

USNDP Fiscal Year 2004 Final Report



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Summary of the U.S. Nuclear Data Program Activity for 2004

I. Introduction

This year-end report summarizes the work of the U.S. Nuclear Data Program (USNDP) for the period of October 1, 2003 through September 30, 2004 with respect to the work plan for FY2004 that was prepared in March 2003. The work plan and final report are prepared at the direction of the DOE Office of Science, Office of Nuclear Physics for the nuclear data program. The support for the nuclear data activity from sources outside the nuclear data program is described in the manning table and in appendix A. This leverage amounts to about 26.7 FTE, mostly at NNSA laboratories, to be compared with 23.35 FTE at USNDP funded by the DOE Office of Science, Office 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 that 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 FY2004. This is followed by the work plan for FY2004. 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 higher than projected by 1.9 FTE. This increase represents a 2.15 FTE increase over projections at ORNL, a 0.25 FTE decrease at TUNL and a minor decrease at ANL.

This fiscal year is the fifth 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 of nuclear physics information critical to basic nuclear research and to the development and improvement of nuclear technologies with the electronic distribution of this information to users in a timely and convenient manner.

This year, for the first time, the program metrics requested by DOE are included below. The first table summarizes the USNDP metrics for the years that such metrics were reported. The second table shows the breakdown of the metrics for this fiscal year by laboratory and compares them with the previous fiscal year. The tables are followed by a description of the meaning of each metric.

Table 1. Summary of USNDP metrics in FY01- FY04

Fiscal Year	Compilations	Evaluations	Dissemination (in thousands)	Reports	Papers	Invited Talks
2001	7,139	334	667	21	25	22
2002	6,159	300	799	23	40	22
2003	4,975	260	966	27	40	23
2004	6,241	276	1,212	35	36	43

Table 2. USNDP metrics in FY04, numbers for FY03 are shown for comparison.

Laboratory	Compilations		Evaluations		Dissemination³		Reports		Papers		Invited Talks	
	FY03	FY04	FY03	FY04	FY03	FY04	FY03	FY04	FY03	FY04	FY03	FY04
BNL ¹	4690	5751	65	117	330	478	6	6	5	5	6	9
LANL			36	30	271	290	4	5	8	7	9	7
LBNL		245	53	54	278	342	3	5	7	3	2	8
ORNL			18	8	56	64⁴	5	7	2	5	2	7
ANL			10	10	5	8	1	4	7	6	2	5
LLNL			-	-	-	-	3	2	3	4	2	3
University ²	285	245	78	57	26	30	5	6	8	6	-	4
Total	4975	6241	260	276	966⁵	1212	27	35	40	36	23	43

1) Includes Idaho.

2) TUNL, NIST, McMaster and Georgia Tech. One half of McMaster funding comes from Canada.

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

4) ORNL includes traditional Radware service only. FY05 will also include the new service at nucastrodata.org.

5) Reduced from 987 to 966 due to new FY03 number from TUNL.

Definitions

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

II. Network Coordination and Data Dissemination

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 2004 in conjunction with the members of the Coordinating Committee. The NNDC Head serves as chair of the USNDP Coordinating Committee, which consists of the Principal Investigators from each of the participating groups, and chairs the annual meeting of the program held at Brookhaven National Laboratory. LANL chairs the Nuclear Reaction Data Working Group, and LBNL, the Nuclear Structure Working Group. ORNL chairs the Astrophysics TASK Force and LLNL chairs the Homeland Security Task Force.

In February 2004, the DOE Office of Nuclear Physics conducted its annual Budget Briefing. The USNDP was represented by P. Oblozinsky, M. Chadwick and C. Baglin who, together, made the case for FY2006 funding.

The NNDC serves as the focal point for U.S. collaboration in international nuclear data activities. Two NNDC staff members and two LBNL staff members served as lecturers at an IAEA-sponsored "Workshop on Nuclear Structure and Decay Data: Theory and Evaluation" in Trieste in November 2003. NNDC provided one lecturer for the Nuclear Reaction Data Workshop at Trieste in February 2004.

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 2003. The major topics of the meeting continue to be the planned release of ENDF/B-VII and nuclear data for Homeland Security. Several USNDP participants attended the May 2004 meeting of the NEA-sponsored Working Party on International Evaluation Cooperation (WPEC) in Aix-en-Provence, France. The US has the lead responsibility for several projects sponsored by this group. The NNDC Head was selected as the chairman of the Working Party for the next two-year term.

The International Conference on Nuclear Data for Science and Technology (ND2004) was held in Santa Fe, New Mexico in the last week of September 2004. The successful conference was organized and hosted by LANL. Four hundred forty-five registered participants gave over 486 oral and poster presentations.

USNDP Databases

The NNDC now operates four Dell servers running Linux operating systems to support their compilation, evaluation, database maintenance, and information dissemination functions. These computers archive and serve the nuclear data produced by the U.S. Nuclear Data Program

and the data obtained by other national and international collaborations. This facility operates 24 hours a day, 7 days a week, to provide electronic access to the data.

The past fiscal year saw the successful completion of a multi-year project to upgrade the NNDC computing system and modernize its database and customer service software. The project was a joint effort with the IAEA's Nuclear Data Section. The project included the following activities:

- Databases were migrated into the modern relational database software Sybase under the Linux operating system.
- Completely new DELL database computer system was purchased and installed.
- Entirely new Web interfaces were developed with extensive use of Java technology.

The NNDC maintains seven nuclear physics databases for the USNDP. These databases have been updated continuously in FY2004 with new and revised information from efforts of the NNDC, the USNDP and international collaborators. Distributions of all or parts of these databases have been made to national and international collaborators as scheduled.

Data Dissemination

Retrievals from the USNDP databases increased by 45% as compared to FY2003. The new website shown below was inaugurated by the NNDC on April 19, 2004

National Nuclear Data Center
BROOKHAVEN NATIONAL LABORATORY

NSR XUNDL ENSDF
NuDat Databases MIRD
CINDA CSISRS ENDF
Empire
Nuclear Wallet Cards
Tools and Publications
Nuclear Data Sheets
Networks
CSEWG USNDP

Nuclear Structure and Decay Databases
Nuclear Structure and Decay Tools
Nuclear Reaction Databases
Nuclear Reaction Tools
Bibliography Databases
Networks and Links
About the Center
Publications
Meetings

CSEWG: Nov 2-4, 2004 Nuclear Data Portal USNDP: Nov 3-5, 2004

Site Index - Search the NNDC: go

CapGam Thermal Neutron Capture Gamma-rays	CINDA Computer Index of Neutron Data	CSEWG Cross Section Evaluation Working Group	CSISRS alias EXFOR Nuclear reaction experimental data
Empire Nuclear reaction model code	ENDF Evaluated Nuclear (reaction) Data File	ENSDF Evaluated Nuclear Structure Data File	For NMSS and DoE NMRDC Standards for decay data
IRDF International Reactor Dosimetry File	MIRD Medical Internal Radiation Dose	NSR Nuclear Science References	Nuclear Data Sheets Nuclear structure and decay data journal
Nuclear Wallet Cards Ground and isomeric states properties	Nuclear Wallet Cards for Homeland Security	NuDat Nuclear structure and decay data	RIPL Reference Input Parameter Library
USNDP U.S. Nuclear Data Program	XUNDL Experimental Unevaluated Nuclear Data List	Coming soon: Atlas of Neutron Resonances	Coming soon: Empire 2.19

Links ordered alphabetically [Order by category](#)

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[Acknowledgements](#) - [Disclaimer](#)

Fig. 1. Front page of new NNDC Web service, www.nndc.bnl.gov.

Based on the success of the Nuclear Wallet Cards and in response to emerging needs of the Department of Homeland Security (DHS), the NNDC issued a modified and updated version, Nuclear Wallet Cards for Radioactive Nuclides, in March 2004. The objective was to provide DHS personnel in the field with a tool to identify the sources of observed radioactivity. The booklet contains basic properties of various radioactive isotopes likely to be encountered in almost all foreseeable conditions, such as in a smuggled cargo, a naturally-occurring radioactive source, or in a dirty bomb.

5,000 copies of this handy booklet were produced. Most of them were distributed to 50 states' emergency preparedness offices as well as to various Police and Fire Departments throughout the United States.

In addition to hardcopy publication, the Nuclear Wallet Cards can be also retrieved from the new Web page shown below.

Nuclear Wallet Cards

NNDC
To NNDC

Nuclear Wallet Cards for Radioactive Nuclides (Homeland Security)

This version of Nuclear Wallet Cards contains decay properties only of radioactive nuclides, with $T_{1/2} \geq 1\text{h}$ and $Z \leq 100$. There are two nuclear data tables ordered by isotope and by gamma-ray energy and produced as standard [hardcopy](#) and in PDA-adaptable format. PDA version of Nuclear Wallet Cards ordered by gamma-ray energy and isotope can be found [here](#).

Nuclear Wallet Cards for Radioactive Nuclides
March 2004
Jagdish K. Tuli
National Nuclear Data Center
Brookhaven National Laboratory
P.O. Box 5000
Upton, New York 11973-5000
USA

[General Information](#) [Current Version](#) [Radioactive Nuclides \(Homeland Security\)](#) [Nuclear Materials Management & Safeguards](#) [Palm Pilot](#) [Sixth Edition 2000](#)

Fig. 2. Web page for Nuclear Wallet Cards, www.nndc.bnl.gov.

The nuclear astrophysics data site at www.nuastrodata.org at ORNL has been improved to include a new computational infrastructure for nuclear astrophysics. This suite of computer codes enables users to: perform simple evaluation-related tasks with cross sections, to share libraries of reaction rates and to utilize these libraries in online element synthesis calculations.

