CSEWG-USNDP

Annual Meetings 2010

Preface

The 2010 meeting s have been held in Santa Fe in concomitance with the Division of Nuclear Physics meeting of the American Physical Society with the intention to allow participants to attend the DNP meeting and facilitate interaction between nuclear data community and other nuclear physics communities, in particular to strengthen with the basic research community. As usual, the USNDP/CSEWG meetings were accompanied by the Nuclear Physics Working Group (NPWG) and Nuclear Data Advisory Group of the Criticality Safety Program to form the **Nuclear Data Week.** In 2010 the schedule of the Nuclear Data Week was the following

- CSEWG Annual Meeting, Nov 1-3,
- USNDP Annual Meeting, Nov 2-3,
- AFCI Physics Working Group Meeting, Nov 4-5, and
- Nuclear Data Advisory Group, Criticality Safety Program Meeting, Nov 5,

The present document contains the Summary of the CSEWG and USNDP Meetings that is produced in the electronic form only. It is available, along with all presentations given at these two meetings, at www.nndc.bnl.gov/meetings/csewg2010/.

January 18, 2011 Michal Herman
CSEWG chair
USNDP chair

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Summary of the 60th Cross Section Evaluation Working Group Meeting

Held at
Eldorado Hotel, Santa Fe, New Mexico
November 1 - 3, 2010

Cross Section Evaluation Working Group

Chairman's Summary

Michal Herman
National Nuclear Data Center, BNL

The 60th CSEWG meeting was held on November 1-3, 2010 at the Eldorado Hotel in Santa Fe, New Mexico. Seventy registered participants attended the meeting. This relatively high number - plus six compared to the last year - reaffirms interest in nuclear reaction data especially in the perspective of the forthcoming release of the ENDF/B-VII.1 library. Among the participants were representatives of national laboratories, academia and nuclear industry of the United States and Canada, as well as a few participants from abroad. As usual, the CSEWG meeting was held next to the USNDP annual meeting, with a common session on modeling nuclear reactions.

ENDF/B-VII.1 release

CSEWG reviewed progress towards the release of VII.1 version of the ENDF/B library. The beta0 version has been assembled and released on Oct 22, 2010. Preliminary results of the beta0 validation were presented during the CSEWG meeting.

The essential change in the management of the ENDF/B-VII.1 development was introduced in January 2010 with the deployment of the GForge server at the NNDC, which facilitates collaboration between evaluators and allows for a detailed tracking of the development.

The next beta1 version is expected to be released by the end of 2010. This should be the release containing most of the critical changes and subject to the large-scale validation. Additional prerelease (beta2) is scheduled for May 2011 before the mini-CSEWG meeting. This will contain full set of covariances to be included in the VII.1.

A micro-CSEWG meeting will be held March 30-31, 2011 at the NNDC. The purpose of this meeting is be to bring together key representatives of the validation community and evaluators from the leading Labs to review performance of the beta1 release of the library.

A mini-CSEWG meeting will be held on June 21-23, 2011 on Long Island, a year after a similar meeting held in Port Jefferson in 2010. This meeting is supposed to finalize the VII.1 release. No major changes are expected in the critical evaluations after this meeting.

Review of evaluation work

Discussion during the evaluation session (November 1) concentrated on review of new and/or updated evaluations in VII.1beta0. Details of this discussion can be found in the report of the evaluation committee below and individual presentations available at http://www.nndc.bnl.gov/meetings/csewg2010/. Original notes, recorded during the meeting can be consulted at the NNDC GForge site: https://ndclx4.bnl.gov/gf/project/endf/tracker/?action=TrackerItemBrowse&tracker_id=69 by selecting tracker items created or modified on November 1, 2010. All together 29?? issues were discussed and recorded.

Covariance data

The presentations addressed various topics including the ongoing evaluation of covariances, processing of these covariances, quality assurance requirements for ENDF/B-VII.1 covariances, user experience in testing the new covariance evaluations, sources of experimental uncertainty information that affect the evaluation of covariance data. Of particular importance is the fact that explicit comparisons are being made between different evaluations as well as between the results obtained from processing these evaluations with both the NJOY and PUFF processing codes.

Next Meeting

The next Nuclear Data Week will be held at BNL Nov. 14 through 18, 2011. This period was chosen instead of the traditional first week of November to avoid conflict with the ANS meeting. The USNDP annual meeting will be held on Nov. 14-16 (Mon – Wed), while CSEWG will be held on Nov. 15-17 (Tue - Thu). The NDAG Criticality Safety meeting will be held on Nov. 14 (Mo) and the AFCI Physics Working Group on Nov. 17-18 (Thu – Fri).

CSEWG Executive Committee Meeting

The Executive Committee met during the lunchtime on November 1, 2010, with all 11 members present. This included chair (M. Herman), five committee chairs (M. Chadwick, Y. Danon, M. Dunn, A. Kahler, D. Smith) as well as five regular members (N. Summers, A. Carlson, T. Kawano, L. Leal, R. McKnight).

