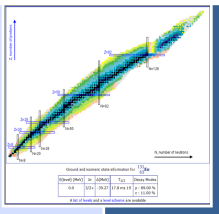
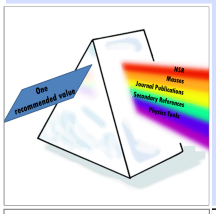
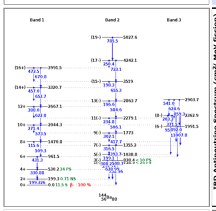
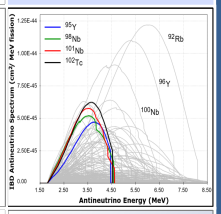
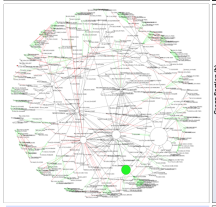
BNL-224258-2023-INRE

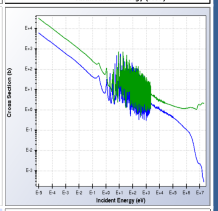


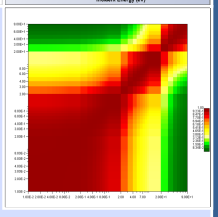












United States Nuclear Data Program

Annual Report for FY2022

This document describes the activities including related metrics performed by the US Nuclear Data Program members during Fiscal Year 2022.

Prepared by
David Brown
National Nuclear Data Center
Brookhaven National Laboratory

With contributions from
Lee Bernstein, UCB/LBNL
Jun Chen, MSU
John Kelley, TUNL
Filip G. Kondev, ANL
Hye Young Lee, LANL
Elizabeth McCutchan, BNL
Ninel Nica, TAMU
Michael Smith, ORNL
Ian Thompson, LLNL

and the entire USNDP

www.nndc.bnl.gov/usndp

BNL

Contents

Acknowledgements

Work at Argonne National Laboratory was sponsored by the Office of Nuclear Physics, Office of Science of the U.S. Department of Energy under Contract No. DE-AC02-06CH11357.

Work at Brookhaven National Laboratory was supported by the Office of Nuclear Physics, Office of Science of the U.S. Department of Energy under Contract No. DE-SC0012704.

Work at Lawrence Berkeley National Laboratory was supported by the Office of Nuclear Physics, Office of Science of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Work at Lawrence Livermore National Laboratory was supported by the Office of Nuclear Physics, Office of Science of the U.S. Department of Energy under Contract No. DE-AC52-07NA27344.

Work at Los Alamos National Laboratory was supported by the Office of Nuclear Physics, Office of Science of the U.S. Department of Energy. Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218CNA000001).

Work at Michigan State University was supported by the Office of Nuclear Physics, Office of Science of the U.S. Department of Energy under Contract No. DE-SC0016948.

Work at Oak Ridge National Laboratory was supported by the Office of Nuclear Physics, Office of Science of the U.S. Department of Energy under Contract No. DE-AC05-00OR22725.

Work at Texas A&M University was supported by the Office of Nuclear Physics, Office of Science of the U.S. Department of Energy under Contract No. DE-FG02-93ER40773.

Work at Triangle Nuclear Laboratory was supported by the Office of Nuclear Physics, Office of Science of the U.S. Department of Energy under Contract Nos. DE-FG02-97ER41033 (Duke University) and DE-FG02-97ER41042 (North Carolina State University).

USNDP Membership

Argonne National Laboratory

Filip Kondev (PI)
Daniel Burdette
Nathan Callahan
Soumen Nandi

Brookhaven National Laboratory

David Brown (PI)
Ramon Arcilla
Allan Carlson (NIST (ret.), contractor)
Emanuel Chimanski
Olena Gritzay
Stanislav Hlavac (contractor)
Sam Kim
Letty Krejci
Amber Lauer-Coles
Donnie Mason
Andrea Mattera
Elizabeth McCutchan
Christopher Morse
Gustavo Nobre
Boris Pritychenko
Shuya Ota
Otto Schwerer (contractor)
Balraj Singh (U. McMaster (ret.), contractor)
Benjamin Shu
Dmitro Symochko (contractor)
JoAnn Totans
Matteo Vorabbi
Jin Wu
Shaofei Zhu (deceased)

Lawrence Berkeley National Laboratory

Lee Bernstein (PI)
Shamsu Basunia
Jon Batchelder (UC, Berkeley)
Bethany Goldblum
Aaron Hurst (UC, Berkeley)
Walid Younes (LLNL (ret.), contractor)

Lawrence Livermore National Laboratory

Ian Thompson (PI)

Los Alamos National Laboratory

Hye Young Lee (PI)
Toshihiko Kawano
Michal Herman
Sean Kuvin
Panos Gastis

Michigan State University

Jun Chen (PI)

Oak Ridge National Laboratory

Michael Smith (PI)
Murry Martin (contractor)
Caroline Nesaraja
Larry Zhang (student)
Eric Lingerfelt (contractor)

Texas A&M University

Ninel Nica

Triangle University Nuclear Laboratory

John Kelley (PI)
Jim Purcell (contractor)
Grace Sheu

I. Introduction

The US Nuclear Data Program (USNDP) Annual Report for Fiscal Year 2022 (FY22) summarizes the work of USNDP for the period of October 1, 2021 through September 30, 2022, with respect to the Work Plan for FY22 that was prepared in 2020. The Work Plan and Final Report for USNDP are prepared for the DOE Office of Science, Office of Nuclear Physics. The support for the nuclear data activity from sources outside the nuclear data program is described in the staffing table and in Appendix A. Much of this is a direct result of NDIAWG associated funding. This leverage is significant in FY22 and amounts to about 14.5 FTE scientific, to be compared with 25.83 FTEs at USNDP units funded by the DOE Office of Science, Office of Nuclear Physics. Since it is often difficult to separate accomplishments funded by various sources, some of the work reported in the present report was accomplished with nuclear data program support leveraged by other funding.

FY22 was the 23rd year in which the USNDP has operated under a Work Plan developed by the program participants. The program continued to carry out important work in support of the DOE mission. The work balances the ongoing collecting, analyzing, and archiving of nuclear physics information critical to basic nuclear research and to the development and improvement of nuclear technologies with the electronic distribution of this information to users in a timely and easily accessible manner. The present section of the report consists of activity summaries for the major components of the USNDP. This is followed by an updated staff level assignment table that reflects the final distribution of effort among the tasks carried out during FY22. Then, we continue with the detailed status of work performed during FY22.

In terms of personnel changes, the USNDP has undergone several changes in FY22:

- Emanuel Chimanski joined the NNDC as a post-doc in April 2022,
- Panagiotis Gastis was converted from a postdoc to staff at LANL in Aug. 2022
- Adam Hayes left the NNDC to work in the private sector in January 2022,
- Samuel Kim joined the NNDC as a post-doc in March 2022,
- Shuya Ota joined the NNDC as scientific staff in May 2022,
- Jagdish Tuli left LBNL as an ENSDF contractor
- Matteo Vorabbi left the NNDC to become a Lecturer at the University of Surrey, UK, in September 2022
- Walid Younes joined LBNL as a Natural Language Processing contractor
- Jin Wu joined the NNDC as scientific staff in September 2022
- Shaofei Zhu passed away in November 2021

Table 1 summarizes the USNDP metrics since 2001. Table 2 shows the breakdown of the metrics by laboratory for the reported fiscal year and comparison with the previous fiscal year. The tables are followed by a definition of each metric and any comments pertaining to the metrics.

Table 1: Summary of the USNDP funding and metrics.

Fiscal year	USNDP funding ($K)	Change (%)	Compilations	Evaluations	Disseminations (in thousands)	Articles	Invited talks
2001			7,139	334	667	25	22
2002	4,890		6,159	300	799	40	22
2003	4,932	+0.9	4,975	260	966	40	23
2004	5,015	+1.7	6,241	276	1,212	36	43
2005	5,437	+8.4	6,623	422	1,642	59	42
2006	5,099	-6.6	4,936	318	1,863	60	48
2007	5,841	+14.6	5,355	366	2,239	56	51
2008	5,967	+2.2	5,104	385	2,996	72	68
2009	6,267	+5.0	4,047	400	3,294	61	56
2010	6,549	+4.5	4,662	395	2,843	83	51
2011	6,534	-0.2	4,662	479	3,252	96	67
2012	6,785	+3.8	5,221	209	3,013	90	48
2013	6,249*	-7.9	4,925	282	3,447	84	79
2014	7,032*	+12.5	3,738	166	3,411	107	81
2015	7,381*	+5.0	4,949	271	4,246	98	50
2016	7,597*	+2.9	3,936	375	4,655	82	72
2017	6,953	-8.5	3,684	404	4,730	95	51
2018	8,496[a]	+22.2	4,097	221	4,722	79	58
2019	8,797[b]	+3.5	3,663	203	5,148	67	60
2020	9,344[c]	+6.2	3,603	159	5,678	63	49
2021	9,435[d]	+0.99	5,380	273	7,297	71	59
2022	10,290[e]	+9.06	3,988	292	9,016	71	71

*: It includes $500K of Early Career Award (LANL).

a: It includes the following (a) FIRE collaboration funding $100 (LLNL), (b) LAB17 call funding: $325K (ANL), $220K (LANL), (c) LAB18 call funding $26K (ANL), $282K (BNL), $120K (LANL), $75K (LBNL), $100K (LLNL), $372K (ORNL).

b: It includes the following (a) FIRE collaboration funding $100 (LLNL), (b) LAB17 call funding: $325K (ANL), $220K (LANL), (c) LAB18 call funding $27K (ANL), $289K (BNL), $120K (LANL), $75K (LBNL), $50K (LLNL), $373K (ORNL), (d) WANDA organization: $25K (ORNL).

c: It includes the following (a) FIRE collaboration funding $100 (LLNL); (b) LAB calls funding: $354K (ANL), $619K (BNL), $120K (LANL), $75K (LBNL), $50K (LLNL) and $375K (ORNL); (c) WANDA organization: $150K (ORNL) and $20K (LLNL).

d: It includes the following (a) FIRE collaboration funding $100 (LLNL); (b) LAB calls funding: $950K (ANL), $717K (BNL), and $173K (ORNL).

e: (b) LAB calls funding: $950k (ANL)

Table 2: USNDP metrics in the last two fiscal years, numbers from the previous fiscal year are shown for comparison.