III. Nuclear Structure and Decay Data

The Working Group's principal activity during the 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 *Nuclear Data Sheets* or *Nuclear Physics A*. In addition, the currency of evaluated super-deformed band data in ENSDF has been maintained, Wallet Card and NuDat files have been updated, and the Nuclear Science Reference and XUNDL databases have been extended. Frequently-accessed websites are maintained at several data centers for the dissemination of these data in various user-friendly forms; of particular note is the very significant enhancement this year of user access, search and interactive level drawing capabilities associated with the NuDat database.

Evaluations for ENSDF

USNDP nuclear structure and decay data evaluation groups in the US and Canada engaged in the revision of 16 mass-chain and 13 individual nuclide evaluations (206 nuclides altogether, 22 of them priority nuclides) that were submitted during FY2004 for inclusion in the ENSDF database. The evaluations of 31 of these nuclides were performed in collaboration with several newly-recruited non-US evaluators as part of a training and mentoring effort, and the evaluation of another 7 of the nuclides resulted from a separate Canadian-Russian collaboration. The USNDP evaluators have also reviewed 16 mass chain evaluations, and additional prepublication checks have been done at NNDC for all published evaluations. Super-deformed band data for 4 nuclides have been updated in ENSDF. Twelve issues of the journal *Nuclear Data Sheets* were published by Elsevier; these issues contained 13 mass chain evaluations (including one from each of France and Japan) and the annual nuclear science references update.

Compilations for XUNDL

The XUNDL file contains experimental unevaluated data sets compiled primarily from recent papers. The McMaster group has submitted 226 new and 21 updated data sets, which are mostly, but not exclusively, for high-spin data. These data have been entered into XUNDL by BNL. Private communications obtained from authors concerning some of the data entered into XUNDL during the year have been collected and forwarded to NNDC so that ENSDF evaluators also can also benefit from the information they contain.

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 continues to coordinate this project and provide general editorial oversight. New evaluations have been completed for 4 nuclides by the Idaho group and 2 by LBNL, and these have been submitted to the DDEP project for review. Also, four radionuclide evaluations were reviewed by USNDP participants in this program.

Nuclear Science References

The nuclear science references included in the NSR file have been expanded by 4899 papers, and keyword abstracts were provided for 3456 of these. The work was performed primarily by the NNDC staff that regularly reviews more than 75 refereed journals, along with laboratory reports and conference proceedings; several foreign collaborators also contribute to this work.

Other Achievements

- In response to the problem of a diminishing and graying nuclear structure data evaluation workforce worldwide, the IAEA held a two-week long evaluator training workshop at the ICTP in Trieste in November 2003. Experienced USNDP evaluators, two from BNL and two from LBNL, lectured at this workshop to 24 participants from 12 countries. Evaluators at BNL and McMaster have served also as mentors for several non-US evaluators who have recently begun evaluation work.
- A US-Australia-Russia collaboration has made excellent progress on the calculations, software changes and extensive cross checking required in order to implement the replacement of the Hager-Seltzer theoretical internal conversion coefficients used in ENSDF with those from the recent Band-Raman calculations.
- Two new versions of the Nuclear Wallet Cards were created this year. One is the PDA-format version of the Wallet Cards for use on PalmPilot 3.0 and higher. The other version, designed for Homeland Security applications, is the *Nuclear Wallet Cards for Radioactive Nuclides*. This includes just those unstable nuclides with half-life greater than 1 hour and adds an energy-ordered list of the strongest radiations; it has been distributed widely to emergency-preparedness groups and various police and fire departments.

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 159 neutron and charged-particle data sets for the experimental nuclear reaction database, CSISRS. Work at NNDC has begun to implement the recommendations of an international review of available neutron evaluations for 218 fission product nuclei. The majority of the recommendations require integrating the results of an NNDC project to evaluate neutron resonance parameters across the periodic table that is nearing completion. The Cross Section Evaluation Working Group (CSEWG) that is partly supported by this program has made good progress toward the release of next version of the US evaluated nuclear data library, ENDF/B-VII.

The activity to supply nuclear data for Homeland Security continues. This Task Force will hold a special session during each annual USNDP meeting. Evaluation of neutron cross sections for the germanium isotopes including gamma-ray production cross sections, has been completed by NNDC.

LANL has completed evaluations of neutron reactions with the uranium isotopes ($^{232-241}\text{U}$) as well as for ^{239}Pu , ^{237}Np and ^{241}Am . These evaluations will be included in ENDF/B-VII, which is on schedule for release at the beginning of FY2006.

The unique measurement (LANSCE) and analysis (T-16) capability at LANL have been combined to produce new nuclear reaction data. The GEANIE facility has been used to measure (n,x γ) data for ^{100}Mo and ^{130}Te . Capture cross sections for ^{237}Np and ^{131}Sm have been measured at DANCE. The interpretation of previously measured data for $^{171}\text{Tm}(n,\gamma)$ and neutron reactions with ^{89}Y and ^{193}Ir producing unstable products and isomers has been completed. The evaluation of ^{238}U prompt-fission gamma data taken at FIGARO has given good results.

Model Code Highlights

A new release of the EMPIRE nuclear reaction code, version 2.19, is being prepared by BNL for release. Added features in this release will include reactions with excited targets, improved fission modeling, pre-equilibrium cluster emission, and improved treatment of exclusive spectra and recoils. A WPEC project to provide a library of modules used in nuclear model programs is being led by LANL. The first version of this library is now being tested prior to release.

Analysis of pre-equilibrium reactions with complex particles in the entrance and/or exit channels is continuing at TUNL. A journal article has been prepared. During the writing of this article several new issues have arisen which will require further study, including such topics as

inelastic scattering of complex components, projectile breakup contributions and their potential impact on the exciton model calculations.

Nuclear Standards Highlights

NIST is leading an international nuclear reaction standards evaluation project that is being carried out under the auspices of an IAEA Coordinated Research Project, the NEA Working Party on International Evaluation Cooperation and the CSEWG. At NIST, all experimental data to be used in the evaluation have been reviewed and an interim set of the most important standards has been prepared for the CSEWG. It is unlikely that there will be much change in the final evaluated cross sections. However, the cross section covariances still need further work. LANL has provided one of the R-matrix evaluations for the light element standards that are combined with other experimental data using the GMA code to provide the final result. LANL has also evaluated the H(n,n) cross section. New measurements for several standards, including $^1\text{H}(n,n)$ at 15 MeV, $^6\text{Li}(n,t)$, and $^{10}\text{B}(n,\alpha)$ are being made that will be useful for a future standards evaluation.

Nuclear Astrophysics Highlights

Work continues on the evaluation of several nuclear reactions important for astrophysics modeling at ORNL [$^{18}\text{F}(p,\alpha)$, $^{18}\text{F}(p,\gamma)$, $^{14}\text{O}(\alpha,p)$, ^{17}F , $^{33,34}\text{Cl}(p,\gamma)$, $^{30}\text{P}(p,\gamma)$], at ANL [$^{33,34,36}\text{S}(p,\gamma)$], at LANL [$^{12}\text{C}(\alpha,\gamma)$] and at McMaster [$^{21}\text{Na}(p,\gamma)$, $^{18}\text{Ne}(\alpha,p)$].

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Final USNDP Manning Table for October 2003 through September 2004

	ANL	BNL Sci/Pro	BNL Support	Idaho	L/ANL	LBNL	LLNL
I. NNDC Facility Operation							
Management	0.00	1.15	1.25	0.00	0.00	0.00	0.00
Secretarial/Administrative Support		0.35					
Library			1.00				
Computer Operation		0.80					
II. Coordination							
National Coordination	0.02	0.55	0.00	0.00	0.40	0.30	0.00
International Coordination	0.02	0.35			0.1	0.3	
		0.20			0.3		
III. Nuclear Physics Databases							
Nuclear Science References (NSR)	0.00	3.85	1.05	0.00	0.00	0.00	0.00
Experimental Nuclear Structure Data (XUNDL)		0.10	0.75				
Evaluated Nuclear Structure Data (ENSDF)		0.05					
Numerical Nuclear Data (NuDat)		0.45	0.30				
Reaction Data Bibliography (CINDA)		0.05					
Experimental Reaction Data (CSIRS)		0.10					
Evaluated Nuclear Data File (ENDF)		0.10					
Database Software Maintenance		0.25					
Future Database Systems		0.10					
		2.65					
IV. Information Dissemination							
Maintenance of Remote Access to USNDP Data	0.02	0.65	0.50	0.00	0.10	0.25	0.00
Customer Services		0.30					
Web Site Maintenance	0.02	0.15	0.45				
		0.20	0.05		0.10	0.25	

Final USNDP Manning Table for October 2003 through September 2004

	McMaster	NIST	ORNL	TUNL	Program Total	
					Sci/Pro	Support
I. NNDC Facility Operation						
Management	0.00	0.00	0.00	0.00	1.15	1.25
Secretarial/Administrative Support					0.35	0.00
Library					0.00	1.00
Computer Operation					0.80	0.00
II. Coordination						
National Coordination	0.00	0.00	0.05	0.00	1.32	0.00
International Coordination			0.05		0.82	0.00
					0.50	0.00
III. Nuclear Physics Databases						
Nuclear Science References (NSR)	0.00	0.00	0.00	0.00	3.85	1.05
Experimental Nuclear Structure Data (XUNDL)					0.10	0.75
Evaluated Nuclear Structure Data (ENSDF)					0.05	0.00
Numerical Nuclear Data (NuDat)					0.45	0.30
Reaction Data Bibliography (CINDA)					0.05	0.00
Experimental Reaction Data (CSIRS)					0.10	0.00
Evaluated Nuclear Data File (ENDF)					0.10	0.00
Database Software Maintenance					0.25	0.00
Future Database Systems					0.10	0.00
					2.65	0.00
IV. Information Dissemination						
Maintenance of Remote Access to USNDP Data	0.00	0.00	2.25	1.00	4.27	0.50
Customer Services					0.30	0.00
Web Site Maintenance			2.25	1.00	0.15	0.45
					3.82	0.05

