USNDP
Fiscal Year 2003
Final Report

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Summary of the U.S. Nuclear Data Program Activity for 2003

I.   Introduction

This year-end report summarizes the work of the U.S. Nuclear Data Program (USNDP) for the period of October 1, 2002 through September 30, 2003 with respect to the work plan for FY2003 that was prepared in March 2002. 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 24.6 FTE, mostly at NNSA laboratories, to be compared with 23.2 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 FY2003. This is followed by the work plan for FY2003. The plan has been annotated with bullets giving the status of each commitment made by the program participants.

Total staff assigned to USNDP activities during the year was lower than projected by 1.6 FTE, a reduction of about 6.5%. A reduction in the expected scientific/professional staff at LBNL and TUNL was partially compensated by a .55 FTE increase at BNL resulting from a mid-year permanent hire. The lower level of effort at LBNL results from a hire that was delayed until mid-year and an unanticipated staff member reassignment. The remainder of the reduction results from a correction to the original work plan where some effort was erroneously assigned to the nuclear data program instead of the "other funding" category. TUNL was unable to hire a post doc as planned due to lack of funding.

This FY has been the fourth 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.

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 2003 in conjunction with the members of the Coordinating Committee. The NNDC Head serves as chair of the program 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. Due to the SARS problem in Canada in April 2003, both the USNDP and the international NSDD network meetings were postponed until November 2003 and so will be reported in the next annual USNDP report. LANL chairs the Nuclear Reaction Data Working Group, and LBNL, the Nuclear Structure Working Group. ORNL chairs the Astrophysics TASK Force, LANL, the RIA Task Force and TUNL, the Task Force on the Impact of Nuclear Data on Society.

In March 2003, the DOE Office of Nuclear Physics conducted its annual Budget Briefing. The USNDP was represented by P. Oblozinsky, M. Chadwick (via teleconferencing), C. Baglin, and M. Smith, who together made the case for FY2005 funding.

The NNDC serves as the focal point for U.S. collaboration in international nuclear data activities. One NNDC staff member participated in the technical meeting of the IAEA-sponsored Nuclear Reaction Data Center (NRDC) in Vienna in June 2003. The NRDC coordinates the compilation of nuclear reaction data and the dissemination of nuclear data worldwide. Two NNDC staff members and one LBNL staff member served as lecturers at an IAEA-sponsored Nuclear Structure Data Workshop in Vienna in November 2002. LBNL provided one lecturer for an IAEA-sponsored workshop on Nuclear Data for Science and Technology that was held in Trieste in May 2003.

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 2002. The major topics of the meeting were the planned release of ENDF/B-VII in the coming year and nuclear data for Homeland Security. Several USNDP participants attended the May 2003 meeting of the NEA-sponsored Working Party on International Evaluation Cooperation (WPEC) in Coronado, California that was hosted by the United States. 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.

Planning for the next international Nuclear Data for Science and Technology conference continues. The conference will be held in Santa Fe in September 2004 and will be hosted by LANL.

USNDP Databases

The NNDC operates a Compaq Alpha 4100 computer, which archives and serves the nuclear data produced by the U.S. Nuclear Data Program and the data obtained by other national and international collaborations. This facility operates 24 hours a day, 7 days a week, to provide electronic access to the data. A major capital acquisition to upgrade the NNDC computing system was approved by DOE. The NNDC will be migrating from HP ALPHA hardware and VMS operating system to DELL servers running Linux. The first two phases of a three-phase purchase have been completed. To comply with DOE cybersecurity requirements, all web services will be supplied from a computer located outside the BNL firewall. The USNDP databases will be installed on a server separate from the server on which NNDC staff will work. A second database server will provide data through the firewall to the external web server. Sybase ASE relational database software will be used for storage of the databases.

The NNDC maintains seven nuclear physics databases for the USNDP. These databases have been updated continuously in FY2003 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.

The nuclear data base migration to a new generation of relational database software and technology (Sybase/Linux) continues on schedule. The work on the nuclear structure databases is being done at NNDC while the migration of the nuclear reaction databases is being done as a joint project between NNDC and the IAEA's Nuclear Data Section. Work has been completed on the migration of the ENSDF and NuDat database (nuclear structure data). These are now undergoing extensive testing.

Data Dissemination

In FY2003, the NNDC made its new ENSDF and NuDat databases, with improved Web interfaces, available for testing. LANL group T-16 has added nuclear data for astrophysics to its Web site. Retrievals from the network databases located at NNDC increased about 20% as compared to the prior fiscal year.

III.   Nuclear Structure and Decay Data

The principal activity of the Structure and Decay Data effort during the past year has been the evaluation of nuclear structure and decay data, for entire mass chains or for individual nuclides, and the entry of these results into the Evaluated Nuclear Structure Data File (ENSDF). These include a number of priority nuclides, and most evaluations will ultimately be published in *Nuclear Data Sheets* or *Nuclear Physics A*. In addition, the currency of evaluated superdeformed-band data in ENSDF has been maintained, Wallet Card and NUDAT files have been updated, and the Nuclear Science Reference and XUNDL databases extended. Websites are maintained at several data centers for the dissemination of these data in various user-friendly forms.

Evaluations for ENSDF

The USNDP nuclear structure and decay data evaluation groups in the US and Canada have submitted 15 mass chain and 24 nuclide evaluations (approximately 197 nuclides altogether, 20 of them priority nuclides) for inclusion in the ENSDF database. The evaluators have also reviewed 13 mass chain evaluations, and additional prepublication checks have been done at NNDC for all published evaluations. Superdeformed-band data for 17 nuclides have been updated. Twelve issues of the journal *Nuclear Data Sheets* were published by Elsevier; these issues contained 16 mass chains (including two from foreign data centers), the revised version of the *Table of Superdeformed Nuclear Bands and Fission Isomers* 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 178 new and 15 updated data sets, which are mostly, but not exclusively, for high-spin data. These data have been entered into XUNDL by BNL. The translation of published tabular text files into ENSDF format has been further refined to make the compilation process even more efficient. Private communications obtained from authors concerning some of the data entered into XUNDL have been collected and forwarded to NNDC so ENSDF evaluators also can 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 coordinates this project. New evaluations have been completed for 4 nuclides by LBNL and the Idaho group, and these have been submitted to the DDEP project for review. Ultimately, these will be made available to ENSDF evaluators for incorporation into ENSDF. Also, a number of radionuclide evaluations have been reviewed by USNDP participants in this program.

Nuclear Science References File

The NSR file has been expanded by 3673 papers. Keyword abstracts were provided for 2802 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 Items

- The products from an International Atomic Energy Agency Coordinated Research Project (1999-2003) for the "Development of a Database for Prompt Gamma-ray Neutron Activation Analysis" are in press. They include a database of 35,000 evaluated prompt and decay gamma-ray cross sections, a TECDOC publication with CD-ROM, an associated website, and database search software. This project was led by LBNL.

- In response to the problem of a diminishing and graying nuclear structure data evaluation workforce worldwide, the IAEA held an evaluator training workshop in Vienna in November 2002. Experienced USNDP evaluators lectured at this workshop and/or served as mentors for several of the participants who subsequently undertook evaluation work.

- Work was begun on software changes required in order to implement the replacement of the Hager-Seltzer theoretical internal conversion coefficients used in ENSDF by those from the recent Band-Raman calculations.

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 97 neutron and charged-particle data sets for the experimental nuclear reaction database, CSISRS. The NNDC is leading an international effort to review available neutron evaluations for fission product nuclei. A review of 89 material evaluations has been completed, 20 done by NNDC. The evaluation of neutron resonance parameters across the periodic table continued with emphasis on fission product nuclei.

An activity to supply nuclear data for Homeland Security has begun. A task force has been formed. This Task Force will hold a special session during the USNDP meeting in November 2003. In a cooperative effort between LANL and BNL, nuclear data for the 9.17 MeV resonance in ^{14}N was prepared in ENDF format. Gamma production cross sections were evaluated for neutrons on ^{74}Ge.

