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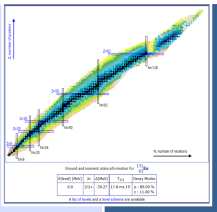

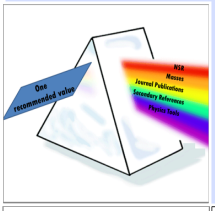

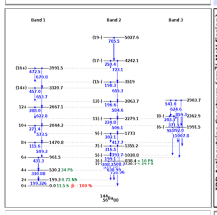

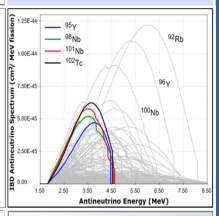

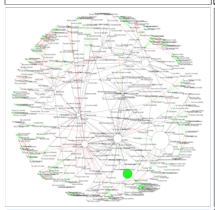

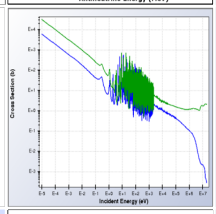

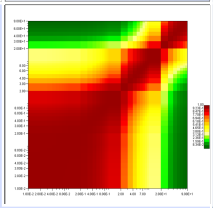

United States Nuclear Data Program

Annual Report for Fiscal Year 2023

This document describes the activities including related metrics performed by the US Nuclear Data Program members during Fiscal Year 2023.

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BNL

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I. Introduction

The US Nuclear Data Program (USNDP) Annual Report for Fiscal Year 2023 (FY23) summarizes the work of USNDP for the period of October 1, 2022 through September 30, 2023, with respect to the Work Plan for FY23 that was prepared in 2022. 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. **This leverage amounts to about 17.4 FTE scientific, to be compared with 23.8 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.

FY23 was the 24th 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 FY23. Then, we continue with the detailed status of work performed during FY23.

In terms of personnel changes, the USNDP has undergone several changes in FY23:

- C. Dunn joined the NNDC as the NNDC administrative assistant in February 2023
- E. Chimanski was converted to staff in April 2023
- A. Lauer-Coles left the NNDC to join the scientific staff of SRNL in July 2023
- L. Krejci was promoted in December 2022 and is no longer the NNDC administrative assistant
- L. Ricard started training for a part-time position in BNL NN department and will continue at the 20% time level in FY24
- B. Goldblum was converted from an LBNL staff to a 50% UCB faculty/50% LBNL faculty scientist position
- K. Setoodehnia joined TUNL in June 2023
- H. Sasaki at LANL converted from postdoc to staff in August 2023
- Daniel Burdette accepted a post-doc appointment at ANL
- Nathan Callahan accepted appointment in industry

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	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	10,860[e]	+15.10	3,988	292	9,016	71	71
2023	10,933[f]	+0.7	4,245	181	15,136	71	87

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

a: It includes the following (a) FIRE collaboration funding $100K (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 $100K (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 $100K (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 $100K (LLNL); (b) LAB calls funding: $884K (ANL), $717K (BNL), and $173K (ORNL).

e: Includes LAB calls funding: $825k (ANL), $693k (BNL), $702k (LANL), $61k (LLNL), and $424k (ORNL).

f: Includes LAB calls funding: $293k (ANL), $600k (BNL), $836k (LANL), $344k (LBNL), $64k (LLNL), $772k (ORNL) and $113k (PNNL).

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	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
ANL	0	2	12	13	-	-	15	17	5	9
BNL*	3,907	4,184	148.5	128.4	9,015.6	12,867	20	20	36	33
LANL	-	-	26	2.8	-	-	9	15	7	15
LBNL	0	0	22	16	7.5	24	20	17	14	13
LLNL	-	-	0	15	-	-	1	0	6	2
MSU	40	21	24	24	-	-	4	7	2	2
ORNL	-	-	9	13	2,983	2,168	5	7	5	9
TAMU	1	1	17	17	-	-	1	1	0	0
TUNL	40	37	7	2	57	77	0	1	0	1
Total	5,380	4,250	265	231	7,453.5	15,136	71	85	71	84

*: BNL compilations consist of (a) 3,624 NSR articles, including keywords for 2,705 of them; (b) 333 articles for EXFOR; (c) 227 articles encompassing 466 XUNDL datasets. BNL evaluations consist of (a) 120 nuclides for ENSDF and 8.4 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 NSR (bibliographic), EXFOR (experimental reaction) and XUNDL (experimental structure and decay) data libraries. The compilation activities are in a healthy state, 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 263 ENSDF evaluations and 9.14 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 US Nuclear Data 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 14, 2023, the DOE Office of Nuclear Physics conducted its annual Budget Briefing. Lee Bernstein, David Brown, Martin Schoonen, Hye-Young Lee, Elizabeth Ricard, Alejandro Sonzogni represented USNDP and made the case for the FY25 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 also chairs the Cross Section Evaluation Working Group (CSEWG), which produces the ENDF/B evaluated nuclear data library for nuclear science and applied nuclear technology use. In FY23, the NNDC organized and hosted the 2022 CSEWG meeting and co-organized the 2023 mini-CSEWG Meeting in LLNL and the 2023 Hackathon in LANL. Most of the focus where on the improvement of the ENDF/B library for the next release, ENDF/B-VIII.1. This work encompassed multiple Beta releases, evaluated file reviews, and library repository maintenance and development.

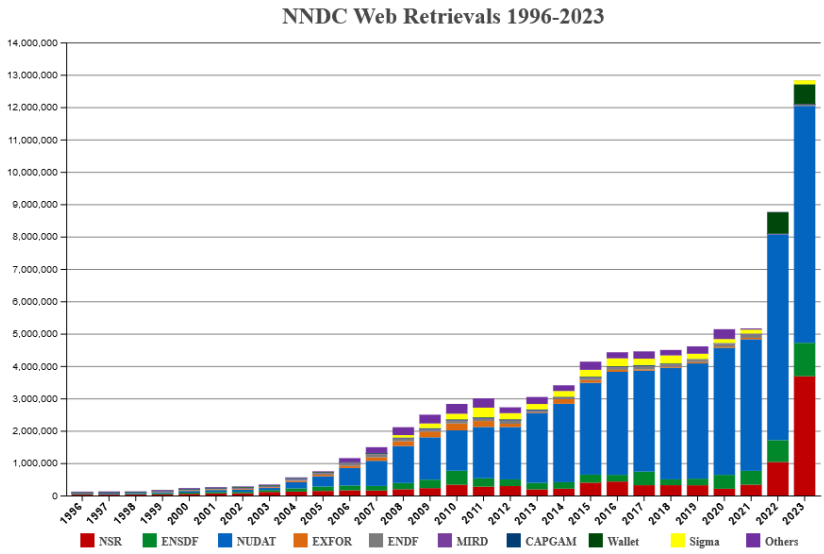
The USNDP also continues to play a leading role in the annual Workshop for Applied Nuclear Data Activities (WANDA) conference series, with the inaugural workshop held in Washington, DC in 2019 organized by LBNL. WANDA 2023 was held in Crystal City VA with several USNDP members serving as speakers and session organizers and the focus was on fission yields, isotopes, level densities, gamma-ray strength functions, processing and open data.

USNDP Databases

The NNDC operates several servers that support its compilation, evaluation, database maintenance, and information dissemination functions. These computers serve the nuclear data produced by USNDP and the data obtained by other national and international collaborations. The data on these computers are archived on AWS GovCloud providing geographical redundancy and rapid disaster recovery capabilities. In addition, the NNDC maintains the GitLab collaboration server that facilitates data and codes development and keeps track of changes. In particular, the GitLab server is the linchpin of NNDC's continuous quality assurance system for nuclear data processing codes and libraries and Web applications. 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 12.867 million database retrievals this fiscal year, significantly higher than the number of retrievals in the previous year. Most of the retrievals were from the NNDC web site, with NuDat as the most popular product as shown in the graph below.



Major Publications

USNDP continues to publish the refereed journal Nuclear Data Sheet: six issues were published this fiscal year containing ENSDF evaluations and articles relating to nuclear data.

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 2023, 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 presented on neutron-induced cross section measurements and progress on the NSF/NASA motivated 2020 Decadal Survey on Astronomy and Astrophysics.

Status of ENSDF

ENSDF evaluations submitted to the database increased considerably over the previous year, with 205 nuclide submissions compared with 230 in FY2022. The evaluations were a combination of nuclides resulting from mass chain evaluations (13 mass chains in total) along with single nuclide submissions.

Contributions to ENSDF from the international community continue to be less than 10% of the total effort. 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.

Status of XUNDL

Based on regular scanning of nuclear physics journals, 552 datasets were compiled from 293 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 FY2023, 3,624 new articles were added to the NSR database and 2,705 keyworded abstracts were produced. 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 NSR database contents were updated using the discovery of nuclides project in collaboration with M.Thoennessen (FRIB); The database is current and in good shape. The number of NSR web retrievals was 3.686 million retrievals.

