Nuclear Data for Homeland Defense and National Security

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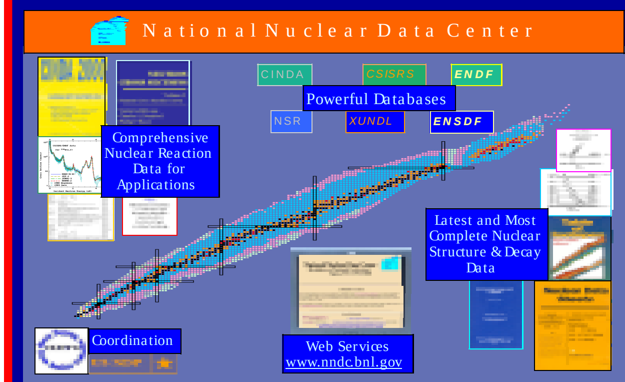
U.S. Nuclear Data Program: Status

Mission. The US Nuclear Data Program (USNDP) collects, evaluates, and disseminates nuclear physics data that are of critical importance for a number of nuclear technology applications, including reactors, weapons, nonproliferation & safeguards, radiation protection & shielding, nuclear spectroscopy, and medicine. These are highly relevant to nuclear aspects of homeland defense and national security. In this context, nuclear data play a role in the nuclear technology infrastructure of strategic importance, with substantial potential for future developments and related benefits.

US Nuclear Data Program. The Program has primary responsibility for the national nuclear data effort. Its major product is the evaluated nuclear structure data file, ENSDF. The Program involves BNL, LANL, LBNL, ORNL, ANL, INEEL, LLNL, TUNL, McMaster and NIST. It is sponsored by DOE Office of Science, Division of Nuclear Physics (26FTE, $4.9M).

Cross Section Evaluation Working Group. The Group is responsible for the US evaluated nuclear reaction data file, ENDF/B. It involves BNL, LANL, ANL, LLNL, ORNL, NIST, RPI, Bechtel, Knolls, Lockheed, and Westinghouse. It is sponsored by DOE-SC via US Nuclear Data Program, by DOE-EM, -NNSA, and other sponsors.

National Nuclear Data Center. The Center plays a pivotal role in the national nuclear data effort and is the core facility of the US Nuclear Data Program. It coordinates the US Nuclear Data Program and the Cross Section Evaluation Working Group.



Nuclear Databases - National Resource. Nuclear databases represent carefully extracted scientific information that has been accumulated over 50-years of low-energy nuclear physics research worldwide. These databases have enormous value and they represent a genuine national resource. Six core nuclear databases fall into 3 categories:

- Bibliography
  NSR – abstracts of 168,000 papers from 75 journals, CINDA – 265,000 neutron references.
- Experimental
  CSISRS – reaction data from 12,700 papers, XUNDL – structure data from 870 papers.
- Evaluated/Recommended
  ENSDF – nuclear structure and decay properties of all known 2,898 nuclei, ENDF/B – nuclear reaction cross sections of all practically important 325 nuclei, mostly with neutrons up to 20 MeV, and partly up to 150 MeV.

Importance for Homeland Defense and National Security

- Structure database ENSDF and its derivatives are of critical importance for nuclear materials management, safeguards, dosimetry, and radiological protection. For example, derived database Nuclear Wallet Cards was adopted, in March 2002, as the standard for radioactive decay data by DOE Office of Security, Nuclear Materials Management & Safeguards System.
- Reaction database ENDF is indispensable in all neutronics calculations, including reactor, weapon and accelerator design, and shielding. For example, ENDF database is inherent part of the Los Alamos neutronics code MCNP used in vast amount of nuclear simulations.

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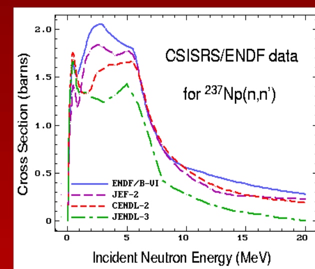
U.S. Nuclear Data Program: Initiative

1. Safeguards and Nuclear Materials Management

The ENSDF database contains evaluated structure and decay data for all known nuclei (currently 2,898). This information, such as decay energies and intensities, is of critical importance for **identification of radioactive nuclei**, primarily via alpha and gamma-ray counting. Current funding allows for an ENSDF update cycle of about 8-10 years. Improved maintenance and speedy updates are essential for providing reliable information for development of detectors and correct analysis of measured data.

There are 32 actinides with known half-lives greater than 10 years. Of these, 8 are under constant safeguards surveillance by the IAEA as Special Nuclear Materials of the Atomic Energy Act (1954) and its amendments.
7 of the remaining 24 isotopes pose a potential **proliferation threat**.

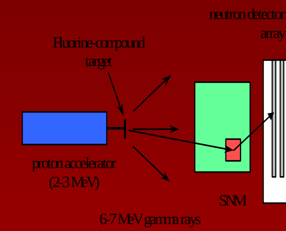
Neptunium 237 is most suitable candidate for construction of illicit fission device (as a single long-lived isotope of Np, it is easily extracted chemically from nuclear waste; typical reactors produce critical amounts in 2-3 years). Improved nuclear reaction data (ENDF) are most important for determining 237Np critical mass and assessing potential terrorist threats. In particular, discrepancies of almost 50% in neutron inelastic scattering must be resolved. Data for other actinides also need to be addressed.



2. Nuclear Interrogation

Special nuclear materials and explosives can be detected via signature radiation (γ-rays, fission neutrons) passively or using neutrons, and photons as probes.