Final USNDP Manning Table for October 2003 through September 2004

	ANL	BNL		Idaho	LANL	LBNL	LLNL
		Sci/Pro	Support				
V. Nuclear Structure Physics	0.73	2.05	0.00	0.50	0.10	2.38	0.00
NSR Abstract Preparation		0.45					
Compilation of Experimental Structure Data							
Evaluation of Masses and Nuclides for ENSDF	0.68	1.40		0.40		2.10	
Ground and Metastable State Properties		0.10					
Radioactive Decay Data Evaluation	0.05			0.10		0.13	
Thermal Capture Gamma Data Evaluation						0.15	
Light Mass Evaluations for Nuclear Physics A.							
Nuclear Structure Data Measurement					0.10		
ENSDF Physics and Checking Codes		0.10					
VI. Nuclear Reaction Physics	0.05	1.25	0.00	0.00	1.70	0.00	0.40
Experimental Data Compilation	0.00	0.40					
Neutron Data		0.10					
Charged Particle Data		0.25					
EXFOR Manuals		0.05					
ENDF Manuals and Documentation		0.05					
ENDF Evaluations		0.35			0.10		0.40
Nuclear Reaction Standards					0.20		
Nuclear Model Development	0.02	0.20			0.60		
Nuclear Reaction Data Measurements					0.30		
Astrophysics Nuclear Data Needs	0.03	0.25			0.30		
Reaction Data for RIA Target Design					0.20		
DOE/Science Nuclear Data Funded Staff	0.82	9.50	2.80	0.50	2.30	2.93	0.40
Staff Supported by Other Funding	0.23	0.25	0.20	0.20	14.40	0.80	7.50
TOTAL STAFF	1.05	9.75	3.00	0.70	16.70	3.73	7.90

Final USNDP Manning Table for October 2003 through September 2004

	McMaster	NIST	ORNL	TUNL	Program Total	
					Sci/Pro	Support
V. Nuclear Structure Physics	0.50	0.00	0.40	1.00	7.66	0.00
NSR Abstract Preparation					0.45	0.00
Compilation of Experimental Structure Data	0.15				0.15	0.00
Evaluation of Masses and Nuclides for ENSDF	0.35		0.40	0.55	5.88	0.00
Ground and Metastable State Properties					0.10	0.00
Radioactive Decay Data Evaluation					0.28	0.00
Thermal Capture Gamma Data Evaluation					0.15	0.00
Light Mass Evaluations for Nuclear Physics A.				0.45	0.45	0.00
Nuclear Structure Data Measurement					0.10	0.00
ENSDF Physics and Checking Codes					0.10	0.00
VI. Nuclear Reaction Physics	0.50	0.20	0.60	0.40	5.10	0.00
Experimental Data Compilation					0.40	0.00
Neutron Data					0.10	0.00
Charged Particle Data					0.25	0.00
EXFOR Manuals					0.05	0.00
ENDF Manuals and Documentation					0.05	0.00
ENDF Evaluations					1.25	0.00
Nuclear Reaction Standards		0.20			0.40	0.00
Nuclear Model Development				0.40	1.22	0.00
Nuclear Reaction Data Measurements					0.30	0.00
Astrophysics Nuclear Data Needs	0.50		0.60		1.68	0.00
Reaction Data for RIA Target Design					0.20	0.00
DOE/Science Funded Staff	1.00	0.20	3.30	2.40	23.35	2.80
Staff Supported by Other Funding	0.50	2.80	0.00	0.00	26.68	0.20
TOTAL STAFF	1.50	3.00	3.30	2.40	50.03	3.00

Detailed Status of the Work Plan

I. NNDC Facility Operation

A. Management

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

B. Library

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

C. Computer Operation

The NNDC will be operating four Dell servers running Linux operating systems to support their compilation, evaluation, database maintenance, and information dissemination functions. The migration to this computing configuration from its current Compaq Alpha 4100 server using the OpenVMS operating system will be completed this fiscal year. The migration project tasks include software upgrades, hardware and software procurements, machine operations and internal user support.

BNL Deliverables:

- Keep downtime on the central database server to less than 3%.
- Provide full computer support for database migration project.
- Upgrade hardware and software of Windows-based desktop computers.

Status:

- Using one-time capital equipment money, the following hardware was purchased and installed: one external Web server, two database servers and one backup server.
- The Compaq Alpha server running VMS has been decommissioned.
- Seven aging PCs were replaced with new Dell PCs and 3 new Dell laptops were purchased. PC monitors were replaced with large-screen flat-panel monitors.
- Installed a wireless LAN for easy access of NNDC staff and visitors.
- Considerable unplanned effort was required to install software security patches on servers and desktops to comply with DOE Cyber Security directives.
- Backup procedures for primary and secondary database servers was implemented using new hardware and software.

- Synchronized the Web server environment (Apache/Tomcat) on the external and the working servers.

II. Coordination

A. National Coordination

ANL -- Chair the Measurement and Basic Physics Committee of the Cross Section Evaluation Working Group and represent U.S. measurement interests in the NEA Working Party for Evaluation Cooperation.

ANL Deliverables:

Organize and Chair Measurement and Basic Physics Committee meeting at CSEWG meeting in FY2003.

Provide Measurement and Basic Physics Committee report for CSEWG.

Status:

- ANL organized and chaired the committee at the November 2003 CSEWG Meeting and prepared report for the meeting.

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

BNL Deliverables:

Prepare FY2005 work plan for USNDP in time for spring 2004 FWP submittals.

Organize and chair CSEWG Meeting at BNL in November 2003.

Organize and chair USNDP Meeting at BNL in April 2004.

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

Maintain CSEWG and USNDP Web sites.

Status:

- FY2005 work plan for USNDP was prepared in February 2004.
- CSEWG Meeting was held at BNL in November 2003.
- USNDP Meeting was rescheduled and held adjacent to CSEWG Meeting in November 2003.
- Summary report of CSEWG-USNDP 2003 meeting was published.
- Newly designed CSEWG and USNDP web sites were completed in April 2004.

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

LANL Deliverables:

Organize and chair CSEWG Evaluation Committee meeting at BNL, November 2003.

Organize and chair Nuclear Reaction Working Group meeting at USNDP meeting in April 2004.

Help organize and help lead the CSEWG Homeland Security Task Force, and interact with LANL NA22 representative to provide feedback on user needs.

Status:

- Organized and chaired the Evaluation Committee at the November 2003 CSEWG meeting.
- Organized and chaired Nuclear Reaction Working Group meeting at USNDP meeting in November 2003.
- Homeland Security data needs were investigated.

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

LBNL Deliverables:

Organize and chair Nuclear Structure and Decay Data Working Group meeting at USNDP meeting, April 2004.

Status:

- Served on USNDP Coordinating Committee.
- Organized and chaired USNDP Nuclear Structure and Decay Working Group meeting in Nov. 2003.

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

ORNL Deliverables:

Summarize USNDP efforts in nuclear data for nuclear astrophysics at USNDP Meeting in May 2004.

Summarize USNDP efforts in nuclear data for nuclear astrophysics in FY03 for USNDP written reports.

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

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

Status:

- USNDP efforts in nuclear data for nuclear astrophysics summarized in an oral presentation and a written report for USNDP meeting in November 2003. Work was also summarized at the Nuclear Structure and Decay Data (NSDD) Network meeting at the IAEA in November 2003.

- Presentation of future needs in nuclear astrophysics data, and some mechanisms to reach these needs, made to USNDP/NNDC, to DOE program officers, to the NSDD Network, and in an invited talk at the Nuclear Data 2004 meeting. Numerous written documents were generated outlining future data needs in nuclear astrophysics and recommending approaches to meet these needs.
- Initiated numerous communications with data centers pursuing work relevant for astrophysics at the ND2004 meeting, and prospects for three joint research / data projects in the future are now being explored.

B. International Coordination

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

BNL Deliverables:

Host and participate in the NRDC meeting at BNL in 2004.

Participate in NEA WPEC annual meeting in 2004.

Provide director and lecturers for the NSDD Workshop at Trieste in November 2003.

Status:

- NNDC made all arrangements as a host of the NRDC meeting to be held at BNL in October 2004.
- The NNDC head led the US team at the NEA Working Party on International Evaluation Cooperation (WPEC) meeting at Aix-en-Provence, France, May 2004. He chaired the meeting.
- The NNDC center head led the US-delegation to the IAEA's International Nuclear Data committee meeting in May 2004.
- Provided director and 2 lecturers for NSDD Workshop at Trieste in November 2003. Contributed to IAEA-NDS NSDD Manual.
- Hosted one nuclear structure evaluation trainee from India.
- Provided a lecturer for the Nuclear Reaction Data Workshop at Trieste in February 2004.
- Provided a lecturer for the Nuclear Reaction Data Compilation Workshop in Vienna in December 2003.

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. LANL will host visits by foreign scientists with international reputations to benefit from the exchange of information and ideas.

LANL Deliverables:

Complete the organization of the next international nuclear data conference (ND2004) to be held in Santa Fe, September 26-October 1, 2004.

Participate in NEA WPEC June 2004 meeting.