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.G. Kondev – continuing.
- IAEA-ICTP organized workshops: J. Chen, S. Basunia, E. McCutchan, F.G. Kondev, B. Singh.
- The Atomic Mass Evaluation (AME) and the evaluation of basic nuclear physics properties for ground states and isomers (NUBASE): F.G. Kondev – continuing.
- 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 – continuing.
- IAEA-led decay data library for monitoring applications: J. Chen, F.G. Kondev, B. Singh, J. Tuli – continuing.
- IAEA-led NSDD meeting in Canberra, Australia: F.G. Kondev, E. Ricard, S. Ota, J. Wu, C. Morse, D. Mason
- IAEA Consultancy meeting on Evaluated Decay Data for Reactor Antineutrinos: F.G. Kondev
- IAEA Technical Meeting on Nuclear Data Needs for Antineutrino Spectra Applications: F.G. Kondev, E. Ricard, A. Sonzogni, A. Mattera
- IAEA Technical Meeting on Nuclear Data for Medical Applications: F.G. Kondev, E. Ricard
- Compilation of current papers on mass measurements on a yearly basis and make data file available on nuclearmasses.org: B. Singh, M. Smith – continuing.
- IAEA-CRP on Delayed Neutron Emission Probabilities: Reference database at IAEA-NDS: B. Singh - continuing
- WalletCraft: Object-oriented database for ground and long-lived isomeric properties: E. Ricard, B. Shu, D. Mason, C. Morse, S. Ota, J. Wu, A. Mattera continuing.
- Atlas of Isomers project**:** B. Singh – update of 2015Ja04 Atlas has been completed with the addition of new isomers in literature from 2015 to 2021 and re-evaluation of half-lives and isomer energies. A paper is in preparation for submission in February 2022.
- Update of 1998Si17 Review of log *ft* values: B. Singh – all the beta decay schemes in the December 2021 version of ENSDF and significant portion of newer literature updated for AME-2020 Q values and 2021 literature. 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 under preparation for submission in March 2022.
- Update of 2000Am02 magnetic dipole rotational bands: B. Singh – this work has been completed. A paper is under preparation for submission in February 2022
- 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.
- "Two-neutrino mode Double-beta Decay Half-Lives Evaluation: B.Pritychenko (NNDC) and V.Tretyak (KINR, Ukraine). Double-beta decay data for 14 parent nuclei have been reviewed and

recommended T1/2 and nuclear matrix elements were produced." This work is completed and intended for publication at the end of 2024.

Status of ENSDF Codes

Jun Chen continues developing new and constantly maintaining existing 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 ENSDF evaluation process, and updates and improvements for this code continues. The functions for checking format and keynumber errors have been added.

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.

The Java code 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 dataset.

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 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.

The Java code FormatCheck has been developed to replace the legacy FMTCHK for checking ENSDF datasets against errors and inconsistencies in ENSDF format.

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 and vice-versa. 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.

The Cross Section Evaluation Working Group (CSEWG), which is chaired by BNL on behalf of the USNDP, is actively preparing its next library release, ENDF/B-VIII.1. ENDF/B-VIII.1 is due in the first half of FY24. In preparation for this release, a new peer-review system was developed and implemented, dramatically increasing the quality of the evaluated files by identifying issues and errors well in advance before the final release. Pivotal in his task was the development of the continuous integration, continuous development platform ADVANCE, and its integration with the NNDC GitLab repository. Once a file is updated in the repository, ADVANCE automatically creates a virtual environment where many checking and processing codes are run on the updated file, generating a series of reports that aid in the quality assessment of the evaluated file. It is worth mentioning that, on previous library release cycles, these errors were often only discovered after a Beta release or even after the final release. We also shepherded community through at times contentious decisions processes, resolving issues of competing evaluations for the ^{239}Pu neutron file, the photonuclear sublibrary, and thermal scattering neutron files for lucite and polyethylene. Finally, multiple Beta versions of the upcoming ENDF/B-VIII.1 library were released in FY23, each successively and incrementally improving on quality and approaching the level necessary for the final release: ENDF/B-VIII.1-Beta2 (released 4 August, 2023); ENDF/B-VIII.1-Beta1.1 (released 18 April, 2023); ENDF/B-VIII.1-Beta1 (released 1 March 2023); plus multiple very preliminary “Beta0” versions released in October 2022.

In FY23, 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, in particular, impact strongly deformed target nuclei. We expanded the technique to solve the finite amplitude method (FAM) without any iterative procedures to the quasi-particle random-phase approximation (QRPA) for deformed systems. This allows us to calculate neutron radiative capture cross sections on the basis of microscopic description of nuclear structure, where the E1 and M1 giant resonances are consistently calculated with the same interaction. Consideration of memory of spin and parity in the fissioning compound nucleus was performed using Hauser-Feshbach Fission Fragment Decay (HF^{3}D) model to the photo-nuclear reactions on ^{235,238}U and ^{239}Pu. We proposed to solve the Schrodinger equation for a one-dimensional potential model to calculate the penetration probabilities in the fission channel of compound nuclear reactions, instead of applying the WKB approximation for uncoupled fission barriers as often done in the past. This new method was validated with experimental data on fission cross sections. New reaction evaluations were performed on platinum isotopes for neutron-induced reactions, chlorine-35 for updating the charged-particle emission channels, uranium-235 by comparing with the newly obtained experimental neutron capture data using DANCE at LANSCE, and plutonium-239 for the collective enhancement in the pre-equilibrium process.

The experimental cross sections on long-lived radioactive isotope ^{40}K and stable ^{39}K were obtained up to the neutron energy, 5 MeV using LENZ (Low Energy NZ instrument) at the Los Alamos Neutron Science Center (LANSCE) for the interest of the radiogenic heating of terrestrial-type planets. Experimental partial (n,p) and (n,α) cross sections show underproduction when compared with available libraries such as ENDF/B-VIII.0, JEFF-3.3, and JENDL-5, however a remarkable agreement was observed when the Koning-Delaroche global optical model potential was used. The effort of improving gas production data on structural materials is continued with the new experimental data sets on Zn isotopes. The (n,p) and (n,α) cross sections were analyzed for natural Zn, and analyses of the enriched ^{68}Zn data are underway. In order to improve angular resolutions of measured differential cross sections on the ^{16}O(n,α) reaction for constraining the R-matrix analysis of the ^{17}O system evaluation, we have performed the Monte Carlo simulations for a new time projection chamber (TPC), called Spatially Resolved Fission Tracker (SREFT) to be used at LANSCE. Three-dimensional tracking of charged particles reduce the experimental resolutions substantially (current prediction is about 2 degrees), which allows to meet the required or even better precision for resonance analyses.

Finally, during FY23 an important pioneering work on employing machine-learning (ML) to automatize the spin assignments of neutron resonances, authored by the BNL group, was published in Physical Review C. This article described the innovative method of using resonance data to sample synthetic resonance data, with the same statistical properties of the original resonance sequence, to be used as training and validation data for a ML classifier. This was successfully applied to the ENDF/B file of ^{52}Cr to identify resonances with improper spin assignments.

Nuclear Astrophysics Highlights

A review article was written on "Nuclear Data for Space Exploration" [published in Frontiers in Astronomy and Space Sciences]. This work details the status and gaps in the nuclear data relevant for space exploration in experiments, databases, dissemination, compilation, reaction models, radiation transport, electronics effects, human effects, spacecraft design, sensitivity studies, and uncertainty quantification. The review also details interdisciplinary research efforts that may potentially advance the field and improve the safety and viability of space exploration.

Another review article was written on "Nuclear data resources and initiatives for nuclear astrophysics" [published in Frontiers in Astronomy and Space Sciences]. This is a comprehensive review with over 230 references that describes the data types needed for nuclear astrophysics research, the available resources in nuclear reaction data, nuclear structure data, thermonuclear reaction rates, simulation codes, processing codes, and software services. It also discusses problems and challenges, a prioritized list of the most critical data needs, possible solutions in the form of initiatives, and the challenges of implementing these initiatives.