Laboratory	Compilations		Evaluations		Disseminations (In thousands)		Articles		Invited Talks	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
ANL	0	0	13	12	-	-	14	15	6	5
BNL*	5,291	3,907	181.1	148.5	5,426.5	9015.6	22	20	16	36
LANL	-	-	0.7	26	-	-	8	9	13	7
LBNL	0	0	24.5	22	7.5	7.5	19	20	12	14
LLNL	-	-	0	0	-	-	1	1	6	6
MSU	50	40	25.5	24	-	-	4	4	1	2
ORNL	-	-	8	9	1,979.5	2,983	4	5	5	5
TAMU	3	1	17	17	-	-	5	1	0	0
TUNL	36	40	3	7	40	57	1	0	0	0
Total	5,380	3,988	273	265	7,453.5	7,453.5	71	71	59	71

*: BNL compilations consist of (a) 3,284 NSR articles, including keywords for 2,391 of them; (b) 368 articles for EXFOR; (c) 187 articles encompassing 336 XUNDL datasets. BNL evaluations consist of (a) 139 nuclides for ENSDF and 9.5 for ENDF/B. For the remaining groups, all compilations are for XUNDL, while all evaluations are either ENSDF (ANL, LBNL, MSU, ORNL and TAMU) or ENDF/B (LANL, LLNL).

Metric definitions and comments:

1. **Compilations**: The sum of the new entries added to the USNDP bibliographic (NSR - articles) and experimental databases (EXFOR - reactions, XUNDL - structure data sets). The compilation activities are on a healthy situation, and these databases are updated regularly with newly published material.
2. **Evaluations**: The sum of new evaluations submitted or accepted for inclusion in the USNDP evaluated nuclear databases. For ENSDF, it is the number of evaluated nuclides, while for ENDF, it is the number of evaluated reactions/covariances. There were 230 ENSDF evaluations and 9.5 ENDF/B evaluations submitted. The number of ENSDF evaluations remains well below the number needed, about 340, to evaluate each of the ENSDF nuclides on average every 10 years.
3. **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 accessed is not tallied.
4. **Articles**: The number of articles published in refereed journals. The number of articles per FTE has remained relatively constant in the last few years, but the number of FTEs in the USNDP has grown. A selected list of articles published is given in the Appendix C.
5. **Invited talks**: The number of presentations given at the explicit invitation of the organizers of conferences, symposia, workshops, and training courses. The number of invited talks has not changed significantly from last year's value.

II. Network Coordination and Data Dissemination

The National Nuclear Data Center (NNDC) continues to serve as the core facility of the U.S. Nuclear Data Program (USNDP). It has the main responsibility for national and international coordination, database maintenance, and data dissemination. However, other program participants are also involved in coordination and dissemination activities.

National and International Coordination

The NNDC, while serving as the secretariat for the program, has prepared the Work Plan for this fiscal year in cooperation with the members of the Coordinating Committee. The NNDC Head serves as the chair of the USNDP Coordinating Committee, which consists of the Principal Investigators from each of the participating group and chairs the annual meeting of the program held at BNL. A representative from LANL chairs the Nuclear Reaction Data Working Group, and a representative from TUNL chairs the Nuclear Structure Working Group. ORNL chairs the Astrophysics Task Force.

On February 15, 2022, the DOE Office of Nuclear Physics conducted its annual Budget Briefing. Lee Bernstein, David Brown, Jun Chen, Martin Schoonen, John Kelley, Filip Kondev, Hye Young Lee, Elizabeth McCutchan, Ninel Nica, Michael Smith, Alejandro Sonzogni and Ian Thompson represented USNDP and made the case for the FY24 funding.

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

The NNDC continues to chair the Cross Section Evaluation Working Group (CSEWG), which produces the ENDF/B evaluated nuclear data library for nuclear science and applied nuclear technology use. Due to the ongoing COVID-19 pandemic, the 2021 CSEWG meeting was held virtually but hosted by BNL. The major topics of the CSEWG meeting was feedback on the recently released ENDF/B-VIII.0 library and next release of the VIII.1 version, now scheduled for February 2024. Additionally, there were presentations about the fission yield evaluation project funded by NA-22.

The USNDP also continues to play a leading role in the annual Workshop for Applied Nuclear Data Activities (WANDA) conference series, with the inaugural workshop held in Washington, DC in 2019 organized by LBNL. WANDA 2022 was held virtually with several USNDP members serving as speakers and session organizers.

USNDP Databases

The NNDC operates several Dell servers running the Linux operating system to support its compilation, evaluation, database maintenance, and information dissemination functions. These computers archive and serve the nuclear data produced by USNDP and the data obtained by other national and international collaborations. In addition, the NNDC maintains the collaboration GitLab server that facilitates data and codes development and keeps track of changes. The NNDC maintains seven nuclear physics databases for USNDP, which were updated continuously this fiscal year with new and revised information from efforts of the NNDC, USNDP and international collaborators. Distributions of all or parts of these databases have been made to national and international collaborators as scheduled.

Data Dissemination

There were 9,015 million database retrievals this fiscal year, about 24% higher than the number of retrievals in the previous year. This reflects a significant increase in traffic to the NNDC due to the significant update to NuDat. This increase is all the more impressive when one realizes that several NNDC webapps had to be disabled for cybersecurity reasons.

Major Publications

USNDP continues to publish the refereed journal Nuclear Data Sheet: eight issues were published this fiscal year.

III. Nuclear Structure and Decay Data

The nuclear structure working group emphasizes the evaluation of measured nuclear structure and decay properties for all isotopes. These data are maintained at the NNDC in the Evaluated Nuclear Structure Data File (ENSDF). Production of ENSDF is an international effort operating under the auspices of the IAEA Nuclear Structure & Decay Data (NSDD) network. ENSDF is an important source of information for derivative databases and applications, including NuDat, Nuclear Wallet Cards, RIPL, MIRD and ENDF/B. Evaluations are published as peer-reviewed articles in the Nuclear Data Sheets. The Nuclear Science Reference (NSR) and Experimental Unevaluated Nuclear Structure Data List (XUNDL) databases have been kept current. The combination of ENSDF and XUNDL databases represents a nearly complete literature coverage of experimental nuclear structure data, which is a salient feature of these databases.

In August 2022, a breakout session related to Nuclear Data was part of the Low-Energy Community Meeting; the session featured several presentations from researchers associated with the USNDP and others who are active in the low-energy nuclear physics community. A similar session was requested by the conveners of the "Nuclear Structure, Nuclear reactions and Nuclear Astrophysics" town hall meeting who are gathering community input to guide their writing of the next "Long Range Plan for Nuclear Science". The town hall meeting was organized by community researchers including many from the USNDP, and it comprised a collection of invited and contributed talks.

Status of ENSDF

ENSDF evaluations submitted to the database are consistent with metrics from the previous year, with 224 nuclide submissions. The evaluations were a combination of nuclides resulting from mass chain evaluations (15 mass chains in total) along with single nuclide submissions.

All evaluations were received from USNDP-funded centers, marking a second year with no contributions from the international community. Per the USNDP Nuclear Data Advisory Committee (NDAC) recommendations, USNDP leadership reached out to International Union of Pure and Applied Physics (IUPAP) and presented a case for more international involvement in ENSDF at their annual meeting.

A Nuclear Data Inter-Agency Working Group (NDIAWG)-funded effort to modernize the ENSDF database was initiated in FY21. Since then, a new object-oriented database format based on JavaScript Object Notation (JSON) has been developed to serve as the updated medium for storing ENSDF data. Conversion from the 80-column format to JSON is ongoing, with migration of several types of datasets already completed. In addition, automated validation of the data after conversion is being implemented to ensure the accuracy of the conversion process, with the side effect that many small mistakes in the current files are caught and can be corrected during conversion.

Status of XUNDL

Based on regular scanning of nuclear physics journals, 606 datasets were compiled from 336 articles. The project to compile and carry out physics checks on the data from nuclear structure manuscripts submitted to Phys. Rev. C and European Physical Journal A continues.

Status of NSR

In FY2022, 3,284 new articles were added to the NSR database. USNDP contributions are from B. Pritychenko (manager), J. Totans, B. Singh, D. Symochko (NNDC) with international input from V. Zerkin and L. Vrapcenjak (IAEA). The database is current and in good shape. The number of NSR web retrievals was 1,035,004, a substantial increase over FY21 that reflects a combination of NucScholar related access from LBNL and library scanning activities at BNL.

Horizontal Evaluations and Other Data Related Activities

A summary list of "Horizontal Evaluations and Other Data Related Activities" involving USNDP structure evaluators includes the following:

- ***IAEA-CRP evaluation of fission yields:*** A. Sonzogni, A. Mattera, E. McCutchan, B. Pritychenko, T. Kawano, F. Kondev – continuing.
- ***IAEA-led activities on improving ENSDF codes:*** J. Chen, F. Kondev, B. Singh – continuing.
- ***IAEA-ICTP organized workshops:*** S. Basunia, J. Chen, E. McCutchan, F. Kondev, B. Singh.
- ***The Atomic Mass Evaluation (AME) and the evaluation of basic nuclear physics properties for ground states and isomers (NUBASE):*** F. Kondev – continuing.
- ***Update of r0 radius parameter and revision of ALPHAD-radD analysis code:*** B. Singh. ALPHAD and ALPHAD-RadD codes available in November 2020; even-even r0 parameter evaluation published in NDS (2020Si16). This work was done in collaboration with Drs. S. Singh and S. Kumar, Akal University, India, and with Dr. A.K. Jain, Amity University, Noida, India.
- ***Modernization of ALPHAD-radD analysis code:*** J. Chen, B. Singh. A new Java code AlphaHF developed and completed to replace the legacy ALPHAD-radD fortran, which uses even-even r0 parameters from 2020Si16 in NDS. Update of r0 parameter to include new papers on even-even alpha decays and from 2020 to 2023 and to incorporate data in AME2020 is continuing. The updated evaluation of alpha-decay data for even-even nuclei, and anticipated publication of a paper on updated r0 parameters is being done in collaboration with Drs. S. Singh and S. Kumar, Akal University, India,
- ***IAEA-led decay data library for monitoring applications***: J. Chen, F. Kondev, B. Singh, J. Tuli – continuing.
- ***Compilation of current papers on mass measurements on an annual basis and make data file available on nuclearmasses.org:*** B. Singh. Compiled file for 2020-2022 was submitted Nov 2022 and is available on nuclearmasses.org webpage. Work is continuing for 2023 update.
- ***IAEA-CRP on Delayed Neutron Emission Probabilities***: Reference database at IAEA-NDS: B. Singh, E. McCutchan, A. Sonzogni – completed, two articles published in NDS. Updates for Z>28 region completed in Jan 2021. Update for Z=2-28 nuclei in progress: B. Singh. This work is being done in collaboration with Drs. P. Dimitriou and M. Verpelli, IAEA-NDS.
- ***WalletCraft:*** Object-oriented database for ground and long-lived isomeric properties: E. McCutchan, B. Shu, A. Sonzogni – continuing.
- ***Atlas of Isomers project:*** B. Singh – update of 2015Ja04 Atlas has been completed with updated version to cover literature up to Oct 2022 for isomers of half-life ≥10 ns, in addition to re-evaluation of half-lives and isomer energies. Paper has now appeared in ADNDT (Jan-Feb 2023 issue). This work was done in collaboration with Drs. S. Garg and Y. Sun, University of Shanghai, Dr. B. Maheshwari, University of Zagreb, and Drs. A.K. Jain and A. Goel, Amity University, Noida, India. Work is continuing for isomers in the half-life range of 0.1-10 ns.