Participate in relevant IAEA meetings, including Trieste Lectures in spring 2004.

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

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

Status:

- The international nuclear data conference (ND2004) was held in Santa Fe in September 2004. There were 450 participants in what was viewed as a very successful conference.
- Two LANL staff members participated in WPEC meeting in Aix-en-Provence, France in June 2004. One member led a small meeting of the WPEC Subgroup A on nuclear model codes. A special meeting on covariances (Subgroup 20) was held during ND2004.
- One staff member gave a talk at the April 2004 IAEA Vienna meeting on spallation sources.
- Upgrades to NJOY were released to the international NJOY data processing community.
- Hosted key researchers from Geel, Erlangen, Caderache and Moldova.

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

LBL Deliverable:

Provide lecturer(s) for structure and decay data evaluator-training sessions at Workshop at Trieste in November 2003.

Status:

- Provided two lecturers for the two-week IAEA/ICTP (Trieste) “Workshop on Nuclear Structure and Decay Data: Theory and Evaluation” in Nov. 2003.

III. Nuclear Physics Databases

A. Nuclear Science References (NSR)

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

BNL Deliverables:

Database distributed to collaborators monthly.

Status:

- NSR files were distributed monthly.

B. Experimental Nuclear Structure Data (XUNDL)

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

BNL Deliverables:

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

Status:

- Database updated as required.

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:

- 20 mass-chains, 8 nuclides, and 9 data sets were received, processed and added to ENSDF in FY2004. Processing includes file checking, review and post-review checking.

- The ENSDF database was distributed in October 2003 and March 2004

D. Numerical Nuclear Data File (NuDat)

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

BNL Deliverables:

Distribute NuDat database to collaborators twice a year.

Status:

- The NuDat database was distributed in October 2003 and March 2004.

E. Neutron Reaction Data Bibliography (CINDA)

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

BNL Deliverables:

Update CINDA database with CINDA transmissions from cooperating centers (12 expected).

Status:

- Five CINDA transmissions were received and the database updated.

F. Experimental Reaction Data File (CSISRS)

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

BNL Deliverables:

Update CSISRS with EXFOR exchange files from cooperating centers (20 expected).

Status:

- Sixty-five EXFOR transmissions were received and the EXFOR database was updated.

G. Evaluated Nuclear Data File (ENDF)

The NNDC is responsible for ENDF, a database of evaluated nuclear data required for many nuclear applications. The work is organized under the Cross Section Evaluation Working Group (CSEWG), coordinated by the NNDC. The ENDF file contains complete descriptions of nuclear reactions of neutrons with many nuclides and elements for energies up to 20 MeV and radiations from radioactive decay. A number of evaluations for energies up to 150 MeV and for incident charged particles and photons are also included. The data are stored in the ENDF format developed at NNDC about 35 years ago—and adopted as an international standard. In addition to the U.S. library, ENDF/B, the database contains evaluated data libraries from the European Union, Japan, Russia, and China. This activity includes the processing and quality control for the U.S. ENDF/B library, the distribution of this database in the United States and the exchange of libraries internationally. A new version of the library, ENDF/B-VII, is being prepared by the members of the Cross Section Evaluation Working Group. There will be no more releases of ENDF/B-VI; the work will focus on ENDF/B-VII.

BNL Deliverables:

Maintain CSEWG Web site; keep information current.

Make ENDF/B-VII evaluations available on the CSEWG Web site after reviews are completed.

Status:

- CSEWG Web site, both public and members-only, was regularly maintained.
- 231 new or revised evaluations including 160 photonuclear evaluations are available on the preliminary ENDF/B-VII library at the CSEWG members Web site. The site provides easy access to files, output of checking codes, and numerous plots that compare evaluations with experimental data.

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 the 1980's, the NNDC migrated most of its databases to run under the Digital Equipment Corporation (DEC) CODASYL database management system (DBMS) on the VMS operating system (this DBMS has since been bought by Oracle). Retrieval programs written in

FORTRAN allowed dial-up, DECNET, and telnet-based online retrieval well before the advent of the World-Wide Web. In the 1990's, Web interfaces were developed using the very same DBMS system.

In recent years, relational database management systems (RDBMSs) using Structured Query Language (SQL) have become standard in business and academia. There are many ways in which the nuclear data program could benefit from an increased use of relational database technology. Because it is a widely used technology, a large variety of auxiliary tools and interfaces exist for the administration and dissemination of data. These tools include replication and synchronization capabilities that would improve the efficiency and reliability of data exchange between centers. Because commercial RDBMSs software is available on a wide variety of platforms, and in a wide variety of price ranges, their use provides an opportunity to explore new options for dissemination to end-users of the data. The use of common standards in data storage will allow data centers to choose the software that best meets their needs, without being tied to a particular vendor.

Migration to this new database format represents a generational shift in the way data are stored. This is a major project that requires substantial effort stretched over a period of several years. Among the tasks that need to be undertaken for each database are:

- Database design: The design of relational schema should be compatible with the current system and allow flexible and efficient access to the data.
- Data migration: Current data will be loaded into the Sybase RDBMS system. The software written to do this will also be used to add new data as it comes in. Until the migration project is complete, parallel instances of the data will be kept in both the old and new database formats.
- Code migration: To the extent that it is feasible, the legacy programs for database administration, written mostly in FORTRAN, will be modified to work with the new RDBMS.
- Code development: For many tasks, and in particular for Web-based data dissemination, new software will be developed. Because of its portability, the Java programming language is being used for new software development.

As discussed in last year's plan, the NNDC is involved in a multi-year project to migrate its databases to a relational format. In FY2003 the Linux/Sybase computing environment was established using existing and newly purchased Dell hardware. The migration of the software supporting the nuclear structure data activities and databases (NSR, ENSDF and NuDat) was completed and extensive testing started. Migration of the software supporting the nuclear reaction data activities and databases (CINDA, CSISRS and ENDF) will be completed in FY 2004. Testing of the migrated nuclear reaction data software will be completed in the first quarter of FY2005 and full implementation of the NNDC activity in the new computing environment will be completed in the second quarter of FY2005.

BNL Deliverables:

Complete testing of the migrated software, which supports the nuclear structure activities and databases (NSR, ENSDF and NuDat) in the new computing environment.

Complete testing of the migrated software, which supports the nuclear reaction data activities and databases (CINDA, CSISRS and ENDF) to the new computing environment.

Status:

- The nuclear structure databases (NSR, ENSDF and NuDat) have been migrated successfully to the Linux/Sybase platform and new user interfaces developed.
- The nuclear reaction databases (CSISRS and ENDF) have been migrated successfully to the Linux/Sybase platform and new user interfaces developed. The CINDA database has been designed but all related programs have not yet been completed and tested.

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:

Maintenance work only will be performed on the existing Web interfaces to the data in the existing VMS computing environment.

Status:

- NNDC Web site redesign and modernization project has been completed including improved interfaces to the USNDP nuclear reaction and structure databases.
- The TELNET service to the VMS versions of the databases has been terminated.

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:

Maintain electronic access to the ANL Nuclear Data Measurements (ANL/NDM) report series web site.

Maintain and upgrade Experimental Resources for the Nuclear Data Web site.

Maintain and upgrade the ANL Nuclear Data Information Web site.

Status:

- The ANL Nuclear Data Information Web Site has been maintained.
- The ANL/NDM reports have been updated, as has the Experimental Resources page.

BNL Deliverables:

Effort required to maintain the currency of the CSEWG, USNDP and the NNDC Web sites.

Status:

- The new NNDC web site was opened to users on April 19, 2004. A significant increase in retrievals was noted.
- A Google search engine for the site was included in the new home page, and files were added to improve indexing by external web search engines.

LANL Deliverables:

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

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

Status:

- The latest LANL evaluations were made available via our WWW site. This has been particularly important for the integral data testing community, who are validating the pre-ENDF/B-VII evaluations.
- Wilson and Moller's new delayed neutron data were also made available on this site.
- Little WWW development work was done this year.

LBNL Deliverables:

Maintain and update the home pages for neutron-capture gammas, nuclear structure and decay systematics, nuclear science education, atomic masses, and others.

Status:

- Maintained and updated web pages as needed.
- Added pages enabling users to perform interactive searches of atomic mass data or of ENSDF Adopted Levels, Gammas data (analogous to WWW of Radioactive Isotopes searches). This work was done in collaboration with two students visiting from EVTEK, Finland
- Revised WWW Table of Radioactive Isotopes page to enable searches on β endpoint energies and on pairs of γ -ray energies.

ORNL Deliverables:

Maintain, update, and improve the Web FTP site providing the RadWare interface to ENSDF and XUNDL information.

Improve the automatic graphical layout routines for ENSDF-to-RadWare conversion.

Improve and update web pages devoted to nuclear astrophysics data.

Status:

- The website radware.phy.ornl.gov has been maintained by uploading the latest versions of ENSDF and converting the files to RADWARE format.
- Discussions with users have provided information on future improvement of graphical layout routines for ENSDF-to-RADWARE conversion
- The site **nucastrodata.org** has been completely revised, with improved performance and organization, enabling users to access hyperlinked nuclear astrophysics datasets much more quickly
- An extensive expansion of **nucastrodata.org** has occurred with the launch of a new *computational infrastructure for nuclear astrophysics*. This suite of computer codes with an easy-to-use graphical interface enables users to: perform simple evaluation-related tasks with cross sections; to generate, modify, plot, store, and compare thermonuclear reaction rates; to create, modify, document, and share libraries of reaction rates; to utilize these libraries in online element synthesis calculations; to store, compare, and visualize these calculations.