LANL continued RIA-related work on a small scale. This included nuclear INC code development in collaboration with ANL for ISOL target design. LANL assisted with analysis of ORNL Hollifield RIA measurements.

LANL carries on varied experimental work at the LANSCE facility. These experiments utilize a number of unique facilities for neutron and gamma-ray measurements (GEANIE, FIGARO, DANCE, N-Z Spectrometer, and Lead Slowing Down Spectrometer). The emphasis is on determining values for difficult neutron cross sections by measurement of partial cross sections coupled with the application of nuclear theory, particularly for actinides and other heavy nuclear isotopes. Measurements of (n,Z) cross sections have been carried out for various structural materials (Fe, Ni, Cr, etc.) using the LANL N-Z Spectrometer. A number of unique measurements have been made of (n,γ) reactions on small samples (some radioactive) at the DANCE facility. Spallation target yields have been measured at several hundred MeV for several materials of interest for applications. Finally, the Lead Slowing Down Spectrometer was used in conjunction with ultra-small samples of actinide materials to measure fission cross sections for several isotopes.

Analysis of experimental measurements is being used to improve nuclear model code predictions. GEANIE (n,xγ) data for ^{193m}Ir are being analyzed by a collaboration of LANL, LANSCE/WNR and LLNL researchers. Analysis of gamma production data obtained for Y, Nb and ^{92,94,96}Mo has been completed; data for ^{59}Co and Mo still needs to be analyzed. The calculation of ^{58,60}Ni(n,xα) shows good agreement with calculation up to 50 MeV. Disagreement increases above that energy. Considerable effort has been made at LANSCE to establish the new FIGARO measurement facility. Work has begun by a collaboration of Ohio University, NIST and LANL to measure the hydrogen elastic scattering at 15 MeV.

ANL has participated in a three-year project to measure activation cross sections. The measurements were completed, previously. The subsequent study of the sensitivity of level density parameters to the measured data has been completed. A report has been submitted to the Nuclear Energy Agency for publication.

Model Code Highlights

TUNL has continued developments of the PRECO codes. A new release is planned for 2004. The current work emphasizes the analysis of preequilibrium phenomenology for neutron reactions in the 26-65 MeV range, based on new measurements from Louvain-la-Neuve. These measurements allow the study of complex particle emission and the amount of surface localization of the initial interaction for incident neutrons. TUNL has also investigated isospin conservation effects in preequilibrium and equilibrium decay.

BNL in cooperation with several partners, continues to improve EMPIRE nuclear reaction code that can be used to model reactions between about 1 keV and 200 MeV. A new 3-hump fission barrier model has been added, as have interactive plotting capabilities.

The McGNASH code, which is a replacement for the LANL GNASH code, has been converted from Fortran-77 to the Fortran-95 programming language. A recent focus has been on width fluctuation corrections and on Monte Carlo preequilibrium and fission models.

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 first meeting of that project that was held in Vienna was chaired by NIST. The next meeting will be held at NIST in 2004. Data sets from the previous evaluation are being reanalyzed and new data are being analyzed for this project. To date, 84 data sets have been analyzed and included in the database. The energy range for the standards will be extended up to 200 MeV. Methods have been developed to handle discrepant data that have led to unrealistic uncertainties in the previous standards evaluation.

V.   Nuclear Astrophysics Data Task Force

A number of efforts within the U.S. Nuclear Data Program (USNDP) either directly or indirectly help improve our understanding of a wide range of exciting astrophysical phenomena. This work spans the activities done within the USNDP Nuclear Reaction and Nuclear Structure Working Groups.

At ANL, work was done with Hiram College on handling positive definite quantities with very large uncertainties using the lognormal distribution and confidence intervals. A collaboration led by ORNL is utilizing this work in simulations of novae.

At BNL, work continues on a project to compile and evaluate alpha-induced nuclear reaction cross sections, focusing on light- to medium-mass nuclei up to $Z = 32$ and alpha particles with energies up to ~ 20 MeV. This work is done in collaboration with scientists from the Former Soviet Union (Russian Federal Nuclear Center).

At LANL, the n-p capture reaction – crucial for studies of the early Universe – is being investigated with R-matrix theory. Fits with accuracy of $0.2 - 2.5$ % have been obtained by combining N-N scattering, capture, and photodisintegration data. Additionally, LANL is collaborating with ORNL on R-matrix calculations (see below).

At McMaster University, a new effort has been funded to perform evaluations of reactions on radioactive isotopes important in stellar explosions. The emphasis will be on reactions that will be measured at TRIUMF's ISAC radioactive ion beam facility, including ^{13}N(p,α)^{14}O, ^{15}O(α,α)^{19}Ne, ^{19}Ne(p,α)^{20}Na, ^{18}Ne(α α)^{21}Na, ^{21}Na(p,α)^{22}Mg, and ^{25}Al(p,α)^{26}Si.

At ORNL, an evaluation of the ^{18}F(p,γ) and ^{18}F(p,α) reactions, important for understanding stellar explosions, has nearly been completed. A Ph.D. thesis and a short paper are finished, and a longer paper including the latest ORNL measurements is in progress. An evaluation is being made, in collaboration with LANL, of ^{14}O(α,p)^{17}F (crucial for energy generation in X-ray bursts) via R-matrix calculations on ORNL measurements of ^{17}F(p,p), ^{17}F(p,p'), and ^{17}F(p,α)^{14}O. Additionally, the levels in ^{34,35}Ar and ^{31}S relevant for proton capture reactions on ^{33,34}Cl and ^{30}P, respectively, are being assessed for studies of stellar explosions and for planned ORNL measurements. Also, a new computational infrastructure is being developed to facilitate the incorporation of nuclear physics evaluations into astrophysics models. This suite of computer codes will enable users, by a series of mouse clicks, to insert their latest evaluations into the reaction rate libraries used by astrophysicists. It will also enable users to create, manipulate, share, and document databases. This infrastructure will be hosted at **www.nucastrodata.org.**

At TUNL, the evaluation "Energy Levels of Light Nuclei: A=5-7" has been published in Nuclear Physics A, posted online, and incorporated into ENSDF. LANL contributed to these evaluations. Additionally, a preliminary version of the $A = 10$ evaluation has been released.

Final USNDP Manning Table for October 2002 through September 2003

	ANL	BNL		Idaho	LANL	LBNL	LLNL
		Sci/Pro	Support				
I. NNDC Facility Operation	**0.00**	**0.90**	**1.25**	**0.00**	**0.00**	**0.00**	**0.00**
Management		0.40					
Secretarial/Administrative Support			1.00				
Library			0.25				
Computer Operation		0.50					
II. Coordination	**0.03**	**0.50**	**0.00**	**0.00**	**0.50**	**0.30**	**0.00**
National Coordination	0.03	0.30			0.2	0.3	
International Coordination		0.20			0.3		
III. Nuclear Physics Databases	**0.00**	**3.80**	**1.05**	**0.00**	**0.00**	**0.00**	**0.00**
Nuclear Science References (NSR)		0.15	0.75				
Experimental Nuclear Structure Data (XUNDL)		0.05					
Evaluated Nuclear Structure Data (ENSDF)		0.45	0.30				
Numerical Nuclear Data (NuDat)		0.05					
Reaction Data Bibliography (CINDA)		0.05					
Experimental Reaction Data (CSISRS)		0.05					
Evaluated Nuclear Data File (ENDF)		0.15					
Database Software Maintenance		0.05					
Future Database Systems		2.80					
IV. Information Dissemination	**0.02**	**0.65**	**0.50**	**0.00**	**0.10**	**0.25**	**0.00**
Maintenance of Remote Access to USNDP Data		0.40					
Telnet Service		*0.05*					
WWW Service		*0.35*					
Customer Services		0.10	0.45				
Web Site Maintenance	0.02	0.15	0.05		0.10	0.25	