- ***Update of 1998Si17 Review of log ft values:*** B. Singh – all the beta decay schemes available up to the December 2022 version of ENSDF and from significant newer literature were considered, updated for AME-2020 Q values. All the files have been run through new BetaShape code for log *ft* values. Filtering codes developed at Dresden have been executed. A paper is nearly ready for submission in February 2023. This work is being carried out in collaboration with Dr. X. Mougeot, CEA, Saclay, Mr. S. Turkat and Prof. K. Zuber, TU, Dresden.
- ***Update of 2000Am02 magnetic dipole rotational bands***: B. Singh – this work has now evolved to compilation of multi-qp high-spin dipole bands with dominant M1 transitions, which is a much larger project - continuing. This work is being done in collaboration with Drs. S. Singh and S. Kumar, Akal University, India, and Dr. A.K. Jain, Amity University, Noida, India
- ***B(E2) project for first 2+ and 4+ states of all the even-even nuclei:*** B. Pritychenko and B. Singh. Work on the first 2+ states was published in 2016Pr01: ADNDT. The on-going project is an update of the 2016 work as well as first evaluation of B(E2) values for the first 4+ to first 2+ states.
- ***Gamma-ray transition probabilities for all experimentally known multipolarities for all the nuclei:*** J. Chen and B. Singh – update of Endt's work of the 70's. This project has started recently and will take two-three years to complete.
- ***Proton Radioactivity:*** B. Singh, J. Chen, A.A. Sonzogni: compilation and evaluation of known 1p and 2p decays of nuclei on drip lines, about 1-2 year project – started Dec 2022.

Status of ENSDF Codes

Jun Chen continues developing new analysis and utility codes used by ENSDF evaluators, and he is implementing modern programming for legacy codes.

Updates continue for the McMaster-MSU JAVA-NDS code that has been used both to produce print-ready documents for the Nuclear Data Sheets and for retrievals of ENSDF data sets at the NNDC website.
The Java toolkit ConsistencyCheck has been developed and completed to ensure evaluation consistency and facilitate evaluation process, and updates and improvements for this code continues.

Java-RULER, a replacement for the legacy FORTRAN RULER program, has been developed. The utility code is used for calculating transition strengths. Updates include an improved Monte Carlo approach for error propagation for large and asymmetric uncertainties.

A new Java code called GLSC (Gamma to Level Scheme Computation) has been developed to replace the legacy GABS and GTOL codes. The Java code has improvements and offers new interactive features for fitting gammas in a level scheme, for calculating level feedings, and for calculating absolute gamma emission probabilities within decay datasets.

The AME-NUBASE viewer has been developed to provide easy and customized retrieval of AME (Atomic Mass Evaluation) and NUBASE (evaluation of ground-state and isomer properties) entries and also to automatically update all Q records in the adopted datasets and all parent Q values in the decay datasets in an input ENSDF file with the latest AME values.

The new Java code RadiationReport has been developed to replace the legacy RADLIST for calculating energies, intensities and doses of all radiations and LOGFT for calculating logft values for a decay dataset.

It can calculate logft values for forbidden-unique decays with order>2 which are incorrectly treated as allowed decays by the legacy LOGFT code.

A new Java code AlphaHF has been developed to replace the legacy ALPHAD-radD for calculating the alpha-decay hindrance factor (HF) and nuclear radius parameter r_0. The new code can deal with asymmetric uncertainties which is lacked in the legacy code and has improved uncertainty propagation. It also provides a simple tool with a graphical interface to calculate HF and r_0 for a single branch from user's input.

Other new utility and analysis codes that have been implemented and released are: KeynumberCheck for checking NSR keynumbers in ENSDF datasets and Excel2ENSDF for converting an Excel table to an ENSDF dataset. Discussions during the USNDP meeting have motivated updates in the codes and the process for code distribution.

A new toolkit "ETool" is under development to encapsulate all utility and analysis Java codes in one application to further facilitate the workflow and improve the efficiency of ENSDF evaluation.

IV. Nuclear Reaction Data

The nuclear reaction data effort focuses on evaluation of nuclear reaction data and the related measurement and compilation activities. USNDP also makes important contributions to nuclear reaction model code development and improvement of reaction cross-section standards, with close collaboration from experimental groups such as Los Alamos Neutron Science Center, Rensselaer Polytech. Inst., U. Lowell, Massachusetts, Japanese Atomic Energy Agency, and U. Strasbourg.

In FY22, the continued effort on improving nuclear reaction modeling has provided the unified, consistent description of the couple-channel formalism and statistical Hauser-Feshbach nuclear reaction theories, which impacts strongly deformed target nuclei. We developed a new capability of calculating E1 and M1 giant resonances using non-iterative finite amplitude methods, which is important for estimating neutron radiative capture cross sections where experimental data are not available. We continued to improve a proper expression of the compound nuclear reaction cross section in terms of the average decay width. LANL has been applying the Monte Carlo technique to the Gaussian Orthogonal Ensemble (GOE) to better understand the statistical properties in the neutron-induced nuclear reactions. Through this effort, we demonstrated the compound cross section derived from the decay widths is ambiguous when the transmission coefficient is large (meaning strong coupling), where the average widths are calculated for both the S and K matrix cases.

As an evaluation effort, the coupled-channel model was employed to describe the neutron incident channel, and the calculated transmission coefficients in EMPIRE for the case of a strongly deformed nucleus, ^{181}Ta. A preliminary study of new calculations was made for ^{238}U, which found the collective enhancement of the particle-hole excitation hardens the energy spectrum of emitted neutrons in the pre-equilibrium process. The evaluation of ^{239}Pu data based on the CoH3 calculation continued for the future ENDF library, which included upgraded prompt fission neutron spectrum and average fission neutron multiplicity. For the IAEA released photo-nuclear data library, LANL extended the Hauser-Feshbach Fission Fragment Decay (HF_3D) model for calculating prompt fission gamma-ray energy spectrum and the gamma-ray multiplicity to complement the current library.

The experimental differential cross sections on ^{16}O(n, α)^{13}C reaction were finalized based on the measurements performed using LENZ (Low Energy NZ instrument) at the Los Alamos Neutron Science Center (LANSCE), and the work is under journal review. We compared the experimental data of ^{16}O(n, α_0) with energy-averaged ENDF/BVIII.0, ENDF/B-VII.1, and JENDL/AN-2005 cross sections using the LENZ energy resolution function, which are in good agreement with ENDF/B-VIII.0, ENDF/B-VI.8 and JENDL/AN-2005, but inconsistent with ENDF/B-VII.1. We suggest a full evaluation on the ^{17}O system with new experimental data sets including newly available angular distributions of ^{13}C(α, n), and a need of improved angular distribution data using different systematics such as a Time Projection Chamber for (n, α) measurements, in order to enhance the fidelity of the ^{17}O system evaluation.

Neutron-induced charged particle reactions performed at LANSCE were finalized for double differential (n,p) and (n, α) cross sections on ^{54,56}Fe and ^{58,60}Ni isotopes. Measured angular distributions and proton-

and alpha-production cross sections are being used for updating evaluation library, which will be implemented to the next ENDF/B-VIII.1 release. In addition to stable nuclear reaction studies, we also finalized the unstable nuclear reaction cross sections measured at LANSCE in collaboration with the Isotope Production Facility at LANL. The reaction cross sections of ^{59}Ni (n,p) and ^{59}Ni(n, α), and ^{56}Ni(n, p) and ^{56}Co(n, p) were finalized and the reaction rates of ^{56}Ni and ^{56}Co were updated to perform sensitivity studies for estimating the impact in nu-p process. Updated Geant modeling for the case of neutron transports was reported in the peer-reviewed journal with the emphasis of validating Geant results against the LASNCE experimental data and the MCNP simulations.

In preparation for the next US nuclear reaction data release, ENDF/B-VIII.1, scheduled for February 2024, most of this FY was dedicated to the coordination of the multiple submitted contributions, review process and organization of Beta releases. For the first time in many years, all the candidate evaluations for a new release are going through an independent review process, which is significantly improving the quality of the files, allowing us to identify issues and potential problems early. The review procedure, system and interface has been tested, implemented, and successfully deployed, allowing for the review process to begin. The neutron and decay sublibrary for example had some completed reviews done in FY22, while we set up reviews for other sublibraries such as thermal scattering law, alphas, deuteron, photonuclear, fission yields, etc. A positive example and impact of this review approach is the fact that there were multiple neutron evaluations for the very important isotope ^{239}Pu. A review panel with Subject Matter Experts was formed, which identified the strengths and challenges of each file enabling us to move forward, discussing its conclusions among evaluators and reviewers. BNL helped coordinate the review process and is archiving and disseminating the files and reports. We also developed a timeline of milestones and Beta releases leading to the release of ENDF/B-VIII.1, which was approved by the CSEWG Executive Committee. We ended the FY22 with the final preparations for "Beta0" releases and with the organization of the 2022 Nuclear Data Weeks (CSEWG/USNDP).

Additionally, we successfully organized and held a Hackathon meeting at BNL on September 19th – 23rd, 2022, with about 10 in-person participants and about 5 remote attendees. During the week, many old and new issues with the library files were addressed, while others were found and logged. We also successfully organized the workshop "New physics, new capabilities, what's changing in ENDF/B" at the International Conference on Physics of Reactors (PHYSOR) on May 20, 2022.

Nuclear Astrophysics Highlights

Thermonuclear reaction rates derived from a Monte Carlo model of particle emission from the compound nucleus were used in a comprehensive analysis of neutrino-process nucleosynthesis in core-collapse supernovae (CCSNe). Improved rates resulted from careful investigation of the Hauser-Feshbach statistical model parameters, especially for the region in CCSNe where neutrino flavor oscillations occur.

The thermonuclear rates for the ^{59}Cu(p,α) and ^{59}Cu(p,γ) reactions were improved at X-ray burst temperatures through studies of the properties of resonances in ^{60}Zn. The modifications in the rates suggest a reduced role of the (p,α) reaction which causes a “NiCu cycle” in X-ray burst nucleosynthesis,

and an enhancement in the formation of heavier elements. This work was published in FY22 in the Astrophysical Journal.

Because there are few experimental studies of neutron-induced reaction cross sections for proton-rich unstable nuclei, thermonuclear rates for these reactions based on a statistical model must be used for nucleosynthesis studies. They are also used for cosmochronometry studies – wherein the abundance on earth of the decay daughters of certain long-lived radionuclides are used to determine the time between an astrophysical event (such as a supernova explosion) and the formation of our solar system. A new study using improved rates has proposed using shorted-lived radioisotopes of ^{92}Nb and ^{98}Tc as the nuclear cosmochronometers for the supernova neutrino-process occurring in core-collapse supernovae.

