U.S. Nuclear Data Program

Annual Report for FY 2005

Work Plan for FY 2007

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www.nndc.bnl.gov/usndp

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USNDP Annual Report for FY 2005

Summary of the U.S. Nuclear Data Program Activity for 2005

I. Introduction (Report FY05)

The USNDP Annual Report for FY 2005 summarizes the work of the U.S. Nuclear Data Program (USNDP) for the period of October 1, 2004 through September 30, 2005 with respect to the work plan for FY2005 that was prepared in February 2004. The work plan and final report are prepared at the direction of the DOE Office of Science, Office of Nuclear Physics for the nuclear data program. The support for the nuclear data activity from sources outside the nuclear data program is described in the staffing table and in Appendix A. This leverage amounts to about 26.7 FTE scientific, mostly at NNSA laboratories, to be compared with 21.7 FTE scientific at USNDP funded by the DOE Office of Science, Office of Nuclear Physics nuclear data program. When tasks are jointly funded, then it is very difficult to differentiate accomplishments funded by nuclear data program resources from those that were otherwise funded. As a consequence, some of the work reported in the present report was accomplished with nuclear data program support, leveraged by other funding sources.

The present section of the report consists of activity summaries for the major components of the U.S. Nuclear Data Program. 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 FY2005. This is followed by the work plan for FY2005. 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 24.1 FTE (21.7 scientific + 2.4 support), lower by 2.0 FTE compared to FY2004. This decrease reflects loss of 0.5 FTE at the NNDC (secretary), another 0.5 FTE loss at TUNL (dissemination support staff) and smaller losses in several other laboratories.

Fiscal year 2005 is the 7th year during which the Nuclear Data Program has operated under a work plan developed by the program participants. As the following sections illustrate, the nuclear data program is successfully carrying out important work in direct support of DOE missions. The work balances the ongoing collecting, analyzing, and archiving of nuclear physics information critical to basic nuclear research and to the development and improvement of nuclear technologies with the electronic distribution of this information to users in a timely and convenient manner.

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

Table 1. Summary of USNDP metrics in FY01- FY05

Fiscal Year	USNDP Funding	Compilations	Evaluations	Dissemination (in thousands)	Reports	Papers	Invited Talks
2001		7,139	334	667	21	25	22
2002	$4,890k	6,159	300	799	23	40	22
2003	$4,932k	4,975	260	966	27	40	23
2004	$5,015k	6,241	276	1,212	35	36	43
2005	$5,437k	6,623	422	1,642	74	59	42

Table 1 shows that FY05 budget increased by a considerable 8.4% compared to previous fiscal year and the USNDP metrics went up in 5 out of 6 reported categories. The metrics, suggesting productive year, can be understood as follows:

1. **Compilations**. Somewhat unexpected increase is largely caused by high contribution to experimental reaction database by a young and vigorous compiler.

2. **Evaluations**. These include 283 nuclides evaluated for ENSDF and 139 reactions evaluated for ENDF. (ENSDF = 113 BNL, 68 LBNL, 8 ORNL, 11 ANL, 83 Universities; ENDF = 62 BNL, 40 LANL, 12 LLNL submitted to new ENDF/B-VII library, plus 25 partial evaluations by LLNL submitted to ENDF/A).

   Sharp increase in evaluations can be explained by 3 factors:
   - Exceptional amount of 63 super-heavy nuclides (A=266-294) contributed to ENSDF.
   - High activity in reaction evaluations motivated by new ENDF/B-VII library, to be released in summer 2006.
   - Positive impact of collaborations with new ENSDF evaluators trained at recent IAEA Workshops.

3. **Dissemination**. Increase by 35% should be considered as high, to be largely explained by continuing impact of the new NNDC service introduced in the middle of FY2004.

4. **Reports**. Sharp increase by a factor of two is largely due to considerable amount of posters presented at ND2004 conference and published in the Proceedings in 2005.

5. **Papers**. Large increase in refereed papers is likely affected by funding from other sources.

6. **Invited Talks**. These are slightly down compared to FY2004.

Table 2. USNDP metrics in FY2005, numbers for FY2004 are shown for comparison.

Lab	Compilations		Evaluations		Dissemination[3]		Reports		Papers		Invited Talks	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
BNL[1]	5751	6306	117	175	478	778	6	37	5	9	9	9
LANL			30	40	290	312	5	6	7	15	7	10
LBNL	245		54	68	342	376	5	1	3	8	8	8
ORNL			8	8	64[4]	113	7	10	5	4	7	4
ANL			10	11	8	10	4	8	6	11	5	6
LLNL			-	37	-	6	2	4	4	5	3	5
University[2]	245	317	57	83	30	47	6	8	6	7	4	-
Total	6241	6623	276	422	1212	1642	35	74	36	59	43	42

1) Includes Idaho. Evaluations in 2005 consist of 113 nuclides for ENSDF and 62 reactions for ENDF.
2) TUNL, NIST, McMaster. One half of McMaster funding comes from Canada.
3) Data retrievals in thousands. LBNL scaled in accord to retrievals/hits ratio observed at BNL.
4) Includes traditional Radware service only.

Definitions

- *Compilations*: The sum of the new entries added to the USNDP bibliographic (NSR) and experimental databases (CSISRS, XUNDL).

- *Evaluations*: The sum of new evaluations submitted or accepted for inclusion in the USNDP evaluated nuclear databases. Structure − number of evaluated nuclei (ENSDF), reactions − number of evaluated reactions (ENDF).

- *Dissemination:* The number of electronic data retrievals made from USNDP maintained web sites. Data retrieval is defined as a request for data from any of the databases that receives a result. Total pages, gifs, etc., accessed is not tallied.

- *Reports*: The number of technical documents (includes conference proceedings) or papers other than journal publications and invited talks. No administrative documents such as meeting minutes are reported.

- *Papers*: The number of articles published in refereed journals.

- *Invited talks*: The number of presentations given at the invitation of the organizers of a conference, symposium, workshop, training course, etc.

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II.   Network Coordination and Data Dissemination (Report FY05)

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 FY 2005 in conjunction with the members of the Coordinating Committee. The NNDC Head serves as chair of the USNDP Coordinating Committee, which consists of the Principal Investigators from each of the participating groups, and he chairs the annual meeting of the program held at Brookhaven National Laboratory. LANL chairs the Nuclear Reaction Data Working Group, and LBNL the Nuclear Structure Working Group. ORNL chairs the Astrophysics Task Force, LANL the Nuclear Data for RIA Task Force, and LLNL chairs the Homeland Security Task Force.

In February 2005, the DOE Office of Nuclear Physics conducted its annual Budget Briefing. Pavel Oblozinsky, Coral Baglin and Don Smith represented the USNDP and made the case for FY2007 funding.

The NNDC serves as the focal point for U.S. collaboration in international nuclear data activities. Two NNDC staff members, two LBNL staff members and one ANL staff member served as lecturers at an IAEA-sponsored "Workshop on Nuclear Structure and Decay Data: Theory and Evaluation" in Trieste in April 2005.

NNDC continues to chair the Cross Section Evaluation Working Group, which produces the ENDF/B evaluated nuclear data library for applied nuclear technology use. The NNDC hosted the CSEWG annual meeting in November 2004. The major topic of the meeting continues to be the planned release of ENDF/B-VII library in 2006.

Several USNDP participants attended the April 2005 meeting of the NEA-sponsored Working Party on International Evaluation Cooperation (WPEC) in Antwerp, Belgium. The US has the lead responsibility for several projects sponsored by this group. The NNDC Head completed his two-year term as the chairman of the Working Party.

McMaster group hosted biennial IAEA-sponsored NSDD meeting from June 6-10, 2005. The meeting was attended by 33 scientists from 13 countries.

USNDP Databases

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

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

The NNDC maintains seven nuclear physics databases for the USNDP. These databases have been updated continuously in FY2005 with new and revised information from efforts of the NNDC, the USNDP and international collaborators. Distributions of all or parts of these databases have been made to national and international collaborators as scheduled.

Data Dissemination

In FY2005, retrievals from the USNDP databases as offered by the NNDC web service increased by 62% in comparison to FY2004, see Fig.1. This sharp increase should be viewed as continuing impact of entirely new services launched by the NNDC in April 2004 that approximately doubled retrievals on a daily basis. In future, we assume that the trend will slow down substantially and return to about the 15-20% yearly increase observed before 2004.

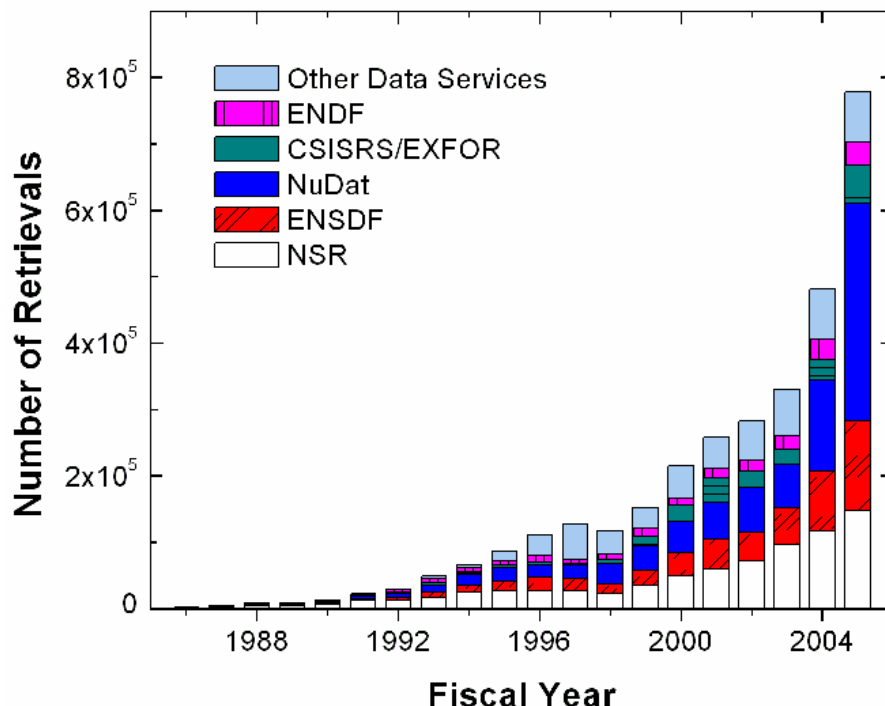Fig. 1. Retrievals from the USNDP databases as offered by the NNDC at www.nndc.bnl.gov. Considerable increase in 2004-2005 is largely due to NuDat.

If measured by the number of retrievals, then by far the most successful database and product is NuDat. In FY2005, NuDat retrievals have shown a remarkable 130% increase compared to FY2004. NuDat received several recognitions, including the one by *Science Magazine*, see Fig.2.
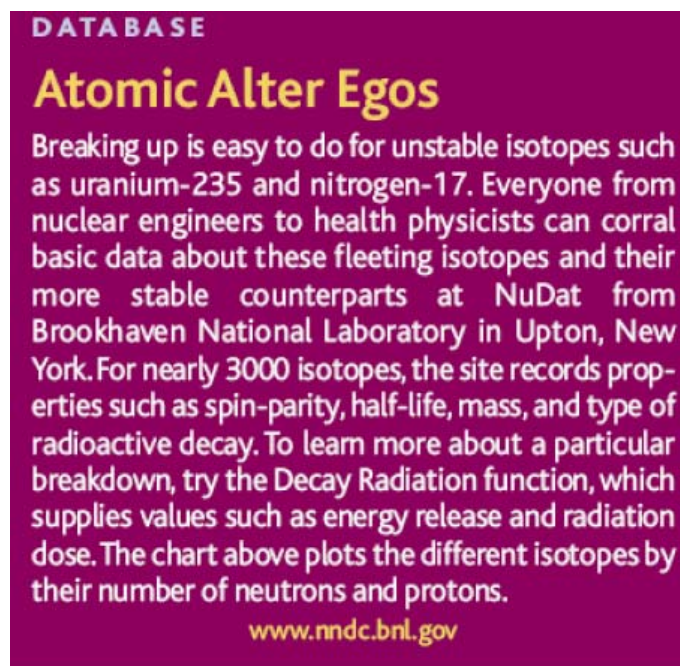
Fig. 2. NuDat recognition published in *Science Magazine*, January 14, 2005.

The **Computational Infrastructure for Nuclear Astrophysics**, online at ORNL's nuclear astrophysics data web site at **nucastrodata.org**, has been significantly expanded and improved in FY05. New features include additional data handling tasks for user-uploaded cross sections, improvements in the reaction rate generation software, an email-like tool to add comments to data sets, a comparison tool to find and quickly compare distinct rates for a given reaction, and a greatly expanded astrophysics simulation and visualization package. Also new is a mass model evaluator system, enabling users to upload theoretical mass models and compare with other mass models and with experimental masses from the AMDC. With a few mouse clicks, users can generate nuclide charts with customized color maps showing masses, mass differences, separation energies, and Q-values.

The **Nuclear and Atomic Data System (NADS)** at LLNL allows for interactive viewing, modifying, plotting and saving reaction data, **nuclear.llnl.gov/CNP/nadsNADSApplet.html** . At the user (client) end, NADS loads a Java Applet that presents a graphical user interface for browsing the available data. When the user selects data, those data are downloaded onto the user's computer, making data manipulations faster and allowing the user to save data. Plots are interactive and can be rescaled, relabeled, rotated, etc. Three main types of data are currently available:

1) Experimental cross-section data from the EXFOR database,
2) Evaluated cross-section and outgoing particle data from various databases including ENDL99 (LLNL), ENDF/B-VII (BNL), JEFF (Europe) and JENDL (Japan), and
3) LLNL deterministic transport data.

Cross-section data from the different databases can be overlaid on a plot for simple comparison. NADS has 3-d and 4-d plotting used, for example, for plot of outgoing particle probabilities P(E, μ) versus incident energy E and outgoing angle μ (3-d plotting), or outgoing particle probabilities P(E, μ, E') versus incident energy E, outgoing angle μ and outgoing energy E' (4-d plotting). 4-d plotting treats one of the independent parameter as an "effective time" parameter.