Final USNDP Manning Table for October 2002 through September 2003

	McMaster	NIST	ORNL Sci/Pro	TUNL	Program Total Sci/Pro	Program Total Support
I. NNDC Facility Operation	**0.00**	**0.00**	**0.00**	**0.00**	**0.90**	**1.25**
Management					0.40	0.00
Secretarial/Administrative Support					0.00	1.00
Library					0.00	0.25
Computer Operation					0.50	0.00
II. Coordination	**0.05**	**0.00**	**0.05**	**0.05**	**1.48**	**0.00**
National Coordination	0.05		0.05	0.05	0.98	0.00
International Coordination					0.50	0.00
III. Nuclear Physics Databases	**0.00**	**0.00**	**0.00**	**0.00**	**3.80**	**1.05**
Nuclear Science References (NSR)					0.15	0.75
Experimental Nuclear Structure Data (XUNDL)					0.05	0.00
Evaluated Nuclear Structure Data (ENSDF)					0.45	0.30
Numerical Nuclear Data (NuDat)					0.05	0.00
Reaction Data Bibliography (CINDA)					0.05	0.00
Experimental Reaction Data (CSISRS)					0.05	0.00
Evaluated Nuclear Data File (ENDF)					0.15	0.00
Database Software Maintenance					0.05	0.00
Future Database Systems					2.80	0.00
IV. Information Dissemination	**0.00**	**0.00**	**0.05**	**1.20**	**2.27**	**0.50**
Maintenance of Remote Access to USNDP Data					0.40	0.00
Telnet Service					*0.05*	*0.00*
WWW Service					*0.35*	*0.00*
Customer Services					0.10	0.45
Web Site Maintenance			0.05	1.20	1.77	0.05

Final USNDP Manning Table for October 2002 through September 2003

	ANL	BNL Sci/Pro	BNL Support	Idaho	LANL	LBNL	LLNL
V. Nuclear Structure Physics	**0.75**	**2.20**	**0.00**	**0.50**	**0.10**	**2.13**	**0.00**
NSR Abstract Preparation		0.55					
Compilation of Experimental Structure Data							
Evaluation of Masses and Nuclides for ENSDF	0.70	1.40		0.40		1.75	
Ground and Metastable State Properties		0.10					
Radioactive Decay Data Evaluation	0.05			0.10		0.13	
Thermal Capture Gamma Data Evaluation						0.25	
Light Mass Evaluations for Nuclear Physics A.							
Nuclear Structure Data Measurement					0.10		
ENSDF Physics and Checking Codes		0.15					
VI. Nuclear Reaction Physics	**0.10**	**1.20**	**0.00**	**0.00**	**1.60**	**0.00**	**0.40**
Experimental Data Compilation	0.05	0.30					
Neutron Data		0.05					
Charged Particle Data		0.20					
EXFOR Manuals		0.05					
Evaluation of Fission Product Nuclides		0.25					
ENDF Manuals and Documentation							
ENDF Evaluations		0.25			0.10		0.20
Nuclear Reaction Standards							
Nuclear Model Development	0.03	0.40			0.65		0.20
Nuclear Reaction Data Measurements					0.35		
Astrophysics Nuclear Data Needs	0.02				0.30		
Reaction Data for RIA Target Design					0.20		
DOE/Science Nuclear Data Funded Staff	**0.90**	**9.25**	**2.80**	**0.50**	**2.30**	**2.68**	**0.40**
Staff Supported by Other Funding	**0.20**	**0.25**	**0.20**	**0.20**	**14.40**	**0.55**	**7.50**
TOTAL STAFF	**1.10**	**9.50**	**3.00**	**0.70**	**16.70**	**3.23**	**7.90**

Final USNDP Manning Table for October 2002 through September 2003

	McMaster	NIST	ORNL	TUNL	Program Total Sci/Pro	Program Total Support
V. Nuclear Structure Physics	**0.45**	**0.00**	**0.55**	**1.00**	**7.68**	**0.00**
NSR Abstract Preparation					0.55	0.00
Compilation of Experimental Structure Data	0.10		0.05		0.15	0.00
Evaluation of Masses and Nuclides for ENSDF	0.35		0.50	0.45	5.55	0.00
Ground and Metastable State Properties					0.10	0.00
Radioactive Decay Data Evaluation					0.28	0.00
Thermal Capture Gamma Data Evaluation					0.25	0.00
Light Mass Evaluations for Nuclear Physics A.				0.55	0.55	0.00
Nuclear Structure Data Measurement					0.10	0.00
ENSDF Physics and Checking Codes					0.15	0.00
VI. Nuclear Reaction Physics	**0.00**	**0.20**	**0.40**	**0.40**	**4.30**	**0.00**
Experimental Data Compilation					0.30	0.00
Neutron Data					0.05	0.00
Charged Particle Data					0.20	0.00
EXFOR Manuals					0.05	0.00
Evaluation of Fission Product Nuclides					0.25	0.00
ENDF Manuals and Documentation					0.00	0.00
ENDF Evaluations					0.55	0.00
Nuclear Reaction Standards		0.20			0.20	0.00
Nuclear Model Development				0.40	1.68	0.00
Nuclear Reaction Data Measurements					0.35	0.00
Astrophysics Nuclear Data Needs			0.40		0.72	0.00
Reaction Data for RIA Target Design					0.20	0.00
DOE/Science Funded Staff	**0.50**	**0.20**	**1.05**	**2.65**	**20.43**	**2.80**
Staff Supported by Other Funding	**0.50**	**0.80**	**0.00**	**0.00**	**24.40**	**0.20**
TOTAL STAFF	**1.00**	**1.00**	**1.05**	**2.65**	**44.83**	**3.00**

Detailed Status of Work Plan

I. NNDC Facility Operation

A. Management

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

B. Library

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

C. Computer Operation

The NNDC operates a Compaq Alpha 4100 server using the OpenVMS operating system to support our compilation, evaluation, database maintenance, and information dissemination functions. In addition to the primary production server, the NNDC operates WINDOWS-2000 and LINUX servers in support of its database migration project. Task includes system and database administration, software upgrades, hardware and software procurements, machine operations and internal user support.

BNL Deliverables:
Keep downtime to less than 3%.
Upgrade NNDC computing infrastructure
Status:
- Replaced nine 466-MHz Celeron-based PCs (Windows 2000) with 2.6-GHz Pentium 4-based PCs (Windows XP); replaced one with a Pentium 4-based Linux workstation. Purchased another Pentium 4-based Linux workstation for use by new staff member.
- Installed and configured a powerful Xeon-based dual-processor Linux working server. It will be central Linux working machine for the NNDC staff once migration project is complete.
- Installed and configured a Xeon-based external Web server with assistance from BNL's IT Division. It will be official Web server of the NNDC once migration project is complete.
- Replaced three aging laser printers with fast, higher resolution laser printers.
- Implemented centralized backup for all NNDC servers and clients except Alpha 4100.
- Installed regularly security patches on servers and clients in compliance with DOE Cyber Security regulations.

II. Coordination

A. <u>National Coordination</u>

ANL -- Lead 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**:
> Chair Measurement and Basic Physics Committee session at the Cross Section Evaluation Working Group.
> Provide Measurement and Basic Physics Committee report for CSEWG.
> Compile U.S. contributions to NEA High Priority Request List.
> **Status:**
> - ANL organized and chaired the committee at the November 2002 CSEWG Meeting and prepared report for the meeting.
> - Continued to maintain US responsibility for the US contributions to the NEA High Priority Request List.

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

> **BNL Deliverables:**
> Prepare FY2004 work plan for USNDP in time for spring 2003 FWP submittals.
> Organize and chair CSEWG Meeting at BNL in November 2002.
> Organize and chair USNDP Meeting at McMaster University in April 2003.
> Edit and publish summary reports of the CSEWG and USNDP meetings.
> Maintain USNDP Web site.
> **Status:**
> - FY2004 USNDP Work Plan was completed as scheduled in March 2003.
> - The November 2002 CSEWG meeting was organized and chaired by BNL.
> - The CSEWG 2002 meeting summary was edited and distributed.
> - The USNDP meeting was postponed to November 2003 due to the SARS problems in the area around Toronto, Canada.
> - The USNDP Web site was redesigned and updated.