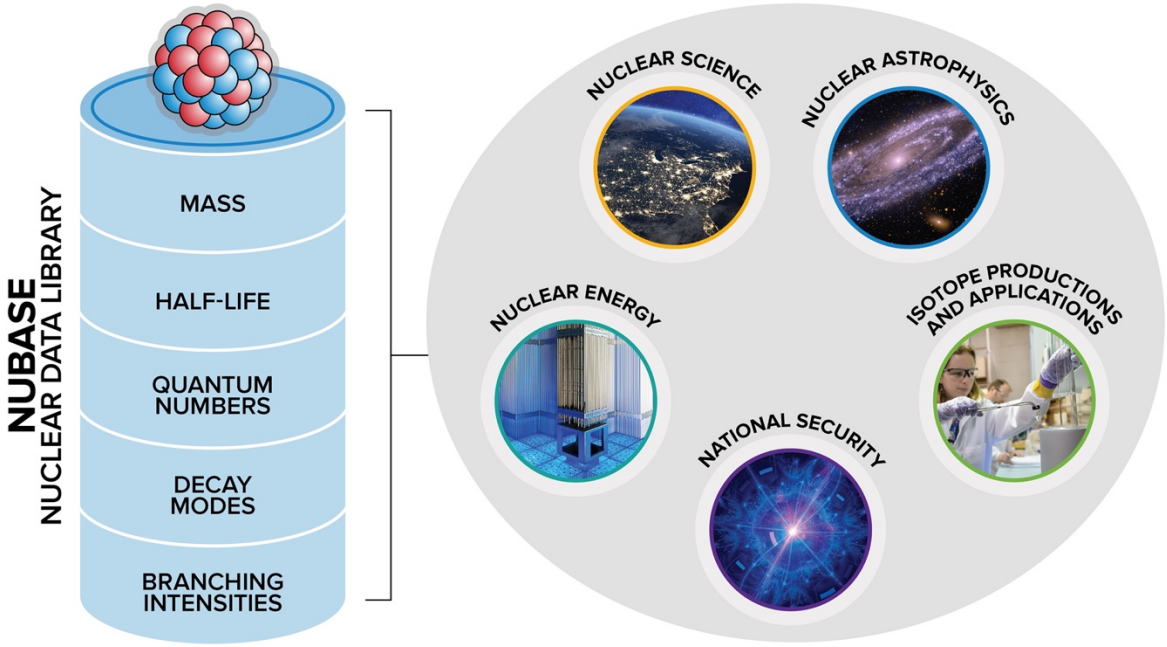
ENDF/B-VIII.1 library release creates multiple opportunities for nuclear astrophysics. Integral quantities (resonance integrals, Westcott factors, thermal neutron, and Maxwellian-averaged cross sections) relevant to nuclear energy and stellar nucleosynthesis calculations have been produced. Preliminary

analysis shows that the new ENDF/B library Ce evaluation resolves an issue with negative r-process abundances in ^{140}Ce, and a new Ba evaluation is needed to resolve this issue in ^{138}Ba.

Additional Highlights

NUBASE2020 is the IOP top cited paper in North America!

The current NUBASE2020 nuclear data library contains recommended values and uncertainties for nuclear physics characteristics of all nuclei in their ground and excited isomeric states. It incorporates a variety of experimental data produced at world-wide nuclear physics facilities. The entries are drawn from primary sources such as journal articles and secondary sources, primarily laboratory reports and conference proceedings. Each datum is accompanied by pertinent bibliographic details. The entry data are critically evaluated, discrepant results are dismissed, and statistical analysis is applied when recommending the final values. Where experimental data are lacking, estimates are given based on trends in the behavior of the properties for neighboring nuclei. The recommended data can be applied to many areas. Examples include fundamental science, astrophysics, power production, space exploration, national security, human health, and environmental protection.



Publications

Kondev F.G., et al., The NUBASE2020 evaluation of nuclear physics properties. Chinese Physics C 45, 030001 (2021). [DOI: 10.1088/1674-1137/abddae]

Related Links

Top Cited Paper Awards North America 2023, IOP Publishing. [Argonne physicist recognized for "Top Cited Paper" by Institute of Physics, Argonne National Laboratory]

Library Disaster Solves 12 Year Old Puzzle and Fuels an Award

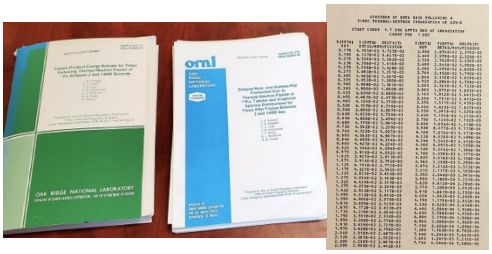


Figure 1: ORNL reports on delayed gamma-and electron data following fission uncovered in a shelf collapse of the NNDC library.

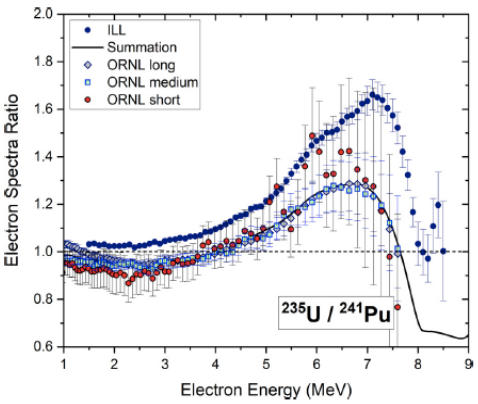


Figure 2: Summation calculations of the $^{235}U/^{241}Pu$ electron spectra ratio compared with the traditional ILL data and the recently uncovered ORNL data.

While most of BNL was working from home during COVID, a shelf in the library of the NNDC suffered a collapse. In the process of boxing and re-cataloging the material, several ORNL reports by Dicken's *et al*., were recovered. The reports detailed the measurement of delayed gamma and electron data following thermal fission of ^{235}U, and $^{239,241}Pu$. These data were not available on-line and missing from the major USNDP nuclear databases. With the help of SULI interns, 260 tables of data of significant relevance to reactor decay heat and antineutrino physics were digitized and incorporated into EXFOR. The newly discovered experimental data were compared with summation calculations of gamma and electron spectra from nuclear reactors, incorporating nuclear data from the two major libraries maintained by the USNDP, the Evaluated Nuclear Structure Data File (ENSDF) and the Evaluated Nuclear Data File (ENSDF). As shown in Figure 2, the summation calculations are in good agreement with the ORNL measurements, which differ from those measured at the ILL in the 1980's and had been the standard for antineutrino calculations. These results were published in Physical Review C in August 2023.

Many SULI interns have collaborated with the NNDC on projects relating to the calculation of reactor antineutrino spectra and summer 2023 was no exception.

Adam Oppenheimer, a math and physics major at the University of Chicago, joined the Nuclear Science and Technology group at BNL as a summer SULI intern to investigate unexplained features in radiation spectra from nuclear reactors. At the conclusion of the internship, he participated in the DOE 2023 Ignite Off Competition and his research was award the first place prize. To quote Adam "It was a wonderful experience even if I hadn't won."