NADS can also perform computations on the data. For example, if `sigma` represents the cross-section versus incident neutron energy E of a neutron hitting a target, `rho` the density of the target and `l` the thickness of the target, than the attenuation of the neutron beam versus energy E can be plotted by entering the expression "`exp(-sigma * rho * l )`". In this expression, NADS will multiply every point of the cross-section by "`rho * l`" and then exponentiate each point to produce the attenuation versus energy.

Publications

Atlas of Neutron Resonances, a seminal book of ~1,500 pages, was completed by the NNDC guest scientist Said Mughabghab and submitted for publication. It contains evaluated neutron data for Z = 1 – 100 nuclei (473 isotopes, 353 with resolved neutron resonances) and represents one of the most comprehensive low-energy neutron data resources. Wealth of available information is of considerable importance both for applied nuclear technology (such as nuclear reactors) and basic nuclear physics.

Atlas, to be published by Elsevier, should appear on the market in spring 2006.

Atlas of Neutron Resonances

Resonance Parameters and Thermal Cross Sections

S.F. Mughabghab

Elsevier 2006
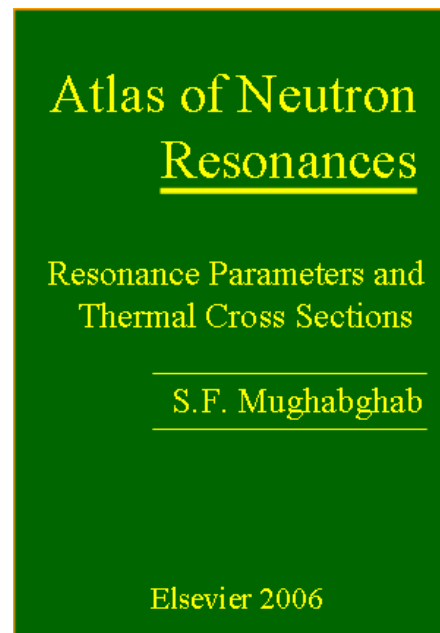
III.   Nuclear Structure and Decay Data (Report FY05)

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

Evaluations for ENSDF

USNDP nuclear structure and decay data evaluation groups in the US and Canada were involved in 289 nuclide evaluations (43 of them for priority nuclides) out of total 344 nuclide evaluations that were submitted during FY2005 for inclusion in the ENSDF database. The evaluations of 103 of these nuclides were performed in collaboration with several new non-US evaluators, recruited as part of a training and mentoring effort, while the evaluation of 12 others resulted from a separate Canada-Kuwait collaboration. The USNDP evaluators have also reviewed 16 mass chain evaluations, and additional prepublication checks have been done at NNDC for all published evaluations. Super-deformed band data for 14 nuclides have been updated in ENSDF. Twelve issues of the journal *Nuclear Data Sheets* were published by Elsevier and these issues contained 20 mass chain evaluations (including one each from Belgium and China and two from France); the annual nuclear science references update issue has been discontinued. One of another the three additional US mass chain evaluations published in *Nuclear Physics A* this FY has already been added to ENSDF.

Compilations for XUNDL

The XUNDL file contains experimental unevaluated data sets compiled primarily from recent papers. The McMaster group submitted 300 new and 15 updated data sets during FY05. These data have been incorporated into XUNDL by BNL. Private communications obtained from authors concerning some of the data entered into XUNDL during the year have been collected and forwarded to NNDC so that ENSDF evaluators also can also benefit from the information they contain.

Horizontal Evaluations

The international **Decay Data Evaluation Project** (DDEP), which also includes non-ENSDF evaluators from France, Germany, Russia, Spain, and the United Kingdom, prepares evaluations for radionuclide decays of importance in applied research. LBNL continues to coordinate this project and provide general editorial oversight. In addition, six radionuclide evaluations were reviewed by USNDP participants in this program.

An existing database (EGAF) containing discrete-line photon data from **thermal neutron capture** is being augmented with statistical-model calculations of the photon quasi-continuum as part of an LBNL-LLNL collaboration. New, faster software was developed for the calculations, and data for the Pd isotopes have now been evaluated.

A compilation of all known **three-quasiparticle structures** in deformed nuclei was prepared in collaboration with the new data center in India; it has been accepted for publication in *Atomic Data and Nuclear Data Tables*.

Nuclear Science References

The nuclear science references included in the NSR file have been expanded by 4,756 papers, and keyword abstracts were provided for 3,383 of these. The work was performed primarily by the NNDC staff members, who regularly scan 74 of the 80 journals, that are monitored, along with laboratory reports and conference proceedings. Several foreign collaborators also contribute to this work.

Internal Conversion Coefficient Calculation Utility

A US-Australian-Russian collaboration completed the software package that now enables both nuclear data evaluators and the scientific public at large to obtain internal conversion coefficients interpolated from relativistic Dirac-Fock calculations that take the electron hole into account *via* the frozen-orbitals approximation. The project involved very extensive calculations followed by careful inter-comparison of experimental and calculated values. It now provides coefficients with higher precision and greater reliability than were previously available, and these are now the standard for new ENSDF evaluations. Interpolated internal pair production coefficients and E0-transition electronic factors are also included in the package.

Evaluator Recruitment and Training

In response to the problem of a diminishing and graying nuclear structure data evaluation workforce worldwide, the IAEA held another two-week long evaluator training workshop at the ICTP in Trieste in April 2005. Experienced USNDP evaluators, two from BNL and two from LBNL, lectured on ENSDF-related topics at this workshop, and another from ANL lectured on experimental techniques. 27 participants from 17 countries attended the workshop and, of these, at least 6 have already had some involvement in nuclide evaluations for ENSDF. Evaluators at BNL and McMaster have also served as mentors for several non-US evaluators who recently began evaluation work.

IV.   Nuclear   Reaction Data (Report FY05)

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

Reaction Data Highlights

The NNDC has compiled a record number of 447 papers (124 neutron, 280 charged-particle and 43 photonuclear reactions) for the experimental nuclear reaction database, CSISRS. Work at NNDC continued on creation of the international fission product library of neutron cross sections by assembling initial library with 164 materials out of the expected 219. The Cross Section Evaluation Working Group (CSEWG), which is partly supported by this program, has made good progress towards the release of the next version of the US evaluated nuclear data library, ENDF/B-VII.

The activity to supply nuclear data for Homeland Security continues in the framework of the Task Force that holds a special session during each annual USNDP meeting. LANL has completed an evaluation of proton-induced gamma-ray production cross sections on ^{13}C, which is an important reaction to detect nitrogen for interrogation.

LANL completed evaluations of neutron reactions with the americium isotopes ($^{241,242m, 242g}$Am) that are required by many nuclear applications. These evaluations will be included in ENDF/B-VII.

LLNL completed cross-section evaluations for neutron and charged-particle reactions on over 196 targets in the Br-Kr, I-Xe, Ti-V, and Sm-Eu-Gd mass ranges, enabling detailed reaction network calculations over large regions of the table of isotopes. These evaluations will be included in the ENDF/A library.

The unique measurement (LANSCE) and analysis (T-16) capability at LANL were combined to produce new nuclear reaction data. The GEANIE facility was used to measure (n,xγ) data for ^{191,193}Ir and ^{48}Ti. These data were interpreted by using a modern quantum-mechanical model for pre-equilibrium processes. Capture cross sections for ^{237}Np were measured at DANCE. Fission neutron spectra measured by FIGARO were used to test the Los Alamos model.

Model Code Highlights

A new version of the EMPIRE nuclear reaction code, EMPIRE-2.19, was released in March 2005. Added features in this release include reactions with excited targets, improved fission modeling, pre-equilibrium cluster emission, and improved treatment of exclusive spectra and recoils. The most recent version also includes more features such as an automated fit of optical potentials, and initial capability for covariance data generation. A WPEC project to provide a library of modules used in nuclear model codes is being led by LANL. Many modern model codes that calculate nuclear reaction cross-sections can take advantage of this library to test new physics models or implement advanced methods.

The TUNL program on pre-equilibrium phenomenology produced three journal articles this year on (1) a revised description of the complex particle channels, (2) isospin conservation, and (3) accounting for previously missing residual nucleus configurations in order to resolve a problem with reproducing experimental spectral endpoints.

The McGNASH code has been developed extensively at LANL. The code is capable of generating nuclear reaction cross-sections and the exclusive spectra in the ENDF-6 format directly. A new module to calculate the pre-equilibrium process was also added for the high-energy calculations.

Nuclear Standards Highlights

NIST is leading an international nuclear reaction standards evaluation project that is being carried out under the auspices of an IAEA Coordinated Research Project, the NEA Working Party on International Evaluation Cooperation and the CSEWG. As a result of this effort, an interim set of the most important standards was provided to the CSEWG at its 2004 meeting. Only small changes in these standards are expected for the final results. A suggested change in the hydrogen capture cross section at thermal energy and the availability of additional coherent scattering data has initiated a new hydrogen evaluation at LANL. This evaluation is nearly complete. LANL has provided an R-matrix evaluation of the ^{6}Li(n,t) standard and nearly completed the R-matrix evaluation process for the ^{10}B(n,α) and ^{10}B(n,$\alpha_1\gamma$) standards. These R-matrix evaluations will be combined with additional R-matrix evaluations and other experimental data using the GMA code to provide the final results. Work on the cross section covariances continues. It is anticipated that work will be completed next FY. New measurements for several standards, including ^{1}H(n,n), ^{6}Li(n,t), and ^{10}B(n,α) are being made that will be useful for future standards evaluations.

On the experimental side, LANL is working with NIST and Ohio University on a precise measurement of the H(n,n) differential cross section. The experiment appears to be well understood at this point, and we await the allocation of beam time at the Ohio Accelerator Laboratory for a production measurement.

Nuclear Astrophysics Highlights

Work continues on the evaluation of several nuclear reactions important for astrophysics modeling at ORNL [^{18}F(p,α), ^{17}O(p,α), ^{18}F(p,γ), ^{33,34}Cl(p,γ), and ^{30}P(p,γ)], at LANL [^{12}C(α,γ)] and at McMaster [^{25}Al(p,γ), ^{13}N(p,γ)]. LANL has produced fission barriers for 3,000 nuclei with A>190, which are important for determining influence of fission on the r-process. LANL also established a capability to calculate neutron capture cross sections for unstable isotopes at the important s-process branching point.

Table 3. USNDP Staffing Table for FY2005
Note: BNL includes 0.3 FTE from Idaho

	ANL	BNL		LANL	LBNL	LLNL	Mc Master	NIST	ORNL	TUNL	Program Total	
		Sci/Pro	Support								Sci/Pro	Support
I. NNDC Facility Operation	**0.00**	**1.20**	**0.80**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.20**	**0.80**
Management		0.35									0.35	
Secretarial/Administrative Support			0.55								0.00	0.55
Library			0.25								0.00	0.25
Computer Operation		0.85									0.85	
II. Coordination	**0.11**	**0.65**	**0.00**	**0.40**	**0.30**	**0.00**	**0.05**	**0.00**	**0.05**	**0.00**	**1.56**	**0.00**
National Coordination	0.01	0.35		0.10	0.30				0.05		0.81	
International Coordination	0.10	0.30		0.30			0.05				0.75	
III. Nuclear Physics Databases	**0.00**	**1.90**	**1.35**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.90**	**1.35**
Nuclear Science References (NSR)		0.10	0.70								0.10	0.70
Exper. Nucl. Structure Data (XUNDL)		0.05									0.05	
Evaluated Nucl. Structure Data (ENSDF)		0.20	0.65								0.20	0.65
Numerical Nuclear Data (NuDat)		0.10									0.10	
Reaction Data Bibliography (CINDA)		0.10									0.10	
Experimental Reaction Data (CSISRS)		0.15									0.15	
Evaluated Nuclear Data File (ENDF)		0.40									0.40	
Database Software Maintenance		0.40									0.40	
Future Database Systems (Migration)		0.40									0.40	
IV. Information Dissemination	**0.01**	**1.00**	**0.25**	**0.10**	**0.25**	**0.00**	**0.00**	**0.00**	**1.50**	**0.60**	**3.46**	**0.25**
Nuclear Data Sheets		0.10	0.15								0.10	0.15
Customer Services		0.15	0.10								0.15	0.10
Web Site Maintenance & Development	0.01	0.75		0.10	0.25				1.50	0.60	3.21	

	ANL	BNL		LANL	LBNL	LLNL	Mc Master	NIST	ORNL	TUNL	Program Total	
		Sci/Pro	Support								Sci/Pro	Support
V. Nuclear Structure Physics	**0.72**	**3.20**	**0.00**	**0.10**	**2.38**	**0.00**	**0.45**	**0.00**	**0.40**	**0.90**	**8.15**	**0.00**
NSR Abstract Preparation		0.60									0.60	0.00
Compilation of Exper. Structure Data							0.10				0.10	0.00
Eval. of Masses & Nuclides for ENSDF	0.70	2.05			2.05		0.35		0.40	0.45	6.00	0.00
Ground and Metastable State Properties		0.15									0.15	0.00
Radioactive Decay Data Evaluation	0.02	0.05			0.13						0.20	0.00
Thermal Capture Gamma Data Eval.					0.20						0.20	0.00
Light Mass Eval. for Nuclear Physics A.										0.45	0.45	0.00
Nuclear Structure Data Measurement				0.10							0.10	0.00
ENSDF Evaluation Support Codes		0.35									0.35	0.00
VI. Nuclear Reaction Physics	**0.01**	**1.85**	**0.00**	**1.60**	**0.00**	**0.30**	**0.50**	**0.20**	**0.60**	**0.40**	**5.46**	**0.00**
Experimental Data Compilation		0.50									0.50	0.00
Neutron Data		*0.15*									*0.15*	*0.00*
Charged Particle Data		*0.30*									*0.30*	*0.00*
Photonuclear Data		*0.05*									*0.05*	*0.00*
EXFOR Manuals		0.10									0.10	0.00
ENDF Manuals and Documentation		0.05									0.05	0.00
ENDF Evaluations		0.85		0.10		0.30					1.25	0.00
Nuclear Reaction Standards				0.20				0.20			0.40	0.00
Nuclear Model Development	0.01	0.30		0.60						0.40	1.31	0.00
Nuclear Reaction Data Measurements		0.10		0.30							0.40	0.00
Astrophysics Nuclear Data Needs		0.05		0.40			0.50		0.60		1.55	0.00
Reaction Data for RIA Target Design				0.00							0.00	0.00
DOE-SC Nuclear Data Funded Staff	**0.85**	**9.80**	**2.40**	**2.20**	**2.93**	**0.30**	**1.00**	**0.20**	**2.55**	**1.90**	**21.73**	**2.40**
Staff Supported by Other Funding	**0.16**	**0.50**	**0.20**	**14.40**	**0.80**	**7.50**	**0.50**	**2.80**	**0.00**	**0.00**	**26.66**	**0.20**
TOTAL STAFF	**1.01**	**10.30**	**2.60**	**16.60**	**3.73**	**7.80**	**1.50**	**3.00**	**2.55**	**1.90**	**48.39**	**2.60**

Detailed Status of the Work Plan (Report FY05)

I. NNDC Facility Operation (Report FY05)

A. <u>Management</u>

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

B. <u>Library</u>

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

C. <u>Computer Operation</u>

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

BNL Deliverables:
Keep downtime on the central database server to less than 3%.
Ensure compliance with DOE computer security requirements.
Maintain hardware and software of Linux-based servers.
Maintain hardware and software of Windows-based desktop computers.
Status:
- Considerable effort was required to regularly install software security patches on servers and desktops to comply with DOE Cyber Security directives.
- Additional Dell server was purchased and installed to improve reliability and availability of web services to external users.
- Two powerful Dell workstations were purchased and installed, one for ENDF/B-VII library processing and the other for CPU- and memory intensive Java applications development.
- Automatic replication of updates for EXFOR and ADLIST databases from primary to secondary database server was implemented.
- Disk-to-disk backup for all PCs was implemented, for quick recovery during catastrophic system failures.
- Wireless laptop with VPN access to computing resources in the Internet was provided to each scientific and professional staff member.