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 2002.
  Organize and chair Nuclear Reaction Working Group meeting at USNDP meeting in 2003.
Status:
  - The November 2002 CSEWG Evaluation Committee meeting was organized and chaired by LANL.
  - The USNDP meeting was postponed to November 2003 due to the SARS problems in the area around Toronto, Canada.

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

LBNL Deliverables:
  Organize and chair Data Dissemination Working Group meeting at USNDP meeting, April 2003.
Status:
  - Dissemination Working Group was disbanded in April 2002 (after the submission of this Work Plan). At that time, LBNL assumed Chairmanship of the Structure and Decay Data Working Group, with responsibility to organize and chair the Structure and Decay Working Group's meeting at the USNDP's April 2003 meeting.
  - Meeting organized but ultimately postponed until FY03 due to the SARS problems in the area around Toronto, Canada.

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 2003
  Summarize USNDP efforts in nuclear data for nuclear astrophysics in FY02 and 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:
  - Since the Nuclear Structure and Decay Data (NSDD) Network meeting was postponed to November, 2003, no report was made in this fiscal year.

- Presentation of future needs in nuclear astrophysics data, and some mechanisms to reach these needs, made to USNDP/NNDC, to DOE program officers at the USNDP Budget Briefing and in a second separate meeting, and to the NSDD Network.
- Communications between data centers pursuing astrophysics-related data work resulted in pursuit of two joint research projects.

TUNL -- Chair task force on "The Impact of Nuclear Data on Society"

TUNL Deliverables:
Coordinate discussion of Nuclear Data applications and prepare report.
Status:
- Distributed draft report and gave oral presentation at USNDP meeting.

B. International Coordination

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

BNL Deliverables:
Participate in technical meeting of NRDC at Vienna in 2003.
Participate in NEA Working Party on International Evaluation Cooperation in 2003.
Provide a lecturer for the NSDD Workshop at Trieste in 2003.
Status:
- One staff member participated in the 2003 NRDC technical meeting in Vienna in June 2003.
- Two staff members participated in the NEA meeting in Coronado, CA. The BNL Center Head was selected to be chairman for the coming two years.
- The Trieste NSDD Workshop was scheduled only for the beginning of FY 2004. Two lecturers were provided for a pilot NSDD Workshop at Vienna, November 12-22, 2002.

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

LANL Deliverables:

Continue organization of the major international nuclear data conference (ND2004), to be held in Santa Fe, September 2004.

Participate in NEA WPEC 2003 meeting.

Participate in relevant IAEA meetings, including Trieste Lectures.

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

Status:

- Organization is well underway. First and second announcements have been sent. Over 400 abstracts have been received. The Web site for the conference is http://t16web.lanl.gov/nd2004/
- Several staff participated in the May 2003 WPEC meeting.
- Hosted 2 international visitors to light nucleus reaction modeling and fission modeling.

LBNL -- Chair the international Decay Data Evaluation Project and participate as requested in IAEA collaborative activities.

Status:

- Coordinated international collaboration on Decay Data Evaluation (see "Radioactive Decay Data Evaluation" below).
- Led international IAEA-CRP collaboration (see "Thermal Capture Gamma Data Evaluation" below).
- Provided lecturer for a Workshop on Nuclear Structure and Decay Data Evaluation, Vienna, 18-22 November 2002, sponsored by the IAEA in an effort to increase international participation in the nuclear structure data evaluation effort.
- Mentored several graduates of the above training workshop as they took on data evaluation responsibilities.
- Provided lecturer for ICTP (Trieste) workshop on Nuclear Data for Science and Technology (May 2003).

McMaster – Host 2003 annual USNDP meeting and the biennial IAEA- sponsored international meeting of nuclear structure evaluators.

McMaster Deliverables:

Host USNDP and NSDD (IAEA) meetings in May 2003.

Status:

- All the arrangements for both the meetings, website maintenance for the NSDD-2003, registrations, lodging and other details were handled by the McMaster group, but just one week prior to the scheduled dates (May 1-9), both meetings had to be postponed due to SARS situation in the Greater Toronto Area.
- The McMaster group has, however, been maintaining and updating the NSDD-2003 website since May 2003 for the rescheduled meeting in Vienna from Nov 10-14, 2003.

III. Nuclear Physics Databases

A. <u>Nuclear Science References</u> (NSR)

The NNDC is responsible for NSR, the bibliographic database for nuclear physics research. 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. <u>Experimental Nuclear Structure Data File</u> (XUNDL)

The NNDC is responsible for XUNDL, the database of unevaluated experimental nuclear structure data. Recent additions contain mostly "high-spin" data sets. NNDC responsibility is limited to maintaining database and access to it. Data compilation is carried out at McMaster University. Updates are done by BNL as data sets are received.

C. <u>Evaluated Nuclear Structure Data File</u> (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. Task includes database updates and distribution to collaborators. Updates are done upon completion of reviews. Corrections implemented on a continuing basis.

BNL Deliverables:
Database distributed to collaborators twice in the year.
Status:
- Two updates, as well as full distributions were made during the year.

D. <u>Numerical Nuclear Data File</u> (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. Database is also available in a PC version. The database is updated twice a year.

BNL Deliverables:
Database distributed to collaborators twice in the year.
Status:
- NuDat was distributed twice during the year.

E. <u>Neutron Reaction Data Bibliography</u> (CINDA)

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

BNL Deliverables:
Update CINDA database with CINDA transmissions from cooperating centers
(12 expected).
Status:
- 5 CINDA transmissions sent, 13 received; all added to database.

F. <u>Experimental Reaction Data File</u> (CSISRS)

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

BNL Deliverables:
Update CSISRS with EXFOR exchange tapes from cooperating centers (20
expected).
Status:
- 14 exchange files sent, 27 received; all added to database.

G. <u>Evaluated Nuclear Data File</u> (ENDF)

The NNDC is responsible for ENDF, a database of evaluated nuclear data required for many nuclear applications. The file contains complete descriptions of nuclear reactions of neutrons with many nuclides and elements for energies up to 20 MeV and radiations from radioactive decay. A number of evaluations for energies up to 150 MeV and for incident charged particles are also included. The data are stored in the ENDF format developed at NNDC about 35 years ago. This format has been adopted as an international standard. In addition to the U.S. library, ENDF/B, the database contains evaluated data libraries from 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. There will be no more releases of ENDF/B-VI before ENDF/B-VII is ready.

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:
- The CSEWG Web site was redesigned, updated, and several new useful features for CSEWG members were introduced, in particular, a Preliminary ENDF/B-VII Library.
- 210 new evaluations including 160 photonuclear evaluations were submitted by LANL, ORNL and BNL for inclusion into ENDF/B-VII library. These evaluations were made available 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

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 amount of 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.

Over the last three years, the NNDC has worked to develop a path forward for migration of nuclear data to a relational format, evaluated several software options, and began the process of migrating databases to a Sybase RDBMS on the Linux operating system. We started with NSR in FY2001, followed by ENSDF in FY2002. The three reaction databases (CINDA, CSISRS and ENDF) will be created in FY2004; they will undergo intensive testing and should be ready for use in FY2004. The project includes migration of legacy codes and modernization of dissemination software. We intend to accomplish migration without interrupting our present electronic data access. It is expected that this major project will be completed in about two years, depending on the level of support available.

BNL Deliverables:
Migrate NSR database administrative functions to the new system. Once this is accomplished, the RDBMS version will replace the current version of NSR on the Web.
Develop ENSDF relational database and supporting software, and make Web-based access publicly available.
Migrate legacy FORTRAN codes associated with NSR and ENSDF.
Complete code migration and code development for evaluated reaction data (ENDF together with CSISRS and CINDA). Once this is accomplished, the RDBMS version will replace the current versions on the Web.