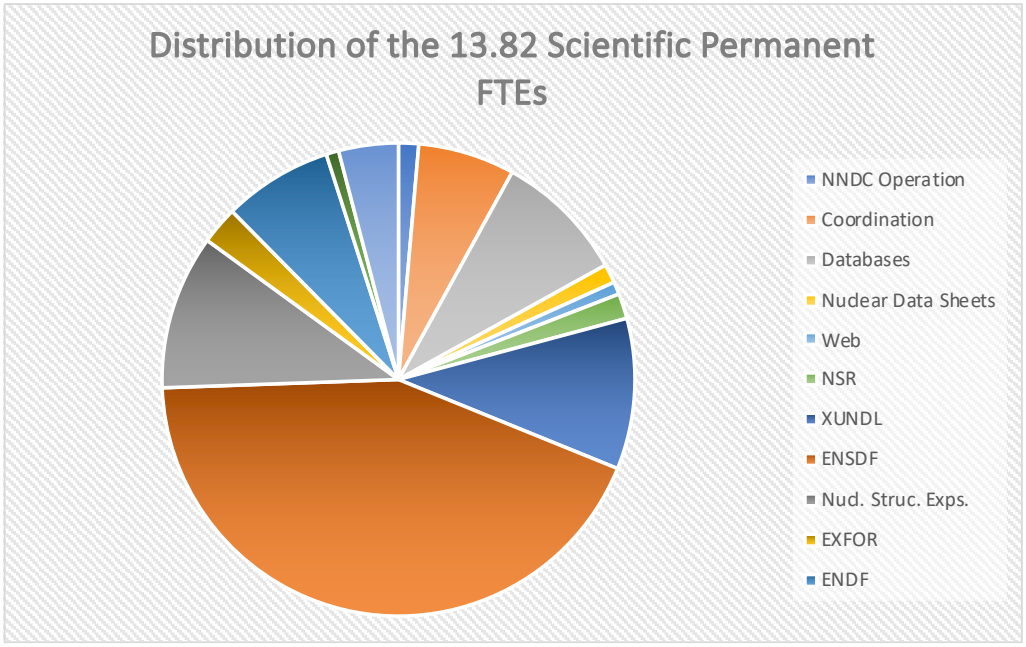
USNDP Staffing Table FY 2023

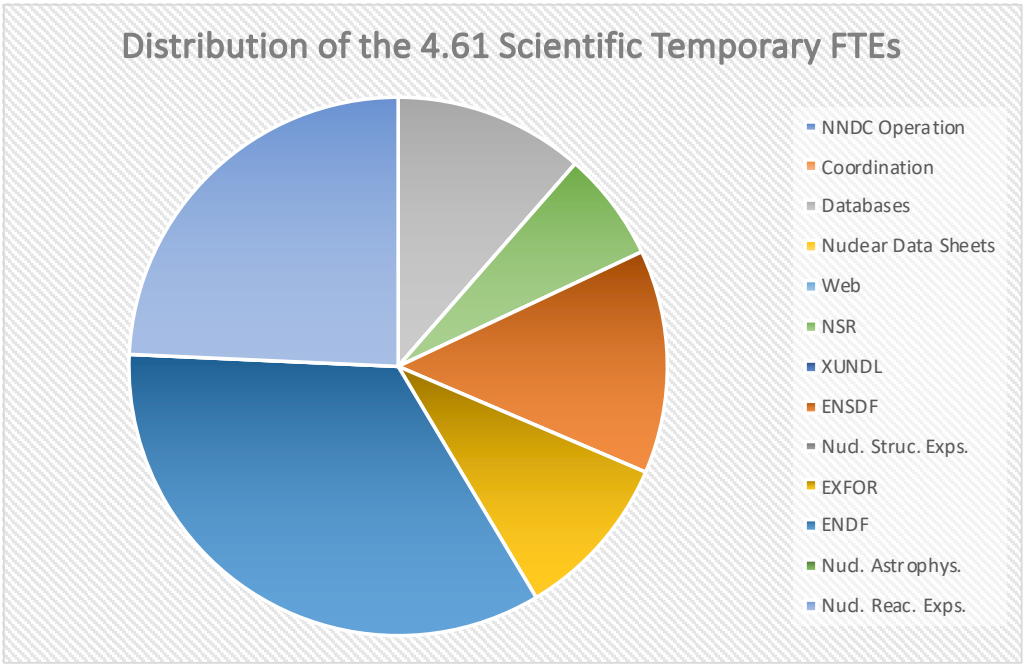
The table below gives the FTE distribution for each USNDP group according to activity. The values in this table and following plots are for the based funding only. In this table, PhD P means PhD Permanent; PhD T means PhD Temporary, which includes post-docs and scientists working under contract; T/A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

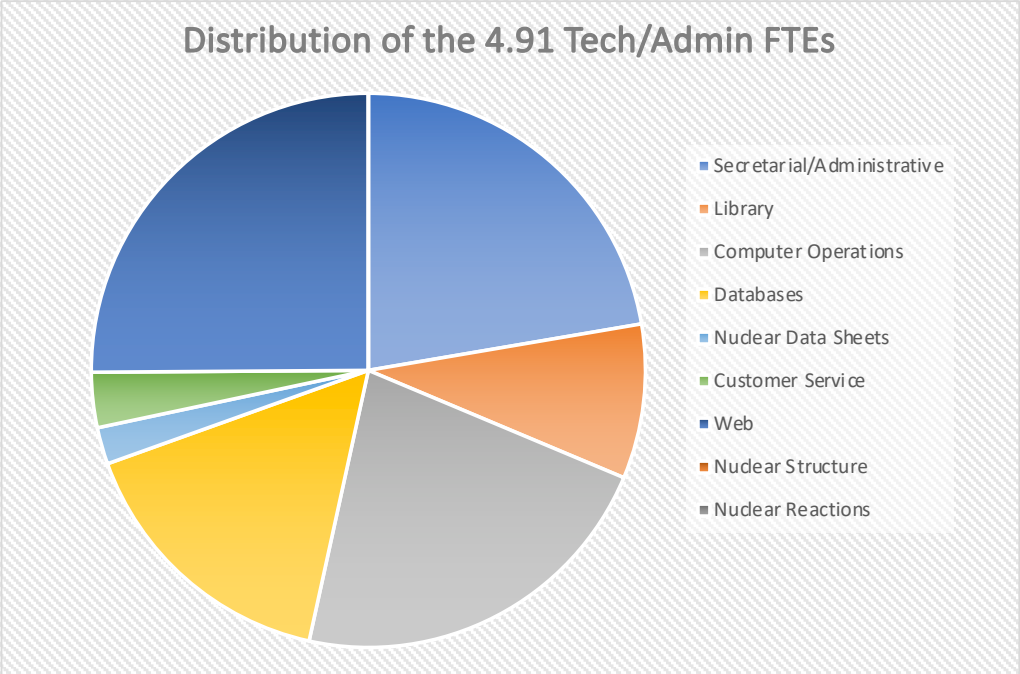
Activity	ANL	BNL			LANL			LBNL		LLNL	MSU	ORNL		TAMU	TUNL		
	PhD P	PhD P	PhD T	T/A	PhD P	PhD T	GS	PhD P	PhD T	PhD P	PhD P	PhD P	GS	PhD P	PhD P	PhD T	Totals
I. NNDC Facility Operation	0	0.16	0	2.49	0	0	0	0	0	0	0	0	0	0	0	0	2.65
Management		0.16															0.16
Secretarial/Administrative Support				1.04													1.04
Library				0.42													0.42
Computer Operations				1.03													1.03
II. Coordination	0.1	0.27	0	0	0.1	0	0	0.3	0	0	0	0	0	0	0	0	0.77
National Coordination	0.05	0.25			0.05			0.2									0.55
International Coordination	0.05	0.02			0.05			0.1									0.22
III. Nuclear Physics Databases	0	0.52	0.24	0.75	0	0	0	0.53	0.4	0	0	0	0	0	0	0	2.435
Nuclear Science References, NSR		0.2		0.5													0.7
Exper. Nucl. Structure Data, XUNDL		0.1	0.12														0.22
Eval. Nucl. Structure Data, ENSDF		0.1	0.12														0.22
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.		0.01						0.53	0.4								0.935
IV. Information Dissemination	0	0.15	0	1.42	0	0	0	0	0.2	0	0	0.1	0	0	0	0	1.87
Nuclear Data Sheets		0.15		0.1													0.25
Customer Services				0.15													0.15
Web Maintenance & Development				1.17					0.2			0.1					1.47
V. Nuclear Structure Physics	0.55	3.25	1.06	0	0	0	0	1.48	0	0	1	1	0	1	1	0.1	10.435
NSR Abstract Preparation		0.2	0.23												0	0	0.43
Compilation of Exper. Structure Data		0.96									0.1				0.14	0.05	1.25
Eval. of Masses & Nuclides for ENSDF	0.3	0.81	0.42					0.9			0.65	1		1	0.83	0.05	5.96
Ground & Metastable State Properties	0.2	0.1															0.3
Radioactive Decay Data Evaluation	0.05							0.38									0.425
Thermal Capture Gamma Data Eval.								0.15									0.15
Light Mass Eval. for Nucl. Physics A																	0
Nuclear Structure Data Measurement		1.18	0.41					0.05							0.03		1.67
ENSDF Evaluation Support Codes											0.25						0.25
VI. Nuclear Reaction Physics	0.05	1.12	0.7	0	0.4	1.25	0.4	0.18	0	0.3	0	0.1	0.2	0	0	0	4.695
Experimental Data Compilation		0.3	0.35														0.65
ENDF Manuals and Documentation		0.05															0.05
ENDF Evaluations		0.39			0.05					0.2							0.64
Nuclear Reaction Standards			0.35														0.35
Nuclear Model Development					0.15	0.4				0.1							0.65
Nucl. Reaction Data Measurements		0.1			0.2	0.85	0.4	0.18									1.725
Astrophysics Nuclear Data Needs	0.05				0							0.1	0.2				0.35
Covariances development																	0
Reactor anti-neutrino & decay heat calc.		0.2															0.2
Verification and Validation		0.08															0.08
DOE-SC Nucl. Data Funded Staff	0.7	5.47	2	4.66	0.5	1.25	0.4	2.48	0.6	0.3	1	1.2	0.2	1	1	0.1	22.855
Staff Supported by Other Funds	0.3	9.6	1.38	1.4	2.35	1.15	1.6										17.7817
TOTAL STAFF	1	15.1	3.38	6.06	2.85	2.4	2	2.48	0.6	0.3	1	1.2	0.2	1	1	0.1	40.6367

USNDP FTE Plots FY 2023

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 4.91 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 2023 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. The references stored in this library are not available anywhere else. The NNDC is actively scanning these are archiving them for posterity.

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, BNL's Information Technology Division provides centralized backup, printing and file serving for the PCs. In compliance with the DOE PuRE datacenter requirements, three mission-critical servers are continuously backed up to AWS GovCloud to provide geographical redundancy and rapid disaster recovery capabilities. 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 old Linux cluster.		
Deploy a new Linux cluster with an advanced hardware architecture and a parallel file system.		

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.		
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. -		
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.		

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.		

B. International Coordination

ANL Planned Activities	Status	Issues/Path Forward
Contribute to IAEA-sponsored nuclear data activities.		

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

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

LBNL Planned Activities	Status	Issues/Path Forward
Contribute to IAEA-sponsored nuclear data activities.		We will continue to contribute to data compiled through the CRP process for photon strength functions and to the upcoming CRP on nuclear level density.

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

TAMU Planned Activities	Status	Issues/Path Forward
Contribute to IAEA-sponsored nuclear data activities.		

TUNL Planned Activities	Status	Issues/Path Forward
Contribute to IAEA-sponsored nuclear data activities.		

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.		

LBNL Planned Activities	Status	Issues/Path Forward
Study in depth the possibilities of using AI and ML techniques in NSR, in collaboration with BNL.		Continue to work on NucScholar, primarily through USNDP-funded student employees and our independent contractor, Dr. Walid Younes.