USNDP Collaborative Projects

The formation of the Nuclear Data InterAgency Working Group (NDIAWG) has led to a dramatic increase in the coordination of nuclear data activities across US federal agencies. The NDIAWG's efforts have been aided by the collection of nuclear data needs from Workshop on Applied Nuclear Data Activities (WANDA), the series of workshops organized by the Nuclear Data Working Group (NDWG). NDIAWG coordination has led to several joint NNSA-USNDP FOA's and joint projects. As a result, the USNDP has several funded projects in FY22 directly or indirectly funded by programs represented in the NDIAWG:

- Gamma Rays Induced by Neutrons (BNL/LBNL/LLNL) is an NA-22 funded project aiming to improve inelastic and neutron capture gamma emission data to support active neutron interrogation applications.
- ENSDF Modernization project (BNL/LLNL/ANL) is an Office of Science funded project working to modernize the ENSDF database format and supporting infrastructure.
- DOE Office of Nuclear Energy, Gateway for Accelerated Innovation in Nuclear (GAIN) initiative award through TerraPower (LANL): The new ^{35}Cl(n,p) cross section measurement will improve the nuclear data evaluation on chlorin to impact on reactor physics integral parameters of the Molten Chloride Reactor Experiment.
- The Structure Based Evaluations of Nuclear Data (LANL/LLNL/BNL) is an Office of Science funded project working to integrate more nuclear structure information into R-matrix evaluations and to further streamline the R-matrix evaluation process.
- AIACHNE (LANL/BNL/NIST) is an Office of Science funded project working to identify shortcomings in PFNS measurements and then use AI to design an experiment to address the shortcomings.
- The NA-22 funded "Accurate Decay Data" project (BNL) aims at providing improved intensities of gamma rays emitted in the decay of selected fission products (^{140}I, ^{130}La, ^{143}Ce, ^{135}Xe and ^{135}I) using state-of-the-art experimental techniques, at Gammasphere and at the newly developed NNDC decay station.
- DOE-NE's Nuclear Energy Advanced Modeling and Simulation Program (NEAMS) for the ^{238}U and ^{56}Fe(n,n'g) measurement program using GENESIS funded through the FY18 NDIAWG FOA (LBNL/LANL/BNL).
- DOE-NE's Nuclear Energy University Program (NEUP) for measurements on ^{35}Cl for fast reactor design improvement (LBNL).

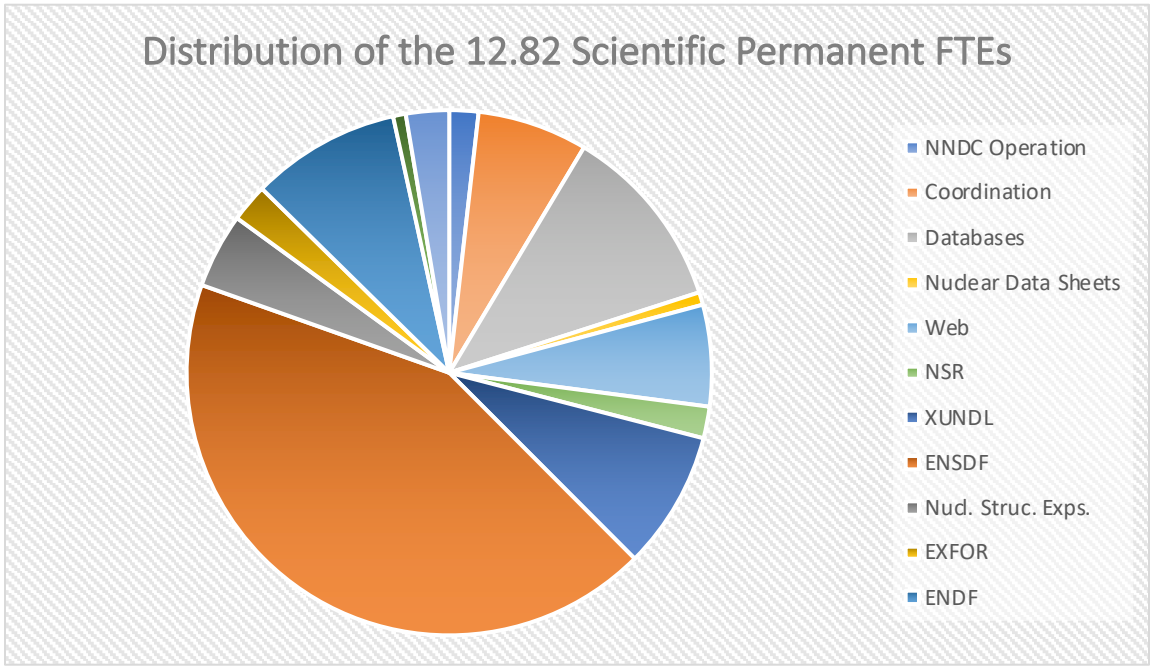
USNDP Staffing Table FY 2022

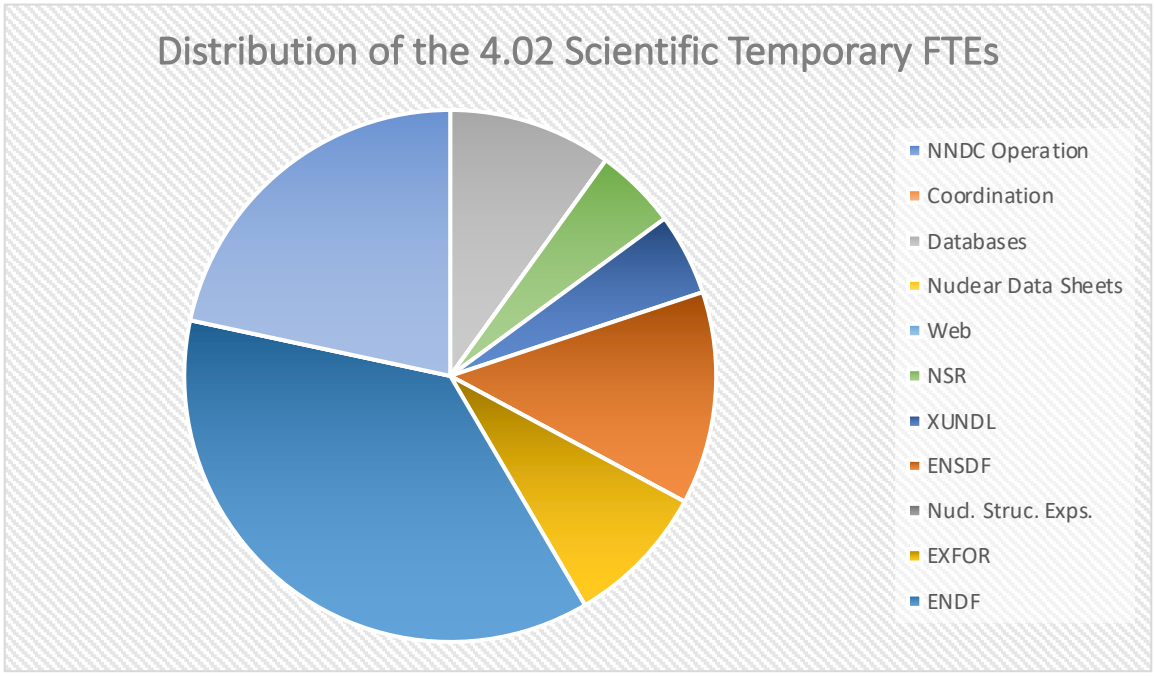
The table below gives the FTE distribution for each USNDP group according to activity. The values in this table and following plots are for the based funding only. In this table, PhD P means PhD Permanent; PhD T means PhD Temporary, which includes post-docs and scientists working under contract; T/A means Technical and Administrative; and GS means Graduate Student.

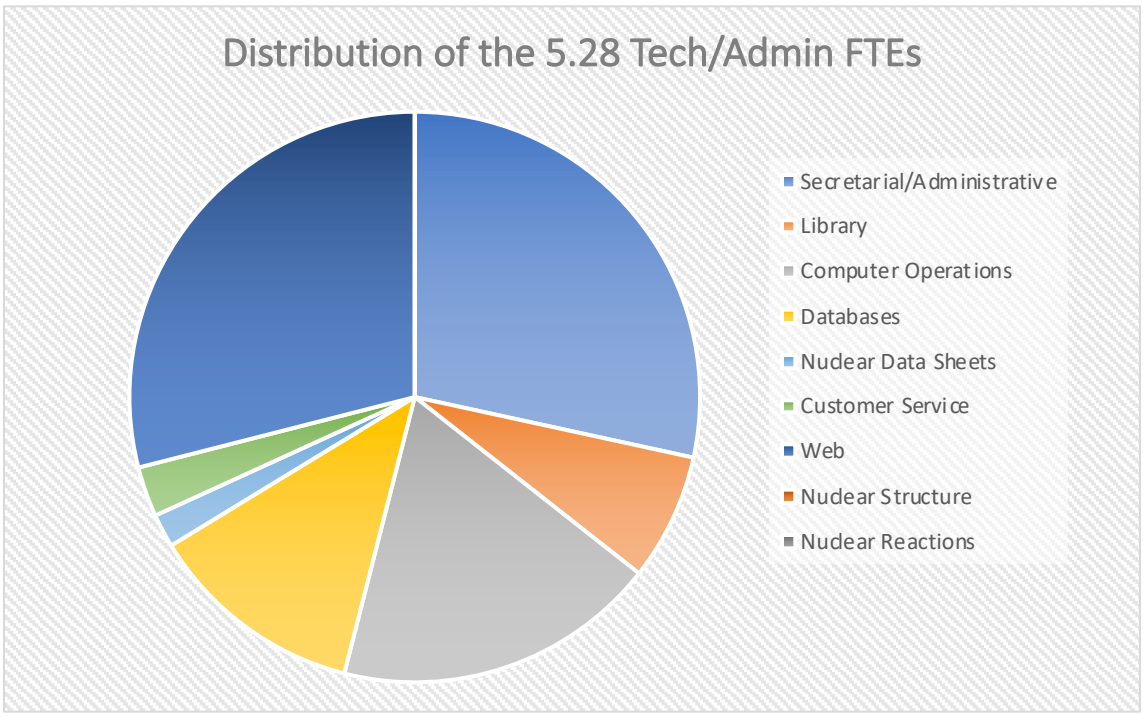
Activity	ANL	BNL			LANL		LBNL		LLNL	MSU	ORNL			TAMU	TUNL			
	PhD P	PhD P	PhD T	T/A	PhD P	PhD T	PhD P	PhD T	PhD P	PhD P	PhD P	PhD T	GS	PhD P	PhD P	PhD T	T/A	Totals
I. NNDC Facility Operation	0	0.23	0	2.85	0	0	0	0	0	0	0	0	0	0	0	0	0	3.08
Management		0.23																0.23
Secretarial/Administrative Support				1.5														1.5
Library				0.38														0.38
Computer Operations				0.97											0.05			1.02
II. Coordination	0.05	0.27	0	0	0	0	0.5	0	0	0	0	0	0	0	0.05	0	0	0.87
National Coordination		0.25					0.5											0.75
International Coordination	0.05	0.02																0.07
III. Nuclear Physics Databases	0	1.47	0	0.65	0	0	0	0.4	0	0	0	0	0	0	0	0	0	2.52
Nuclear Science References, NSR		0.25		0.4														0.65
Exper. Nucl. Structure Data, XUNDL		0.1																0.1
Eval. Nucl. Structure Data, ENSDF		0.1																0.1
Numerical Nuclear Data, NuDat				0.25														0.25
Experimental Reaction Data, CSISRS		0.06																0.06
Evaluated Nuclear Data File, ENDF		0.05																0.05
Database Software Maintenance																		0
Future Database System Develop.		0.91						0.4									0.3	1.61
IV. Information Dissemination	0	0.1	0	1.53	0	0	0	0.1	0	0	0.1	0	0	0	0	0	0	1.83
Nuclear Data Sheets		0.1		0.1														0.2
Customer Services				0.15													0.3	0.45
Web Maintenance & Development				1.28				0.1			0.1				0.7	0.1	0.25	2.53
V. Nuclear Structure Physics	0.7	1.9	0.8	0	0	0	2.3	0	0	1	1	0.1	0	1	0	0	0	8.81
NSR Abstract Preparation		0.25	0.2												0.1		0.05	0.6
Compilation of Exper. Structure Data		0.34	0.2							0.15					0.6	0.1	0.2	1.59
Eval. of Masses & Nuclides for ENSDF	0.4	0.73	0.42				2.2			0.65	1	0.1		1				6.5
Ground & Metastable State Properties	0.2	0.13																0.33
Radioactive Decay Data Evaluation	0.05									0.01								0.06
Thermal Capture Gamma Data Eval.																		0
Light Mass Eval. for Nucl. Physics A																		0
Nuclear Structure Data Measurement	0.05	0.49					0.05											0.59
ENSDF Evaluation Support Codes										0.19								0.19
VI. Nuclear Reaction Physics	0	0.73	0.8	0	0.7	1.05	0.14	0	0.25	0	0.1	0	0.2	0	0	0	0	3.97
Experimental Data Compilation		0.3	0.35															0.65
ENDF Manuals and Documentation		0.01																0.01
ENDF Evaluations		0.3	0.18		0.4	0.2												1.08
Nuclear Reaction Standards			0.25															0.25
Nuclear Model Development							0.1		0.15									0.25
Nucl. Reaction Data Measurements			0.02		0.3	0.85	0.04											1.21
Astrophysics Nuclear Data Needs											0.1		0.2					0.3
Covariances development																		0
Reactor anti-neutrino & decay heat calc.		0.1																0.1
Verification and Validation		0.02							0.1						0.75	0.1	0.55	1.52
DOE-SC Nucl. Data Funded Staff	0.75	4.74	1.62	5.03	0.7	1.05	2.89	0.5	0.25	1	1.2	0.1	0.2	1	0	0	0	21.03
Staff Supported by Other Funds	0.25	6.89	3.8	0.47			2.16	1.4							0.75	0.1	0.55	16.37
TOTAL STAFF	1	11.6	5.42	5.5	0.7	1.05	5.05	1.9	0.25	1	1.2	0.1	0.2	1	0.75	0.1	0.75	37.6