II. Coordination (Report FY05)

A. <u>National Coordination</u>

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

ANL Deliverables:
- Attend the annual CSEWG meeting in November 2004
- Provide Measurement and Basic Physics Committee report for CSEWG.

Status:
- Two ANL participants attended the FY05 CSEWG meeting
- ANL organized and chaired the Measurement and Basic Physics Committee at the November 2004 CSEWG Meeting and prepared the final report

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

BNL Deliverables:
Prepare FY2006 work plan for USNDP in time for spring 2005 FWP submittals.
Organize and chair CSEWG Meeting at BNL in November 2004.
Organize and chair USNDP Meeting at BNL in November 2004.
Edit and publish summary reports of the CSEWG and USNDP meetings.
Maintain CSEWG and USNDP web sites.
Status:
- FY2006 work plan for USNDP was prepared in February 2005.
- CSEWG Meeting was held at BNL in November 2004.
- USNDP Meeting was held adjacent to CSEWG Meeting in November 2004.
- Summary report of CSEWG-USNDP 2004 meeting was published.
- CSEWG and USNDP web sites were regularly maintained.

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

LANL Deliverables:
Organize and chair CSEWG Evaluation Committee meeting at BNL, November 2004.
Organize and chair Nuclear Reaction Working Group meeting at USNDP meeting in November 2004.

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

Status:
- Organized and chaired the Evaluation Committee at the November 2004 CSEWG meeting.
- Organized and chaired Nuclear Reaction Working Group meeting at USNDP meeting in November 2004.
- Homeland Security data needs were investigated.

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

LBNL Deliverables:
Organize and chair Nuclear Structure and Decay Data Working Group meeting at USNDP meeting, November 2004.

Status:
- Served on USNDP Coordinating Committee.
- Organized and chaired USNDP Nuclear Structure and Decay Data Working Group meeting in November 2004.

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

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

Status:
- Three LLNL participants attended the FY05 CSEWG meeting
- LLNL prepared the final Task Force on Nuclear Data Needs for Homeland Security report for CSEWG

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

ORNL Deliverables:
Summarize USNDP efforts in nuclear data for nuclear astrophysics at USNDP Meeting in November 2004.

> Communicate current efforts and future plans with researchers in nuclear astrophysics data.
> Discuss future plans in nuclear astrophysics data with USNDP/NNDC and DOE.

Status:
- USNDP efforts in nuclear data for nuclear astrophysics summarized in an oral presentation and a written report for USNDP meeting in November 2004.
- Presentation of future needs in nuclear astrophysics data were made in a conference proceedings paper for the Nuclear Data 2004 meeting, written and published in FY05.
- Explored prospects for joint research / data projects in nuclear astrophysics involving multiple USNDP sites.

B. <u>International Coordination</u>

ANL − − Represent U.S. measurements interest in the NEA Working Party on International Evaluation Cooperation.

ANL Deliverables:
- Attend NEA WPEC annual meeting.
- Contribute to development and maintenance of a recently upgraded NEA system for compiling requests for nuclear reaction data measurements and evaluations.

Status:
- It was not possible for the ANL delegate to attend WPEC meeting, held in Antwerp, Belgium, because of a conflict with jury duty. ANL prepared a report on experimental activities in the U.S. that was presented at the annual WPEC meeting in absentia by the delegate from NIST.
- ANL continues to contribute to this activity through its membership in WPEC Subgroup C.
- ANL staff attended and participated in the activities of the 16th Meeting of the NSDD Network held at McMaster University, Canada.
- Two lectures were prepared and presented at the IAEA/ICTP organized workshop "Nuclear Structure and Decay Data: Theory and Evaluation" held in Trieste, Italy, April 2005.

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

BNL Deliverables:
Participate in NEA WPEC annual meeting in 2005.
Provide director and lecturers for the NSDD Workshop at Trieste in April 2005.

Status:
- The NNDC head led the US team at the NEA Working Party on International Evaluation Cooperation (WPEC) meeting at Antwerp, Belgium in April 2004. He chaired the meeting.
- NNDC provided director and 2 lecturers (6 lectures) for NSDD Workshop at Trieste in April 2005. In addition, the NNDC contributed to the NSDD Manual published by the IAEA.
- NNDC staff members (5) participated in the NSDD meeting at McMaster. Tuli helped organize and chaired the technical sessions.
- NNDC hosted three nuclear structure evaluation trainees, two from India (G. Mukherjee, M. Gupta) and one from Argentina (D. Abriola).
- NNDC created a web site for the NSDD that is updated regularly.

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

LANL Deliverables:
Host the next International nuclear data conference (ND2004), to be held in Santa Fe, September 26-October 1, 2004.
Participate in NEA WPEC April 2005 meeting.
Participate in relevant IAEA meetings.
Make latest version of NJOY data processing code available to the international community.
Host a couple of international visitors to LANL to collaborate on the evaluation of reaction data, such as Vladimir Pronyaev (fission standards).

Status:
- The international nuclear data conference (ND2004) was held in Santa Fe in September 2004. The proceedings were published, and sent to all participants in June 2005.
- LANL staff member participated in WPEC meeting in Antwerp, Belgium in April 2005. One member led a meeting of the WPEC

Subgroup A on nuclear model codes. A talk on a covariance evaluation was given at the specialists' meeting for Generation-IV reactors, Antwerp, April 2005.

- One staff member gave a talk at the Dec 2004 IAEA Vienna meeting on Th-U fuel cycle.
- Upgrades to NJOY were released to the international NJOY data processing community.
- Hosted key researchers from BRC/CEA, JAERI, and Geel.

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

LBNL Deliverables:
Provide lecturer(s) for structure and decay data evaluator-training Workshop if one is scheduled during FY05.

Status:
- Provided two lecturers (6 lectures) and lab instructors for the two-week IAEA/ICTP (Trieste) "Workshop on Nuclear Structure and Decay Data: Theory and Evaluation" in April 2005.
- Provided one lecturer (2 lectures) for the ICTP "Workshop on Nuclear Data for Science and Technology: Materials Analysis Activation Analysis" in Trieste in March 2005.
- Two staff members participated in the IAEA-NSDD-2005 meeting at McMaster University in June 2005.

McMaster – Organize NSDD-2005 meeting and continue participation in new evaluators training program (added after Work Plan 2005 had been distributed).

McMaster Deliverable:
Host IAEA's NSDD-2005 international meeting of evaluators. Collaborate with new evaluators for ENSDF work.

Status:
- Hosted IAEA-NSDD-2005 meeting from June 6-10, 2005, made all the administrative arrangements, maintained website for the meeting.
- Hosted Dr. A.K. Jain from the data center in India for three weeks to work on ENSDF updates of A=165 and 218, as part of new evaluator training program. The mentoring/training work with the team of evaluators at PNPI was brought to completion in February 2005 with the publication of A=132 in the March 2005 issue of NDS.

III. Nuclear Physics Databases (Report FY05)

A. Nuclear Science References (NSR)

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

BNL Deliverables:
Database distributed to collaborators monthly.
Status:
- NSR files were distributed monthly.

B. Experimental Nuclear Structure Data (XUNDL)

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

BNL Deliverables:
Update database as new data sets are received from McMaster University.
Status:
- Database updated as required, 300 new and 15 updated files were included.

C. Evaluated Nuclear Structure Data File (ENSDF)

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

BNL Deliverables:
Database distributed to collaborators twice a year.
Status:
- 20 mass-chains, 8 nuclides, and 9 data sets were received, processed and added to ENSDF in FY2005. Processing includes file checking, review and post-review checking.

- The ENSDF database was distributed in October 2004 and March 2005.

D. Numerical Nuclear Data File (NuDat)

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

BNL Deliverables:
Distribute NuDat database to collaborators twice a year.
Status:
- The NuDat database was distributed in October 2004 and March 2005.

E. Neutron Reaction Data Bibliography (CINDA)

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

BNL Deliverables:
Update CINDA database with CINDA transmissions from cooperating centers
(12 expected).
Status:
- The database serves as an index to the reaction data (neutrons, charged-particle and photonuclear), updates are automatically created from CSISRS. The database was updated regularly.

F. Experimental Reaction Data File (CSISRS)

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

BNL Deliverables:

Update CSISRS with EXFOR exchange files as compilations are received from cooperating centers (20 expected).

Status:

- 66 EXFOR exchange files were received and the CSISRS database was continuously updated.

G. Evaluated Nuclear Data File (ENDF)

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

BNL Deliverables:

Maintain CSEWG website; keep information current.
Maintain Preliminary ENDF/B-VII website to facilitate ENDF/B-VII review process.
Maintain ENDF discussion list to facilitate validation of ENDF/B-VII.
Assemble ENDF/B-VII library for release in FY06.

Status:

- CSEWG website, both public and members-only, was regularly maintained.
- Preliminary ENDF/B-VII website was maintained, with beta0 version released in March 2005. The site provides easy access to files, output of checking codes, and numerous plots that compare evaluations with experimental data.
- ENDF discussion list, endf@lists.bnl.gov, was maintained.
- ENDF/B-VII beta1 version was assembled and prepared for release and testing. It contains a complete set of sub-libraries, including a neutron sub-library with 387 evaluations and a photonuclear sub-library with 160 evaluations.

H. Database Software Maintenance

This activity includes software bug fixes and enhancements for the six nuclear physics databases maintained by NNDC.
   BNL Deliverables:
      Perform maintenance as necessary.
   Status:
   - Bugs fixed, enhancements and maintenance performed as necessary.

I. Future Database Systems

As discussed in the work plans for the previous years, the NNDC is involved in a multiyear project to migrate its databases to a relational format. In FY2003, the Linux/Sybase computing environment was established using newly purchased Dell hardware. In FY2004, the migration and testing of the software supporting the nuclear structure data activities and databases (NSR, ENSDF and NuDat) was completed. Migration of the software supporting the nuclear reaction data activities and databases (CINDA, CSISRS and ENDF) will be completed in the first quarter of FY2005 and full implementation of the NNDC activity in the new computing environment will be completed in the second quarter of FY2005 at which time the legacy OpenVMS system will be retired.

   BNL Deliverables:
      Complete testing of the migrated software, which supports the nuclear reaction activities and databases (NSR, ENSDF and NuDat) in the new computing environment.
      Terminate operation of legacy Alpha Server that operates under OpenVMS.
   Status:
   - Testing of nuclear reactions databases (CINDA, CSISRS and ENDF) on the Linux/Sybase platform has been successfully completed. Web interfaces operate smoothly, comments from users were collected and improvements in interfaces were identified.
   - Operation of the legacy Alpha Server has been terminated. The server currently runs in the residual mode for a few remaining needs of the NNDC staff.

IV.   Information Dissemination (Report FY05)

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. <u>Maintenance of Remote Access to USNDP Databases</u>

The NNDC provides electronic access to the nuclear physics databases that it maintains. This access is supported *via* the web.

> **BNL Deliverables:**
>> Complete move of web interfaces from OpenVMS to Linux.
>
> **Status:**
>> - Web interfaces were moved from OpenVMS to Linux already in April 2004.

B. <u>Customer Services</u>

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

> **BNL Deliverables:**
>> Effort is required to maintain help desk and provide technical support to users as necessary.
>
> **Status:**
>> - The NNDC staff responded to user inquiries by phone, email or via web. Comments/questions option was introduced and maintained for CSISR and also for the NNDC web service.

C. <u>Web Site Maintenance</u>

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 and upgrade the ANL Nuclear Data Information web site.

Status:

- The three web sites were maintained and periodically upgraded.

BNL Deliverables:

Effort required maintaining the currency of the CSEWG, USNDP and the NNDC web sites.

Status:

- The NNDC web site was maintained regularly. A significant increase in data retrievals was noted.
- CSEWG and USNDP web sites were redesigned and updated regularly.
- A number of new or updated products were put on web: NuDat-2.1 in January 2005, Empire-2.19 in March, Q-calc in May, 7th edition of Nuclear Wallet Cards in June, HSICC and Logft in September 2005.

LANL Deliverables:

Include access to new reaction and structure data evaluations supported by DOE/Nuclear Physics, via the T-16 web site.
Provide actinide ENDF/B-VII data via LANL web site for criticality data testing.

Status:

- The latest LANL evaluations were made available via our web site. This has been particularly important for the integral data testing community that is validating the preliminary ENDF/B-VII evaluations.
- The LANL T-16 web site was totally renewed, by using a modern web technology and language.

LBNL Deliverables:

Maintain and update the home pages for neutron-capture gammas, nuclear structure and decay systematic, nuclear science education, atomic masses, and others.
Support Isotope Explorer 2 and 3 and NSR search software previously developed by LBNL.

Status:

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

LLNL Deliverables:

Maintain LLNL Nuclear Data and Atomic Data Viewer.