TUNL Deliverables:

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

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

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

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

Status:

- PDF and HTML files for "Energy Levels of Light Nuclei $A = 8, 9, 10$ " evaluation placed online and submitted to Elsevier
- PDF and HTML files are online for *Fay Ajzenberg-Selove and TUNL reviews* for 1970-present. This year we added $A = 5 - 10$ (1959Aj76), $A = 11$ (1968Aj02), $A = 13 - 15$ (1970Aj04), and $A = 16, 17$ (1971Aj02).
- Modified HTML documents to incorporate both Netscape and Internet Explorer browser HTML code functionality and compatibility.
- Energy Level Diagrams are online for *Fay Ajzenberg-Selove and TUNL reviews* for 1966-present. This year we added $A = 5 - 10$ (1959Aj76), $A = 5 - 10$ (1966La04), $A = 11, 12$ (1968Aj02), $A = 13 - 15$ (1970Aj04), and $A = 16, 17$ (1971Aj02).

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, but receives some assistance from Russia.

BNL Deliverables:

Prepare entries for 4100 new references with keyword abstracts for 3100.

Status:

4899 entries added to the NSR database, 3456 with keywords.

B. Compilation of Experimental Structure Data

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

McMaster Deliverables:

Compile data sets (in ENSDF format) of current publications, primarily in high-spin physics. Selected low-spin publications will also be compiled.

Compile, on a time available basis, high-spin data from older publications not yet incorporated in outdated (older than about 7 years) ENSDF evaluations

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

Status:

- 226 new data sets from current journal publications in experimental nuclear structure (high-spin and low-spin) were compiled and sent to BNL. Another 21 data sets were updated based on new papers from the same groups or authors as in data sets from earlier papers. The above number includes about 15 data sets from older papers.
- Four data sets received from other data centers were reviewed and edited.
- Throughout the year there was active communication with the original authors of the papers to resolve data-related problems and to obtain additional details of data that are useful to include in XUNDL and/or ENSDF databases. Copies of these communications (about 60 in all) were sent to BNL in print form and as a computer file for archival purpose and for potential use by the mass-chain evaluators and other researchers.

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.

Finish debugging code that was recently ported from Fortran to C.

Status:

- No progress was made on the tabular/graphic conversion software, as this would duplicate a USNDP effort at McMaster University.
- The ported code is now completely debugged, and no further testing is required. New features are being incorporated on the basis of user suggestions.

C. Data Evaluation for ENSDF

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

ANL Deliverables:

One and one-half equivalent mass chains will be evaluated.

At least one mass chain will be reviewed.

Status:

- A=205 was evaluated and the ENSDF file submitted to NNDC
- No requests for reviews were made to the ANL program.

BNL Deliverables:

Three and one-half equivalent mass chains will be evaluated.

At least four mass chains will be reviewed.

Status:

- Mass chains A=48, 70, 88 were evaluated
- Nuclides: ¹³⁵Tb, ¹⁴⁴Er, ¹⁴⁵Tm were evaluated.
- Mass chains for A=158,197,205,211,212,240,247 were reviewed.

Idaho Deliverables:

One equivalent mass chain will be evaluated.

Two mass chains will be reviewed.

Status:

- Three mass chains, A=155, 157, and 158, were completed and submitted.
- The A=158 mass chain has been published.
- Two mass chains, A=153 and 160, are in progress.
- Three complete mass-chain reviews, A=70, 149, and 157, were prepared.

LBNL Deliverables:

5 mass chain equivalents chosen from regions for which LBNL is responsible (including at least one from the A=21-30 region) will be evaluated.

Mass chains will be reviewed as requested.

Status:

- Submitted evaluations for A=175, 185, 212, 169, ^{92}Kr , ^{171}Hg , ^{184}Bi (52 nuclides, including 3 priority nuclides).
- Reviewed two mass chain evaluations (A=73, 175).

McMaster Deliverables:

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

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:

- Four full-length mass chains (A=80, 132, 194, 240) and 7 individual nuclides were evaluated and sent to BNL for inclusion in ENSDF and publication in NDS. Two of these mass chains (A=132 and 240) were collaborations with groups in Russia; A=132 was also a part of the training and mentoring process with the new team of evaluators in Petersburg, Russia. Two of the individual nuclides were also a shared work with a new evaluator from India.
- One evaluator from Petersburg, Russia and one from Roorkee, India spent about a month each at McMaster for training purposes and working on ENSDF evaluations of A=132, 131 with the visitor from Russia and A=165 with the visitor from India. While A=132 is currently with the referee, work is progressing on the other two with active e-mail communications.
- Four full-length mass chains (A=21, 123, 134, 155) were reviewed during FY-04.
- Four nuclides were updated for new SD band data and revised data sets were sent to BNL for inclusion in ENSDF. Except for two papers that require complete nuclide updates, we are current on the coverage of SD band information in ENSDF.

ORNL Deliverables:

Evaluate A=217 and A=247 nuclei.

Begin to evaluate A=243 nuclei which are connected to A=247 and 239 nuclei via alpha decay.

Status:

- A=243 has been completed, and is currently being reviewed
- A=247 has been published

- A document for a method of obtaining r_0 parameters required for alpha-decay hindrance factor calculations for odd-A and odd-odd nuclei was prepared. The proposed method was approved by the US and the International evaluators and was discussed at the NSDD meeting in Nov. 2003.
- A document for the classification of beta transitions was prepared for the "Summary of Bases for Spin and Parity Assignments" section of the Nuclear Data Sheets; the document was approved by the US Nuclear Structure Working Group and by the International Network of Nuclear Structure and Decay Data Evaluators and was discussed at the NSDD meeting in Nov. 2003.
- Murray Martin has been brought back into the ORNL Nuclear Data Project to replace Yurdanur Akovali who tragically died during this fiscal year.

TUNL Deliverables:

Submit ENSDF files for $A = 8, 9, 10$ to correspond with the *Nuclear Physics A* publication.

Begin to prepare the ENSDF files for $A = 11 - 12$ to correspond with the future *Nuclear Physics A* publication.

Status:

- Data files for $A = 8, 9, 10$ will be submitted to ENSDF after *Energy Levels of Light Nuclei* manuscript (submitted) is published in *Nuclear Physics A*.
- Preliminary work on $A=11$ ENSDF file is underway.

D. Ground and Metastable State Properties

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

BNL Deliverables:

NNDC will include data revisions in the NuDat databases.

Status:

- A special edition of the Nuclear Wallet Cards, Nuclear Wallet Cards for Radioactive Nuclides was produced for use by homeland security personnel and is available on the Web.
- Palm Pilot versions of both Wallet Card editions and the new Nuclear Wallet Cards for Radioactive Nuclides were created.

E. Radioactive Decay Data Evaluation

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

ANL Deliverables:

Decay data for one nuclide will be evaluated.

Status:

- ^{240}Pu nuclide was reviewed for DDEP.

LBNL Deliverables:

Coordinate and plan activities of this international collaboration.

Review the evaluations of about five radionuclides.

Submit decay datasets for two radionuclides.

Status:

- Coordinated and planned activities of collaboration.
- Evaluated decay data for two radionuclide, ^{56}Co , and ^{243}Am .
- Reviewed evaluations of decay data for three radionuclides, ^{56}Co , $^{123\text{m}}\text{Te}$ and ^{125}Sb .

Idaho Deliverables:

Decay data for 3 nuclides will be evaluated.

Status:

- Decay data evaluations for ^{125}Sb , ^{140}Ba , ^{140}La , and ^{159}Gd were prepared and submitted.

F. Thermal Capture Gamma Data Evaluation

As new measurements from the Budapest Reactor become available, they will be evaluated and added to the "Prompt Gamma Activation Analysis" database that resulted from a recent IAEA CRP in which LBNL was involved. Total capture cross sections will also be extracted from those data when possible.

LBNL Deliverables:

Evaluate new (n, γ) data as they become available from the Budapest reactor and add them to the Prompt Gamma Activation Analysis database.

Status:

- Revised EGAF database files for A=1-20; however, these will not be added to the database at this time.
- Began advising on nuclear structure aspects of statistical-model gamma-ray quasicontinuum calculations which, augmented by discrete-line data from the EGAF database, will ultimately be used to

update thermal n, γ information in the ENDF database (in collaboration with LLNL).

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

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

TUNL Deliverables:

Publish "*Energy Levels of Light Nuclei, A = 8, 9, 10*" in *Nuclear Physics A*.
Prepare evaluation of "*Energy Levels of Light Nuclei, A = 11 - 12*" manuscript for future publication in *Nuclear Physics A*.

Status:

- "*Energy Levels of Light Nuclei, A = 8, 9, 10*" manuscript submitted to *Nuclear Physics A*. Prepared with collaboration from D.J. Millener.
- Continuing to evaluate $A=11$ nuclides; evaluation preprint is expected for review in FY05.
- Continuing to evaluate $A=3$ nuclides; evaluation preprint is expected for review in FY05.

H. Nuclear Structure Data Measurement

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

LANL Deliverables:

Examine prompt gamma-ray emission data on ^{191}Ir and ^{193}Ir to search for previously unobserved transitions.
Interact with mass chain evaluators on the nuclear structure of these nuclei.

Status:

- More than 10 previously unobserved transitions were identified in ^{191}Ir and in ^{193}Ir .
- Interaction with the evaluators for these nuclei continues.

I. ENSDF Physics and Checking Codes

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

BNL Deliverables:

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

Status:

- Due to a change in priorities upgrades of RadList and LOGFT were deferred to concentrate on implementing the new Band-Raman conversion coefficients.
- As part of a US-Australian-Russian effort, participated in the development of the new program BRICC to interpolate the Band-Raman conversion coefficients as a replacement for HSICC (beta-release version completed in FY2004).
- All ENSDF analysis and utility programs have been converted to Fortran-95. They are now undergoing testing before release.