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 maintaining and providing access to the 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.		
Contribute to WPEC Subgroup 50 on creating a critically reviewed version of EXFOR.		

F. Evaluated Nuclear Data File (ENDF)

The NNDC is the secretariat for the Cross Section Evaluation Working Group (CSEWG). CSEWG is responsible for ENDF, a database of evaluated nuclear data required for many nuclear applications. The ENDF library 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.)		The Sigma web app is the next major web app slated for modernization on the NNDC website.
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.		

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 NNDC database 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.		These webapps were removed from the NNDC website in FY22 in response to glaring cybersecurity vulnerabilities. The NNDC intends to replace this app with an enhanced Sigma web interface in FY24.
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.		
Purchased new hardware to replace aging GitLab, development, database and Web servers.		

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.		
Provide access to compiled and evaluated data on light nuclei related to p-, alpha- and n-capture reactions, and ground-state decays.		
Provide access for TUNL dissertations collection.		

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.		

BNL Planned Activities	Status	Issues/Path Forward
Compile new B(E2) experimental data. Continue work on a B(E2) evaluation project.		
Compile new double-beta decay experimental data. Finalize evaluated two-neutrino mode half-lives with 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.		
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.		LBNL is no longer compiling data for XUNDL as per discussions with the NNDC this activity will be carried out by other centers.

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.		

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.		
Review mass chain evaluations, as requested.		

BNL Planned Activities	Status	Issues/Path Forward
Evaluate at least four mass chains or their equivalent nuclides.		
Review at least four mass chains or their equivalent nuclides.		
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.		

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.		
Review mass-chain evaluations, as requested.		

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 chain 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.		The transition from the Nuclear Physics A "Energy Levels of Light Nuclei" to Nuclear Data Sheets formatted reviews is moving slowly. New effort from Kiana Setoodehnia should increase the progress of this transition.
Evaluate and update ENSDF for A=2-20 near drip-line nuclides, especially for first observations or when ENSDF has no previous dataset.		
Update various reaction datasets in ENSDF, such as for beta-decay and beta-delayed particle emission.		

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.		

BNL Planned Activities	Status	Issues/Path Forward
Develop new database for ground and metastable state properties (WalletCraft).		
Begin evaluation process to provide recommended ground and metastable state properties.		

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."		

BNL Planned Activities	Status	Issues/Path Forward
Contribute to the beta-delayed neutron emitters IAEA CRP.		

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.		This work has been folded into the pace_ENSDF project, which is now nearing completion. A publication has been produced.

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'gamma) as well as with additional sources of energy differential (n,n'gamma) 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.		
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.		Work has so far only utilized TALYS, but is proceeding at LBNL.
Explore the role of quasi-continuum contributions through collaboration with researchers from LLNL and the University of Oslo.		

G. Nuclear Structure Data Measurements

ANL Planned Activities	Status	Issues/Path Forward
Contribute to 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.		

BNL Planned Activities	Status	Issues/Path Forward
Precisely determine decay schemes of relevant medical isotopes using state-of-the-art gamma-ray spectroscopy.		
Contribute to 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.		

Perform gamma-ray spectroscopy experiments with GRETINA to remedy data deficiencies uncovered during ENSDF evaluations.		
Setup new gamma-alpha coincidence station.		

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.		No experiment were performed during this period, but the results from several activation experiments on ^{86}Sr targets were published via a collaboration with the group from Jülich under the leadership of Prof. S. Qaim. The LBNL lead is Dr. S. Basunia.

MSU Planned Activities	Status	Issues/Path Forward
Contribute to gamma-ray spectroscopy and lifetime measurements with GRETINA at FRIB		

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.		
Work on the development of the next generation ENSDF format and develop applications that apply Machine Learning techniques to the new format.		

MSU Planned Activities	Status	Issues/Path Forward
Maintain and improve the ENSDF utility and analysis codes in Java developed at MSU.		
Develop new Java codes to replace the legacy ENSDF codes in Fortran that lack maintenance and to facilitate and streamline data evaluation process.		
Develop new Java-NDS program to work with the new ENSDF JSON format		

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.		David Brown (BNL) has stepped down as the EG GNDS chair. EG GNDS is now chaired by Caleb 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.		Collected evaluation contributions from the community, ran checks and implemented appropriate fixes
Collect and address users feedback related to the ENDF library.		Developed review system and continuous integration automated checks
Complete evaluations for Zr isotopes to support new reactor fuel concepts.		External issues with experimental facilities, allied with strong focus on the next ENDF/B release has delayed Zr evaluation efforts. However, collaborations with RPI and ORNL have been intensifying.
Work with CSEWG on upgraded evaluations for future release of the ENDF/B library.		Released ENDF/B-VIII.1-Beta1, Beta1.1, and Beta2 and distributed for testing
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.		Project shifting to NCSP funding in FY24.
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.		
Contribute to 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 both the prompt and delayed fission observables, based on the statistical Hauser-Feshbach 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.		
Contribute evaluated angular distributions and energy spectra for charged particle outputs to ENDF/B-VIII.1		

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 inelastic scattering reference cross sections; adding ranges 30 keV MACS for the Au(n,γ) cross section standard; and proposing updates for the evaluations of the ^{252}Cf spontaneous fission neutron spectrum and the 235U 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		Attended an IAEA meeting on the "maintenance of the neutron cross section standards" and gave a presentation on work on the hydrogen standard cross section. Monitored standards work activity

literature and other sources for possible measurements related to standards.		by reading literature, attending meetings, interaction with experimenters and other possibilities.
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.		• Continued work with the ISRD-17 meeting. It was held May 21-26, 2023 in Lausanne Switzerland after a long delay due to covid. As a program committee member, meetings were attended related to the ISRD-17 agenda and the upcoming ISRD-18 meeting. The ISRD-18 International Symposium on Reactor Dosimetry will be held May 19-23, 2025 at the Francis Marion Hotel, Charleston, SC. This Symposium is being organized by ASTM and is jointly sponsored by the ASTM International Committee E10 on Nuclear Technology and Applications and the European Working Group on Reactor Dosimetry (EWGRD). Program committee meetings are planned concerning the details of that meeting. Possibly a paper on the standards may be submitted if work on the next version of the standards is completed. • The 5th International Workshop on Nuclear Data Covariances (originally called CW2020), was delayed due to the pandemic and became CW2022. A paper was presented on use of integral data in standards evaluations that was co-authored by me. Because of the covid complications, the meeting was virtual from Tokyo. Also a paper was published based on the database work for the new cross section standards evaluation that was presented at the ND2022 conference. Also reviewed papers for the ND2022 Nuclear Data Conference.
Work will continue on both ^{6}Li(n,t) and ^{235}U(n,f) measurements at NIST with sub-thermal neutrons.		Work on these cross sections has been slowed due to the reactor being at a very low level of power. Work has been done on characterizing the samples.
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		The report on the IAEA meeting in 2020 was published as IAEA(NDS)-0820. Also reports for 2021, IAEA(NDS)-0837 and 2022, IAEA(NDS)-0865 were prepared. An IAEA meeting in FY24 is planned, eventually leading to a new standards

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.		evaluation. The work with Professor Zhang's group has been very successful. The work on the $^{10}B(n, \alpha)^{7}Li$ cross section and that of the the $^{6}Li(n, t)^{4}He$ reaction were limited due to structure from the $^{235}U(n,f)$ standard being used below the standards energy range. I suggested taking ratios of the data. It was done and they wanted to make me a co-author on the paper. I said I did not work on the experiment so I should not be included. A very positive acknowledgement for me was given in the paper. The paper is "Ratios of the cross sections for the $^{10}B(n, \alpha)^{7}Li$ reaction to the $^{6}Li(n, t)^{4}He$ reaction" in the European Physical Journal A in 2023.

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.		Work on this project halted as the staff member performing this activity (Matteo Vorabbi) has taken a position at the University of Surrey, UK.
Model (n,gamma) spectra to address a major shortcoming in the ENDF library as noted in WANDA 2020.		Work continuing under 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
Perform double-differential cross sections of (n,p) and (n,a) reactions on ^{58}Ni and ^{60}Ni 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 using a time projection chamber, SREFT, for improved angular distributions at the neutron energy range of 2 – 15 MeV.		
Perform double-differential (n,p) and (n,a) cross sections on ^{63}Cu for the neutron energy range of 0.5 – 20 MeV.		
Measure double-differential cross sections of (n,p) and (n,a) reactions on ^{68}Zn and ^{nat}Zn in respect to incoming neutron energies and outgoing particles angles for the neutron energy range of 0.5 – 20 MeV.		
Finalize double-differential (n,p) and (n,a) cross sections of ^{39}K and ^{40}K 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'gamma) and ^{238}U(n,n'gamma) reactions using the Gamma Energy Neutron Energy Spectrometer for Inelastic Scattering (GENESIS).		The ^{56}Fe data has been submitted for publication. It formed the corpus of the doctoral dissertation work of Joseph Gordon. The ^{238}U data is being analyzed by UCB student Speero Tannous.
Perform energy-dependent measurements of short-lived fission fragments on ^{235,238}U using the		No activities performed this period.