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

Maintain and upgrade LLNL Computational Nuclear Physics web pages.

Status:

- Nuclear Data and Atomic Data Viewer was maintained.
- Computational Nuclear Physics web pages were maintained.
- EXFOR experimental data added.
- Ability to perform calculations on 2-d data within the applet itself.

ORNL Deliverables:

Continue to maintain, update, and improve the web/FTP site providing the RadWare interface to ENSDF and XUNDL data sets.

Begin porting the RadWare-to-ENSDF conversion program for use in Microsoft Windows.

Investigate the development of a Microsoft Windows application for displaying and editing RadWare level schemes, as a helper application for web browsers.

Develop online software suite to convert nuclear data to astrophysical reaction rates and plot, manipulate, and share results online.

Status:

- The website radware.phy.ornl.gov has been maintained by uploading the latest versions of ENSDF and converting the files to RADWARE format.

- The **Computational Infrastructure for Nuclear Astrophysics**, online at **nucastrodata.org**, has been significantly expanded and improved in FY05. This tool enables users to upload cross sections, perform simple data evaluation tasks, convert cross sections into reaction rates, and use these rates in element synthesis calculations. New features in FY05 include additional data handling tasks for user-uploaded cross sections, improvements in the reaction rate generation software, an email-like tool to add comments to data sets, a comparison tool to find and quickly compare distinct rates for a given reaction, and a greatly expanded astrophysics simulation and visualization package. In collaboration with a mass model theorist from JAEA, we have added a mass model evaluator system, enabling users to upload theoretical mass models and compare with other mass models and with experimental masses from the AMDC. With a few mouse clicks, users can generate nuclide charts with customized color maps showing masses, mass differences, separation energies, and Q-values.

TUNL Deliverables:

Prepare PDF and HTML documents of the most recent TUNL reviews of $A = 11$ and 12 nuclei. PDF and HTML documents are currently available for TUNL and FAS publications for the years 1968-present.

Provide PDF and HTML documents for FAS reviews for the $A = 3$ - 20 series; prepare PDF and HTML documents for earlier Fay Ajzenberg-Selove evaluations based on A = 5 – 10 (66La04) and $A = 5 – 20$ (56AJ76).

Continue to provide General Tables to accompany the most recent TUNL reviews of the $A = 3$ - 20 series; update General Tables for $A = 11$ and 12 nuclei to correspond to the review to be published in *Nuclear Physics A*.

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

Status:

- PDF and HTML files are online for *Fay Ajzenberg-Selove and TUNL reviews* for 1968-present. This year we added A = 5 - 9 (1966La04) and A = 12 (1968AJ02).
- Energy Level Diagrams are online for *Fay Ajzenberg-Selove and TUNL reviews* for 1959 (A = 5 – 10)-present.
- A new effort to provide compiled and evaluated information on Thermal Neutron Capture data for A = 2 - 20 nuclei is presently underway.

V. Nuclear Structure Physics (Report FY05)

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

The literature search and preparation of KEYWORD abstracts for publications included in NSR require scientific expertise. The NNDC staff creates most of the entries, but receives some assistance from Russia.

> **BNL Deliverables:**
> Prepare entries for 4,100 new references with keyword abstracts for 3,100.
> **Status:**
> - About 80 refereed journals were scanned regularly and a number of conference proceedings were scanned as they were published. 4,756 entries were added to the NSR database including 3,383 with keywords.

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

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

> **McMaster Deliverables:**
> Compile data sets (in ENSDF format) for current publications with emphasis on high-spin physics, but selected low-spin and decay-data publications will also be compiled.
> Compile, on a time available basis, high-spin data from older publications not yet incorporated in outdated ENSDF evaluations
> Review compiled data sets submitted by other data centers prior to inclusion in the XUNDL database.
> Communicate with the authors of the original papers for data-related problems and to request additional details of unpublished data. On an annual basis send a copy of all such private communications to NNDC for archival and distribution purpose.
> **Status:**
> - 300 new data sets from current journal publications in experimental nuclear structure (high-spin and low-spin) were compiled and sent to BNL. Another 15 data sets were updated based on new papers from the same groups or authors as in data sets from earlier papers. The above number includes about 10 data sets from older papers.
> - No compiled data sets received this year from other data centers.
> - Throughout the year there was active communication with the original authors of the papers to resolve data-related problems and to obtain additional details of data that are useful to include in XUNDL and/or ENSDF databases. Copies of these communications (about 50 in all) were sent to BNL in print form and as a computer file for archival purpose and for potential use in ENSDF evaluations.

ORNL Deliverables:
> Improve software for converting tabular/graphic published level-scheme data in journals as well as unpublished data supplied by researchers to RadWare database into ENSDF format.
>
> Finish debugging code that was recently ported from Fortran to C.

Status:
- The RadWare site enables users to convert experimental level information (evaluated, unevaluated) into level diagrams that can be used in further data analysis with the RadWare package. Further development of these tools was, however, halted in FY05.

C. Data Evaluation for ENSDF

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

ANL Deliverables:
> One equivalent mass chain will be evaluated and published.
>
> At least one mass chain will be reviewed.

Status:
- One mass chain (A=201) was completed and submitted to NNDC.
- Two mass chains (A=88 and 176) were reviewed, as requested.

BNL Deliverables (includes Idaho):
> Hire one post doc at mid-year for training as an evaluator.
>
> Three and one-half equivalent mass chains will be evaluated (plus 2 mass chains for Idaho).
>
> At least 4 mass chains will be reviewed (plus 4 mass chains for Idaho).

Status:
- Post-doc has not been hired due to the lack of funding. A contract was given to a new evaluator (N. Nica, Texas A&M) for ENSDF evaluation work.
- 6 mass chains and a large number of super-heavies with $A \geq 266$ were evaluated
  - $A = 67$ (collaboration, 4 nuclides by Tuli)
  - $A = 153$ (collaboration, 10 nuclides by Helmer &Tuli)
  - $A = 160$ (14 nuclides by Reich)
  - $A = 233$ (collaboration, 4 nuclides by Tuli)
  - $A = 252$ (8 nuclides by Nica)
  - $A = 254$ (collaboration, 10 nuclides by Tuli)
  - $A = 266-294$ (63 nuclides in super-heavy range by Gupta & Burrows)

- 7 mass chains were published in Nuclear Data Sheets
  - A = 70, 233, 254 (Tuli)
  - A = 88 (Mukherjee & Sonzogni)
  - A = 155, 160 (Reich)
  - A = 157 (Helmer)
- 12 mass chains were reviewed
  - A = 105,165,181,185 (Reich)
  - A = 54 (Sonzogni)
  - A = 67, 109, 115, 241, 243 252 and 254 (Tuli).

Idaho Deliverables:
  Two equivalent mass chains will be evaluated.
  Two mass chains will be reviewed.
Status:
  - Dick Helmer passed away. Charlie Reich continued to work under the NNDC contract, their results were incorporated into BNL deliverables, see above.

LBNL Deliverables:
  Hire one post doc at mid-year for training as an evaluator.
  At least 4 mass chain equivalents chosen from regions for which LBNL is responsible (including one from the A>212 region and at least one from the A=22-30 region) will be evaluated.
  Mass chains will be reviewed as requested.
Status:
  - Existing post doc position was extended by 6 months.
  - Evaluations for A=22, 166, 176, 181, 232, 237, ^{225}Fr (68 nuclides, including 19 priority nuclides) were submitted.
  - Reviewed two mass chain evaluations (A=203, 233).

McMaster Deliverables:
  1.5 equivalent mass chains (including one in the A=31-44 region) will be evaluated.
  Mass chains will be reviewed as requested.
  Update superdeformed-band data in ENSDF for new publications. All nuclides will be covered that do not require a complete and extensive reevaluation.
Status:
  - Five full-length mass chains (A=39, 74, 165, 199, 218) and 4 individual nuclides (including A=1) were evaluated and sent to BNL for inclusion in ENSDF and publication in Nuclear Data Sheets. Two of these mass chains (A=165 and 218) were collaborations with group in India. This was also part of the training and mentoring process with the new team of evaluators in India. A=74 was a collaboration with

the data center in Kuwait; with more than 75% of the work done at McMaster.

- One evaluator from Roorkee, India spent about 3 weeks at McMaster for training and worked on ENSDF evaluations of A=165 and 218. Both these mass chains have been submitted. The collaborative work with the team of new evaluators at PNPI, Russia that started in 2003 was brought to completion in February 2005 with the publication of A=132 in the March 2005 issue of Nuclear Data Sheets and inclusion in the ENSDF database.
- Three full-length mass chains (A=22, 153 and 193) were reviewed during FY-05. Partial review was done on the A=122 mass chain, which was found to be incomplete in many ways, and was thus sent back to the evaluator for resubmission. For A=153, in addition to complete review and subsequent editing of the data file, McMaster group is also adding several new datasets based on papers published after the mass chain was originally submitted in October 2004. This work is continuing in FY-06.
- Fourteen nuclides were updated for new super-deformed band data and revised data sets were sent to BNL for inclusion in ENSDF. We are current on the coverage of super-deformed band information in ENSDF.

ORNL Deliverables:
Complete evaluation of structure information for nuclei with A=243.
Evaluate structure information for A=233 nuclei.
Start evaluation of A=229 nuclei.
Train one evaluator.
Status:
- A=241 evaluation is complete, and is at BNL for publication
- A=208 evaluation will be completed in December 2005
- Murray Martin has been training post-doc Caroline Nesaraja in A-chain evaluations, and she has also attended the Trieste evaluation workshop in Spring 2005

TUNL Deliverables:
Prepare and submit ENSDF files for A = 3 nuclei.
Begin to prepare the ENSDF files for A = 11 - 12 corresponding with the *Nuclear Physics A* publication.
Status:
- The data file for A = 8 was accepted in ENSDF in April; the file for A = 9 will be completed by year's end, and the file for A = 10 will be completed in FY06.
- Preliminary work on A = 11 & 12 ENSDF files is underway.

D. Ground and Metastable State Properties

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

BNL Deliverables:
NNDC will publish the next edition of the Nuclear Wallet Cards.
Status:
- The 7th edition of the Nuclear Wallet Cards was published in July 2005 with the literature cut-off date of April 2005. Out of the 10,000 copies printed about 7,000 copies have already been distributed.

E. Radioactive Decay Data Evaluation

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

ANL Deliverables:
- Evaluate decay data for one radionuclide.
- Review decay data evaluation for one radionuclide.

Status:
- Evaluation work on ^{177m}Lu and ^{178m}Hf is continuing.
- One nuclide (^{65}Zn) was reviewed, as requested.

LBNL Deliverables:
Coordinate and plan activities of this international collaboration.
Review the evaluations of about five radionuclides.
Submit decay datasets for two radionuclides.
Status:
- Coordinated and planned the activities of this collaboration and exercised editorial oversight.
- Reviewed five radionuclide evaluations (^{108}Ag, ^{108m}Ag, ^{233}Pa, ^{233}Th, ^{242}Cm).

Idaho Deliverables:
Decay data for 3 nuclides will be evaluated.
Status:
- Dick Helmer passed away and the task had to be cancelled.

F. Thermal Capture Gamma Data Evaluation

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

LBNL Deliverables:

Evaluate new (n,γ) data as they become available from the Budapest reactor, add them to the EGAF database and make the revised evaluation available for use in other relevant databases.

Collaborate with LLNL on a project (see Section VI.B) to incorporate data from the EGAF database into the ENDF/B database. Quasi-continuum neutron capture gamma-ray information will be generated as part of this project and that will also be used to refine the EGAF database.

Status:

- Collaborated with Chemical Research Centre, Budapest, Hungary for measurement of ^{24}Mg(n,γ) cross section at thermal energy.
- Statistical analysis performed for (n,γ) E=thermal cross sections for Pd isotopes (with LLNL).
- Developed new software, "COSMO", designed to enable faster statistical-model calculations. These calculations will generate the photon quasi-continuum information needed to augment discrete-line photon data from the EGAF database for all but the lightest nuclides. The combined information will ultimately be used to update the ENDF database.

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:

Evaluated and distribute preliminary review for *A = 12* nuclides for comments.

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

Prepare evaluation of *A = 3* nuclides for publication in *Nuclear Physics A*.

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

Status:

- *"Energy Levels of Light Nuclei, A =* 8, 9, 10*"* published in October 2004. Nuclear Physics A 745 (2004) 155. Prepared with collaboration from D.J. Millener.

- Continuing to prepare evaluation of A = 11 nuclides; evaluation preprint is expected for review in FY06
- Continuing to prepare evaluation of *A = 3* Nuclides. Manuscript preprint is expected for review in FY06
- Preliminary work for evaluation of A = 12 nuclei is underway.

H. Nuclear Structure Data Measurement

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

LANL Deliverables:
Examine prompt gamma-ray emission data on ^{191}Ir and ^{193}Ir to search for previously unobserved transitions.
Interact with mass chain evaluators on the nuclear structure of these nuclei.
Status:
- More than 10 previously unobserved transitions were identified in ^{191}Ir and in ^{193}Ir.
- A similar study was completed in ^{197}Au, where 32 new levels and 52 new transitions were found.
- Interaction with the evaluators for these nuclei continues.

I. ENSDF Physics and Checking Codes

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

BNL Deliverables:
Upgrade RadList and LOGFT to properly treat higher-order ($\geq$ 3) unique forbidden $\beta^{\pm}$ transitions and to use the Schoenfield electron-capture probabilities.
Status:
- Due to a change in priority to complete new BrIcc code, upgrades to RadList and LOGFT were not completed.
- As part of a US-Australian-Russian effort, a new program, BrIcc, to interpolate the Band-Raman conversion coefficients was completed as a replacement for HSICC and released in September 2005.
- Effort was given to evaluation of precise experimentally measured coefficients, in particular, 'no hole' and 'frozen orbital' approximations in BrIcc were assessed.
- Upgrades to NSDFLIB and RULER were released in October 2004.

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VI.   Nuclear Reaction Physics (Report FY05)

A. Experimental Data Compilation

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

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

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

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

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

> **ANL Deliverables**:
> - Submit EXFOR files to the NEA Data Bank for those original data sets provided to ANL by IRMM for processing.
>
> **Status:**
> - This activity was completed. The files have been submitted.