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.

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

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

BNL Deliverables:

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

Status:

- Data from 159 publications, 122 charged-particle and 37 neutron.

B. ENDF Evaluations

Evaluated nuclear reaction data, for applications and for basic science needs, are stored in the ENDF database, which is maintained by BNL. As chair of the CSEWG evaluation committee, LANL staff works with BNL to insure quality control, particularly for new evaluations. New evaluations funded primarily from other sources are prepared for archival in the ENDF library. BNL, LANL, LLNL and ORNL will provide neutron, proton and photonuclear reaction data evaluations for ENDF/B-VII, planned for release in FY2005.

BNL Deliverables:

Lead international effort (WPEC Subgroup 21) to review the bulk of fission products.

Recommend the best available fission product neutron reaction evaluations for ENDF/B-VII.

Submit new evaluations for Germanium isotopes with photon production data for use in homeland security applications.

Status:

- NNDC led the international effort (WPEC Subgroup 21) to review the bulk of fission products. The effort completed its work, a complete set of 218 fission product materials were reviewed. The results were reported at the ND2004 conference in Santa Fe.

- Recommendations of best available fission product neutron reaction evaluations for 218 materials were made. These recommendations should be, in part, considered for inclusion into ENDF/B-VII.
- Evaluation of $^{70,72,73,74,76}\text{Ge}+n$ was performed. Evaluations were submitted to ENDF/B-VII and reported at the ND2004 conference in Santa Fe.

LANL Deliverables: (work mostly supported from other sources)

Work with BNL to coordinate upgraded evaluations for the new version of ENDF: ENDF/B-VII.

Submit new improved evaluations that will eventually be available in ENDF/B-VII ($^{232,233,234,235,236,238,239,241}\text{U}$ isotopes, ^{239}Pu , ^{237}Np , ^{241}Am).

Complete and submit to CSEWG high energy LA150 actinide evaluations for ^{239}Pu and ^{238}U .

Complete and submit to CSEWG new photonuclear actinide evaluations for U and Pu isotopes that include delayed neutron information, for Homeland Security detection of SNM.

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

Status:

- New improved evaluations for the Uranium isotopes, ^{239}Pu , ^{237}Np , ^{241}Am have been submitted for ENDF/B-VII.
- Preliminary ENDF LA150 files have been produced, but not yet submitted to CSEWG – further testing is still needed.
- We have performed new GNASH analyses for photonuclear data on $^{240,242}\text{Pu}$ and ^{241}Am . These results must be converted to complete ENDF evaluations before we submit them to CSEWG. Our goal is to replace the Obninsk evaluations with LANL evaluations.
- Modified evaluations for the $A=8$ reactions were produced, and will be submitted for ENDF/B-VII.

LLNL Deliverables:

An exhaustive search of the literature on fusion reactions for compound systems of $A < 12$ will be completed. The experimental CSISRS database will be updated where appropriate.

A recommended set of evaluations will be submitted to CSEWG in ENDF format.

Status:

- We have completed the search of literature for fusion reactions for systems with $A < 12$ and we have compiled a list of 87 new datasets to be included in the CSISRS/EXFOR database.
- We have assembled a set of 25 new evaluations and, pending documentation and translation into ENDF format, we will submit them to CSEWG in the near future. As part of this project, we have

performed peer review of many of the light nucleus charged particle reactions recently submitted for inclusion in ENDF/B-VII.

C. ENDF Manuals and Documentation

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

BNL Deliverables:

Maintain ENDF-6 format manual that is available on the Web.

Status:

- ENDF format manual has been updated and will be reviewed at the next CSEWG meeting before posting on the Web.

D. Nuclear Reaction Standards

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

LANL Deliverables:

Participate in the international effort to reevaluate the light-element standard cross sections.

Participate in test problems designed to investigate the nature of output covariance data from R-matrix analyses of systems containing the light-element standard cross sections.

Participate in a standards measurement of the angular distribution of n-p scattering near 15 MeV with Ohio University and NIST. This quantity is the primary standard in neutron cross section measurements.

Status:

- Light-element standard cross sections are being provided from R-matrix analyses of the A=2, 4, 7, and 11 systems.
- Simple (but semi-realistic) test problem for the ${}^7\text{Li}$ reactions was devised and distributed to standards CRP participants. EDA output covariances were checked extensively in simulated data sets with known statistical properties.
- A test run on n-p scattering at 15 MeV and problem areas were identified. These areas have been addressed and, we believe, corrected. The first measurements will be conducted in FY05 (see NIST below).

NIST Deliverables:

- Coordinate the international standards activity (Subgroup 7 of the NEA Working Party on International Evaluation Cooperation) and chair the IAEA CRP on the Improvement of the Standard Cross Sections.
- Complete the review of new experimental data for use in the standards evaluation.
- Complete the examination of older experiments with an emphasis on discrepant data that will have the highest impact on the evaluation.
- Establish the methodology for performing a comprehensive standards evaluation.
- Provide interim standards for the ENDF/B-VII library.
- Continue work on understanding the uncertainties obtained from the standards evaluation.
- Continue to recommend new measurements and perform examinations of the data from them for use in future evaluations of the standards.
- Continue the collaboration with Ohio University and LANL on the measurement of hydrogen elastic scattering angular distributions with the completion of the measurements and analysis of data measured at a neutron energy of 15 MeV.

Status:

- Coordinated, monitored, chaired and participated in the activities of Subgroup 7 of the WPEC and the IAEA CRP on the improvement of the Neutron Cross Section Standards. Planned, organized the administrative details for, developed the agenda and hosted the second IAEA CRP RCM that was held at NIST. Wrote (with IAEA) the Summary report of the Second Research Coordination Meeting on Improvement of the Standard Cross Sections. Participated in a standards workshop hosted by LANL in April. Chaired the Standards session at the ND2004 conference. Prepared the agenda and chaired a side-meeting after the ND2004 conference on the status of the standards evaluation.
- Completed the review of the new experimental data for use in the standards evaluation. All experimental data are now in the evaluation for the standards.
- Completed the examination of experiments with an emphasis on discrepant data that will have the highest impact on the evaluation. This study led to the introduction of medium energy range correlations to account for differences between data sets and the prior fit.
- Plans have been made to use a methodology based on GMA and R-matrix evaluations for performing the standards evaluation. A backup plan will be used if problems with differences between R-matrix codes cannot be resolved before the CSEWG meeting in November.
- Interim standards for important standards will be made available at the November CSEWG meeting for use in the ENDF/B-VII library.
- Work continues on understanding the uncertainties obtained from the standards evaluation. It is clear that some increases in the uncertainties

will occur, but they will still be small. The importance of covariances in this context must be emphasized.

- New measurements continue to be recommended. Though the database is now closed for the present evaluation, work must be continued to improve the database for the next evaluation. New differential cross section measurements previously recommended have been made by Zhang for the ${}^6\text{Li}(n,t)$ and ${}^{10}\text{B}(n,\alpha)$ reactions. New fission measurements were discussed with LANL staff. As new data become available, they will be examined for use in future evaluations of the standards.
- Initial measurements at 15 MeV neutron energy were made by the collaboration with Ohio University and LANL on the hydrogen elastic scattering angular distributions. These measurements indicated further improvements are needed in the new data acquisition system to achieve the accuracy needed for this experiment.

E. Nuclear Model Development

This task covers activities such as development and validation of nuclear reaction models used for prediction of nuclear reaction cross sections. The LANL code development work will be coordinated with the proposed LLNL work. The collaboration will include intercomparison of results, validation of the models 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 and LANL along with 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.

ANL – Analysis of neutron activation cross section data measured at IRMM, Geel, Belgium, will continue in collaboration with scientists from IRMM. Results will be archived in the EXFOR system and special evaluations will be prepared for inclusion in ENDF, where possible.

ANL Deliverables:

Compile experimental data into EXFOR format for selected neutron activation reactions.

Assist in evaluations for some of these reactions by coding data into ENDF format and submit the results to the NNDC for inclusion in ENDF.

Status:

- The analyses for ${}^{58}\text{Ni}(n,p){}^{58m+g}\text{Co}$, ${}^{58}\text{Ni}(n,p){}^{58m}\text{Co}$, ${}^{58}\text{Ni}(n,x){}^{57}\text{Co}$, ${}^{58}\text{Ni}(n,2n){}^{57}\text{Ni}$, ${}^{60}\text{Ni}(n,p){}^{60m+g}\text{Co}$, ${}^{60}\text{Ni}(n,p){}^{60m}\text{Co}$, ${}^{61}\text{Ni}(n,p){}^{61}\text{Co}$, ${}^{61}\text{Ni}(n,x){}^{60m}\text{Co}$, ${}^{62}\text{Ni}(n,x){}^{61}\text{Co}$, ${}^{59}\text{Co}(n,2n){}^{58m+g}\text{Co}$, ${}^{58}\text{Ni}(n,p){}^{58m+g}\text{Co}$, ${}^{60}\text{Ni}(n,p){}^{60m+g}\text{Co}$ and ${}^{59}\text{Co}(n,2n){}^{58m+g}\text{Co}$ have been completed and the results were published in *Nucl. Phys.*
- Additional reactions are being analyzed and prepared for publication.