USNDP FTE Plots FY 2022

The plots below give the FTE distribution for Scientific Permanent, Scientific Temporary and Tech/Admin FTEs, in pie charts according to activity.






Distribution of the 5.28 Tech/Admin FTEs
Secretarial/Administrative
Library
Computer Operations
Databases
Nuclear Data Sheets
Customer Service
Web
Nuclear Structure
Nuclear Reactions

Detailed Status of the Work Plan – Fiscal Year 2022 Report

Each task area in this section is summarized with a status table listing individual tasks and their completion status. Below we present a sample task area table with the meaning of each status indicator.

XNL Planned Activities	Status	Issues/Path Forward
This is the name of the first activity.		This task is on schedule/going well/etc. It is not required to mention anything in the Issues/Path Forward box.
This is the name of the second activity.		This task is complete. Again, It is not required to discuss it.
This is the name of the third activity.		This task is behind schedule. The Issues/Path Forward field will explain/elaborate. There may be an issue HQ can help with.
This is the name of the fourth activity.		A milestone was missed. The Issues/Path Forward field will explain/elaborate. There may be an issue HQ can help with.

I. NNDC Facility Operation

A. Management

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

B. Library

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

C. Computer Operation

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

BNL Planned Activities	Status	Issues/Path Forward
In collaboration with ITD, ensure continuous availability of mission-critical Web services		

through full compliance of NNDC's computers with DOE cyber security requirements.		
Provide technical computer support to NNDC staff, visitors, and external collaborators to enable them to effectively and securely use NNDC computing resources as well as procure computer hardware, software and support services to meet NNDC's computing requirements.		
Manage NNDC/NE cluster.		

II. Coordination

A. National Coordination

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

BNL Planned Activities	Status	Issues/Path Forward
Prepare and organize USNDP budget briefing.		
Prepare USNDP reports and work plans.		The FY2023 workplan is late
Organize and chair CSEWG meeting at BNL.		
Organize and chair USNDP meeting at BNL.		
Edit and publish summary reports and proceedings of the CSEWG and USNDP meetings. -		The 2021 CSEWG minutes are late but the 2022 CSEWG minutes are nearly complete
Maintain CSEWG and USNDP websites.		
Organize mini-CSEWG meetings in the summer if needed. Host and help organize NDAC meeting.		

LANL Planned Activities	Status	Issues/Path Forward
Organize and chair CSEWG Evaluation Committees meeting at BNL.		
Organize and chair CSEWG Covariance Committee meeting at BNL.		
Organize and chair Nuclear Reaction Working Group.		

LBNL Planned Activities	Status	Issues/Path Forward
Help organize WANDA meeting.		No issues to report. LBNL continued to plan coordinated activities with NASA.

ORNL Planned Activities	Status	Issues/Path Forward
Coordinate and outreach USNDP Nuclear Astrophysics activities.		

TUNL Planned Activities	Status	Issues/Path Forward
Organize and chair USNDP Nuclear Structure Committee.		Organized session after ANL town hall meeting

B. International Coordination

ANL Planned Activities	Status	Issues/Path Forward
Participate in IAEA-sponsored nuclear data activities.		Participated in the NSDD meeting in April, 2022 and in the TM on Decay Data for Monitoring Applications
Organizer of the FRIB-TA Topical program on "Isomers in the Era of FRIB"		
Hosted and mentored evaluator (Fulbright scholar) from NSDD data center		

BNL Planned Activities	Status	Issues/Path Forward
Participate in IAEA-sponsored nuclear data activities.		
Participate in NEA WPEC annual meeting.		
Participate in IAEA CRP and technical meetings.		
Continue to participate in training/mentoring of new ENSDF evaluators through collaborative work.		

LANL Planned Activities	Status	Issues/Path Forward
Participate in IAEA-sponsored nuclear data activities.		
Participate in NEA WPEC annual meeting.		

LBNL Planned Activities	Status	Issues/Path Forward
Participate in IAEA-sponsored nuclear data activities.		

MSU Planned Activities	Status	Issues/Path Forward
Participate in IAEA-sponsored nuclear data activities.		

TAMU Planned Activities	Status	Issues/Path Forward

Participate in IAEA-sponsored nuclear data activities.		

TUNL Planned Activities	Status	Issues/Path Forward
Participate in IAEA-sponsored nuclear data activities.		Attended NSDD meeting in Canberra

III. Nuclear Physics Databases

A. Nuclear Science References (NSR)

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

BNL Planned Activities	Status	Issues/Path Forward
Distribute database to collaborators.		
Perform database updates and maintenance.		
Continue joint project with the NRDC network to transfer missing nuclear reaction references to NSR.		
Study in depth the possibilities of using AI and ML techniques in NSR, in collaboration with LBNL.		None. Walid Younes working as a contractor with the LBNL group on NucScholar.

B. Experimental Nuclear Structure Data (XUNDL)

The NNDC is responsible for maintaining and providing access to the XUNDL database. This database contains compilations (in ENSDF format) of recently published or completed level-structure data for high-spin and low-spin physics. The NNDC coordinates this work and updates the database as new/revised data sets are received from collaborators.

BNL Planned Activities	Status	Issues/Path Forward
Perform weekly updates of the database using input received from compilers.		
Distribute database yearly to the NSDD network.		

C. Evaluated Nuclear Structure Data File (ENSDF)

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

BNL Planned Activities	Status	Issues/Path Forward
Maintain ENSDF database, includes continuous updating.		
Process evaluations received from NSDD evaluators.		
Distribute ENSDF database to collaborators on a monthly basis.		
Proceed with the ENSDF modernization project.		

D. Numerical Nuclear Data (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-ray properties extracted from ENSDF, ground and metastable state properties (Wallet Cards), and atomic and nuclear radiations derived from ENSDF. Additionally, NuDat contains an interactive Chart of Nuclides and interactive level schemes.

BNL Planned Activities	Status	Issues/Path Forward
Update NuDat database as necessary.		

E. Experimental Reaction Data File (EXFOR)

The NNDC is responsible for maintaining the EXFOR 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 ≤ 12. Many groups worldwide compile experimental data and send it to the central database in Vienna in the EXFOR format. Then, each center is responsible to update its own database. The effort described here includes quality control, file update, and data transfer activities. The NNDC database is updated as compilations are exchanged and checked from the compiling centers. The compilation activity is given under Nuclear Reaction Physics.

BNL Planned Activities	Status	Issues/Path Forward
Update EXFOR database with compilations from cooperating centers (500 entries expected). The NNDC compilation work can be found under Nuclear Reaction Physics, Section V of the present document.		
Participate in WPEC Subgroup 50 on creating a critically reviewed version of EXFOR.		

F. 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 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 in the 1960s 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 of the U.S. ENDF/B library, the distribution of this database in the U.S. and the exchange of libraries internationally. New evaluations for the next release of the library, following ENDF/B-VIII.0, are assembled, tested and made available to users through NNDC's Web servers and GitLab collaboration server at git.nndc.bnl.gov.

BNL Planned Activities	Status	Issues/Path Forward
Maintain and improve Sigma database and web interface for users without specialized knowledge of ENDF-6 format. (See also information dissemination, Section IV.)		
Maintain and extend ADVANCE, the ENDF continuous integration system that continually checks for modification to the ENDF database then runs all available tests on the changed data files.		Issues with GitLab's support for BNL's cybersecurity profile delayed (re)deployment of ADVANCE into FY2023

G. Database Software Maintenance

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

BNL Planned Activities	Status	Issues/Path Forward
Fix software bugs and develop enhancements for the six nuclear physics databases maintained by NNDC.		

H. Future Database Systems Development

BNL Planned Activities	Status	Issues/Path Forward
Upgrade the Linux/MySQL server software to fix bugs, provide new functionalities, and improve the system's performance, security and reliability.		

IV. Information Dissemination

The goal of the dissemination activities of the USNDP is to provide scientists and engineers with nuclear data from the USNDP-maintained nuclear databases in a variety of user-friendly formats and media.