> **BNL Deliverables:**
> Compile data from 90 charged-particle and neutron induced reaction publications.
>
> **Status:**
> - Data from the record number of 447 reaction publications were compiled (280 charged-particle, 124 neutron and 43 photonuclear), thanks to young dynamic compiler. These were largely older papers, left un-compiled by the compiler who retired in December 2004.

B. ENDF Evaluations

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

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

ANL should collaborate with TSI Research (Solana Beach, CA) in conducting a survey of the status of nuclear data for helium production in fusion reactors.

ANL Deliverables:
- Prepare a report on the status of nuclear data for helium production in fusion reactors.

Status:
- This investigation was completed. An ANL/NDM-158 report was prepared and posted on the ANL/NDM web site.

BNL Deliverables:
Create preliminary files for recommended fission product evaluations for ENDF/B-VII (new WPEC subgroup collaboration).
Submit new evaluations for Germanium isotopes with photon production data for use in homeland security applications and ENDF/B-VII.

Status:
- NNDC led the international effort (WPEC Subgroup 23) to produce the neutron cross-section library for the bulk of fission products. The initial library including 164 materials was prepared and partly tested. These evaluations should be included in ENDF/B-VII beta1, scheduled to be released for testing in October 2005.
- New evaluations on 5 isotopes of Germanium with photon production data were submitted to ENDF/B-VII.
- 20 priority fission products were completely re-evaluated in collaboration with KAERI and submitted to ENDF/B-VII.
- New evaluation for ^{51}V(n,np) and (n,t) was submitted to ENDF/B-VII.
- Atlas of Neutron Resonances, a seminal book of ~1,500 pages, was completed by the NNDC guest scientist (S. Mughabghab). In September 2005, the manuscript was submitted to Elsevier for publishing.

LANL Deliverables: (work mostly supported from other sources)
Work with BNL to coordinate upgraded evaluations for the new version of ENDF: ENDF/B-VII.
Submit new improved evaluations that will eventually be available in ENDF/B-VII. For ^{235}U, create an evaluation that combines LANL high-energy evaluated data with ORNL unresolved resonance results to 20 keV. For ^{238}U, create an evaluation that contains LANL high-energy data with ORNL unresolved resonance data.

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

Complete and submit to CSEWG new actinide evaluations for americium isotopes.

Provide upgraded ENDF evaluated data files for charged-particle reactions having A ≤ 10, correcting some problems identified in the review process.

Status:

- New improved evaluations for the uranium isotopes that are based on the new standards and ORNL resonance analysis have been submitted for ENDF/B-VII.
- Upgraded ^{241,242g,242m}Am evaluations have been submitted for ENDF/B-VII.
- The new actinide evaluations were provided for the criticality data testing.
- Completed an evaluation of the proton-induced gamma-ray production cross section on ^{13}C, which is an important reaction to detect nitrogen for interrogation.
- Modified evaluations for the Be elastic scattering were produced, and submitted for ENDF/B-VII.
- Collaborated with BNL to produce covariance data of gadolinium isotopes, which will be submitted for ENDF/B-VII.

LLNL Deliverables: (work mostly supported from other sources)

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

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

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

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

Status:

- The `fete` code is being released.
- The `endl2endf` code is being developed and already has enabled a large number of LLNL evaluations to be submitted to the ENDF community.
- A large suite of partial evaluations was submitted to the NNDC. These partial evaluations will be included into ENDF/A library.
- Three complete evaluations, for ^{73,74}As and ^{240}Am, were submitted to ENDF/B-VII.
- A LLNL report describing the current state of plutonium evaluations has been written (report # UCRL-TR-213291) for the DNEA program. Detailed evaluation work will begin once suitable funds have been identified.

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

LLNL Deliverables:
Provide peer review of the EGAF database.
Simulate the gamma-ray cascade from resonance capture in order to add information on the quasi-continuum of gamma rays for A > 40 nuclei where level spacings become comparable to detector resolution. This information is usually not available experimentally because the targets used were not typically mono-isotopic.
Extend the data files up to approximately E_n = 100 keV based on the results of the simulations.
Produce ENDF files with the discrete and quasi-continuum gamma-ray spectra.

Status:
- ENDF files with the discrete gamma-ray spectra have been created for ^{1,2}H, ^{6,7}Li, ^{9}Be, ^{10,11}B, ^{nat}C, ^{23}Na, ^{nat}Mg, ^{27}Al, ^{28}Si, ^{31}P, ^{nat}S, ^{35,37}Cl, and ^{nat}K.
- Files with the quasi-continuum gamma-ray spectra are being developed.
- Collaborating with LBNL on paper validating results using Pd.

C. <u>ENDF Manuals and Documentation</u>

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

BNL Deliverables:
Maintain ENDF-6 format manual that is available on the web.
Status:
- ENDF-6 format manual has been updated in accordance with the decisions of CSEWG.

D. <u>Nuclear Reaction Standards</u>

Nearly all nuclear reaction data measurements are made relative to some reaction standard such as the hydrogen elastic cross section. Maintaining accurate current values for the standard cross sections is the objective of this task that can be accomplished only through international

cooperation. A new international evaluation of the neutron cross-section standards was initiated to provide the improved standards that are needed. This evaluation, which is nearly complete, has been largely performed by an IAEA Coordinated Research Project (CRP) with support, largely experimental in nature, through the Working Party on International Evaluation Cooperation (WPEC) of the Nuclear Energy Agency and the CSEWG.

ANL Deliverables:
- Contribute to an IAEA sponsored international effort to finalize a neutron reaction standards file adopted by ENDF/B-VII.

Status:
- ANL staff was active in various aspects of this project. Specifically, ANL is coordinating the preparation of a chapter on Peelle's Pertinent Puzzle that will be included in the final documentation for the international neutron standards project.

LANL Deliverables:
Host IAEA staff member in a visit to LANL to work on actinide fission cross-section standards (^{235}U and ^{239}Pu), and produce new evaluations.

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

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

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

Status:
- Light-element standard cross sections evaluated with the R-matrix theory have been completed, and those were submitted as the ENDF/B-VII standards.
- New ^{10}B(n,α) evaluation was completed.
- LANL is working with NIST and Ohio University on a precise measurement of the H(n,n) differential cross section. The experiment appears to be well understood at this point, and we await the allocation of beam time at the Ohio Accelerator Laboratory for a production measurement.

NIST Deliverables:
Coordinate the international standards activity (Subgroup 7 of the NEA Working Party on International Evaluation Cooperation) and chair the IAEA CRP on the Improvement of the Standard Cross Sections.

Add remaining experimental data for use in the standards evaluation to the database.

Complete examination of discrepant (inconsistent) data in the experimental database that will be used for the evaluation.

Work with the CRP to perform a comprehensive evaluation of the standards.

Provide standards and uncertainties for the ENDF/B-VII library.

Complete work on understanding the uncertainties obtained from the standards evaluation.

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

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

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. With the IAEA, planned, developed the agenda for, and chaired the third IAEA CRP Research Coordination Meeting (RCM). Wrote (with the IAEA) the Summary report of the Third RCM on Improvement of the Standard Cross Sections.

- Added the remaining experimental data for use in the standards evaluation. All acceptable experimental data are now in the evaluation for the standards.

- Completed the examination of experiments containing discrepant data. Medium energy range correlations were used in this analysis.

- A detailed procedure was established and implemented for doing the evaluation of the standards, taking into account differences obtained between the EDA and RAC R-matrix evaluations. This procedure involves a combination of the results of R-matrix evaluations, experimental data and a thermal constants evaluation using GMAP

- Interim standards for the most important standards were provided at the November CSEWG meeting for use in the ENDF/B-VII library. The covariances for the standards are nearly completed

- The covariance work has led us to a better understanding of the uncertainties obtained from the standards evaluation. Larger uncertainties compared with the ENDF/B-VI evaluations have been obtained. The importance of considering the covariances, not just the variances, is stressed for any discussion of uncertainties.

- We continue to recommend new measurements. Though the database is now closed for the present evaluation, work must be continued to improve the database for the next evaluation. We have emphasized the need for additional work on the hydrogen, boron, lithium and fission standards. Also analysis of the 194 MeV hydrogen data obtained at Indiana University continues. At IRMM, new boron measurements both at the Van de Graaff by Hambsch *et al.* and the LINAC by Giorginis *et al.* are underway. Also improved measurements are being made by Zhang *et al.* for the lithium and boron reactions. New fission measurements have been discussed with LLNL and LANL staff. As

new data become available, they will be examined for use in future evaluations of the standards.

- Data taking has begun for the measurements at 15 MeV neutron energy in collaboration with Ohio University and LANL on the hydrogen elastic scattering angular distributions. Very careful background measurements will be required in order to get the small uncertainties desired for this work.

E. <u>Nuclear Model Development</u>

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

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

> **ANL Deliverables**:
> - Assist IRMM in preparing publications to document completed work.
> **Status:**
> - This activity was completed. ANL contributed to a final report to the Nuclear Energy Agency on Subgroup 19 of WPEC that is now in press.

BNL – We are active in nuclear reaction model development focusing on the BNL code EMPIRE. The work in this fiscal year will concentrate on further extensions and improvements of its capabilities, including advanced treatment of the fission channel, preequilibrium emission of clusters, and merging resonance and fast neutron energy ranges. The work on validation of the code will be actively pursued, in particular in relation to emerging requirements for homeland security applications. Close collaboration with LANL will continue focusing on validation of the fission models in EMPIRE and GNASH. New algorithm for calculation of exclusive particle spectra (as required by the ENDF-6 format) will be developed and implemented in the new release of EMPIRE. Interactive and manual search of optical model parameters will be added.

> **BNL Deliverables**:
> Release new version (2.19) of the code EMPIRE with above-mentioned improvements.
> **Status:**
> - New version of EMPIRE-2.19 was released in March 2005. Among the most important improvements are:
>   - Multi-modal fission with multi-humped barriers, applied to ^{232}Th(n,f).

- Preequilibrium emission of clusters using Iwamoto-Harada mechanism.
- Merging of resonance region (MF2) and fast region.
- Improved treatment of exclusive spectra.
- Preliminary version of interactive search of optical model parameters.
- A study was performed to predict neutron induced fission cross sections on a set of Am isotopes. The aim was to provide independent information to T-16 group at LANL to validate their predictions by GNASH code.

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

LANL Deliverables:

Calculate and interpret gamma-ray reactions measured with GEANIE at LANSCE. A current area of research is understanding preequilibrium spin transfer physics, by studying residual nucleus gamma-ray decay cross sections as a "spin window". We will focus on $n+^{90}Zr$ data initially.

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

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

Obtain information on nuclear level densities on some fission product nuclei through $(n,xn\gamma)$ and (n,n') reactions.

Measure the fission neutron spectrum from neutron-induced fission of ^{235}U and ^{238}U with the FIGARO array for neutron energies from 1 to 100 MeV.

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

For Homeland Security attribution users, model and evaluate $^{236}U(n,\gamma)$ reactions, based in part on new DANCE measurements, and make these data available to CSEWG.

Status:
- The calculation and interpretation of the $^{40}Zr(n,n'x\gamma)$ reaction and reactions producing unstable products have been completed. A modern

technique that includes spin-physics in the preequilibrium process gives a good agreement with the GEANIE data. The technique has also been applied to ^{48}Ti(n,n'xγ) data.

- We have developed a new technique to calculate a correlated neutron emission for prompt fission neutrons, using Monte Carlo methods.
- Radiative capture calculation was performed for ^{234}U in the unresolved resonance region, and compared with DANCE experimental data.
- The fission neutron spectrum from neutron-induced fission of ^{235}U and ^{238}U was measured with the FIGARO array for neutron energies from 1 to 200 MeV and compared with the Los Alamos model and with extensions of this model by the CEA-Bruyeres-le-Chatel.

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

TUNL Deliverables:
New release of PRECO and its users manual
An expanded dataset of spectra for (N,N) reactions at incident energies of 40 to 100 MeV.
Possible revisions to the models and/or global input set and thus to the code.
Status:
- A major article on reactions with complex particle channels was completed and published in Physical Review C.
- Results on isospin conservation in preequilibrium reactions were put into the context of other work on isospin conservation. Present results represent the most comprehensive study of isospin in preequilibrium reactions.
- An article on isospin conservation was written and published in Physical Review C.
- Earlier work on including the configurations that were previously missing in the residual nucleus state densities was extended to complex particle channels. A comprehensive comparison with measured inclusive continuum energy spectra led to minor adjustments in standard default model parameters. This work solves a long-standing problem with reproducing observed spectral endpoints in (p,xn) and (n,xp) reactions.
- An article describing the work on the missing residual nucleus states was written and submitted to Physical Review C.

- Calculations to estimate deuteron, triton and He-3 production were performed in support of an evaluation of neutron induced reaction on the tungsten isotopes being completed in Vienna.

F. Nuclear Reaction Data Measurements

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

> **LANL Deliverables:**
> Complete the experiment and analysis of prompt neutron emission following interactions of fast neutrons with ^{99}Tc gated by gamma rays in the residual nuclei.
> Measure prompt gamma rays from neutron interaction with a stable fission product, e.g. molybdenum isotopes and ^{130}Te, with the goal of deducing partial reaction cross-sections.
> Measure the neutron capture cross-section of ^{237}Np at DANCE for neutron energies less than 200 keV.
> Measure neutron capture cross-section at DANCE on at least one radioactive isotope of importance to nuclear astrophysics.
> **Status:**
> - The experimental measurements have been completed on ^{99}Tc and analysis is in progress.
> - Data have been taken in the GEANIE facility on ^{130}Te and ^{100}Mo; they are being analyzed.
> - Data for the neutron capture cross section of ^{237}Np have been taken at DANCE.
> - For astrophysics, neutron capture cross sections on radioactive ^{151}Sm were investigated at DANCE. Results show that the ENDF/B-VI resonance near 0.46 eV does not exist and was mistakenly added from a ^{151}Eu impurity in an experiment from another laboratory.
> - The ^{237}Np neutron capture cross section was measured from thermal to 100 keV at DANCE.

> **LLNL Deliverables** (funded with non-USNDP funds):
> Neutron induced reaction measurements on one or more isomer targets.
> Perform surrogate (n,n'), (n,2n), (n,γ) and (n,f) measurements on several nuclei with programmatic and/or astrophysical importance.
> **Status:**
> - Produced ^{237}U(n,f) measurement using surrogate technique. Result to appear in Phys. Rev. C.