BNL – We will enter actively into the nuclear reaction model development arena with the BNL code EMPIRE. The work will focus on further extensions and improvements of its graphic user interface, including merging capability (resonance and fast energy) and extended plotting features. The work on validation and improvements of the code will be actively pursued, in particular in relation to emerging requirements of homeland security applications. Close collaboration with LANL will continue on validation of the pre-equilibrium code HMS. Development of a new module of EMPIRE will be initiated that would allow interactive search for optical model parameters.

BNL Deliverables:

- Release updated version of the code EMPIRE with extended GUI capabilities.
- Study the gamma production from Ge+n reactions for homeland security applications.
- Study the performance of the LANL preequilibrium code HMS.
- Preliminary version of the new module of the code EMPIRE that would allow an interactive search for optical model parameters.

Status:

- New version of EMPIRE-2.19 was developed including extended GUI capabilities. Among the most important improvements are
 - multi-modal fission with multi-humped barriers
 - GDR for photo-nuclear reactions
 - reactions on excited targets
 - improved treatment of exclusive spectra and recoils
 - suite of gamma-ray strength functions from RIPL-2
 - pre-equilibrium emission of clusters
 - enhanced GUI capabilities
 - formatting of photon production cross sections

This new version is currently available at BNL; its release is scheduled for the end of CY 2004.

- A study of the performance of the LANL pre-equilibrium code HMS was completed. The work, done in collaboration with LANL, used extensive set of 150 nucleon-induced reactions on 35 target nuclei, focusing on incident energies 10, 14 and 26 MeV. The results were reported at the ND2004 conference in Santa Fe.
- The study of gamma production from Ge+n reactions for homeland security applications was completed. Evaluations were performed for the germanium isotopes.
- Development of an interactive optical model parameter search module was not pursued beyond its initial design. Instead, the calculation of the fission channel for neutron-induced reactions in EMPIRE was considerably upgraded, with promising results demonstrated on ^{232}Th fission. The results were reported at the ND2004 conference in Santa Fe.

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

LANL Deliverables:

- Calculate and interpret gamma-ray reactions measured with GEANIE/DANCE at LANSCE, including $^{171}\text{Tm}(n,\gamma)$ reactions producing unstable products and isomers; finalize the $n+^{89}\text{Y}$, $n+^{193}\text{Ir}$ analysis.
- Work with LANSCE on the interpretation of new $^{28}\text{Si}(n,n')$ data obtained with the new FIGARO detector, in terms of compound, pre-equilibrium, and direct reaction mechanism theory.
- Collaborate with LANSCE experimentalists on the interpretation of new FIGARO measurements of prompt neutron spectra.
- For Homeland Security attribution users, model and evaluate $^{236}\text{U}(n,\gamma)$ reactions, based in part on new DANCE measurements, and make these data available to CSEWG.
- Provide data on neutron emission spectra following inelastic scattering (n,n') at FIGARO to provide “exclusive” data gated by specific gamma rays. These data will test the LANL code McGNASH now in development. Test cases will include ^{28}Si and ^{56}Fe and molybdenum isotopes.
- Continue work with Ohio University on neutron-induced charged particle emission cross sections and spectra to study the effect of isospin. This degree of freedom is just now being included in GNASH and McGNASH. Test data will come from nuclei near $N=Z$.
- Obtain information on nuclear level densities on some fission product nuclei through (n,n' γ) reactions.
- Measure the fission neutron spectrum from neutron-induced fission of ^{235}U and ^{238}U with the FIGARO array for neutron energies from 1 to 100 MeV. Collaborators include scientists from CEA (France). The data will test the Los Alamos Model of fission neutron emission.

Status:

- The calculation and interpretation of the $^{171}\text{Tm}(n,\gamma)$ reaction and reactions producing unstable products and isomers in the $n+^{89}\text{Y}$, $n+^{193}\text{Ir}$ have been completed. The work on ^{89}Y was recently given a Defense Program Award of Excellence (2004).
- We developed a new GNASH analysis for $^{28}\text{Si}(n,n')$ and have compared our results with LANSCE data, and with EMPIRE calculations at BNL.

- The ^{238}U prompt-fission evaluation of FIGARO data has produced extremely good results. We have also made progress on a new correlated neutron emission model for fission neutrons, using Monte Carlo methods.
- Experiments have been conducted on ^{130}Te and ^{100}Mo at GEANIE and on ^{99}Tc at FIGARO.
- The ^{237}Np fission chamber arrived from CEA at the end of the LANSCE run cycle. It was shown to work, but data with good statistics await the next run cycle.
- Neutron capture cross sections for ^{151}Sm and ^{237}Np have been measured. Other samples, ^{171}Tm , ^{147}Pm , and ^{155}Eu have been prepared.

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++.

Status:

- Progress on this project has halted since the lead developers on this project have both left LLNL's Theory and Modeling Group.

TUNL – Ongoing work involves the development of preequilibrium nuclear reaction models, as well as the improvement and benchmarking the computer code PRECO. Work will continue on extending model verification—and, where necessary, modification—as well as code benchmarking for (N,N) reactions at higher incident energies. This involves studying the incident energy dependence of the matrix elements for the residual interactions causing nuclear energy equilibration. Other tasks (possibly related to interfacing with Hauser-Feshbach codes or to expanding stand-alone code functionality) may be substituted based on user input.

TUNL Deliverables:

- An expanded dataset of spectra for (N,N) reactions at incident energies of 40 to 100 MeV.
- Possible revisions to the models and/or global input set and thus to the code.

Status:

- Virtually none of the work listed above has even been started. Because this program involves basic research, it is impossible to predict eight or nine months before the beginning of the fiscal year what work it will be appropriate to carry out. As reported in the FY03 report, the work on reactions with complex particles in the entrance and/or exit channel has proven to be far more extensive and

complicated than was anticipated. In the process of writing up the results, new issues repeatedly arose and needed to be investigated. Yet this is one of the unique strengths of the TUNL program on pre-equilibrium phenomenology and so has been pursued.

- Additional work on complex particle channels included modifying the dependence of the nucleon transfer components on the neutron excess of the target; consideration of alternatives for the relative intensities of cluster reactions and nucleon exchange reactions for inelastic scattering of complex projectiles; and a study of the potential influence of breakup contributions on the initial configuration for particle emission in the exciton model with complex particle projectiles.
- The article on reactions with complex particle channels is complete and undergoing final editing for submission to a journal.
- Conditions for default assumptions on isospin conservation were included in the computer code PRECO.
- A set of three lectures forming a “special topics” course on the phenomenology of pre-equilibrium reactions was prepared and delivered at l’Université Catholique de Louvain, in Louvain-la-Neuve, Belgium. This course along with reviewing a doctoral thesis (in French) from Louvain-la-Neuve, required roughly 1.5 to 2.0 months of the investigator’s part-time effort.

F. Nuclear Reaction Data Measurements

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

LANL Deliverables:

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

Measure prompt gamma rays from neutron interaction with at least one other fission product with the goal of deducing partial reaction cross sections.

Consult with evaluators on neutron interactions with fission products.

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

Status:

- Data have been taken on ^{99}Tc .
- Data have been taken in the GEANIE facility on ^{130}Te and ^{100}Mo ; they are being analyzed.
- Data for the neutron capture cross section of ^{237}Np have been taken at DANCE. Preliminary data were presented at the International Conference on Nuclear Data for Science and Technology, Santa Fe, 2004.
- For astrophysics, neutron capture cross sections on ^{151}Sm were investigated at DANCE.

G. Evaluation of Data Needed for Astrophysics

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

ANL – The compilation of charged-particle data of the type (p,α) and (p,γ) for mass $A = 30-50$ nuclides will continue. The main focus during this period will be on completing the evaluation for the (p,γ) reactions on stable sulfur isotopes. The objective is the preparation of evaluated data files that can be used for computation of astrophysical nuclear reaction rates. A report on this activity will be issued in the ANL/NDM series.

ANL Deliverables:

Data will be compiled, evaluated and documented for the $^{33,34,36}\text{S}(p,\gamma)$ reactions.

Status:

- The compilation of data on $^{33,34,36}\text{S}(p,\gamma)$ reactions is nearly complete. ANL continues collaboration with ORNL on the issue of data uncertainties and their implications for astrophysics.

BNL – In support of the increasingly sophisticated nuclear data needs for astrophysics, NNDC is involved in a joint project with VNIIEF, Sarov, Russia, and ORNL to compile and evaluate alpha-induced nuclear reaction cross sections for astrophysics. The work is expected to be partially funded by the U.S. Civilian Research and Development Foundation, and will focus on nuclei with $8 < Z < 32$ and alpha particles with an incident energy below 20 MeV. These reactions, which are important in the helium burning stage of stars, novae, and supernovae events, include (α,α) , (α,n) , (α,p) and (α,γ) reaction channels. Based upon thorough compilation of data, including reactions and structural information, a critical analysis of the data will be done, and related cross sections and reaction rates will be evaluated.

BNL Deliverables:

Compile all available (α,α) , (α,n) , (α,p) and (α,γ) data for $8 < Z < 32$.

Install the statistical model code MOST at NNDC.

Develop preliminary module for Empire that would allow interactive search for alpha optical model parameters.

Perform preliminary calculations of (α,n) , (α,p) and (α,γ) cross sections for target nuclei $8 < Z < 32$.

Status:

- Most data for ^{20}Ne , ^{24}Mg , ^{28}Si , ^{32}S , ^{36}Ar and ^{40}Ca have been compiled.

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

LANL Deliverables:

In FY03 we developed the folded Yukawa macroscopic-microscopic code to include an axial-asymmetry shape-degree of freedom; in FY04 we will use this new capability to calculate and analyze barriers for nuclides important in “termination of r-process”.

Continue n-n analysis to higher energies and provide evaluated n-p data; compare evaluation with new microscopic high-precision calculations.