Status:
- The new RDBMS versions of the NSR, ENSDF and NuDat databases are operating successfully using Sybase under the Linux operating system.
- New web retrieval interfaces for NSR, ENSDF and NuDat have been completed.
- The Nuclear Data Sheets publication program and associated software have been successfully ported to the Linux environment.
- Except for RadList, all ENSDF analysis and utility codes were ported to Linux.
- CINDA and CSISRS databases have been developed. CSISRS is running in Sybase running under Linux. The programs and web retrieval interfaces are now being tested.

- No work on ENDF migration was done.

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:
Migrate Web interfaces for NSR and ENSDF to new relational databases.
Maintain and upgrade current Web interfaces to NNDC nuclear physics databases while migration to relational databases is in progress.
Status:
- CGI scripts for producing tables and drawings from ENSDF were ported to Linux and SybPerl
- Current Web interfaces were maintained and upgraded
- NSR and ENSDF interfaces were migrated.
- A new NuDat interface has been designed and implemented.

B. Customer Services

This task accounts for the non-electronic services which the USNDP renders to customers. At the scientific staff level, we provide direct assistance to users needing advice of 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 Nuclear Data Web site.
Maintain 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 keeping the USNDP and the NNDC site current.

Status:

- USNDP and NNDC sites maintained.

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:

- LANL continually updates the T-16 nuclear Information Service Web site to include access to new evaluated reaction and structure data. Recent additions were new publications, available online, on nuclear structure data related to astrophysics (especially fission barriers for r-process and beta decay properties), and access to databases that will be released in ENDF/B-VII, for friendly collaborators to undertake critical assembly data testing.

LBNL Deliverables:

Home pages for nuclear astrophysics, structure and decay systematics, superdeformation, atomic masses, and other topics will be updated and maintained as needed.

Status:

- Web pages maintained; responsibility for updating nuclear astrophysics rates now rests with LBNL.
- Software support (Isotope Explorer 2 and 3, WWW Table of Radioactive Isotopes) continued.

ORNL Deliverables:

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

Migrate the server to a faster computer to improve CGI inquiry performance.

Status:

- The website radware.phy.ornl.gov has been maintained by uploading the latest versions of ENSDF and converting the files to RADWARE format three times.
- CGI performance improved by migration of site to a faster server.

TUNL Deliverables:

Continue to prepare new PDF and HTML documents of the most recent TUNL reviews ($A = 10$ preliminary) and when published, $A = 8, 9, 10$.

Continue to provide PDF and HTML documents for older Fay Ajzenberg-Selove reviews for the $A = 3 - 20$ series; provide new PDF and HTML documents for earlier Fay Ajzenberg-Selove evaluations based on $A = 18 - 20$ (78AJ03), $A = 16 - 17$ (77AJ02), $A = 13 - 15$ (76AJ04), and $A = 11 - 12$ (75AJ02).

Continue to provide General Tables to accompany the most recent TUNL reviews of the *A* = 3 - 20 series; General Tables for *A* = 10 and 11 to be completed to correspond to preliminary reports; update A = 8, 9, 10 General Tables to correspond to the review published in *Nuclear Physics A*.

Continue to provide scanned versions (in GIF, PDF and PS formats) of earlier Energy Level Diagrams to accompany the PDF and HTML documents for those nuclides.

Status:

- Distributed "Energy Levels of Light Nuclei: *A*=10" (preprint - August).
- Provided HTML and PDF documents (& figures) for Fay Ajzenberg-Selove publications: (72Aj02, 74Aj01, 75Aj02, 76Aj04, 77Aj02, 78Aj03, 81Aj01, 82Aj01, 83Aj01)
- Updated *A*=10 General Tables.
- Updated online information for A=3 - 4

V. Nuclear Structure Physics

A. <u>NSR Abstract Preparation</u>

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

> **BNL Deliverables:**
> Prepare entries for 4200 new references with keyword abstracts for 3200.
> **Status:**
> - 3673 new NSR references were added, 2803 with keyword abstracts

B. <u>Compilation of Experimental Structure Data</u>

Compilation of currently published or completed experimental nuclear structure data (primarily high-spin) for inclusion in XUNDL.

> **McMaster Deliverables:**
> Compile data sets (in ENSDF format) of current publications, primarily in high-spin physics. Selected low-spin publications will also be compiled. Compile high-spin publications for outdated (older than about 7 years) ENSDF evaluations on a time available basis.
> Review compiled data sets submitted by other data centers prior to inclusion in the XUNDL database.
> **Status:**
> - 178 datasets from individual current journal publications in high-spin and low-spin structures were compiled and sent to BNL for inclusion in XUNDL. Another 15 datasets were updated based on new papers from the same groups/authors as earlier.
> - The above number includes about 20 datasets for outdated mass chains in ENSDF
> - Two datasets obtained from other centers were checked and edited.
> - New computer code has been written to translate tabular text files to ENSDF format. This code has many additional features not available in earlier code from D. Radford. The new code is now routinely used for XUNDL work at McMaster.
> - Copy (in print and as a composite computer file) of all e-mail communications from 1999-2003 with the original authors of the papers was sent to BNL for archival storage there and for possible use by the mass- chain evaluators and other researchers.

ORNL Deliverables:

Improve software for converting tabular/graphic published level-scheme data in journals and unpublished data supplied by researchers to Radware database into ENSDF format.

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

Status:

- Code ported to C now thoroughly debugged.
- The table-to-ENSDF programs been updated and improved.

C. Data Evaluation for ENSDF

The USNDP evaluates nuclide and mass chain nuclear structure and decay data for inclusion in the ENSDF database. LBNL hired a physicist in April 2003 for a 2 year postdoctoral appointment, allowing roughly equal time for nuclear structure and decay data evaluation and for experimental work (initially astrophysics-related experiments at the 88" cyclotron).

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ANL Deliverables:

One equivalent mass chain will be evaluated.

One mass chain will be reviewed.

Status:

- One mass chain (A=205) has been evaluated.
- One mass chain (A=179) has been reviewed.

BNL Deliverables:

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

At least four mass chains will be reviewed.

Status:

- A=60, 134 and ^{70}Ni, ^{78}Y, ^{78}Sr, ^{80}Y, and ^{129}Ag were evaluated.
- A=180,186,210,217 were reviewed.

Idaho Deliverables:

Complete evaluation of A=159.

Continue evaluation of A=155.

Two mass chains will be reviewed.

Status:

- The evaluation for A=156 was completed and published.
- The evaluation for A=159 was completed and published.
- The evaluation for A=158 was 99% completed.
- The evaluation for A=155 was 85% completed.
- Reviews were carried out for mass chains A=60, 156, and 159.

LBNL Deliverables:

Four equivalent mass chains will be evaluated.

Mass chains will be reviewed as requested.

Status:

- Submitted evaluations for A=21, 168, 180, 211 and ^{59}Zn, ^{92}Sr, ^{173}Au, ^{173}Hg, ^{183}Pb, ^{184}Au, ^{184}Pb (i.e., 53 nuclides).
- Provided three mass chain reviews (A=177, 190, 244).

McMaster Deliverables:

1.5 equivalent mass chains (including some in the A=31-44 region) will be evaluated. Evaluations for A=39, 80 and 194 are planned.

Mass chains will be reviewed as requested.

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

Status:

- Three full-length mass chains (A=40, 73, 149); and 10 individual nuclides were evaluated and sent to BNL for inclusion in ENSDF and/or NDS. The mass chains (39, 80, 194) mentioned above are currently being evaluated.
- A full-length mass chain (A=189) was reviewed.
- 17 nuclides were updated for new SD band data; the revised datasets for each nuclide were sent to BNL for inclusion in ENSDF. As of this date we are current on the coverage of all SD band data in ENSDF.

ORNL Deliverables:

Evaluate A=247 nuclei

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

Status:

- Evaluation of A = 247 nuclei completed and submitted for review.
- Evaluation of A = 243 nuclei in progress.
- Reviewed evaluations of A = 235 and A = 239 nuclei.
- Published evaluations this fiscal year: A=238, A = 244, A = 217.
- 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.
- A document for the method of obtaining r0 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 International evaluators

TUNL Deliverables:

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

Status:

- Will submit *A*=8-10 ENSDF files after *NPA* manuscript is published
- Updated *A*=2 ENSDF file

- Submitted A=5, 6, 7 data for inclusion in ENSDF.