G. Evaluation of Data Needed for Astrophysics

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

ANL – Continue ongoing collaboration with ORNL on the development of methods to handle nuclear data uncertainties in stellar nucleosynthesis calculations.

> **ANL Deliverables**:
> - Assist in preparing publications to document completed work.
> **Status:**
> - There was no activity in this area during FY05 and hence no publications were prepared.

BNL – In support of the increasingly sophisticated nuclear data needs for astrophysics, NNDC is involved in a joint project with VNIIEF, Sarov, Russia, and ORNL to compile and evaluate alpha-induced nuclear reaction cross sections for astrophysics. The work is expected to be partially funded by the U.S. Civilian Research and Development Foundation, and will focus on nuclei with $8 < Z < 32$ and alpha particles with an incident energy below 20 MeV. These reactions are important in the helium burning stage of stars, novae, and supernovae events. Compilation of (α,α), (α,n), (α,p) and (α,γ) data should be completed in FY2004. These data should be analyzed, used to deduce optical model potential parameters and validate cross sections obtained by model calculations.

> **BNL Deliverables:**
> Deduce α-nucleus optical mode potential and calculate cross sections for reactions (α,α), (α,n), (α,p) and (α,γ) for $8 < Z < 32$.
> **Status:**
> - Due to staff retirement the planned calculations were not pursued. The project was completed by delivering compilations that were reported in a poster at ND2004 conference (Santa Fe, 2004), published in the Proceedings 2005.

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

> **LANL Deliverables:**
> Continue N-N analysis to energies above 50 MeV and provide evaluated n-p capture cross-section, rates, and uncertainties.
> Perform analyses of other processes important to Big Bang nucleosynthesis and provide S-factors and reaction rates. Work on the t+α capture will be

completed, and cross sections and rates for ^{7}Li-abundance reactions ^{7}Li(p,α)^{4}He, ^{7}Li(p,n)^{7}Be, and ^{7}Be(n,p)^{7}Li will be updated.

Complete the re-analysis of ^{12}C(α,γ)^{16}O, using an improved description of photon channels in order to determine the extrapolated cross section at astrophysically relevant energies.

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

Continue analyses of reactions involving radioactive light isotopes, especially those being measured at the HRIBF in Oak Ridge.

Complete neutron-rich fission barrier calculations (Moller), using new and improved multidimensional macroscopic-microscopic fission model.

Status:
- The N-N analysis up to 20 MeV has been submitted to the ENDF standards evaluation, but the extension to higher energies has not been completed.
- R-matrix analysis for ^{7}Li(p,α), (p,n), (p,d), ^{7}Be(n,α), (n,p), (n,d), and 6Li(d,a), (d,p), (d,n) has been completed, and the results were converted into the ENDF format.
- The folded Yukawa macroscopic-microscopic code including an axial-asymmetry shape-degree of freedom was used to calculate and analyze barriers for nuclides important in "termination of r-process". Calculated potential energy surfaces for the inner barrier region for more than 3000 nuclei in the region 190<A were made.
- Existing data for the ^{12}C(α,γ)^{16}O reaction were reanalyzed using the constraint from measuring the asymptotic normalization constant in the sub-threshold (-45 keV) 1$^-$ level in ^{16}O while fitting the other data in the system.
- No new work this year for the TUNL Energy Levels of Light Nuclei project.

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

McMaster Deliverables:
Evaluate the reaction rate of radiative proton capture on ^{25}Al and ^{13}N.

Re-evaluate the rates of the ^{21}Na(p,γ)^{22}Mg and ^{18}Ne(α,p)^{21}Na reactions as current experiments progress.

Status:
- All published data to date on the ^{25}Al(p,γ)^{26}Si and ^{13}N(p,γ)^{14}O reactions have been compiled and evaluated. The corresponding reaction rates have been calculated, and in particular the ^{13}N(p,γ)^{14}O reaction rate has already been fitted with the aid of the computational software suite for nuclear astrophysics (www.nucastro.org) created by ORNL.

ORNL – Evaluate capture reactions on radioactive proton-rich nuclei that are important for element synthesis and energy generation in stellar explosions. Develop online software tools for nuclear astrophysics data that process nuclear reaction information.

ORNL Deliverables:
Complete evaluations of proton capture on ^{18}F.
Continue assessments of capture reactions on ^{33,34}Cl and ^{30}P.
Develop software suite to determine astrophysical reaction rates from cross sections, S-factors, and nuclear structure data.

Status:
- The evaluations of ^{18}F$(p,\alpha)^{15}$O and ^{18}F$(p,\gamma)^{19}$Ne reactions are being updated to include latest information from a new FY05 measurement of ^{18}F(p,α). A paper for the measurement is in preparation and will be part of a Ph.D. thesis for a graduate student. A paper for the evaluations of the ^{18}F+p reactions is in final editing before submission to PRC; a second paper describing the astrophysical implications of the new rate is in progress; numerous presentations on conference proceedings discussed this work, including the APS DNP and Spring meetings and 3 invited international symposia.
- Two new measurements of ^{17}O+p reactions – one of (p,γ) and another of (p,α) – combined with some theoretical work on the importance of these reactions, motivated us to shift effort to look at this hot topic. We have performed a series of measurements of ^{17}O(p,α) and now have the highest precision measurement of a new resonance, as well as an excellent measurement of the resonance strength. This work is being folded in with the other recent results in an evaluation by a graduate student as part of a Ph.D. thesis.
- Continued progress on analysis of ^{30}P$(p,\gamma)^{31}$S reaction and ^{31}S levels for stellar explosion studies, folding in a reanalysis of the data from an 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. LANL will collaborate in order to provide key reaction cross-sections using theory calculations and measurements to evaluate the data.

LANL Deliverables:
Because of insufficient support in our program, we are unable to provide nuclear data for RIA target design in FY05. However, we will continue to maintain a presence in the RIA planning community via participation in RIA meetings and workshops.

Status:
- We have participated in RIA meetings but we have not had sufficient resources to contribute to RIA target design in FY05.

- New versions of spallation and fission model codes, CEM and LAQGSM have been released.
- Neutron capture calculations were done for some important s-process branching points. The cross sections obtained were compared with the ENDF and other evaluations.

Appendix A

Nuclear Data Activities Funded from Sources Outside the Nuclear Data Program (Report FY05)

ANL – Additional support for the ANL Nuclear Data participants comes from an ANL LDRD project related to the development of a gamma-ray tracking detector system. The project expired at the end of FY05.

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

1. Elsevier supports the production of computer-generated photo-ready copy of manuscripts for the Nuclear Data Sheets.

2. DOE Nuclear Criticality Safety program, funded by DOE NNSA, supports the NNDC consultant services and its data development work on improved fission products evaluations.

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

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

2. AFCI (Advanced Fuel Cycle Initiative). This supports the development of improved nuclear data important for transmutation in the fast neutron energy region, as well as high-energy spallation models important for describing processes in the spallation target. Recent focuses have been improved ENDF data on minor actinides (ATW fuel), and lead and bismuth (target/coolant), as well as better intra-nuclear cascade codes for modeling neutron production and radionuclide production in the spallation target. This program

also supports experimental nuclear reaction measurements at LANSCE for both fission and capture cross sections.

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

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

LBNL – Members of the Isotopes Project have always been encouraged to spend a portion of their time working on experiments in the area of low energy nuclear physics. Our Post-doctoral associate will spend 50% of his time working on experiments, primarily at the 88" cyclotron, until that appointment expires half way through the FY. Planned activities include the continuation of the measurement of the half-life of ^{108m}Ag, additional total (n,γ) cross section measurements in collaboration with the Budapest group at the Budapest reactor, and the continuation of neutron activation analysis experiments using a neutron generator at LBNL. Support for these activities is drawn from the DOE low-energy nuclear physics component of our budget.

- Cross section data were measured and data analysis is in progress for the reaction ^{64}Zn(α,γ).
- Measured fast and thermal neutron fluxes from the LBNL neutron generator.
- Continued data taking for ^{108m}Ag half-life measurement.
- Continued investigation of means to identify fissionable material using neutron bombardment and detection of delayed photons for sea-cargo screening.
- Initiated a collaboration to examine the possible inter-relation between the disappearance ~13,000 years ago of both the mammoths and the Clovis people who hunted them and the effects of a debris cloud that may have impacted Earth in the Hudson Bay area at that time following a possible near-earth supernova explosion ~40,000 years ago.
- Continued to participate in an IAEA-CRP on "New Applications of Prompt Gamma Neutron Activation Analysis".

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 47% of the total support for the program.

2. NIST provides 1 FTE for interferometry work, which has yielded coherent scattering lengths (which provide scattering data) needed for neutron cross-section evaluations.

3. NSF provided 1 FTE for a graduate student to work on the interferometry experiments cited above.

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

ORNL – The nuclear data work is partly funded by the 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 (Report FY05)

Coordinating Committee (chair P. Oblozinsky, BNL)

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

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

USNDP Work Plan for FY 2007

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Introduction (Work Plan FY07)

The work plan described in this document has been developed to cover work to be done by the United States Nuclear Data Program (USNDP) during fiscal year 2007 that begins on October 1, 2006. Previously, 7 work plans have been prepared for the data program covering fiscal years 2000 - 2006. This plan has been prepared in consultation with the members of the Coordinating Committee who represent the organizations participating in the program. Each Coordinating Committee member prepared a draft plan for his or her organization. Each contribution was integrated into a unified work plan. The draft plan was then circulated to the Coordinating Committee for comments and corrections before the final document was submitted to the Department of Energy.

As was the case in the work plan for FY2006, the tasks proposed by the various organizations were reviewed internally according to the following criteria which were developed considering the mission and goals outlined in past review panel reports and oversight committee discussions, and in consultation with the DOE program manager.

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

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

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

The following section details the proposed work plan for FY2007, defining tasks, organizational responsibilities, and planned activities. It is envisioned that this document will serve as the basis for a performance review at the end of fiscal year 2007. Since the Idaho group is down to 0.2 FTE level and is supported by the NNDC, it has been incorporated in the NNDC plan.

The major challenge for the USNDP is the current and projected funding situation. In FY06, the program is losing considerable portion (almost 7%) of its funding. Assuming flat-flat scenario for FY07 means that in 2 years the program will effectively lose around 15% of funding when 4% cost increase per year is taken into account. The impact on the program is discussed below.

Table 5 summarizes the US Nuclear Data Program metrics for previous years and provides projections for the current year FY2006 and for FY2007.

Table 5. US Nuclear Data Program Metrics for FY 2001 – 2007, for definitions see p.7.

Fiscal Year	USNDP Funding	Compilations	Evaluations	Dissemination (in thousands)	Reports	Papers	Invited Talks
2001		7,139	334	667	21	25	22
2002	$4,890k	6,159	300	799	23	40	22
2003	$4,932k	4,975	260	966	27	40	23
2004	$5,015k	6,241	276	1,212	35	36	43
2005	$5,437k	6,623	422	1,642	72	59	42
2006*	$5,081k	5,200	300	1,850	40	40	40
2007**	$5,081k	4,900	270	2,150	40	35	40

*) Tentative
**) Projected (assuming flat-flat budget scenario)

The sharp decrease in FY06 and FY07 compilation is due to reduced activity in NSR bibliography compilation, to be compensated by a new effort at the IAEA Vienna. The sharp decrease in evaluations reflects an expected return to standard productivity, with FY2005 being considered exceptional due to ENSDF super-heavies and due to the large number of evaluations for new ENDF/B-VII library. Continuing growth in dissemination is expected to slow down to an annual growth rate of 15-20%.

A comment on the FY2006 Work Plan seems to be appropriate. In that Work Plan, the projected staff reduction was estimated to be 2.0 FTE, with the most significant reductions expected at BNL, LANL and TUNL. The expectation was that these decreases would be partially offset by increases in staff at LBNL and ORNL. An approximately 47% cut in the funding in the "Universities" category that includes McMaster University, NIST and TUNL was not reflected in that plan. However, given that compilation and evaluation have been given the highest priority in the President's FY2006 budget proposal, it seemed clear that the nuclear modeling work at TUNL and the neutron reaction standards effort at NIST would not be carried out without additional funding. Furthermore, the nuclear astrophysics effort at McMaster would be discontinued when the three-year contract terminates in FY2006.

Table 6. USNDP scientific effort: Projected levels in FY 2007 compared with FY 2005.

Activity	2005	2007	Comment
I. NNDC Operation	1.20	1.10	Reduced effort in BNL
II. Coordination	1.56	1.37	Reduced effort in several laboratories
III. Databases	1.90	1.40	Reduced effort in BNL
IV. Dissemination	3.46	2.56	Reduced effort in ORNL and LBNL
V. Nuclear Structure	8.15	8.17	Stable effort due to priority given to ENSDF evaluations
VI. Nuclear Reactions	5.46	4.00	Reduced effort in several laboratories, reduction may still increase if TUNL and NIST will not be funded
Total FTE scientific	**21.73**	**18.60**	Loss of 15%

Detailed FY2007 projection of staffing levels is given at the end of the present document. Here, we focus on the scientific effort, representing its most important aspect. Projected scientific staffing levels in FY 2007 are summarized in Table 6 where comparison with final FY2005 is made. The DOE-SC supported scientific and professional effort should decrease more than 15%, by 3.1 FTE (from 21.7 in FY05 to 18.6 in FY07). This may still be optimistic forecast since Table 6 assumes that both NIST and TUNL reaction effort will continue on FY05 level.

This reduction in scientific staffing level will have dramatic negative impact on the program. Individual laboratories foresee the following impact:

- **BNL.** The NNDC will lose 1 FTE in FY06-FY07. This will have negative impact on maintenance of ENDF checking codes, assembly and testing of ENDF/B-VII library, USNDP coordination and reporting and on NSR bibliography compilation (partly offset by shifting compilation of 3 major European journals to the IAEA). An overall reduction of productivity will have negative impact on the currency of databases, some urgent data needs, such as covariance data, will be very difficult to address.

- **ANL.** The ANL LDRD project that provided additional funding to support 1 FTE staff at ANL expired at the end of FY05. The ANL staff will have to seek additional funding in FY06-07, presumably from other programs, in order to compensate the shortage. Future reduced support to the ANL staff would have negative impact on travel to professional conferences and meetings, and on the nuclear structure data evaluation productivity.

