia.  
Database maintained separately by each of the collaborating organizations.  
Database heavily application oriented.

#### CSEWG – Cross Section Evaluation Working Group

US group, comprising about 20 organizations (national labs, academia, industry) and coordinated by NNDC, that produces the Evaluated Nuclear Data File (ENDF).  
Complete evaluations of nuclear reaction and decay data using theory where necessary.  
Largely used in nuclear technology applications such as power reactors and medicine, and in design of nuclear research facilities.

#### CSISRS – Cross Section Information, Storage and Retrieval System

Database of experimental neutron, charged particle and photo-nuclear reaction data.  
Data compiled in an internationally adopted format, EXFOR, in use since 1969.  
Data jointly compiled by the members of the NRDC network.  
Database maintained separately by each of 4 core collaborating organizations (NNDC, NEA Data Bank, IAEA Nuclear Data Section and CJD).  
Fairly complete for neutron reaction data.

#### ENDF – Evaluated Nuclear Data File

Database of evaluated nuclear reaction data, which is primarily used in nuclear applications.  
Contains all of the world's evaluated nuclear reaction data files (see WPEC below).  
Master source for the US file ENDF/B maintained by NNDC.

#### ENSDF – Evaluated Nuclear Structure Data File

Database of evaluated experimental nuclear structure and radioactive decay data.  
Data evaluated by the members of the international NSDD network.  
Theory **NOT** used to fill in gaps in experimental data.  
Basis for the Nuclear Data Sheets publication.  
Database maintained and distributed by the NNDC.

IAEA - International Atomic Energy Agency, Vienna, Austria

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

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

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

INDC – International Nuclear Data Committee

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

US delegation of three is lead by NNDC head.

NEA - Nuclear Energy Agency, Paris, France

Membership restricted to OECD countries.

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

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

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

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

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

Focal point of US international nuclear data activities.

NSDD – Nuclear Structure and Decay Data network

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

US is the leading partner in this effort.

NRDC – Nuclear Reaction Data Center network

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

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

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

NSR – Nuclear Science References

Bibliography for publications in low and intermediate energy nuclear physics.

Literature scanned. Keyword abstracts are prepared for appropriate papers.

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

Database maintained and distributed by NNDC.

Most popular database. Heavily used by basic research.



NuDat – Nuclear Data

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

Derived from the ENSDF and ENDF databases.

Useful for nuclear property searches.

Database maintained and distributed by the NNDC.

MIRD – Medical Internal Radiation Dose tables

Radiation dose information useful to medical science.

Originated at Oak Ridge Nuclear Data Project.

Derived from ENSDF.

USNDP – United States Nuclear Data Program

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

Wallet Cards

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

Database maintained, published and distributed by the NNDC.

WPEC – Working Party on International Evaluation Cooperation

Nuclear Energy Agency sponsored effort to improve the world's nuclear reaction data files.

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

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

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

XUNDL – Experimental Unevaluated Nuclear Data List

Database of experimental nuclear structure data.

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

Data sets prepared/reviewed at McMaster University, Canada.

Database maintained and distributed by the NNDC.