Perform analyses of other processes important to Big Bang nucleosynthesis and provide S-factors and reaction rates. We will begin new work on the $t+\alpha$ capture in FY04.

Reanalyze the important $^{12}\text{C}(n,\gamma)^{16}\text{O}$ reaction using our R-matrix tools that include an improved photon channel in order to determine the extrapolated cross section at astrophysically-relevant energies.

Continue to contribute to the TUNL Energy Levels of Light Nuclei project.

Continue analyses of reactions involving radioactive light isotopes, including $^{17}\text{F}+p$, and possibly other reactions being measured at ORNL.

Status:

- The folded Yukawa macroscopic-microscopic code including axial-asymmetry shape-degree of freedom was used to calculate and analyze barriers for nuclides important in “termination of r-process”. Calculated potential energy surfaces for the inner barrier region for more than 1500 nuclei in the region $190 < A < 290$ were made.
- Some σ_T data were added up to 50 MeV for the n-n analysis. Evaluated n-p cross sections were provided for the new standards evaluations. Capture cross sections were determined within 2.5 % or less in the BBN region from the analysis, and were found to agree within 1% with microscopic calculations in which MEC corrections had been made.
- Revised cross sections and reaction rates were obtained for the $n+^7\text{Be}$ and $p+^7\text{Li}$ reactions from a re-analysis of reactions in the ^8Be system. $t+\alpha$ capture data were added to the ^7Li analysis.
- Existing data for the $^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$ reaction were reanalyzed using the improved photon channel description. New $\alpha+^{12}\text{C}$ scattering data are being added to the analysis.
- No new work this year for the TUNL Energy Levels of Light Nuclei project.
- Journal publication on $^{17}\text{F}+p$ work is nearly complete.

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

McMaster Deliverables:

Evaluate the reaction rate of radiative proton capture on ^{21}Na .

Evaluate the $^{18}\text{Ne}(\alpha,p)^{21}\text{Na}$ reaction rate.

Status:

- Data on the $^{21}\text{Na}(p,\gamma)^{22}\text{Mg}$ and $^{18}\text{Ne}(\alpha,p)^{21}\text{Na}$ reactions published up to August 2004, have been compiled and evaluated. The corresponding reaction rates have been calculated and fitted with the aid of a new software suite for nuclear astrophysics (www.nucastro.org) created by ORNL.

ORNL – Evaluation work will be carried out for capture reactions on radioactive proton-rich nuclei that are important for element synthesis and energy generation in stellar explosions as well as for capture reactions important for understanding Red Giant Stars and reactions important for nuclear burning in the interior of the sun.

ORNL Deliverables:

Complete evaluations of proton capture on ^{18}F and ^{17}O .

Continue assessments of capture reactions on proton-rich radioactive nuclei.

Provide technical support for BNL in the compilation and evaluation of α -induced nuclear reaction cross sections ($8 < Z < 32$) for astrophysics.

Status:

- The evaluations of $^{18}\text{F}(p,\alpha)^{15}\text{O}$ and $^{18}\text{F}(p,\gamma)^{19}\text{Ne}$ reactions are being updated to include latest information from measurements of $^{18}\text{F}(p,p)$ and $^{18}\text{F}(d,p)$ at ORNL's HRIBF, and a reanalysis of $^{15}\text{N}(\alpha,\alpha)$ that is currently in progress; numerous presentations on conference proceedings discussed this work, and it has led to new element synthesis calculations and a published paper in PRC in 2004.
- With two exceptions, the properties of levels in the ^{18}Ne nucleus above the $^{14}\text{O} + \alpha$ and $^{17}\text{F} + p$ thresholds are now finalized utilizing R-matrix fits to the yields of four different ORNL reaction measurements. A manuscript of the evaluation is being drafted, and a new $^{14}\text{O}(\alpha,p)^{17}\text{F}$ reaction rate in nova explosions and X-ray bursts is being calculated.
- Continued progress has been made on analysis of $^{33,34}\text{Cl}(p,\gamma)^{34,35}\text{Ar}$ reactions and $^{34,35}\text{Ar}$ levels for stellar explosion studies, in preparation for ORNL measurements with radioactive Cl beams
- Continued progress on analysis of $^{30}\text{P}(p,\gamma)^{31}\text{S}$ reaction and ^{31}S levels for stellar explosion studies, folding in latest ORNL measurement of $^{32}\text{S}(p,d)^{31}\text{S}$.
- Discussions on an extension of the BNL-led CRDF proposal with FSU scientists have begun; this project will involve compilation and evaluation of charged-particle induced reactions at energies important for astrophysics.

H. Reaction Data for RIA Target Design

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

LANL Deliverables:

Work closely with Nuclear Physics RIA community to determine nuclear data needs for RIA target design, and support these needs.

Develop spallation and fission models in intra-nuclear cascade models and codes (CEM), including reaction products from light ions on heavy targets.

Provide spallation and fission predictions of radionuclides to guide the design of the two-stage experiment being planned for TRIUMF.

Study performance of new LANL isospin-dependent global relativistic Schrödinger optical model.

Status:

- We have participated in RIA meetings but we have not had sufficient resources to contribute to RIA target design in FY04.
- There have been major improvements to spallation and fission models in the CEM and LAQGSM codes (see ND2004 paper).
- We have assisted in the modeling of neutron-induced induced fission products for neutron-rich species for TRIUMF.
- The new LANL isospin-dependent global relativistic Schrödinger optical model has been used to look at the optical model for ^{40}Ca and ^{208}Pb .

Appendix A

Nuclear Data Activities Funded from Sources Outside the Nuclear Data Program

ANL – Additional support for the nuclear data staff comes from an ANL LDRD project (due to expire at the end of FY05) aimed at developing the γ -ray tracking technology for nuclear imaging applications.

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

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

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 Germanium 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 on important materials used for diagnostics (radiochemical reactions). Nuclear model code development, for both statistical and pre-equilibrium models, and for light R-matrix codes, is supported by this program, as is the development of the NJOY data processing code for providing data usable by Monte Carlo and deterministic transport codes in applications. The funding also supports physics research developments in nuclear reaction and structure theory (with a recent emphasis on nuclei

and isomers away from stability), and fission theory. Data testing using integral benchmarks such as fast critical assemblies is used to validate the ENDF data.

2. AFCI (Advanced Fuel Cycle Initiative). This supports the development of improved nuclear data important for transmutation in the fast neutron energy region, as well as high-energy spallation models important for describing processes in the spallation target. Recent focuses have been improved ENDF data on minor actinides (ATW fuel), and lead and bismuth (target/coolant), as well as better intra-nuclear cascade codes for modeling neutron production and radionuclide production in the spallation target. This program also supports experimental nuclear reaction measurements at LANSCE for both fission and capture cross sections.
3. Nuclear criticality safety. This funding supports improved nuclear data important in criticality safety studies, such as uranium isotopes, as well as data on chlorine, aluminum, etc. Data testing using critical assemblies, and NJOY processing code development, is also funded by the program.
4. RIA R&D. The RIA R&D program funds LANL participation in the national program at a modest level. The funding supports improved intra-nuclear 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.

LBNL – Members of the Isotopes Project have always been encouraged to spend a portion of their time working on experiments in the area of low energy nuclear physics. This year, we plan to increase our activities in the area of experiments related to needs of nuclear data and nuclear astrophysics. We anticipate that a newly hired post doc will spend 50% of his or her time working on experiments at the 88” cyclotron. A measurement of the half-life of ^{108m}Ag is planned. Other experimental activities include total (n,γ) cross section measurements in collaboration with the Budapest group at the Budapest reactor, and a Prompt Gamma Activation Analysis feasibility study and the continuation of other neutron activation analysis experiments using a neutron generator at LBNL. Support for these activities is drawn from the DOE low-energy nuclear physics component of our data budget, except as noted.

- (α,γ) cross section measurements: $^{63}\text{Cu}(\alpha,\gamma)$, $E_\alpha=5.9\text{-}8.7$ MeV undertaken and completed; analysis of earlier data taken for the $^{107}\text{Ag}(\alpha,\gamma)$ reaction was completed.
- Measured $^{238}\text{U}(n,f)$ γ yield at $E(n)=2.5$ MeV using LBNL neutron generator.
- Designed and constructed beam port and pneumatic-rabbit sample-transport system at LBNL neutron generator (funded by LBNL Nuclear Science Division fabrication grant)
- Explored means to identify fissionable material using neutron bombardment and detection of delayed photons for sea-cargo screening.

- Collaborated with ANL on ^{251}Cf α -decay measurements.
- Continued data taking for $^{108\text{m}}\text{Ag}$ half-life measurement.
- Hosted second meeting for IAEA Coordinated Research Programme on “New Applications of Prompt Gamma Neutron Activation Analysis”, Aug. 9-13, 2004.

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

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

NIST – A variety of sources support nuclear data activities.

1. The Nuclear Data Verification and Standardization program has funding through the Commerce Department (NIST). This provides 44% of the total support for the program.
2. NIST provides 1 FTE for interferometry work, which has yielded coherent scattering lengths (which provide scattering data) needed for neutron cross section evaluations.
3. NSF provided 1 FTE for a graduate student to work on the interferometry experiments cited above.
4. NIST provided 1 FTE (75% experimental, 25% evaluation) for nuclear structure and decay data work. Much of this work also has applications in radioactivity standards and 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)
- Nuclear Data for Homeland Security (chair D. McNabb, LLNL)

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, Office of Nuclear Physics.

Wallet Cards

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

Database maintained, published and distributed by the NNDC.

WPEC – Working Party on International 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.