A. Nuclear Data Sheets

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 journal published by Elsevier and various versions of the Nuclear Wallet Cards.

BNL Planned Activities	Status	Issues/Path Forward
Prepare issues of Nuclear Data Sheets for publication.		
Work on a new version of Nuclear Wallet Cards.		
Work on a new version of Handbook of Radioactive Nuclei.		

MSU Planned Activities	Status	Issues/Path Forward
Continue development of software for Nuclear Data Sheets publication.		

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" as well as for administrative/clerical support of its customer services.

BNL Planned Activities	Status	Issues/Path Forward
Provide technical support to nuclear data end-users as necessary.		

C. Web Site Maintenance

The NNDC provides electronic access to the nuclear physics databases that it maintains on behalf of the USNDP as well as access to other nuclear physics information through its website. Other USNDP members also offer nuclear physics information through their websites. These services require resources to maintain currency and improve performance.

BNL Planned Activities	Status	Issues/Path Forward
Solicit user suggestions on enhancements to the ENSDF, NSR, NuDat, and Sigma web interfaces and be responsive to those needs. Expand search and plotting capabilities for ENSDF data.		
Maintain web interfaces for ENDF and EXFOR databases.		Due to severe cybersecurity issues with legacy website, the site was disabled and traffic redirected to the IAEA mirror.
Maintain currency of the CSEWG, USNDP and the NNDC websites, proactively respond to users' requests.		
Maintain the NNDC Web Services availability on the 99% and higher level.		
Strictly follow all BNL and DOE cybersecurity rules and regulations during the Web application design, development and		

implementation. Address issues that arise during BNL scans.		
Upgrade GitLab server software to provide more powerful and advanced functionalities in the NNDC collaboration services.		
Make progress with modernization of the website, enhancing capabilities and follow industry best practices.		
Continue development of mobile applications targeting highly used databases.		

ORNL Planned Activities	Status	Issues/Path Forward
Incorporation of new mass compilations and new rate libraries into online collections.		

TUNL Planned Activities	Status	Issues/Path Forward
Provide access to present and past evaluations of Energy Levels of Light Nuclei for A=3-20 nuclides, including associated figures and energy-level diagrams and tables.		Maintained website
Provide access to compiled and evaluated data on light nuclei related to p-, alpha- and n-capture reactions, and ground-state decays.		With the retirement of our assistant, this literature search, and compilation of data was not carried out this year. Information from past years was maintained and available on the site.
Provide access for TUNL dissertations collection.		Maintained updated list of graduates

V. Nuclear Structure Physics

A. NSR Abstract Preparation

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

BNL Planned Activities	Status	Issues/Path Forward
Prepare entries for approximately 3,100 new references and keyword abstracts for 2,000 of them. Provide coverage for 80 major journals, including complete coverage of Physical Review C and Nuclear Physics A.		

B. Compilation of Experimental Nuclear Structure Data

This activity involves compilation of recently published or completed experimental nuclear structure data for inclusion in XUNDL. The compilation is managed by the NNDC.

ANL Planned Activities	Status	Issues/Path Forward
Compile and review datasets for recently published experimental nuclear structure data for inclusion in the XUNDL database. Interact with the authors for requesting additional experimental data or for further clarification of the published results.		No requests for compilations were made by the XUNDL coordinator

BNL Planned Activities	Status	Issues/Path Forward
Compile new B(E2) experimental data. Continue work on a B(E2) evaluation project in collaboration with McMaster University.		
Compile new double-beta decay experimental data. Start working on a data project with Dr. V. Tretyak, Kyiv Institute for Nuclear Research.		
Compile and review datasets for recently published experimental nuclear structure data for inclusion in the XUNDL database. Interact with the authors for requesting additional experimental data or for further clarification of the published results.		464 datasets were compiled from 255 papers.
Review compiled datasets submitted by other data centers prior to inclusion in the XUNDL database. Work with PRC and EPJA to check and compile data prior to publication.		
Compile new mass measurements and submit data file to nuclearmasses.org webpage at ORNL.		

LBNL Planned Activities	Status	Issues/Path Forward
Compile and review datasets for recently published experimental nuclear structure data for inclusion in the XUNDL database. Interact with the authors for requesting additional experimental data or for further clarification of the published results.		None. LBNL is no longer compiling data into XUNDL, as agreed upon with BNL.

MSU Planned Activities	Status	Issues/Path Forward
Compile and review datasets for recently published experimental nuclear structure data for inclusion in the XUNDL database. Interact with the authors for requesting additional experimental data or for further clarification of the published results.		
Work with PRC and EPJA to check and compile data prior to publication.		

TUNL Planned Activities	Status	Issues/Path Forward
Compile and review datasets for recently published experimental nuclear structure data for inclusion in the XUNDL database. Interact with the authors for requesting additional experimental data or for further clarification of the published results.		49 data sets were compiled from 40 articles.

C. A-Chains and Nuclides Evaluations for ENSDF

USNDP evaluates nuclear structure and decay data for inclusion in the ENSDF database. This effort includes the critical analysis of all available experimental nuclear structure and radioactive decay data for a nuclide or a group of related nuclei to deduce recommended values from the measured data and prepare a file in ENSDF format that is the basis for publications in Nuclear Data Sheets and is used to update the contents of the USNDP nuclear structure and decay database, ENSDF.

ANL Planned Activities	Status	Issues/Path Forward
Evaluate at least one mass chain from the ANL region of responsibility.		A=200 (12 nuclides) was completed and submitted to NNDC for review; A=201 (13 nuclides) was revised following the reviewer's comments and submitted to NNDC for publication
Review mass chain evaluations, as requested.		On a request by the ENSDF manager, A=213 was reviewed

BNL Planned Activities	Status	Issues/Path Forward
Evaluate at least four mass chains or their equivalent nuclides.		139 nuclides were evaluated and submitted to the ENSDF database
Review at least four mass chains or their equivalent nuclides.		5 mass chains were reviewed
Update ENSDF for the identification of new nuclides and for the first publication on the findings of the excited states of nuclides.		
Edit all evaluations submitted for publication, including checking their format and physics content.		
Continue mentoring new ENSDF evaluators.		New ENSDF evaluators Shuya Ota and Jin Wu were trained in ENSDF policies and procedures.

LBNL Planned Activities	Status	Issues/Path Forward
Evaluate the equivalent of at least two mass chains (20 nuclides), including a minimum of one from the A=21-30 region. Emphasis will be placed on evaluating data of current interest to the nuclear structure and nuclear application communities.		None. LBNL exceeded its planned mass chain evaluation goal this year.

Review mass-chain evaluations, as requested.		No issues. Mass chain reviews were performed.

MSU Planned Activities	Status	Issues/Path Forward
Evaluate the equivalent of at least two mass chains.		
Review one mass-chain evaluation.		

ORNL Planned Activities	Status	Issues/Path Forward
One equivalent mass chains and the data for new nuclides will be evaluated.		
Review mass-chain evaluations, as requested.		

TAMU Planned Activities	Status	Issues/Path Forward
At least one mass chain, or their equivalent nuclides, will be evaluated.		
Review mass-chain evaluations, as requested.		

TUNL Planned Activities	Status	Issues/Path Forward
Evaluate one or two A-chains per year for publication in Nuclear Data Sheets and inclusion in the ENSDF database.		An evaluation of A=13 nuclides was submitted in September. ^{13}Li, ^{13}Be, ^{13}B, ^{13}C, ^{13}N, ^{13}O, ^{13}F
Evaluate and update ENSDF for A=2-20 near drip-line nuclides, especially for first observations or when ENSDF has no previous dataset.		This year we focused on submission of A=13.
Update various reaction datasets in ENSDF, such as for beta-decay and beta-delayed particle emission.		At present we are mostly focused on nuclide and A-chain evaluations. This should be removed.

D. Ground and Metastable State Properties

ANL Planned Activities	Status	Issues/Path Forward
Compile and evaluate atomic masses and complementary nuclear structure data for the Atomic Mass Evaluation and the NUBASE evaluation of nuclear properties.		Work is continuing on the new AME and NUBASE libraries; compiled 100 datasets and evaluated 60 datasets for AME and NUBASE

BNL Planned Activities	Status	Issues/Path Forward
Develop new database for ground and metastable state properties (WalletCraft).		New CouchDB database containing data for over 3,300 nuclides with more than 15,000 individual measurements was constructed.
Begin evaluation process to provide recommended ground and metastable state properties.		New evaluation of ground state and long-lived isomeric properties was completed.

E. Non-ENSDF Decay Data Evaluations

ANL Planned Activities	Status	Issues/Path Forward
Contribute to the IAEA-led project on "Evaluated Decay Data Library for Monitoring Applications."		continuing

BNL Planned Activities	Status	Issues/Path Forward
Contribute to the beta-delayed neutron emitters IAEA CRP.		McMaster continues to update the beta-delayed neutron database maintained by the IAEA.

LBNL Planned Activities	Status	Issues/Path Forward
Work with researchers at Pacific Northwest National Laboratory on the development of a numerical database with complete Gamma-ray-X ray coincidence data in a joint effort with the Defense Threat Reduction Agency. The database will be benchmarked against existing decay data from ENSDF as well as recently published datasets not yet included in ENSDF. These efforts will be coordinated with the ENSDF modernization initiative led by BNL.		DTRA funding ended this year, but work continued on the database, which is being distributed on the LBNL nuclear data group database. The database will continue to be updated into FY23 and beyond.

MSU Planned Activities	Status	Issues/Path Forward
Contribute to the IAEA-led project on "Evaluated Decay Data Library for Monitoring Applications."		

F. Neutron-induced g-Ray Data Evaluation

LBNL Planned Activities	Status	Issues/Path Forward
Continue updating the Inelastic Scattering of Reactor Fast Neutrons Database (e.g., the "Baghdad Atlas") with modern ENSDF data, as a validation database for (n,n'γ) as well as with additional sources of energy differential (n,n'γ) data from GELINA at Geel, neutronELBE at HZDR, and the GENESIS array at LBNL. Extract information from ENDF needed to produce flux-weighted partial gamma-ray cross sections and comparing the result to values in the Atlas.		No issue. This work is being continued as a part of the Gammas Rays Induced by Neutrons (GRIN) NDIAWG project.
Start benchmarking reaction modeling codes, including Talys and EMPIRE. This work will be performed in collaboration with researchers from the IAEA and Naval Nuclear Laboratory.		No issues. This work is continuing.
Explore the role of quasi-continuum contributions through collaboration with		No issues. This work is continuing.

researchers from LLNL and the University of Oslo.		