Fast Loading and Unloading Facility for Fission Yields (FLUFFY).		
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.		No activities performed this period.

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.

ANL Planned Activities	Status	Issues/Path Forward
Provide recently compiled and evaluated nuclear data of nuclear physics properties for update of the REACLIB library		

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.		Completed in FY22
Develop the sensitivity study for neutron-induced reactions with radioactive isotopes in nuclear network simulations relevant for heavy element production		

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.		Uncertainty updates were provided in FY23, but a full covariance format does not yet exist for the ENDF-6 format. A format exists for the GNDS-2.0 format, but it is untested.

LBNL Planned Activities	Status	Issues/Path Forward
Continue to develop an experimentally driven fission covariance database		The database has been posted on the Berkeley group website and is continuing to be maintained by LBNL/UCB staff.

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 Contribute to 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 one LAB 18-1903 funded proposals (DOE/SC/NP and DOE/NNSA/NA-22)

BNL

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.

The full list of non-USNDP NNDC projects is:

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. Evaluation of energy dependent fission product yields, funded by NA-22.
3. NA-22 Intentional Forensics Venture, a project to develop a tagging system for nuclear fuel.
4. DOE-NE's Nuclear Energy University Program (NEUP) to serve on thesis committee of RPI student developing Pb evaluations for ENDF.
5. High precision decay measurements of isotopes relevant to nuclear forensics, funded by NA-22.
6. Four NDWIAG FOA-funded proposals:
   - Modernization and optimization of the Evaluated Nuclear Structure Data File
   - Gamma Rays Induced by Neutrons, performing outgoing gamma evaluations, funded by NA-22 (with LBNL, LLNL)
   - Structure Based Evaluations of Nuclear Data, using proper structure information to perform R-matrix evaluations (with LANL, LLNL)
   - AI Guided re-evaluation of the ^{252}Cf(sf) spectrum (with 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. Improvements to R-matrix evaluations using information from nuclear structure (in collaboration with LLNL and BNL)
6. Science Campaign support under Office of Experimental Sciences by NNSA.
7. DOE-NE Gateway for Accelerated Innovation in Nuclear (GAIN) initiative through TerraPower

LBNL

Additional supports for the LBNL nuclear data project are as follows:
1. DOE-NE's Nuclear Energy University Program (NEUP) for measurements on ^{35}Cl for fast reactor design improvement. This project is ending in 12/23 with the publication of the experimental data and the graduation of UCB student Tyler Nagel.
2. DOE Isotope Program under 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. The Stewardship Science Academic Alliance (SSAA) Program (NNSA/NA-113) supported GENESIS measurements on natural niobium. Data analysis is being performed by UCB student Keenan Myers.
5. NNSA/NA-22 is supporting measurements of neutrons and gamma-rays on carbon and sodium targets using the GENESIS array.
6. An NDIAWG FOA funded measurement program is being carried out using DT-API generators at LBNL under the lead of Dr. Arun Persaud at LBNL and Dr. Patrick Peplowski at JHUAPL.

LBNL Leveraged Activities	**Status**
Dissemination of the "Baghdad Atlas" database of Gamma-ray emission from the inelastic scattering of reactor fast neutrons.	This work began with USNDP funding, was supported for some time under NA-22 funding, and is now being supported again by the USNDP.
Dissemination of the Curie Data Analysis Software Package. Curie uses data from EXFOR, TENDL and ENSDF decay data to facilitate the analysis of activation data.	Distribution of the Curie package is carried out using github (https://jtmorrell.github.io/curie/build/html/index.html)
Development of a new Database of gamma-ray/X-ray coincidences.	The Berkeley group is working with PNNL using both DTRA and USNDP support to produce a JSON-formatted database of decay data for select nuclei of interest for nuclear forensics applications. This work is ongoing.

LLNL

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.

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).
3. ENSDF modernization project (with BNL)
4. Gamma Rays Induced by Neutrons, performing outgoing gamma evaluations, funded by NA-22 (with BNL, LBNL)
5. Structure Based Evaluations of Nuclear Data, using proper structure information to perform R-matrix evaluations (with LANL, BNL)

MSU

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ORNL

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TAMU

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TUNL

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Appendix B – USNDP Data and Code Products

Joint Products		
Evaluated Nuclear Data File (ENDF)	**POC:** David Brown (dbrown@bnl.gov) CSEWG Chair, Gustavo Nobre (gnobre@bnl.gov) ENDF Library Manager	**URL:** https://www.nndc.bnl.gov/endf/
	Description: Core nuclear reaction database containing evaluated (recommended) data from the ENDF/B-VIII.0 library. It provides data in the ENDF-6 format, covering all nuclides of practical relevance for neutrons up to 20 MeV and partly up to 150 MeV. It serves as principal input for neutronics calculations, including nuclear reactor design, national security, accelerators, criticality safety, shielding, radiation protection and detector simulation.	
Evaluated Nuclear Structure Data File (ENSDF)	**POC:** Elizabeth Ricard (mccutchan@bnl.gov)	**URL:** https://www.nndc.bnl.gov/ensdf/
	Description: Core nuclear structure and decay database containing evaluated (recommended) data for 3,171 nuclides, organized in over 17,269 individual datasets. It serves as principal source of data for nuclear structure research, nuclear spectroscopy applications, MIRD, NuDat, and publications such as Nuclear Data Sheets and Table of Isotopes.	
eXperimental Unevaluated Nuclear Data Library (XUNDL)	**POC:** Elizabeth Ricard (mccutchan@bnl.gov)	**URL:** https://www.nndc.bnl.gov/xundl/
	Description: Experimental nuclear structure and decay data, covering more than 2,500 recent nuclear structure and decay articles. The XUNDL database contains 4,212 datasets for 1,990 nuclides.	

Argonne National Laboratory		
Argonne Nuclear Data and Measurements Reports (ANL/NDM)	**POC:** Filip Kondev (kondev@anl.gov)	**URL:** https://www.anl.gov/phy/reference/argonne-nuclear-data-measurement-anlndm-reports
	Description: Contain experimental and evaluated data produced at ANL since 1978, including a) measured microscopic nuclear parameters, b) experimental techniques and facilities employed in measurements, c) the analysis, correlation and interpretation of nuclear data, d) the compilation and evaluation of nuclear data	
Atomic Mass Evaluation (AME)	**POC:** Filip Kondev (kondev@anl.gov)	**URL:** https://www.anl.gov/phy/atomic-mass-data-resources
	Description: Provides evaluated (recommended) data for the atomic masses and their derivatives for 3557 nuclides; uses NSR and NUBASE	
Evaluation of Properties of K-Isomers in	**POC:** Filip Kondev	**URL:** https://www.sciencedirect.com/science/article/pii/S0092640X15000029

Deformed Nuclei	(kondev@anl.gov)	
	Description: Contain evaluated (recommended) data for the properties of K isomers in deformed nuclei; uses NSR, NUBASE and ENSDF	
NUBASE Evaluation of Basic Nuclear Properties (NUBASE)	**POC:** Filip Kondev (kondev@anl.gov)	**URL:** https://www.anl.gov/phy/atomic-mass-data-resources
	Description: Provides evaluated (recommended) data for the basic properties for 3340 nuclides in their ground state and 1938 isomers (T1/2>100 ns); uses NSR, AME and ENSDF	

Brookhaven National Laboratory, National Nuclear Data Center		
Atlas of Neutron Resonances	**POC:** David Brown (dbrown@bnl.gov)	**URL:** https://www.nndc.bnl.gov/atlas/
	Description: The sixth edition of the vaunted BNL-325 "Barn book", authored by Dr. Said Mughabghab and published by Elsevier in two volumes on April 17, 2006. The present sixth edition differs from previous editions in that available capture, fission, and total neutron cross sections in the keV-Mev neutron energy region were analyzed by the author with the objective of determining average neutron resonance parameters and compared to those obtained from the resolved energy regions. In addition to the extensive list of detailed individual resonance parameters for each nucleus, this contains thermal cross sections and average resonance parameters as well as a short survey of the physics of thermal and resonance neutrons with emphasis on evaluation methods.	
B(E2) Evaluation	**POC:** Boris Pritychenko (pritychenko@bnl.gov)	**URL:** https://www.nndc.bnl.gov/be2/
	Description: Recent data on electric quadrupole transition probabilities or B(E2; 0+ → 2+) values	
CapGam	**POC:** Benjamin Shu (bshu@bnl.gov)	**URL:** https://www.nndc.bnl.gov/capgam/
	Description: The energy and photon intensity with uncertainties of gamma rays as seen in thermal-neutron capture are presented in two tables, one in ascending order of gamma energy and a second organized by Z, A of the target.	
Computer Index of Nuclear (reaction) Data (CINDA)	**POC:** Boris Pritychenko (pritychenko@bnl.gov)	**URL:** https://www.nndc.bnl.gov/cinda/
	Description: Bibliographical neutron induced reaction information, including experimental, theoretical and evaluation works. It contains references to 275,000 reactions from 55,000 works.	
Double Beta Decay Data	**POC:** Boris Pritychenko (pritychenko@bnl.gov)	**URL:** https://www.nndc.bnl.gov/bbdecay/
	Description: Data on double beta (ββ) decay, data content is integrated with the Nuclear Science References (NSR) database.	
Medical Internal	**POC:** Elizabeth Ricard (mccutchan@bnl.gov)	**URL:** https://www.nndc.bnl.gov/mird/