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:
- Nuclear Wallet Cards file (and NUDAT) was updated.

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 ^{177}Lu and ^{177m}Lu will be evaluated.
Status:
- Evaluation for ^{177}Lu (reported last FY) has been finalized.
- Evaluation for ^{177m}Lu is currently ongoing.
- Reviewed evaluation for ^{204}Tl.

LBNL Deliverables:
Coordinate and plan activities of this international collaboration
Submit decay datasets for two radionuclides.
Review evaluations of ~5 radionuclides.
Status:
- Planned and coordinated activities of this collaboration.
- Submitted evaluations for ^{66}Ga decay and ^{227}Th decay.
- Reviewed evaluations for 8 radionuclides (^{11}C, ^{18}F, ^{33}P, ^{66}Ga, ^{85}Kr, ^{140}La, ^{140}Ba, ^{123m}Te).

Idaho Deliverables:
Decay data for 5 nuclides will be evaluated.
Status:
- Decay data for two nuclides, ^{140}La and ^{140}Ba, have been provided to both the Decay Data Evaluation Project and the Coordinated Research Program of the IAEA and reviews of other evaluations have been provided.

F. Thermal Capture Gamma Data Evaluation

This work is being performed by LBNL as part of an IAEA Coordinated Research Project entitled "Prompt Gamma Activation Analysis." The specific task assigned to LBNL is to evaluate thermal and cold (n,γ) data sets for stable nuclei. A database will be prepared and LBNL will coordinate the CRP evaluation and research efforts.

LBNL Deliverables:
Complete CRP work.
Prepare evaluated data from this CRP in ENSDF format for integration into ENSDF.
Status:
- The final meeting of CRP members was held in March 2003. The *Evaluated Gamma-ray Activation File* (EGAF) database containing 35,000 evaluated prompt and decay gamma-ray cross sections, along with total thermal radiative capture cross sections deduced there from, has been completed and the associated web site and TECDOC publication (with CD-ROM) are in press.
- ENSDF-format files have been prepared and will be submitted to NNDC when release of the CRP material is imminent.

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 - 10"* in *Nuclear Physics A*.
Evaluate and distribute for comment *A* = 11 preliminary version.
Status:
- Preparing *"Energy Levels of Light Nuclei, A = 8 - 10"* manuscript for submission to *Nuclear Physics A*
- Evaluation of *A*=11 nuclides is in progress.
- Exploratory research of *A*=3 nuclides in progress, plans for update of "Energy Levels of Light Nuclei: *A*=3" to be published in *Nuclear Physics A*.

H. Nuclear Structure Data Measurement

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

LANL Deliverables:
Examine the prompt gamma-ray emission data on ^{181}Ta and ^{197}Au to search for previously unobserved transitions.

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

Status:
- No additional transitions have been identified that can be uniquely assigned to reaction products.
- Not completed. No evaluation work presently underway for 181 or 197.
- Interaction has been however with evaluator of mass A=59 from work on cobalt.

I. <u>ENSDF Physics and Checking Codes</u>

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 ($\geq$3) unique forbidden $\beta^{\pm}$ transitions and to use the Schoenfield electron-capture probabilities.

Begin to implement the "Evaluator's Corner" that will allow ENSDF evaluators remote interactive Web access to ENSDF physics and checking codes.

Status:
- LOGFT upgraded to properly treat higher-order ($\geq$3) unique forbidden $\beta^{\pm}$ transitions — Still requires extensive testing before release.
- Implementation of new Band-Raman Internal Conversion Coefficients given higher priority and work was begun on this.
- No work was done on "Evaluator's Corner"

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 150 charged-particle and neutron reaction publications.
> **Status:**
> - 97 charged-particle and neutron reaction data sets compiled.

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

> **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.
> **Status:**
> - An NNDC staff member led the international effort (WPEC Subgroup 21) to review the bulk of fission products. In FY03, the effort reviewed 89 materials including 20 materials by the NNDC, and made recommendations for the best available fission product neutron reaction evaluations.
> - A new project was started on a limited scale to address nuclear reaction data needs for homeland security. First, photonuclear data on

^{14}N were evaluated for 9.17 MeV resonance photons, to be used at BNL for MCNP simulations of the Gamma Resonance Technique to detect explosives. Second, preliminary evaluation of ^{74}Ge+n was performed with a focus on complete discrete and continuous photon production data that are needed for MCNP simulations of detector systems using Germanium. In both instances, close collaboration with LANL was maintained.

LANL Deliverables:
Work with BNL to coordinate upgraded evaluations for new version of ENDF: ENDF/B-VII.
Submit new improved evaluations that will be eventually available in ENDF/B-VII (uranium and plutonium isotopes including improved fission and prompt and delayed neutron information; various nuclides with improved capture cross sections important in astrophysics and neutron dosimetry, and new high-energy (LA150) evaluations as they become available).
Provide ENDF evaluated data files for charged-particle reactions having A<=9.

Status:
- Charged-particle evaluations provided to BNL and accepted by CSEWG.

LLNL Deliverables:
A ^{11}B evaluation will be submitted to NNDC for inclusion in ENDF/B. This submission will require data formatting, testing, and documentation.
Community activities such as refereeing other evaluations and contributing to CSEWG will be performed.

Status:
- We reviewed many ENDF/B-7 submissions and uncovered several bugs in the ENDF/B-6 database while incorporating ENDF/B data into LLNL codes.

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:
Complete ENDF-7 formats manual and make it available on Web.
Status:
- Updated ENDF-6 formats manual is available on Web. No major changes in ENDF formats were approved for ENDF-/B-VII library. This new version of the library will use ENDF-6 formats.

D. Nuclear Reaction Standards

Nearly all nuclear reaction data measurements are made relative to some reaction standard such as the hydrogen elastic cross section. Maintaining accurate current values for the standard cross sections is the objective of this task. The task can be accomplished only through international cooperation. The OECD Nuclear Energy Agency is the umbrella organization for completing the project to update these recommended data.   The IAEA has initiated a Coordinated Research Project CRP in support of this activity.

LANL Deliverables:
Participate in international effort to reevaluate the light-element standard cross sections.
Participate in test problems designed to investigate the nature of output covariances from R-matrix analyses of systems containing the light-element standard cross sections.

Status:
- Participated in the IAEA CRP as one of the R-matrix evaluators of the light-element standard cross sections.
- Helped design and participated in test problems to compare the results of the three R-matrix codes involved in the CRP project.

NIST Deliverables:
Coordinate the international standards activity (NEA Working Party on Evaluation Cooperation Subgroup 7) and chair the IAEA CRP on the Improvement of the Standard Cross Sections.
Examine the methodology for performing a comprehensive standards evaluation.
Recommend new measurements to support the standards effort.
Review discrepant experimental data with the highest impact.
Collaborate with Ohio University and LANL in the measurement of hydrogen elastic angular distributions; initiate the 15 MeV measurements.

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. Wrote (with LANL and IAEA staff) the Summary Report of the First Research Coordination Meeting on Improvement of the Standard Cross Sections. Planned and organized the administrative details and agenda for the second IAEA CRP RCM on the standards to be held at NIST.
- Worked with the CRP in defining the method for evaluating the standards. It will use input to GMA from R-matrix and thermal constants evaluations. The energy range is now extended to 200 MeV.
- Recommended additional measurements on the ^{6}Li(n,t) cross section by Zhang to remove "particle leaking" effect. Also suggested work to improve the database for the ^{10}B(n,α) cross section database by

Hambsch, and Plompen; and the ^{235}U(n,f) cross section database by Nolte.

- Worked on the database for the standards. It now includes 84 data sets. A method for handling discrepant data was implemented by adding a medium range correlation component to the experimental data.