G. Nuclear Structure Data Measurements

ANL Planned Activities	Status	Issues/Path Forward
Participate in nuclear physics research activities at ANL, MSU, and other nuclear physics user facilities with the main emphasis on decay studies of neutron-rich nuclei, spectroscopy of heavy actinide nuclei, and nuclei far from the line of stability.		Participated in several research activities at ATLAS and CARIBU related to structure of neutron-rich nuclei in the fission-product region and in the heavy actinide region; participated in the first decay station campaign at FRIB

BNL Planned Activities	Status	Issues/Path Forward
Precisely determine decay schemes of relevant medical isotopes using state-of-the-art gamma-ray spectroscopy.		A gammasphere experiment on the decay of 186Ir was performed and analyzed by a SULI student.
Participate in beta-decay measurements at facilities, such as Argonne's CARIBU, with an emphasis on nuclei relevant to decay heat, antineutrino spectra, and delayed nu-bar.		Participated in the first decay station measurement at FRIB. Published an article on the decay of the fission fragment 141Ba.
Perform gamma-ray spectroscopy experiments with GRETINA to remedy data deficiencies uncovered during ENSDF evaluations.		Task was not completed due to the passing of Shaofei Zhu.
Setup new gamma-alpha coincidence station.		New decay station has been constructed at Brookhaven.

LBNL Planned Activities	Status	Issues/Path Forward
Perform targeted decay-data measurements to address inconsistencies in decay data using light-ion and neutron activation and the Fast Loading and Unloading Facility for Fission Fragment Yields (FLUFFY) combined with a local array of single-crystal and Clover HPGe detectors. Results from these experiments will be published and updates presented to the ENSDF database manager.		These experiments have been moved to FY23 due to beam scheduling limitations.

H. ENSDF Physics and Checking Codes

BNL Planned Activities	Status	Issues/Path Forward
Maintain and upgrade ENSDF checking and physics programs for format changes as required.		FMCHK was updated based on requests from users.
Work on the development of the next generation ENSDF format and develop		New ENSDF schema was developed along with an associated API. All current Adopted Levels and

applications that apply Machine Learning techniques to the new format.		Gammas datasets were converted from the 80 column ascii format to the new JSON schema.

MSU Planned Activities	Status	Issues/Path Forward
Maintain and improve the ENSDF utility and analysis codes in Java developed at MSU: McMaster-MSU Java-NDS, ConsistencyCheck, GLSC, Java-RULER, Excel2ENSDF, KeynumberCheck, AME-NUBASE viewer, RadiationReport, AlphaHF		
Develop new Java codes to replace the legacy ENSDF codes in Fortran that lack maintenance and to facilitate and streamline ENSDF evaluation		

LLNL Planned Activities	Status	Issues/Path Forward
Collaborate with BNL in the development of the next generation ENSDF format and develop applications that apply Machine Learning techniques to the new format.		

VI. Nuclear Reaction Physics

A. Experimental Data Compilation

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

BNL Planned Activities	Status	Issues/Path Forward
Compile experimental data for neutron, charged-particle, and photon-induced reactions from 120 publications.		
Explore possibilities of recovering previously unobtainable reaction data and proactively respond to users' needs.		

B. ENDF Manuals and Documentation

The NNDC is responsible for maintaining the format and procedures manual for the ENDF system as well as producing the documentation supporting the contents of the ENDF/B library.

BNL Planned Activities	Status	Issues/Path Forward
Maintain the GitLab version of the ENDF-6 formats manual current with CSEWG-endorsed format changes. Issue official release of the manual.		

Automate the generation and posting of the latest unofficial version of the ENDF-6 formats manual.		
Chair the WPEC Generalized Nuclear Database Structure (GNDS) Expert Group and maintain the format specification for the GNDS, the successor format to ENDF-6.		D. Brown stepped down as the EG GNDS at the May 2022 WPEC meeting; the new chair is C. Mattoon (LLNL)

C. ENDF Evaluations

Evaluated nuclear reaction data, for applications and 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 ensure 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.

BNL Planned Activities	Status	Issues/Path Forward
Respond to user needs for evaluated nuclear reaction data.		
Collect and address users feedback related to the ENDF library.		
Complete evaluations for Zr isotopes to support new reactor fuel concepts.		Work transitioning to Ph.D. project of RPI student.
Work with CSEWG on upgraded evaluations for future release of the ENDF/B library.		
Improve methodology for providing covariance data in the resonance and fast neutron region to the next release of ENDF.		
Update the Decay Data Sub-library as new data for neutron-rich nuclides become available.		
Improve methodology for generating unresolved resonance region cross section probability distributions.		
Maintain the Atlas of Neutron Resonances electronic files in preparation for a future update of the Atlas of Neutron Resonances. Continue working on the use of ML techniques to better determine resonance properties.		
Participate in the Fission Yield evaluation CRP at the IAEA.		

LANL Planned Activities	Status	Issues/Path Forward
Upgrade the LANL ENDF evaluations for major actinides as well as some other structural materials that perform well in criticality benchmarks, including new theoretical development of statistical model for deformed		

systems. Close collaboration with international nuclear data library activities at the IAEA and OECD/NEA.		
Provide new evaluations of the prompt fission neutron spectra for major actinides, based on the Monte Carlo technique as well as the deterministic method, including pre-equilibrium emissions at high energies.		
Improve photon production data for neutron capture and inelastic scattering, which will be used in prompt gamma-ray spectroscopy.		
Improve calculations for neutron-induced charged-particle reactions in collaboration with LENZ/LANCE, and produce evaluated files based on these data.		

LLNL Planned Activities	Status	Issues/Path Forward
Perform new evaluations as per LLNL customer requests and submit these as well as other LLNL-generated evaluations into ENDF.		
Perform R-matrix fits for proton and alpha particles incident on selected medium-mass nuclei (4<=A<=50) to accurately describe low-energy resonances and make candidates for future ENDF/B-VIII evaluations.		
Improve transitions from R-matrix resonance regions to statistical models at higher energies, to give better predictions of gamma production.		
Add candidate exit distributions of charged-particle productions (for ENDF/B-VIII.1)		

D. Nuclear Reaction Standards

Nearly all neutron cross section measurements are made relative to a neutron cross section standard, such as the hydrogen elastic cross section. The primary objective of this task is to ensure accurate and current values for standard cross sections and related quantities. In preparation for the new evaluations of the standards, we are improving the standards database and procedures under the auspices of the IAEA data development project "Maintenance of the Neutron Cross Section Standards." Historically, the standards evaluation activity has included data from other than the cross-section standards, i.e., the thermal constants and the ^{252}Cf spontaneous fission neutron spectrum. Recently, the scope has been broadened, largely through the data development project, to include an investigation of possible inelastic scattering cross section reference standards; considering adding additional standards energy ranges for the Au(n,γ) cross section; and proposing updates for the evaluations of the ^{252}Cf spontaneous fission neutron spectrum and the ^{235}U thermal neutron-induced fission neutron spectrum.

BNL Planned Activities	Status	Issues/Path Forward

Continue work on standards evaluations through involvement in the IAEA data development project "maintenance of the neutron cross section standards. Checking the literature and other sources for possible measurements related to standards.		The use of a new python-based program replacing GMA has allowed ratios of spectrum averaged cross sections to be used in the standards evaluation process. This has allowed improvements in several fission cross sections. Further work on this is underway. We continue to examine the literature and sources of appropriate measurements.
Continue involvement with nuclear data groups as a) A member of the program committee of the International Symposium on Reactor Dosimetry's 17th International Symposium on Reactor Dosimetry (ISRD-17). Due to concerns about the virus, the ISRD- 17 meeting will be held May 2021 (instead of 2020) in Lausanne Switzerland. I attended a meeting of the members of the Program Committee on Feb. 2. The agenda included updates on the meeting in May, issues concerning future symposium papers, the location of the meeting in 2023 (in the USA), and assignments for various positions (workshop, poster session and technical chairs) for the 2023 meeting. There are still lingering concerns about the meetings due to Covid-19. b) A member of the International Advisory Board for the 5th International Workshop on Nuclear Data Covariances (CW2020), which has been delayed due to the pandemic.		For a), ISRD-17 is now planned for May 21-26, 2023, at the Switzerland location. Registration began on 1-23-23. The ISRD-18 is now planned for May 18-23, 2025. The location has been established but it cannot be disclosed until it is announced at the end of the ISRD-17 meeting. Both meetings were affected by covid and could possibly be changed if additional covid problems occur. For b), CW2020 became CW2022 due to the covid. It was held Sept. 25-29, 2022. It was only virtual. A. Carlson co-authored a paper and chaired a session. The paper was on the ratios of spectrum averaged cross sections. The proceedings are being worked on.
Work will continue on both 6Li(n,t) and 235U(n,f) measurements at NIST with sub-thermal neutrons.		Work has progressed very slowly on these experiments since the NIST reactor has been shut down due to an accident. It is expected to be available in 2023. Also, the ^{6}Li mass determination has not been completed since the NIST Isotope Dilution Mass Spectrometry facility is over-subscribed due to work not done during the covid era and loss of a staff member.
Finish publishing the report on the IAEA Consultants' Virtual Meeting on Neutron Data Standards Oct.12-16, 2020. Work closely with Professor Zhang of the Peking University in Beijing, China on improvements to new measurements at the China Spallation Neutron Source (CSNS). The CSNS is a major facility for making neutron data measurements. Plans are being made for the next standards meeting where more information may be available on when a new standards evaluation can be available.		The report for the Oct. 12-16, 2020, virtual meeting has been published as an IAEA report. A virtual meeting was held Dec. 6-10, 2021. Also, a hybrid meeting was held Oct. 18-21, 2022. A. Carlson attended that meeting in person. The presentations for the 2021 and 2022 meetings are available online. A. Carlson reported on standards activities at all 3 meetings. The concern now is when a new evaluation of the standards will be done. It awaits several measurements that have been initiated but not completed. The latest work

		by Zhang relates to improvement in ^{6}Li(n,t) and ^{10}B(n,α) cross sections.

E. Nuclear Model Development

This task covers activities, such as the development and validation of nuclear reaction models, used for prediction of nuclear reaction cross sections. The two major codes are CoH3 (LANL) and EMPIRE (BNL). Measurements made by ANL, LANL and LBNL, 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. LANL participates in the IAEA Coordinated Research Project RIPL that improves the accuracy and reliability of input parameters used in nuclear reaction calculations.

BNL Planned Activities	Status	Issues/Path Forward
Develop a new coupled-channels code using modern coding techniques for use in future evaluation work, focusing on deformed nuclides.		M. Vorabbi left BNL to accept Lecturer position at the University of Surrey, UK. Work on this task halted.
Model (n,γ) spectra to address a major shortcoming in the ENDF library as noted in WANDA 2020.		Work transitioned to the NA-22 funded GRIN project.

LANL Planned Activities	Status	Issues/Path Forward
Continue to develop a microscopic description of the fission process in the fast energy range as well as penetrability calculations through arbitrary fission barrier shapes. Implement the theory into the Hauser-Feshbach code to facilitate actinide evaluations.		
Continue to develop a coupled-channels Hauser-Feshbach method for better prediction of neutron- induced reactions on deformed nuclei, with particular emphasis on fission, capture, and inelastic scattering channels.		
Continue to develop the Hauser-Feshbach fission fragment decay code for evaluating major actinides, which has a unique capability to produce prompt fission neutron and gamma-ray spectra.		
Develop a semi-microscopic model for nuclear structure, which will be incorporated into the reaction calculations.		