- **LANL.** LANL effort will be reduced by 0.3 FTE. We will not be able to hire Post-Docs. Without a new generation of staff for nuclear data measurements and evaluations, the nuclear data activities will slow down, representing a long-standing problem for the USNDP. New measurements and evaluations will also slow down. All these factors will have considerable negative impact on LANL scientific activities as well as other DOE programs that require high quality nuclear data.

- **LBNL**. To accommodate laboratory-mandated increases in salary and overhead, flat-flat funding would probably necessitate a cut of 0.2-0.3 FTE. This would reduce evaluation productivity and could also adversely affect the longer-term functionality of the group.

- **McMaster.** McMaster University will lose 0.5 FTE of DOE supported activity on June 30, 2006. That implies discontinuation of nuclear astrophysics data evaluation effort at McMaster.

- **NIST.** The NIST Neutron Cross Section Standards effort would have to be discontinued if DOE funding is stopped in FY06-FY07. Maintaining this work is important for future standards evaluations that are the basis for cross section libraries. NIST resources that provide leverage to the DOE funding for this work are contingent on DOE support.

- **ORNL.** Due to budget cuts, the ORNL Nuclear Data Project has already lost 3 part-time participants (a consultant, a research staff member, and a graduate student) in the Nuclear Data project in FY06, and will lose one additional part time participant (a research staff member) and 2 full time participants (a graduate student, a programmer) in FY07. Further development of the interface of ENSDF to RADWARE has already been terminated; the nuclear astrophysics online computational suite is at risk of being taken offline in FY07; and reaction evaluations for astrophysics have been reduced.

- **TUNL.** While the nuclear modeling effort at TUNL is shown in the staffing table as continuing at the 0.4 FTE level, there have been indications that this task may be terminated during FY06. The amount of work that will be accomplished in either FY06 or FY07 is directly proportional to the funding available, since virtually all of the funding is for personnel, and all funding for this task currently comes from the U.S. Nuclear Data Program.

Work Plan Tasks and Planned Activities (Work Plan FY07)

I.   NNDC Facility Operation (Work Plan FY07)

A. <u>Management</u>

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

B. <u>Library</u>

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

C. <u>Computer Operations</u>

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

> **BNL Planned Activities:**
> Scan and remediate regularly vulnerabilities on NNDC servers and clients to ensure compliance with DOE cyber security requirements
> Purchase and install a new and powerful Dell server for time-consuming cross-section covariance calculations using Empire-Kalman code system, to be developed by BNL-LANL collaboration.
> Provide computer support to the NNDC staff and its visitors as necessary.

II.   Coordination (Work Plan FY07)

A. National Coordination

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

>   **ANL Planned Activities**:
>   Organize and chair the CSEWG Measurement and Basic Physics Committee.

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

>   **BNL Planned Activities:**
>   Prepare FY2008 work plan for USNDP in time for spring 2007 FWP
>   submittals.
>   Organize and chair CSEWG Meeting at BNL in November 2006.
>   Organize and chair USNDP Meeting at BNL in November 2006.
>   Edit and publish summary reports of the CSEWG and USNDP meetings.
>   Edit and publish USNDP Annual Report for FY 2006.
>   Maintain CSEWG and USNDP websites.

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

>   **LANL Planned Activities:**
>   Organize and chair CSEWG Evaluation Committee meeting at BNL,
>   November 2005.
>   Organize and chair Nuclear Reaction Working Group meeting at USNDP
>   meeting in November 2005, and help coordinate Homeland Security,
>   Astrophysics, and RIA Task Forces.

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

>   **LBNL Planned Activities:**
>   Organize and chair Nuclear Structure and Decay Data Working Group
>   meeting at USNDP meeting, November 2006.

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

> **LLNL Planned Activities**:
>> Organize and chair the CSEWG Task Force on Nuclear Data Needs for Homeland Security.

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

> **ORNL Planned Activities:**
> Summarize USNDP efforts in nuclear data for nuclear astrophysics at USNDP Meeting in November 2006
> Communicate current efforts and future plans with researchers in nuclear astrophysics data.
> Initiate collaborative research projects to raise the visibility of nuclear data projects directed at astrophysics applications
> Discuss future plans in nuclear astrophysics data with DOE and with USNDP/NNDC.

B. International Coordination

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

> **ANL Planned Activities**:
> Participate in IAEA CRP on "Updated Data Library for Actinides".
> Participate in the 2007 NSDD meeting.

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

> **BNL Planned Activities:**
> Participate in the IAEA-sponsored NRDC meeting in 2007.
> Participate in NEA WPEC annual meeting in 2007.

Serve as coordinator of the WPEC Subgroup 23 on fission product neutron cross-section library.

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

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

LANL Planned Activities:

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

Participate in NEA-WPEC 2007 meeting.

Participate in relevant IAEA CRP meetings (Th-U fuel cycle, and RIPL-3).

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

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

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

LBNL Planned Activities:

Participate in IAEA-NSDD 2007 meeting.

Participate in IAEA CRP on "Reference Database for Neutron Activation Analysis".

Participate in new non-US evaluator training and mentoring as needed.

III.   Nuclear Physics Databases (Work Plan FY07)

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

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

> **BNL Planned Activities:**
> Database distributed to collaborators monthly.

B. <u>Experimental Nuclear Structure Data</u> (XUNDL)

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

> **BNL Planned Activities:**
> Update database as input is received from McMaster.

C. <u>Evaluated Nuclear Structure Data File</u> (ENSDF)

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

> **BNL Planned Activities:**
> Database distributed to collaborators twice a year.
> Process evaluations received from NSDD evaluators.

D. <u>Numerical Nuclear Data File</u> (NuDat)

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

BNL Planned Activities:
Update NuDat database as necessary, about 10 times a year.

E. Neutron Reaction Data Bibliography (CINDA)

The NNDC is responsible for the CINDA database that contains references to nuclear reaction data in the published and unpublished literature. Since 2004, CINDA also contains bibliography information on charged-particle and photonuclear reactions. The database serves as an index to the data contained in the experimental database, CSISRS. The database is updated regularly.

BNL Planned Activities:
Update CINDA database with references from the cooperating centers (500 expected), to be done automatically from the CSISRS database.

F. Experimental Reaction Data File (CSISRS)

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

BNL Planned Activities:
Update CSISRS with EXFOR compilations from cooperating centers (500 expected).

G. Evaluated Nuclear Data File (ENDF)

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

BNL Planned Activities:
Maintain ENDF discussion list to facilitate validation of new ENDF/B-VII library.
Complete phase1 testing of the ENDF/B-VII library.
Complete assembly and release of the ENDF/B-VII library.

H. Database Software Maintenance

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

BNL Planned Activities:
Re-write the selector generation program for NSR.

J. Database Systems Development

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

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

BNL Planned Activities:
Continue development of journal tracking database in support of NSR compilation.
Continue development of java-based publication codes for ENSDF.
Develop new CSISRS web interface for users without specialized knowledge of ENDF.
Develop new ENDF web interface for users without specialized knowledge of ENDF format.

IV. Information Dissemination (Work Plan FY07)

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. <u>Web Site Maintenance</u>

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

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

BNL Planned Activities:
Improve NSR and ENSDF web interfaces.
Maintain web interface to the ENDF database.
Improve web interface for B(E2) and develop interface for double-beta decay.
Replace Perl-based programs with Java versions.
Improve reliability and cyber security of its web services by installing the
    latest version of Apache/Tomcat servers and mod-jk2 connector software
    for a new dual web server system.
Maintain currency of the CSEWG, USNDP and the NNDC web sites.

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

LBNL Planned Activities:

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

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

LLNL Planned Activities:

Maintain LLNL's Nuclear and Atomic Data Viewer.

Add search capability to the Nuclear and Atomic Data Viewer.

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

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

ORNL Planned Activities:

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

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

TUNL Planned Activities:

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

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

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

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

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

B. Customer Services

This task accounts for the non-electronic services which the USNDP renders to customers. At the scientific staff level, this means direct assistance to users needing advice from nuclear data experts or advice on solving complex queries *via* electronic access to the database. The NNDC

staff allocation at the support level is for maintaining a "help desk" and for administrative/clerical support of its customer services.

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BNL Planned Activities:
Effort required to provide technical support to users as necessary.
Extend Comments/Questions option for all reaction databases.

C. Publications

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

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

V. Nuclear Structure Physics (Work Plan FY07)

A. NSR Abstract Preparation

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

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

BNL Planned Activities:
Prepare entries for 4,100 new references, and keyword abstracts for 2,200 of them.
Check and edit approximately 1,000 key-worded abstracts (Nucl. Phys. A, Eur. Phys. J. A, and Phys. Lett. B) prepared at the IAEA Nuclear Data Section.

B. Compilation of Experimental Structure Data

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

BNL Planned Activities:
Compile BE(2) experimental data.

McMaster Planned Activities:
Compile data sets (in ENSDF format) for current experimental nuclear structure publications on high-spin and low-spin physics.
Review compiled data sets submitted by other data centers prior to inclusion in the XUNDL database.
Communicate with the authors of the original papers for data-related problems and to request additional details of unpublished data. On a timely basis send a copy of all such private communications to NNDC for archival and distribution purposes.
Train a new undergraduate student in early 2007 for XUNDL compilation work.

ORNL Planned Activities:
This activity will be terminated at ORNL.

C. Data Evaluation for ENSDF

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

ANL Planned Activities:
1.5 equivalent mass chains will be evaluated and published.
At least one mass chain will be reviewed.
 Complete the horizontal evaluation on nuclear K-isomers and initiate drafting of a final publication.
Collaborate with evaluators from new evaluation centers.

BNL Planned Activities:
At least 5 equivalent mass chains will be evaluated.
At least 6 mass chains will be reviewed.
Continue mentoring of 3 new ENSDF evaluators.

LBNL Planned Activities:
Evaluate the equivalent of at least 4 mass chains, including a minimum of one from the A=24-30 region.
Review mass-chain evaluations, as requested.
Participate in training and/or mentoring of new nuclear structure data evaluators, as needed.

McMaster Planned Activities:
1.5 equivalent mass chains (including one in the A=31-44 region) will be evaluated.
Mass chains will be reviewed as requested.
Update superdeformed-band data in ENSDF for new publications. All nuclides will be covered that do not require extensive updating and reevaluation for data sets involving low-spin or non-SD structures.
Collaboration with a new center/evaluator as part of mentoring process as needed.

ORNL Planned Activities:
Complete evaluation of structure information for nuclei with A=248 and 246.
Start evaluations of A=242 and 247 nuclei.

TUNL Planned Activities:
Prepare the ENSDF files corresponding to new publications in the "Energy Levels of Light Nuclei" series.

D. Ground and Metastable State Properties

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

BNL Planned Activities:
Update database as new information becomes available.

E. Radioactive Decay Data Evaluation

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

ANL Planned Activities:
Evaluation of two radionuclides will be carried out as a part of the ANL contribution to the IAEA CRP on "Updated Decay Data Library for Actinides". The data will be made available to ENSDF and DDEP databases. Reviews for selected isotopes will be performed, as requested.

LBNL Planned Activities (no cost to Data Program):
Coordinate and plan activities of this international collaboration.
Review the evaluations of about five radionuclides.

McMaster Planned Activities:
Evaluate decay datasets for one or two radionuclides.

F. Neutron-Induced γ-Ray Data Evaluation

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

experimental and calculated data will constitute a valuable resource required for updating the ENDF database. Additionally, delayed photon data need to be added to EGAF. The k_0-value database currently used by the neutron activation analysis community needs to be assessed and compared with the corresponding decay information in ENSDF, and the resulting evaluated k_0 values then need to be integrated into EGAF and, ultimately, made available to ENSDF evaluators.

LBNL Planned Activities:
Continue to maintain and develop EGAF database:

(i) Continue collaboration with LLNL (see also Section VI.B) to perform statistical-model calculations of quasi-continuum γ-ray cascade information; in FY07, these calculations will be extended to the heavier elements. This project also includes supervision of a doctoral student at LLNL who is generating ENDF-format capture γ-ray datasets for use with MCNP and other transport-code calculations.

(ii) Add to EGAF the neutron-capture decay data produced in the course of participating in the IAEA CRP on "Reference Database for Neutron Activation Analysis"; in FY07, the evaluation of k_0 values should be finalized.

(iii) Add any new thermal (n,γ) data that become available, along with any total radiative-capture cross-sections derived from them.

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

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

TUNL Planned Activities:
Prepare *"Energy Levels of Light Nuclei, A = 11 - 12"* manuscript for publication in *Nuclear Physics A*.
Evaluate nuclei in the $A = 13 - 15$ mass region in preparation for a future *"Energy Levels of Light Nuclei, A = 13 - 15"*.

H. Nuclear Structure Data Measurement

ANL - ANL will devote a relatively small effort (0.1 FTE) at participating through collaborative agreements in experimental nuclear physics activities related to nuclear data. The emphasis will be on measurements aimed at providing answers to specific questions that arise from recent nuclear data evaluations and at improving the quality of existing databases in specific areas. This small effort will complement the main ANL evaluation activities and it will allow maintaining contacts with a broad range of nuclear data user communities

ANL Planned Activities:

Complete decay data measurements on ^{244,245,246}Cm as a part of the ANL contribution to the IAEA CRP on "Updated Decay Data Library for Actinides".

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

LANL Planned Activities:
Examine prompt gamma-ray emission data from neutron reactions on Xenon and Krypton isotopes to search for previously unobserved transitions in these and other, nearby residual nuclei.
Interact with mass chain evaluators on the nuclear structure of these nuclei.

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

LBNL Planned Activities:
Investigate feasibility of (n,γ) measurements at thermal energies for ^{17}O and/or ^{18}O targets and initiate isotopic measurements for the noble gases.
Continue collaboration on study of ^{100}Tc decay; this is of interest because of the importance in reactor physics of the ^{99}Tc(n,γ) reaction.

I. ENSDF Physics and Checking Codes

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

BNL Planned Activities:
Maintenance and upgrades for format changes as required.
Continuing development of ENSDF editor as well as Java versions of LOGFT, BrIcc, ALPHAD and FMTCHK.

VI.   Nuclear Reaction Physics (Work Plan FY07)

A. <u>Experimental Data Compilation</u>

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

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

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

> **BNL Planned Activities:**
> > Compile experimental data from 200 charged particle and neutron reaction publications.

B. <u>ENDF Evaluations</u>

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

> **ANL Planned Activities**:
> > No work planned for FY2007.