- Diagnostic measurements were begun on the hydrogen elastic scattering angular distribution at 15 MeV neutron energy by the Ohio University-NIST-LANL collaboration. Problems with the new data acquisition system slowed the progress on this work

E. Nuclear Model Development

This task covers activities such as development and validation of nuclear reaction models used for prediction of nuclear reaction cross sections. The LANL code development work will be coordinated with the proposed LLNL work. The collaboration will include intercomparison of results, validation of model with experimental data and development of new physics modules. The TUNL pre-compound 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. Final results will be archived in the EXFOR system and special evaluations will be prepared for inclusion in ENDF/A, where possible.

ANL Deliverables:
The experimental data will be submitted in EXFOR format to the NNDC.
Completed evaluations for some of these reactions will be performed and the results submitted to the NNDC for inclusion in ENDF/A.
A study of nuclear model parameter sensitivities will be continued under the auspices of the Nuclear Energy Agency Working Party for Evaluation Cooperation (WPEC) in collaboration with scientists in Belgium, Hungary, and Romania.
Status:
- The WPEC study has been completed and the final report submitted and published by NEA.
- Evaluation work awaits final data from IRRM Geel.

BNL – A new BNL staff member leads the international collaborative effort developing the nuclear model code EMPIRE.

BNL Deliverables:
The develop and maintain the EMPIRE nuclear model code in collaboration with international partners.

Status:
- Collaboration with IAEA Vienna on the development of a modular nuclear reaction model code EMPIRE continued. Several improvements were done, including new graphic user interface, merging of resonance and fast energy region into single ENDF-6 file, and plotting of particle and gamma spectra and angular distributions. In addition, preliminary version of the advanced treatment of the fission channel was prepared, and a new algorithm for decomposition of spectra as required by ENDF-6 format was developed.

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 develop a new version of this code to provide a state-of-the-art capability to predict reaction cross sections. This task also involves a close collaboration between the T16 and the LANSCE program to interpret new measurements using the GEANIE γ-ray detector, as well as (n,charged-particle) data, resulting in advances in our understanding of nuclear reaction mechanisms, as well as improvements in our modeling codes. In addition, we will continue to modernize the EDA R-matrix code used for light nucleus data evaluation.

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

LANL Deliverables:
Continue development of McGNASH, our improved version of the GNASH Hauser-Feshbach code, using FORTRAN90 and modern coding practices, with numerous improved physics packages, particularly: level densities, preequilibrium reactions, transmission coefficients, and γ-ray strength functions. Include a Monte-Carlo option. (Note that this is highly leveraged with support from DOE/DP). Collaborate with LLNL and with the NEA WPEC on code validation.

Calculate and interpret γ-ray reactions measured with GEANIE at LANSCE, including n+^{89}Y and n+^{193}Ir reactions producing far-from-stability products, and reactions in competition with fission of ^{235,238}U.

Calculate prompt fission neutron spectrum matrix for the n + ^{238}U system with the Los Alamos model, and collaborate with LANSCE experimentalists on new measurements for this system.

Focus on the interpretation of nuclear reactions on (and producing) unstable nuclides and isomers, a current thrust of interest in the international nuclear physics community.

Complete analysis of LANSCE data for neutron interactions with ^{56}Fe and ^{58,60}Ni including both charged-particle emission and prompt gamma-ray production with the goal of testing nuclear level density theories and providing cross sections.

Complete analysis of ^{59}Co(n,xγ) data to complement our previous (n,xα) studies.

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

Analyze data to investigate the effect of preequilibrium reactions on both (n,charged particle) and (n,xγ) reactions.

Complete analysis of gamma-ray production from ^{181}Ta and ^{197}Au.

Work with S. Grimes and colleagues on neutron-induced charged particle emission cross sections, in particular for sulfur and calcium.

Status:

- McGNASH has been written entirely in FORTRAN 95, making extensive use of modern coding practices such as modularity, data encapsulation, dynamic memory allocation, etc. The new code implements the statistical Hauser-Feshbach decay cascade using level density prescriptions, optical model transmission coefficients, γ-ray strength functions, etc., similar to those in GNASH. We recently introduced a new F95 module to treat the fission channel. In addition, McGNASH can explicitly calculate and include width-fluctuation correction factors in a consistent way. The preequilibrium Monte Carlo code DDHMS (written by Chadwick in F77) was recently transformed into an F95 module that can now be used within McGNASH straightforwardly. The code is evolving steadily, and is intended to be used for new minor-actinide evaluations later this year (FY04).

- An experimental team at LANSCE recently measured with the GEANIE detector the partial isomer population cross section of ^{193m}Ir by detecting some of the γ-rays feeding the isomer. GNASH calculations were then used to calculate the missing (non-measured) contributions to the population of the isomer, and hence infer the total cross section ^{193}Ir(n,n')^{193m}Ir. Various available integral data confirmed that knowledge of this inelastic cross section was greatly improved by this combined experimental/theoretical study.

- We evaluated new n+^{88}Y cross sections using LANSCE/GEANIE measurements and GNASH calculations, together with previously available measurements. A quantification of the margins and uncertainties led to evaluated cross sections for the (n,2n) population of the ^{88}Y ground and two metastable states, together with uncertainties.

- Experimental results for the prompt fission neutron spectrum at LANSCE are in agreement with the Los Alamos Model for incident neutron energies up to about 20 MeV. At higher energies, there are significant discrepancies.
- Revised level densities for Fe and Ni now account well for charged-particle emission below En = 20 MeV.
- Much of the experimental effort in FY2003 at LANSCE has gone into establishing a facility, FIGARO, for measuring also the neutron emission gated by specific gamma rays in the residual nucleus. The data (on Fe, Ni, Mo, and Pb so far) will provide new tests of reaction models as calculated by McGNASH.
- Analysis of the ^{59}Co(n,xγ) data is being done by a former postdoc who has a full-time position elsewhere. Therefore, it is not yet complete.
- (n,xγ) and (n,n'γ) measurements on molybdenum were recently completed. Analysis is in progress.
- (n,xα) reactions on ^{58,60}Ni show good agreement with calculation up to 50 MeV but with increasing disagreement from 50 to 100 MeV.
- Preliminary analysis of gamma-ray production from ^{181}Ta and ^{197}Au are complete. Final analysis is in progress.
- Awaiting assignment of a graduate student or postdoc from Ohio University to work on the neutron-induced charged emission cross sections for sulfur and calcium.

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

LLNL Deliverables:
Second version of software will be made available to the nuclear physics community through ftp download. This release will incorporate fission as a reaction channel.

Status:
- The release of the new code libraries has been delayed due to staff changes and a retirement.

TUNL – Development of pre-equilibrium nuclear reaction models, improving and benchmarking of the computer code PRECO. Work on revising the description of reactions involving complex particles has taken much longer than anticipated. It should be completed in FY03. This work and related new insights on surface peaking of the initial interaction and on

isospin conservation will be submitted for publication. If time permits, work will be started on extending code validity to higher incident energies for nucleon induced reactions (emphasis on effective matrix element systematics) and/or improvements to the code functionality as requested by users (increasing stand-alone capabilities and simplifying interfacing with Hauser-Feshbach codes). Specific work to be undertaken will be guided by ongoing user input.

TUNL Deliverables:
One or more journal articles submitted for publication, describing work on complex particle channels, surface peaking, and isospin conservation.
Updated version of PRECO, possibly with updated formal release.

Status:
- One journal article discussing surface localization of the first interaction for incident neutrons has been submitted for publication.
- An article on revised descriptions of reactions with complex particle channels is nearing completion, and work on a short paper describing the conditions for isospin to be conserved is beginning
- PRECO has been substantially updated but is not yet ready for a new formal release.

F. Nuclear Reaction Data Measurements

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

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

Status:
- Analysis of prompt gamma-ray emission data for ^{99}Tc is in progress.
- Gamma rays and neutrons emitted in reactions of neutrons with molybdenum isotopes have been measured.

G. Evaluation of Data Needed for Astrophysics

The objective of this activity is to support the nuclear data needs of increasingly sophisticated astrophysics simulation computer codes. The Astrophysics Task Force of the USNDP, presently chaired by Michael Smith (ORNL) plans, initiates and implements cooperative nuclear data evaluation activities involving both the nuclear data and the nuclear astrophysics communities, and serves to improve communication between different evaluators as well as between evaluators and astrophysics modelers.