F. Nuclear Reaction Data Measurements

LANL Planned Activities	Status	Issues/Path Forward

Finalize the precision measurement on the prompt fission-neutron spectrum for fission induced by neutrons of 0.5 to 200 MeV on ^{235}U and ^{239}Pu. With the high-energy neutron detector array, the measurement will be extended to the outgoing neutrons up to 12 MeV.		
Perform double-differential cross sections of (n, p) and (n,α) reactions on 58Ni and 60Ni in respect to incoming neutron energies and outgoing particles angles for the neutron energy range of 0.5 - 20 MeV.		
Perform the precision measurement on the ^{16}O(n, α) reaction cross section at LANSCE.		
Measure energy-dependent reaction cross sections on ^{35}Cl(n,p) and (n,α) reactions for improving insufficient experimental data.		
Finalize double-differential cross sections of ^{54}Fe(n,p) reaction in respect to incoming neutron energies and outgoing particles angles for the neutron energy range of 0.5 - 20 MeV.		

LBNL Planned Activities	**Status**	**Issues/Path Forward**
Study the ^{56}Fe(n,n'γ) and ^{238}U(n,n'γ) reactions using the Gamma Energy Neutron Energy Spectrometer for Inelastic Scattering (GENESIS).		No issues. The analysis and interpretation of the GENESIS data proceeded as planned.
Perform energy-dependent measurements of short-lived fission fragments on ^{235,238U} using the Fast Loading and Unloading Facility for Fission Yields (FLUFFY).		No issues. The analysis and interpretation of the FLUFFY data proceeded as planned.
Measurement of the decay of ^{68m,g}Cu populated via ^{nat}Zn(n,px) using FLUFFY. This experiment will run "piggyback" on the ^{235,238}U(n,f) measurements mentioned above.		This experiment was not fielded in FY22 due to beam time scheduling considerations.

G. Astrophysics Nuclear Data Needs

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.

BNL Planned Activities	**Status**	**Issues/Path Forward**
Work on neutron capture and fission integral values and their uncertainties in the energy region of interest for nuclear astrophysics.		

Evaluate nuclear astrophysics potential of EXFOR library.		

LANL Planned Activities	Status	Issues/Path Forward
Continue improvement of neutron capture, beta-delayed neutron and fission modellings for s- and r-process hydro-dynamics simulations.		
Develop a Monte Carlo simulation using Geant4, to be implemented for radioactive nuclear reaction analysis at Time of Flight facilities, in the interest of providing direct reaction cross sections for better understanding of heavy element productions.		

ORNL Planned Activities	Status	Issues/Path Forward
Continue assessments of capture reactions on p-rich unstable nuclides that are important for novae and X-ray bursts. The nuclei to be studied are those planned for measurements at radioactive beam facilities.		

H. Covariances Development

BNL Planned Activities	Status	Issues/Path Forward
Develop low-fidelity fission yield covariances consistent with the ENDF decay sub-library and with measured yields. This project would allow us to develop expertise for the upcoming Fission Yields CRP.		

LBNL Planned Activities	Status	Issues/Path Forward
Continue to develop an experimentally driven fission covariance database		This database was uploaded onto the LBNL website and is now available for public dissemination.

I. Reactor Antineutrino Spectra and Decay Heat Calculations

BNL Planned Activities	Status	Issues/Path Forward
Improve our methods and databases to calculate anti-neutrino spectra for major actinides.		
Perform decay-heat calculations in collaboration with experimental groups.		
Possibly participate in relevant experiments.		

J. Verification and Validation

Quality Assurance (QA) of a nuclear data library requires that all files are checked for integral consistency and conformance with the adopted format. This part of the QA is called verification and is one of the fundamental functions of the NNDC. Furthermore, checking performance of the library against the integral experiments, known as validation, is also an important step to ensure the usefulness of the library for the end-users. The most extensive validation is performed by LANL and other CSEWG contributors funded with non-DOE-SC sources. The USNDP supports the ultimate validation effort carried out at BNL.

BNL Planned Activities	Status	Issues/Path Forward
Maintain automatic, real-time verification and validation of new/modified ENDF evaluations submitted to the NNDC GitLab server.		

Appendix A – Additional Funding Sources

ANL

Additional support for the nuclear data work comes from two LAB 18-1903 funded proposals (DOE/SC/NP and DOE/NNSA/NA-22) and two LAB 19-2114 funded proposals (DOE/SC/NP).

BNL

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

1. The US Nuclear Criticality Safety Program (NCSP) supports the NNDC services in maintaining NCSP data submitted to the ENDF/B library as well as data development work on evaluations of neutron cross section covariances for criticality safety applications.
2. The Fission in Rapid Process Elements (FIRE) collaboration.
3. Evaluation of energy dependent fission product yields, funded by NA-22.
4. NA-22 Intentional Forensics Venture, a project to develop a tagging system for nuclear fuel.
5. DOE-NE's Nuclear Energy University Program (NEUP) to serve on thesis committee of RPI student developing Pb evaluations for ENDF.
6. High precision decay measurements of isotopes relevant to nuclear forensics, funded by NA-22.
7. Brookhaven National Laboratory Program Development funds used to establish in-house capabilities for decay data measurements.
8. Three NDWIAG FOA-funded proposals:
    - Modernization and optimization of the Evaluated Nuclear Structure Data File
    - High precision decay measurement of isotopes relevant to nuclear medicine
    - AI Guided development of a measurement of the 235U PFNS (led by LANL)
    - Improvements to R-matrix evaluations using information from nuclear structure (led by LANL)

LANL

Additional supports for the nuclear data project are as follows:

1. Advanced Simulation and Computing under NNSA.
2. The US Nuclear Criticality Safety Program (NCSP).
3. Evaluation of energy dependent fission product yields, funded by NA-22.
4. Fission in R-Process Elements (FIRE) collaboration.
5. LANL-LDRD to develop transmission measurement capability for studying radionuclides at LANSCE.
6. Science Campaign support under Office of Experimental Sciences by NNSA.

LBNL

Additional supports for the LBNL nuclear data project are as follows:

1. DOE-NE's Nuclear Energy University Program (NEUP) for ^{35}Cl(n,x) measurements on for fast reactors.
2. DOE Isotope Program the Tri-Laboratory Effort in Nuclear Data (with LANL-IPF and BNL-BLIP);
3. Google Project X faculty support grant for exploring the use of energetic photons and electrons to transmute nuclear waste through photoexcitation.
4. NNSA/NA-113 - Correlated Neutron-Gamma Data for Stewardship Science
5. NNSA/NA-22 for the measurement of neutron-gamma ray coincidences using the GENESIS array.
6. NorthStar RadioIsotopes LLC – Optimized Deuteron Target Fabrication for Radionuclide Production

LLNL
Additional supports for the LLNL nuclear data project are as follows: 1. Advanced Simulation and Computing under NNSA. 2. The US Nuclear Criticality Safety Program (NCSP). 4. ENSDF modernization project.

Appendix B – Non-USNDP funded nuclear data work

This appendix was added to voluntarily capture additional nuclear data work performed at USNDP sites.

Brookhaven National Laboratory

BNL scientists are engaged in a number of non-USNDP funded nuclear data activities, most notably with the continued support of the National Criticality Safety Program (NCSP) and the Defense Nuclear Nonproliferation (NA-22) Program. Currently the NCSP partly funds the operation of the Evaluated Nuclear Data File library project, in conjunction with the USNDP. The NCSP also funds development of analytical methods for thermal neutron scattering data and unresolved resonance probability distribution generation and a neutron resonance spingroup assignment machine learning project. NA-22 funds several projects as a direct result of the Nuclear Data Interagency Working Group proposal process. These projects include measurements of decay data relevant for non-proliferation, library development to support active neutron interrogation, and data work supporting the intentional forensics mission.

Los Alamos National Laboratory

Many projects and scientists at LANL contribute to non-USNDP funded nuclear data activities. Six additional funding sources addressed in Appendix A are all related to nuclear data work at LANL and Los Alamos Neutron Science Center.

Lawrence Berkeley National Laboratory/UC Berkeley

The LBNL/UC Bay Area Nuclear Data (BAND) Group has a diverse set of funding to pursue experimental and evaluation-related work centered on applied nuclear data. This includes neutron and charged-particle cross section measurements for Nuclear Energy, Stockpile Stewardship, Nonproliferation and Isotope Production. Furthermore, several students members of the group receive fellowship and traineeship support from the NNSA/NA-22 under the auspices of the Nuclear Science and Security Consortium. The BAND group also performs targets nuclear technology development research under corporate sponsorship including research into photo-excitation of nuclear isomers under the support of Google Project-X and the development of high-intensity neutron sources for Radioisotope Production as part of a Strategic Partnership Program with NorthStar RadioNuclides LLC.

Lawrence Livermore National Laboratory

Livermore Laboratory has had a program for nuclear data for almost 60 years, and this has been often independent of the national ENDF library format. In that time, LLNL has made its own ENDL libraries in format designed for punched cards, and it has its own groups of evaluators leading to revisions about

twice per decade. In the 70s the ENDL libraries were described by a comprehensive series of 20 descriptive volumes published under the label of UCRL-50400.

Because this original ENDL format was less flexible than the ENDF format, in the recent decade we have had some incentive to make more modern data structure, and this led us to designing, coding and translating the new Generalized Nuclear Data Structure (GNDS). This GNDS method is now maintained internationally by WPEC, and it is used internally at LLNL for all stages of the nuclear pipeline from decay models, data storage, translation, testing and processing for transport codes. It is the most comprehensive method for interchange of nuclear data and is becoming widely adopted as the preferred future standard.

The nuclear data that LLNL uses comes from a variety of sources. We examine existing libraries to determine which provides the best description of nuclear cross sections, and often use our own models for neutron reactions and decay processes. We have optimized our own Hauser-Feshbach models for neutron reactions on a wide variety of fission fragments and other nuclides of use for radiochemistry. As one of the first labs to comprehensively transport both neutrons and charged particles (isotopes of hydrogen and helium) we have a comprehensive library of low-energy charged-particle evaluations, with particular attention to exothermic reactions on targets up to lithium isotopes.

In the last 15 years the experimental groups at LLNL have been using the indirect 'surrogate' method to measure cross-sections for which direct detection is unavailable, and the results have been made into GNDS evaluations to determine the effects of the new cross-sections. We test all evaluations by comparison with the standard database of critical-assembly measurements and also by comparison with the pulsed-sphere measurements once performed at LLNL. New critical assemblies are being created, measured and modeled. The national collaboration to use a Time Projection Chamber to measure actinide and standard cross-sections is being led by LLNL experimentalists. We have used both ENDL and ENDF processed libraries in transport codes for programmatic work.

The USNDP provides a small contribution to the LLNL nuclear data team to enable the sharing of in-house data products with the national community. Our GNDS work is funded outside USNDP and has provided thorough checks of the ENDF libraries submitted by various groups.

Appendix C – Fiscal Year 2022 Articles authored by USNDP staff

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