Radiation Dose (MIRD)	**Description:** Evaluated nuclear decay data for over 2,100 radioactive nuclei. Data are extracted from ENSDF, processed by the program RadList, and used for medical internal radiation dose calculations.	
NuDat3	**POC:** Donnie Mason (dmason@bnl.gov)	**URL:** https://www.nndc.bnl.gov/nudat3/
	Description: Evaluated (recommended) nuclear structure and decay information for 3,175 nuclides, about 161,895 levels, 243,639 gamma-rays, etc. Obtained from ENSDF and Nuclear Wallet Cards.	
Nuclear Wallet Cards	**POC:** Elizabeth Ricard (mccutchan@bnl.gov)	**URL:** https://www.nndc.bnl.gov/nudat3/indx_sigma.jsp
	Description: Observable nuclear properties for ground- and isomer-states of all known nuclides.	
Q Value Calculator (QCalc)	**POC:** Benjamin Shu (bshu@bnl.gov)	**URL:** https://www.nndc.bnl.gov/qcalc/
	Description: QCalc calculates Q-values for nuclear reactions or decay. It uses mass values from the 2020 Atomic Mass Evaluation by M. Wang et al .	
Sigma	**POC:** Donnie Mason (dmason@bnl.gov)	**URL:** https://www.nndc.bnl.gov/sigma/
	Description: Evaluated (recommended) nuclear reaction and decay data from ENDF/B-VII.0, JEFF-3.1, JENDL-4.0, JENDL-3.3, CENDL-3.1, ROSFOND 2008 and ENDF/B-VI.8 libraries. Advanced plotting, browsing, and search options.	
x4i	**POC:** David Brown (dbrown@bnl.gov)	**URL:** https://github.com/brown170/x4i
	Description: x4i provides a "simple" python interface to the EXFOR library, allowing users to search for and then translate EXFOR files into an easy to understand (and then plot) form.	

Los Alamos National Laboratory		
BeoH	**POC:** Toshihiko Kawano (kawano@lanl.gov)	**URL:** None
	Description: Code for calculating statistical decay of compound nucleus that is produced by beta-decay, fission, or any other nuclear reaction mechanisms	
CENS	**POC:** Toshihiko Kawano (kawano@lanl.gov)	**URL:** https://github.com/toshihikokawano/CENS
	Description: Code to translate adopted discrete levels in ENSDF into a Hauser-Feshbach code readable format, such as the discrete level section in RIPL	
CGMF	**POC:** Michael E. Rising (mrising@lanl.gov)	**URL:** https://github.com/lanl/CGMF
	Description: Code for simulating emission of prompt fission neutrons and gamma rays from excited fission fragments right after scission	
CoH3	**POC:** Toshihiko Kawano (kawano@lanl.gov)	**URL:** None
	Description: Code for calculating comprehensive nuclear reaactions in the keV to MeV energy range using the coupled-channels optical model and statistical Hauser-Feshbach theory with the pre-equilibrium process	
DeCE	**POC:** Toshihiko Kawano (kawano@lanl.gov)	**URL:** https://github.com/toshihikokawano/DeCE

	Description: Interactive ENDF-6 formatted data manupulation code to edit/create ENDF files	
KALMAN	**POC:** Toshihiko Kawano (kawano@lanl.gov)	**URL:** None
	Description: Parameter adjustment and production of covariance based on the Bayesian approach	
SOK	**POC:** Toshihiko Kawano (kawano@lanl.gov)	**URL:** None
	Description: Least-squares fitting code for arbitrary shape data, and production of covariance	

Lawrence Berkeley National Laboratory		
Atlas of Gamma-Ray Spectra from the Inelastic Scattering of Reactor Fast Neutrons (Baghdad Atlas)	**POC:** Aaron Hurst (amhurst@lbl.gov)	**URL:** https://nucleardata.berkeley.edu/atlas/index.html
	Description: A relational database based on the original (n,n'γ) work carried out by A.M. Demidov et al., at the Nuclear Research Institute in Baghdad, Iraq. Downloadable SQLite software platform shipped with CSV-style ASCII files for 105 datasets based on irradiation of 76 natural and 29 iostopically-enriched targets. Bundled with SQL scipts and a Jupyter Notebook enabling interaction and manipulation of the data.	
Attenuation code for Prompt Gamma Activation Analysis	**POC:** Aaron Hurst (amhurst@lbl.gov)	**URL:** https://github.com/AaronMHurst/attenuation_integration
	Description: A C++ program to calculate the attenuation integrated over the sample thickness for elemental and compound samples irradiated in prompt gamma activation analysis measurements. The software is shipped complete with mass-attenuation coefficients covering 1 keV to 20 MeV for all elements in the XMuDat database.	
Fission Induced Electromagnetic Response (FIER)	**POC:** Eric Matthews (efmatthews@berkeley.edu)	**URL:** https://nucleardata.berkeley.edu/fier/index.html
	Description: FIER analytically predicts delayed gamma-ray spectra following fission using evaluated nuclear data and solutions to the Bateman equations to calculate the time-dependent populations of fission products and their decay daughters resulting from irradiation of a fissionable isotope.	
Fission Product Yield Covavriance Matrices (COM)	**POC:** Eric Matthews (efmatthews@berkeley.edu)	**URL:** https://nucleardata.berkeley.edu/FYCoM/index.html
	Description: Covariance matrices for all of the fissioning systems of the ENDF/B-VIII.0 and JEFF-3.3 evaluations created using a constrained Monte-Carlo resampling approach.	
Global Heavy Charged-Particle Decay Database (BEApR)	**POC:** Jon Batchelder (JCBatchelder@lbl.gov)	**URL:** https://nucleardata.berkeley.edu/research/betap.html
	Description: A complete compilation of decay data from proton-rich nuclei that decay through the emission of protons and alphas from Tz = -7/2 to Tz = +33/2 are	

	currently included, with additional Tz groups still to be included up to the heaviest nuclei known (Tz = +32). This database will be updated as new papers are published. Information from this database can currently be downloaded as a pdf document as we are developing a more useful format for future dissemination.	
NucScholar	**POC:** Walid Younes (WYounes@lbl.gov)	**URL:** https://nucscholar.lbl.gov/
	Description: NucScholar is a project to automate the processing of nuclear science literature to simultaneously boost researcher productivity while lowering the effort required to maintain important databases.	
Nuclear Structure Experimental Issues (NSEI)	**POC:** Aaron Hurst (amhurst@lbl.gov)	**URL:** https://nucleardata.berkeley.edu/nsei/
	Description: The NSEI website is provides a mechanism for nuclear data evaluators and the low-energy community, in general, to raise awareness of issues in nuclear structure data. Users enter a brief description of the issue they would like to raise, and a committee will make researchers in the field who might be interested in helping to resolve the problem aware of the issue.	
Python Archive of Coincident Emissions from ENSDF (paceENSDF)	**POC:** Aaron Hurst (amhurst@lbl.gov)	**URL:** https://pypi.org/project/paceENSDF/ and https://github.com/AaronMHurst/pace_ensdf
	Description: paceENSDF is an open-source Python-based software package enabling access, manipulation, analysis, and visualization of the radioactive decay data from the Evaluated Nuclear Structure Data File (ENSDF) archive and corresponding gamma-gamma and gamma-X-ray coincidence relationships derived from the original ENSDF-sourced datasets. The library is based on a representative JSON-format for 3254 radioactive-decay datasets (parsed from the September 2023 ENSDF archive) encompassing 834 alpha-, 1141 beta-minus and 1279 electron-capture/beta-plus decay datasets. The software package is also bundled with a Reference Input Parameter Library (RIPL)-translated format of the corresponding decay-scheme data in addition to JSON data structures for the derived coincidence gamma-gamma and gamma-X-ray datasets.	
Python library for the Evaluated Gamma-ray Activation File (pyEGAF)	**POC:** Aaron Hurst (amhurst@lbl.gov)	**URL:** https://pypi.org/project/pyEGAF/ and https://github.com/AaronMHurst/python_egaf
	Description: pyEGAF is an open-source Python-based software package enabling interaction, maipulation, analysis, and visualization of the thermal neutron-capture gamma-ray data in the Evaluated Gamma-ray Activation File (EGAF) based on the prompt gamma activation analysis measurements carried out at the Budapest Research Reactor (BRR). The library comes complete with ENSDF-, RIPL-, and JSON-formatted databases for all 245 isotopes measured at the BRR.	
Scintillator library	**POC:** Bethany Goldblum (bethany@lbl.gov), Thibault Laplace (lapthi@berkeley.edu)	**URL:** https://scintillator.lbl.gov/
	Description: The website provides measured scintillation properties of many inorganic and organic scintillating materials including scintillator response to recoil nuclei along with citations to published papers in which the original measurements were reported.	