ANL – Information on sulfur (p,γ) and (p,α) reactions will be compiled and made available to the NNDC. A report on this activity will be issued in the ANL/NDM series.

ANL Deliverables:
Data will be compiled and documented for all stable sulfur (p,α) reactions.
Data will be compiled and documented for the ^{33,34,36}S(p,γ) reactions.
Status:
- This task is nearly complete.

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

BNL Deliverables:
Complete evaluation of reactions ^{40}Ca(α,γ) and ^{40}Ca(α,p) below 20 MeV.
Create Web site containing these evaluations along with updated decay and
structure data.
Status:
- Planned evaluation of reactions ^{40}Ca(α,γ) and ^{40}Ca(α,p) was not performed. Resources were shifted to evaluations of nuclear reaction data for homeland security, namely, photonuclear resonance cross sections for ^{14}N and photon production in neutron reactions with Germanium (see ENDF evaluations above for more details).
- Web site designed. Evaluation delayed as international portion of project funding was delayed until March 2003.

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

LANL Deliverables:
Develop folded Yukawa macroscopic-microscopic code to include the axial-asymmetry shape-degree of freedom for fission barriers important in "termination of r-process", and calculate shape-isomer properties.
Use beta-decay code with new first-forbidden capability to calculate and compile half-lives and beta-delayed neutron emission probabilities important in nucleosynthesis.
Extend N-N analysis to higher energies and provide evaluated n-p data.
Perform analyses of other processes important to Big Bang Nucleosynthesis, and provide S-factors and reaction rates.
Continue to contribute to the TUNL Energy Levels of Light Nuclei project.

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

Status:

- Folded Yukawa code, including axial asymmetry, was developed and used to calculate shape-isomer properties of about 1000 nuclei for A>190.
- Changed the reference experimental data base from Mainz (Kratz) to NUBASE (Audi), and obtained much improved agreement between calculated and experimental temporal delayed-neutron production. Developed and coded an enhanced model for studying first-forbidden beta decays.
- n+p capture cross sections provided at neutron energies up to 50 MeV, with uncertainties $\leq 2.5\%$. Obtained new cross sections for the ^{7}Li-abundance reactions from an improved analysis of the ^{8}Be system.
- Nothing new since the publication of A=5,6,7 in Nuclear Physics A last year.
- In collaboration with ORNL, determined rates for the ^{14}O(α,p) reactions from analyzing ^{17}F+p data from the HRIBF, and published them in the proceedings of COSMOS VII.

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

ORNL Deliverables:

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

Continue analysis of solar thermonuclear reaction rate evaluations.

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

Status:

- First evaluation of ^{18}F(p,α) and ^{18}F(p,γ) reactions completed; one paper published, one Ph.D. thesis completed.
- The properties of six levels in the ^{18}Ne nucleus above the ^{14}O + α and ^{17}F + p thresholds are being evaluated, in combination with R-matrix fits to the yields of four reaction measurements, to determine a new ^{14}O(α,p)^{17}F reaction rate in nova explosions and X-ray bursts.
- Continued progress on analysis of ^{33,34}Cl(p,γ) reactions and ^{34,35}Ar levels for stellar explosion studies.
- Continued progress on analysis of ^{30}Pl(p,γ)^{31}S reaction and ^{31}S levels for stellar explosion studies, folding in latest ORNL measurement of ^{32}S(p,d)^{31}S.

H. Reaction Data for RIA Target Design

Rare Isotope Accelerator facility design needs high-quality nuclear reaction data for target design, and facility design. The RIA R&D committee has recently endorsed official LANL collaboration in order to provide key reaction cross-sections using theory calculations and measurements to evaluate the data.

LANL Deliverables:
Work closely with RIA community to determine nuclear data needs for RIA target design.
Develop spallation and fission models in intranuclear cascade models and codes (CEM).
Benchmark & validate new LANL isospin-dependent global relativistic Schrödinger optical model

Status:
- LANL has made little progress in this area, because of limited support. We continue to participate in the international and national RIA community (e.g. invited talk at the RIA theory workshop following the Tucson DNP meeting), but we have not had the resources to significantly develop our spallation/fission cascade models this last year. We have made some modest progress on our global optical model work, where an isospin-dependent potential is being tested for ^{40}Ca and ^{208}Pb test cases.

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Appendix A

Nuclear Data Activities Funded from Sources Outside the Nuclear Data Program

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

1. Academic Press supports the production of computer-generated photo-ready copy of manuscripts for the Nuclear Data Sheets.
2. Consultant services and technical work on neutron cross-section evaluation for fission products and assessment of their current evaluations for the DOE-NNSA Nuclear Criticality Safety program.

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

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

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

1. **Nuclear weapons (ASCI program).** This work supports the development of more accurate ENDF cross section databases for actinide fission fuels, light-nucleus thermonuclear fuels, and for reactions important on materials used for diagnostics (radiochemical reactions). Nuclear model code development, for both statistical and preequilibrium models, and for light R-matrix codes, is supported by this program, as is the development of the NJOY data processing code for providing data usable by Monte Carlo and deterministic transport codes in applications. The funding also supports physics research developments in nuclear reaction and structure theory (with a recent emphasis on nuclei and isomers away from stability), and fission theory. Data testing using integral benchmarks such as fast critical assemblies are 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 WNR.

3. **Nuclear criticality safety.** This funding supports improved nuclear data important in criticality safety studies, such as uranium isotopes, as well as data on chlorine, aluminum, etc. Data testing using critical assemblies, and NJOY processing code development, is also funded by the program.

4. **RIA R&D.** The RIA R&D program funds LANL participation in the national program at a modest level. The funding supports improved 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 portion of their time working on experiments in the area of low-energy nuclear physics. Interests include experiments at the 88" cyclotron addressing the needs of nuclear data and nuclear astrophysics and (n, γ) work at both the Budapest reactor and the LBNL neutron generator.
- Analysis of a low-energy ^{107}Ag(α,γ) cross section measurement is ongoing and a determination of the half-life of ^{108m}Ag has been commenced.
- A flux measurement of the LBNL neutron generator has been performed, its prompt-gamma and neutron activation analysis capabilities have been demonstrated and a feasibility test done for nuclear waste characterization using the generator.
- In collaboration with scientists at the Budapest reactor, the thermal neutron capture cross sections for Te isotopes have been measured.

Support for these activities comes from the DOE Office of Science, Low-energy Nuclear Physics component of our budget.

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. DOE NE (Office of Nuclear Energy, Science and Technology) provided NERI funding of 0.75 FTE for iron transmission studies that will have an impact on evaluations of the iron cross sections.

5. NIST provided 1 FTE (75% experimental, 25% evaluation) for nuclear structure and decay data work. Much of this work also has applications in radioactivity standards and radio-pharmaceutical studies.

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

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

Appendix B

USNDP Organization

Coordinating Committee (chair P. Oblozinsky, BNL)

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

Task Forces
- Nuclear Data for Astrophysics (chair M. Smith, ORNL)
- Nuclear Data for Rare Isotope Accelerators (chair M. Chadwick, LANL)
- Impact of Nuclear Data on Society (chair J. Kelley, TUNL)
- 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 if 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 – <u>Nu</u>clear <u>Dat</u>a
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 – <u>M</u>edical <u>I</u>nternal <u>R</u>adiation <u>D</u>ose tables
Radiation dose information useful to medical science.
Originated at Oak Ridge Nuclear Data Project.
Derived from ENSDF.

USNDP – <u>U</u>nited <u>S</u>tates <u>N</u>uclear <u>D</u>ata <u>P</u>rogram
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 – <u>W</u>orking <u>P</u>arty on International <u>E</u>valuation <u>C</u>ooperation
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 – <u>E</u>xperimental <u>U</u>nevaluated <u>N</u>uclear <u>D</u>ata <u>L</u>ist
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.