- Passive techniques exploit unique radioactive decay properties of materials. *Data required*: half-lives; types, energies, and correlations of radiation. Data deficiencies remain for higher actinides and their reaction products, such as Cm, Am(n,f) and (n,γ).
- Active techniques employ externally produced penetrating neutrons or γ-rays. *Data required*: characteristics of source reactions; cross sections & spectra for emission of stimulated secondary radiation. Data deficiencies remain for source properties; neutron scattering; (n,xnγ) and (γ,n) cross sections for actinides, structural elements, and fission products.

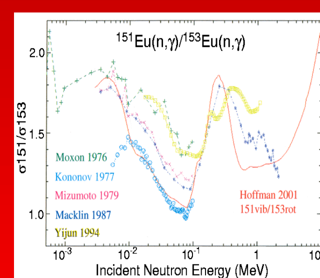


Data needs can be satisfied using existing techniques and facilities plus a dedicated program that combines compilation and evaluation (ENSDF and ENDF) of existing data with selected new measurements to fill critical gaps and improve accuracy.

3. Stockpile Stewardship

This project of critical national importance requires improvements in nuclear data to enable detailed **simulation and diagnostics for nuclear devices**. The current US evaluated nuclear reaction data file, ENDF/B-VI, was released in 1990. Major improvement is needed to address needs of the 21st century. Priorities include reaction data for actinides and light nuclei away from stability that are produced copiously in weapons environments; reaction data for fission fragments as targets, and use of nuclear reaction data in radiochemical diagnostics, such as the recently explored 239Pu(n,2n) reaction.

Radiochemical diagnostics allows extraction of information from archived Nevada tests. The technique is based on use of activation detector foils, such as rare earth Sm. This is followed by analysis of production ratios of various isotopes, requiring precise knowledge of reaction data. The priority is to determine such data for isomers and unstable nuclides produced in radchem reaction chains, using advanced modeling and new measurements. An example, studied in 2001 at LLNL, is ratio 151Sm(n,γ)/153Sm(n, γ).



4. New Generation of Reactors

Revival of nuclear energy (G. Marcus: Nuclear Renaissance, Physics Today, April 2002) represents a serious energy option in the U.S. One of the reasons is national security – to enhance energy independence and to use advanced fuel cycles to reduce the threat of accumulating stockpiles of Pu. In addition to ongoing DOE-NE initiatives, NPP Lifetime Extension and Nuclear Power 2010, two major programs lead the US effort:

- New Generation of Reactors, Gen-IV, to design advanced reactors to be deployed by 2030
- Advanced Accelerator Applications, AAA, to develop an advanced fuel cycle, including its back-end or transmutation.

New and improved nuclear reaction data are needed to address these needs. They can be put into 2 broad categories that go beyond the current ENDF/B-VI library:

- **Uncertainties** (covariances) for all evaluations, to allow realistic design margins to reduce construction and operation costs.
- Data for **innovative fuels, moderators, coolants, absorbers and structural materials**, including new energy ranges of interest.

For example, accurate evaluations of Pu, Am and Cm will be needed. The innovative Th fuel cycle is another example, with required precision (%) of capture and fission cross sections in thermal and fast neutron energy range for 7 nuclides as given in 1999 IAEA study:

	232Th	231Pa	233Pa	232U	233U	234U	236U
Capture thermal	1	10	5	10	5	3	-
Fission thermal	-	-	-	10	1	-	20
Capture fast	1-2	10	3-10	50	3	5	10
Fission fast	5	20	20	20	1	3	5

5. Transmutation of Nuclear Waste

Anticipated extension and expansion of U.S. nuclear power program represents a huge challenge for nuclear waste management. Thus, the DOE-NE initiative Lifetime Extension aims to extend 103 US nuclear power plant for another 20 years, Nuclear Power 2010 aims to issue one or more orders for a new NPP by 2005, to be deployed by 2010, and Gen-IV aims to develop a new generation of NPP, to be deployed by 2030. Conceptually, perhaps the best approach for waste management is transmutation. This would imply **reduction of stored radioactive materials**, with positive impact on national security.

Any transmutation scenario, reactor-based or accelerator-based, requires a range of new and improved nuclear reaction data. For example, current uncertainties (5-30%) for capture and fission for minor actinides, 238Pu and 241-245Am, should be reduced by one half. This would reduce their current 2% impact on criticality, k-eff, and allow their transmutation in a dedicated reactor.

Actinide	Impact on k-eff
238Pu	0.99 %
241Am	1.17 %
242Am	0.53 %
243Am	0.60 %
244Am	0.48 %
245Am	1.14 %
Total	2.13 %

(M. Salvatores, Tsukuba, 2001)

6. Accelerator Design

Future accelerators are vital for US capabilities in several areas critical for national security. The most prominent is **rare isotope accelerator** technology, RIA, that would provide significant boost for the Science-Based Stockpile Stewardship program. Nuclear reaction data play important role in several respects:

- Improved data are needed for target design, recent example being LANL proton and neutron cross sections for Hg target of the ORNL Spallation Neutron Source.
- Improved nuclear reaction fragmentation and spallation models are needed to optimize production of rare isotopes.
- Quantitative understanding of nuclear weapons performance requires information on reaction cross sections involving radioactive nuclei and isomeric nuclear states.

Conclusion

Nuclear data represent an essential part of nuclear technology infrastructure of homeland defense and national security, with substantial need for its improvement and development.