Lawrence Livermore National Laboratory

Ferdinand, Translate R-matrix Evaluations	**POC:** Ian Thompson (thompson97@llnl.gov)	**URL:** https://github.com/LLNL/ferdinand
	Description: Code for reading input files for R-matrix codes fresco, sfresco, eda, amur, rac, azure and standard formats endf and gnds, to translate between them. Can also convert between widths and amplitudes, and generate various kinds of reconstructed cross sections.	
Frescox, Scattering code for coupled-channels calculations	**POC:** Ian Thompson (thompson97@llnl.gov)	**URL:** https://github.com/LLNL/Frescox
	Description: Documentation at https://www.fresco.org.uk/frescox.htm	
Rflow, R-matrix methods for fitting EXFOR data using tensorflow	**POC:** Ian Thompson (thompson97@llnl.gov)	**URL:** https://github.com/LLNL/Rflow
	Description: An R-matrix evaluation and fitting code that reads and writes gnds parameter files. Calculations performed using Tensorflow, which uses GPUs when available otherwise using CPUs with openmp.	

Michigan State University, Facility for Rare Isotope Beams		
AME-NUBASE viewer	**POC:** Jun Chen (chenj@frib.msu.edu)	**URL:** https://github.com/IAEA-NSDDNetwork/AME-NUBASE-viewer
	Description: A useful program to provide easy and customized retrieval of AME (Atomic Mass Evaluation) entries and NUBASE (evaluation of ground-state and isomer properties) entries. It can also be used to update Q records in Adopted datasets automatically for ENSDF evaluation.	
ConsistencyCheck code	**POC:** Jun Chen (chenj@frib.msu.edu)	**URL:** https://github.com/IAEA-NSDDNetwork/ConsistencyCheck
	Description: The program recommended by USNDP and NSDD to check data consistency among ENSDF datasets, group levels and gammas, and average values from different datasets (with user selections), and more.	
Discovery of Nuclide Project (in collaboration with Michael Thoennessen of FRIB)	**POC:** Michael Thoennessen (non-USNDP member), Jun Chen (chenj@frib.msu.edu)	**URL:** https://frib.msu.edu/users/nuclides
	Description: The Discovery of Nuclides Project documents the discovery of all isotopes, with information about discovery year, authors, laboratory, country, publising journal, as well as an abstract briefly descriping each discovery and history. The project was started and led by Michael Thoennessen since 2007. Jun Chen joined in this project in 2023, has modernized the database with JSON and created a viewer/editor of the database as well as webpages to display and query those data, and will maintain the database and webpages regularly. Jun Chen's effort is within the scope of data activities supported by his grant from DOE/NP.	
EXCEL2ENSDF	**POC:** Jun Chen (chenj@frib.msu.edu)	**URL:** https://github.com/IAEA-NSDDNetwork/Excel2ENSDF
	Description: A program widely used by XUNDL compilers and ENSDF evaluators to convert an Excel file (formatted data) to an ENSDF file and vice versa. It can be also used to perform simple operations on column data in Excel, such as	

	multiplying a factor or adding a constant. It was originally developed for XUNDL compilation to convert Excel to ENSDF but the current version is also useful for extracting data from an ENSDF dataset to an Excel table.	
Java-RULER code	**POC:** Jun Chen (chenj@frib.msu.edu)	**URL:** https://github.com/IAEA-NSDDNetwork/Java-RULER
	Description: The program recommended by USNDP and NSDD to calculate gamma-ray transition strengths in ENSDF file with proper propagations of large/asymmetric uncertainties including the Monte-Carlo approach for ENSDF evaluation.	
McMaster-MSU JAVA-NDS code	**POC:** Jun Chen (chenj@frib.msu.edu)	**URL:** https://github.com/IAEA-NSDDNetwork/McMaster-MSU-Java-NDS
	Description: The official program to generate PDF outputs from ENSDF file(s) for the Nuclear Data Sheets journal and web-display of ENSDF and XUNDL databases on NNDC retrieval webpages. This program was initiated by Balraj Singh and his students at McMaster University in 2007 and was re-started by Jun Chen in 2017 at MSU.	
Other ENSDF analysis and utility codes in Java (all hosted at IAEA website)	**POC:** Jun Chen (chenj@frib.msu.edu)	**URL:** https://www-nds.iaea.org/public/ensdf_pgm
	Description: Analysis and utility codes developed at FRIB/MSU to facilitate ENSDF evaluations. Some of them replace the corresponding legacy Fortran codes and the rest are newly developed.	

Oak Ridge National Laboratory		
Computational Infrastructure for Nuclear Astrophysics (CINA)	**POC:** Michael Smith (smithms@ornl.gov)	**URL:** https://nucastrodata.org/infrastructure.html
	Description: unique online nuclear astrophysics data pipeline that enables point-and-click investigations of astrophysical impacts of nuclear data sets via the uploading, manipulation, processing, and sharing of nuclear data sets, thermonuclear reaction rates, and astrophysical simulations	
Nuclear Astrophysics Datasets	**POC:** Michael Smith (smithms@ornl.gov)	**URL:** https://nucastrodata.org/datasets.html
	Description: collection of nuclear data sets needed for research in nuclear astrophysics	
Nuclear Mass Toolkit	**POC:** Michael Smith (smithms@ornl.gov)	**URL:** https://nuclearmasses.org/compute/masses.html
	Description: online system that enables quick quantitative comparisons of evaluated, theoretical, and measured nuclear masses, and features mass measurements compiled over 2008 to 2022 by B. Singh	

Appendix C – Fiscal Year 2023 Articles authored by USNDP staff

[2022Ah03] I.Ahmad, F.G.Kondev, M.Gott, J.P.Greene, K.Teh, "Alpha decay of the longest-lived Cm isotope: 247-96Cm", Phys.Rev. C, 106, 64329, (2022)

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[2022BL06] D.L. Bleuel, S.G. Anderson, L.A. Bernstein, J.A. Brown, J.A. Caggiano, B.L. Goldblum, J.M. Gordon, J.M. Hall, K.P. Harrig, M.S. Johnson, T.A. Laplace, R.A. Marsh, M.E. Montague, A. Ratkiewicz, B.Rusnak, and C.A. Velsko, "The 40Ar(d,p)41Ar cross section between 3–7 MeV", Appl. Rad. Iso., 110509, (2022)

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[2022KO31] H.-M. Ko, D.-j. Jang, M.-K. Cheoun, M. Kusakabe, H. Sasaki, X.G. Yao, T. Kajino, T. Hayakawa, M. Ono, T. Kawano, G.J. Mathews, "Comprehensive Analysis of the Neutrino Process in Core-collapsing Supernovae", Astrophysical Journal, 937, 116, (2022)

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[2022MA65] Andrea Mattera, E. McCutchan, S. Zhu, C. Morse, M. Carpenter, P. Copp, C.C. Maller-Getermann, W. Reviol, J. Greene, M. Gott, “Decay spectroscopy of the blocked fission product 130I”, Physical Review C, 106, 34626, (2023)

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[2022PH01] V. H. Phong, S. Nishimura, G. Lorusso, T. Davinson, A. Estrade, O. Hall, T. Kawano, J. Liu, F. Montes, N. Nishimura, R. Grzywacz, K. P. Rykaczewski, J. Agramunt, D. S. Ahn, A. Algora, J. M. Allmond, H. Baba, S. Bae, N. T. Brewer, C. G. Bruno, R. Caballero-Folch, F. Calvin̆o, P. J. Coleman-Smith, G. Cortes, I. Dillmann, C. Domingo-Pardo, A. Fijalkowska, N. Fukuda, S. Go, C. J. Griffin, J. Ha, L. J. Harkness-Brennan, T. Isobe, D. Kahl, L. H. Khiem, G. G. Kiss, A. Korgul, S. Kubono, M. Labiche, I. Lazarus, J. Liang, Z. Liu, K. Matsui, K. Miernik, B. Moon, A. I. Morales, P. Morrall, N. Nepal, R. D. Page, M. Piersa-Si□lkowska, V. F. E. Pucknell, B. C. Rasco, B. Rubio, H. Sakurai, Y. Shimizu, D. W. Stracener, T. Sumikama, H. Suzuki, J. L. Tain, H. Takeda, A. Tarifen̆o-Saldivia, A. Tolosa-Delgado, M. Woliń ska-Cichocka, P. J. Woods, R. Yokoyama, “β-Delayed One and Two Neutron Emission Probabilities Southeast of 132Sn and the Odd-Even Systematics in r-Process Nuclide Abundances”, Phys. Rev. Lett., 129, 172701, (2022)

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[2022SC17] H Schatz et al, “Horizons: nuclear astrophysics in the 2020s and beyond”, J. Phys. G: Nucl. Part. Phys., 49, 110502 (2022)

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