> **BNL Planned Activities:**
> > Respond to user needs for evaluated nuclear reaction data.
> > Collect and address users' feedback related to the ENDF library.
> > Work with LANL to complete upgraded evaluations for ENDF/B-VII, to be released in December 2005.
> > Develop methodology for providing covariance data, in the fast neutron energy region, to the next release of ENDF.

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

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

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

Assess ENDF evaluated data files for Ti and V, and upgrade the data if needed.

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

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

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

Produce new evaluations of Pu isotopes based on study of systematics in this mass range.

First release of structure based data representation specification to nuclear data community.

Develop predictive model for fission energy distributions. Compute fission fragment energies, gamma energy and multiplicity distributions both versus incident neutron energy.

Re-evaluate d(n,2n).

First principles calculations for $d(t,n)^4He$ and $^6Li(n,t)^4He$.

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

C. ENDF Manuals and Documentation

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

BNL Planned Activities:

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

D. Nuclear Reaction Standards

Nearly all nuclear reaction data measurements are made relative to some reaction standard such as the hydrogen elastic cross section. Maintaining accurate current values for the standard cross sections is the objective of this task, which can be accomplished only through international cooperation. A new international evaluation of the neutron cross section standards was initiated

to provide the improved standards that are needed. This evaluation, which should be completed this year, has been largely performed by an IAEA Coordinated Research Project (CRP) with support, primarily experimental in nature, through the Working Party on International Evaluation Cooperation (WPEC) of the Nuclear Energy Agency and CSEWG.

ANL Planned Activities:
No work planned for FY2007.

LANL Planned Activities:

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

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

Develop a plan with LLNL for measurements of fission cross sections with very high precision and accuracy.

Continue the collaboration with NIST and Ohio University on the measurement of hydrogen elastic scattering angular distributions. This project should be brought to completion in FY07.

NIST Planned Activities:

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

Provide detailed documentation for the standards evaluation process.

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

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

Complete the collaborative measurements with Ohio University and LANL on the measurement of hydrogen elastic scattering angular distributions.

Continue to acquire and monitor samples in the National Repository for Fissionable Isotope Mass Standards. Also make these samples available for loan in physics experiments.

Continue work on a measurement of the ^{6}Li(n,t) standard cross section standard at ~ 4 meV neutron energy using improved fluence determinations based on calorimetry, nu-bar of ^{252}Cf and α-γ coincidences with the ^{10}B(n,α$_1$γ) reaction.

Continue efforts to improve the ^{3}He(n,p) standard cross section using spin-dependent n-^{3}He coherent scattering length work.

E. Nuclear Model Development

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

ANL Planned Activities:
No work planned for FY2007.

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

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

BNL Planned Activities:
Release new version of the code EMPIRE with above-mentioned improvements.
Develop the first version of covariance module in EMPIRE for fast neutrons.

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

LANL Planned Activities:

Calculate and interpret gamma-ray reactions measured with GEANIE at LANSCE. A FY07 area of research centers on neutron reactions on fission products including the noble gases, xenon and krypton.

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

Perform radiative capture calculations on Gd in support of DANCE detector capture measurements, and provide the Maxwellian averaged cross section to s-process study.

Obtain information on nuclear level densities on more fission product nuclei through (n,xγ) and (n,n') reactions. Nuclides in the mass-90 and mass-140 regions will be studied.

Extend the measurements of the fission neutron spectrum and ν-bar from neutron-induced fission of actinides with the FIGARO array for neutron energies from 1 to 100 MeV. We expect to study the target nucleus ^{239}Pu in collaboration with the CEA (France).

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

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

Develop a code to calculate the delayed neutron spectrum, including Los Alamos micro-macroscopic nuclear mass model.

TUNL – Ongoing work involves the development of preequilibrium nuclear reaction models, as well as the improvement and benchmarking of the computer code PRECO. The unique strengths of this program are its ability to describe reactions with complex particles in the exit and/or entrance channel, and the comprehensive nature of the state densities, which contain the effects of shell structure, the pairing interaction and isospin conservation. Preliminary indications are that this task is likely to be terminated for FY06. Should this occur, there will be no planned activities for FY07. Even if funding should continue, the fact that this is basic research makes it difficult to predict how much time and effort a given investigation will take. However, there are a number of key elements that still need to be worked out to capitalize on the strengths of this program. These are mentioned briefly below.

TUNL Planned Activities:

Complete any remaining work on a simple phenomenological model for the breakup of complex projectiles. This is important to make the model suite fully applicable for deuteron, triton and He-3 projectiles at all incident energies and for alpha particles at the higher incident energies.

Evidence exists that fundamental changes in the model parameterization occur for incident nucleons between 100 and 150 MeV. This has been clearly seen in the systematics of continuum angular distributions, and it there is evidence that it may also be represented in the trends of the mean-square matrix elements of the residual interactions bringing about nuclear equilibration. This energy regime needs to be studied in more detail, as it is becoming more important in support of both basic and applied research.

G.   Nuclear Reaction Data Measurements

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

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

BNL Planned Activities:
Participate in (n,n'γ) and fission neutron spectrum measurements at FIGARO at LANSCE.
Participate in the Lead-Slowing Down Spectrometer measurements on ultra-small targets, such as ^{235m}U(n,f), at LANSCE.

LANL Planned Activities:
Measure and analyze prompt neutron emission following interactions of fast neutrons with fission products in the mass-90 and mass-140 regions. These measurements are gated on gamma rays from (n,n'γ) reactions.
Measure the fission neutron spectrum and ν-bar from neutron-induced fission of ^{239}Pu with the FIGARO array for neutron energies from 1 to 100 MeV. Collaborators include scientists from CEA (France).
Measure prompt gamma rays from neutron interactions with stable noble-gas elements, xenon and krypton with the goal of deducing partial reaction cross-sections.
Measure the neutron capture cross-section of ^{241,243}Am at DANCE for neutron energies less than 200 keV.
Measure the neutron-induced fission cross-section of ^{240}Pu and ^{242}Pu up to En = 200 MeV.
Measure the neutron capture cross-section at DANCE for at least one radioactive isotope of importance to nuclear astrophysics.

LBNL encourages members of the Isotopes Project to spend a portion of their time (≤20%) working on experiments in the area of low-energy nuclear physics, with emphasis on experiments related to nuclear data needs.

LLNL Planned Activities (work completely supported from other sources)**:**
- Neutron induced reaction measurements on one or more isomer targets.
- Perform surrogate (n,n'), (n,2n), (n,γ) and (n,f) measurements on several nuclei with programmatic and/or astrophysical importance.
- Perform neutron capture measurements with DANCE array at LANSCE in collaboration with LANL.
- Perform fission cross-section measurements with the lead slowing down spectrometer at LANSCE in collaboration with LANL.

H. Evaluation of Data Needed for Astrophysics

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

ANL Planned Activities:
- No work planned for FY2007.

BNL Planned Activities (largely done by guest scientist not funded by USNDP):
- Perform systematic evaluations of neutron capture cross sections in the energy region of interest for nuclear astrophysics (neutron unresolved resonance region). Produce Maxwellian averages of these data.
- USNDP support to this work will be limited to including the evaluations in appropriate databases and to providing data dissemination.

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

LANL Planned Activities:
- Continue N-N analysis to energies above 50 MeV and provide evaluated n-p capture cross-sections, rates, and covariance data.
- Complete the re-analysis of ^{10}B+n reaction, using a re-constructed set of experimental data including covariance.
- Complete neutron-rich fission barrier calculations, using new and improved multidimensional macro-micro fission model.
- Improve neutron capture models to provide capture cross sections for nucleosynthesis network calculations.

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

McMaster University – Activities at McMaster will terminate on June 30, 2006.

McMaster Planned Activities:
No work planned for FY2007.

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

ORNL Planned Activities:
Complete evaluations of proton capture on ^{17}O and the ^{17}O(p,α)^{14}N reaction for red giant stars.
Continue assessments of capture reactions on p-rich unstable nuclides.
Extract spectroscopic information on nuclei near the N=82 closed shell – 131Sn and 133Sn - from transfer reaction measurements on radioactive Sn nuclei.

I. Reaction Data for RIA Target Design

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

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

Table 7: USNDP Staffing Table in FY2007

Note: BNL includes external 0.7 FTE (0.2 of C. Reich, 0.5 of E. Browne).

	ANL	BNL		LANL	LBNL	LLNL	Mc Master	NIST	ORNL	TUNL	Program Total	
		Sci/Pro	Support								Sci/Pro	Support
I. NNDC Facility Operation	**0.00**	**1.10**	**0.80**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.10**	**0.80**
Management		0.35									0.35	
Secretarial/Administrative Support			0.55									0.55
Library			0.25									0.25
Computer Operations		0.75									0.75	
II. Coordination	**0.02**	**0.60**	**0.00**	**0.40**	**0.30**	**0.00**	**0.00**	**0.00**	**0.05**	**0.00**	**1.37**	**0.00**
National Coordination	0.01	0.30		0.10	0.30				0.05		0.76	
International Coordination	0.01	0.30		0.30							0.61	
III. Nuclear Physics Databases	**0.00**	**1.40**	**1.35**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.40**	**1.35**
Nuclear Science References (NSR)		0.10	0.70								0.10	0.70
Exper. Nucl. Structure Data (XUNDL)		0.05									0.05	
Evaluated Nucl. Structure Data (ENSDF)		0.15	0.65								0.15	0.65
Numerical Nuclear Data (NuDat)		0.15									0.15	
Reaction Data Bibliography (CINDA)		0.05									0.05	
Experimental Reaction Data (CSISRS)		0.10									0.10	
Evaluated Nuclear Data File (ENDF)		0.15									0.15	
Database Software Maintenance		0.40									0.40	
Database System Development		0.25									0.25	
IV. Information Dissemination	**0.01**	**1.00**	**0.25**	**0.10**	**0.10**	**0.00**	**0.00**	**0.00**	**0.75**	**0.60**	**2.56**	**0.25**
Nuclear Data Sheets		0.10	0.15								0.10	0.15
Customer Services		0.15	0.10								0.15	0.10
Web Site Maintenance & Development	0.01	0.75		0.10	0.10				0.75	0.60	2.31	

	ANL	BNL Sci/Pro	BNL Support	LANL	LBNL	LLNL	Mc Master	NIST	ORNL	TUNL	Program Total Sci/Pro	Program Total Support
V. Nuclear Structure Physics	**0.82**	**3.35**	**0.00**	**0.10**	**2.20**	**0.00**	**0.50**	**0.00**	**0.30**	**0.90**	**8.17**	**0.00**
NSR Abstract Preparation		0.45									0.45	
Compilation of Exper. Structure Data							0.15				0.15	
Eval. of Masses & Nuclides for ENSDF	0.62	2.40			1.75		0.33		0.30	0.45	5.85	
Ground and Metastable State Properties		0.15									0.15	
Radioactive Decay Data Evaluation	0.10				0.35		0.02				0.47	
Thermal Capture Gamma Data Eval.												
Light Mass Eval. for Nuclear Physics A.										0.45	0.45	
Nuclear Structure Data Measurement	0.10			0.10	0.10						0.30	
ENSDF Evaluation Support Codes		0.35									0.35	
VI. Nuclear Reaction Physics	**0.01**	**1.60**	**0.00**	**1.10**	**0.00**	**0.30**	**0.00**	**0.20**	**0.40**	**0.40**	**4.00**	**0.00**
Experimental Data Compilation	0.00	0.50									0.50	
Neutron Data		*0.15*									*0.15*	
Charged Particle Data		*0.30*									*0.30*	
Photonuclear Data		*0.05*									*0.05*	
ENDF Manuals and Documentation		0.05									0.05	
ENDF Evaluations		0.60		0.10		0.30					1.00	
Nuclear Reaction Standards				0.10				0.20			0.30	
Nuclear Model Development	0.01	0.25		0.20						0.40	0.85	
Nuclear Reaction Data Measurements		0.10		0.30							0.40	
Astrophysics Nuclear Data Needs		0.10		0.40					0.40		0.90	
Reaction Data for RIA Target Design												
DOE-SC Nuclear Data Funded Staff	**0.85**	**9.05**	**2.40**	**1.70**	**2.60**	**0.30**	**0.50**	**0.20**	**1.50**	**1.90**	**18.60**	**2.40**
Staff Supported by Other Funding		**0.50**	**0.20**	**14.40**		**7.50**	**0.50**	**2.80**			**25.70**	**0.20**
TOTAL STAFF	**0.85**	**9.55**	**2.60**	**16.10**	**2.60**	**7.80**	**1.00**	**3.00**	**2.55**	**1.90**	**44.30**	**2.60**

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Appendix C

Acronyms in the Nuclear Data Program

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

CINDA – <u>C</u>omputer <u>I</u>ndex to <u>N</u>uclear (reaction) <u>D</u>ata
     Bibliography of publications in nuclear reaction physics, primarily for neutrons. Charged-particle and photonuclear added in 2005.
     Emphasis on nuclear data measurements. Entries for each reaction reported in a paper.
     Originated by Prof. Herbert Goldstein, Columbia University, in the early 1960's.
     Input prepared by NNDC in collaboration with NEA Data Bank, Paris, IAEA Nuclear Data Section, Vienna, and Russian Nuclear Data Center (CJD), Obninsk, Russia.
     Database maintained separately by each of the collaborating organizations.
     Database heavily application oriented.

CSEWG – <u>C</u>ross <u>S</u>ection <u>E</u>valuation <u>W</u>orking <u>G</u>roup
     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 – <u>C</u>ross <u>S</u>ection <u>I</u>nformation, <u>S</u>torage and <u>R</u>etrieval <u>S</u>ystem
     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 – <u>E</u>valuated <u>N</u>uclear <u>D</u>ata <u>F</u>ile
     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 – <u>E</u>valuated <u>N</u>uclear <u>S</u>tructure <u>D</u>ata <u>F</u>ile
     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.

The 2nd 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 database.
        The most popular database. 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 Nuclear Data <u>E</u>valuation <u>C</u>ooperation
        Nuclear Energy Agency sponsored effort to improve nuclear reaction data files.
        Use common format, ENDF, invented in the US in the 1960's
        Members are the leaders of 5 major application-oriented evaluated nuclear reaction data
           libraries:

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

XUNDL – <u>Ex</u>perimental <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.