Agenda

- December 2011 has been reconfirmed for release date of ENDF/B-VII.1 library. The mini-CSEWG meeting will be held in June 2011 on Long Island.

- The Quality Assurance procedure for covariance data, intensively discussed on-line before the meeting, has been approved.

- Plans for the Next Special Issue of Nuclear Data Sheets were discussed. The 2010 issue contains the extensive paper on NJOY and two papers on fission product yields prepared by the LANL (leading author M. Chadwick). The future 2011 issue will be totally dedicated to the ENDF/B-VII.1 release. It should contain a leading summary paper, coauthored by all contributors to the library, and a number of smaller papers dedicated to individual evaluations and covariances. These latter papers will be drafted by the respective Labs.

- ND2013 conference: M. Herman reported on the preparations to the Conference on Nuclear Data for Science and Technology in 2013 organized by the NNDC. The venue and the dates have been fixed. The Conference will take place in the New York City Sheraton Hotel, March 4-8, 2013. The contract with the Sheraton has already been signed. Ted Barnes informed that it will be possible to seek financial support from DOE-SC.

- WPEC matters. The next WPEC meeting will be hosted by the NEA Data Bank in Paris. The US delegation should include 4 official members (CSEWG chair and 3 Committee chairs) and two chairs of the acting working groups (M. Dunn and L. Leal).

- Next meeting: See above.

Cross Section Evaluation Working Group

Evaluation Committee Report

M. Chadwick, LANL
Committee chair
M. Herman, BNL
CSEWG chair

Herman and Arcilla (BNL) reported on the content and initial verification of the ENDF/B-VII.1beta0 library that has been released on Oct. 22, 2010. The content of the library is summarized in the Table below.

Total number of materials	411
New or revised materials	**125**
Totally or partially new materials	37
- LANL	8
- LANL/ORNL	7
- ORNL	9
- ORNL/IAEA	6
- BNL	1
- LLNL	6
Bob Little's fixes	7
Other fixes	16
Adopted:	65
- Actinoid file	58
- JENDL-3.3 (R.Q. Wright corr.)	2
- JENDL-4.0	1
- JEFF-3.3 (R.Q. Wright corr.)	4

The beta0 release was meant to mobilize the community and speed up the evaluation process. This goal has been met but it was obvious from the very beginning that this release is very preliminary. Initial verification showed that numerous formal deficiencies were detected in the files and because of the short deadline there was no time to address them. Also, a number of new/revised evaluations were submitted after the deadline. Therefore, CSEWG decided to release a new beta version in a relatively short period after beta0 – around the end of 2010. This time GForge repository would be closed for the time needed by the NNDC to process all the files, and make necessary corrections.

Herman described the new management of the ENDF/B under the GForge development system. The essential part of the GForge is the Subversion versioning system that allows to keep track of the changes in the evaluations and, if used properly, should prevent

unintentional overwriting of the changes by another evaluator. Herman stressed that to take advantage of this feature one must absolutely refrain from moving files outside the system – **all communication among the evaluators must proceed through committing the modified file to Subversion by the evaluator who did a change, and checking out the committed files (or updating) from the Subversion repository by other evaluators**. With the GForge site fully functional, all documents, discussion, action and deficiency lists related to the ENDF/B are now being stored and distributed through the GForge site (https://ndclx4.bnl.gov/gf/project/endf/). The site is open to everybody for reading and downloading but commits are restricted to the registered users.

Chadwick (LANL), Dunn (ORNL), Summers (LLNL), and Mughabghab (BNL) reported status of evaluations at their laboratories. Forrest summarized the IAEA evaluation effort relevant to ENDF/B-VII.1, while Jesse Holmes (NCSU) discussed new SiO_2 thermal scattering evaluation. Finally, activities related to the standards was presented by Carlson. Status of the ENDF/B-VII.1 evaluations along with the agreed actions is summarized below.

4He + n:

The evaluation done originally by Nisley et al in 1973 has been updated to include the results of a more recent R-matrix analysis. New evaluation has slight changes in the cross sections. In addition, covariances (MF=33) are given for MT=2, calculated from the parameter covariances and derivatives from the 5He analysis.

Li-6:

Results of new R-matrix analysis that included absolute WNR measurements of the 6Li (n,t)4He differential cross section made in 2008 were used for MF=3, MT=105 above the standards range (0.94 <= E <= 4) MeV. In the range (4 <= E <= 8) MeV, the (n,t) cross section was obtained from Legendre fits to the new WNR data, matched smoothly to the previous cross section above 8 MeV. The differences with the previous (n,t) cross section above about 1 MeV were distributed between the elastic (MT=2) and inelastic (MT=58) cross sections, so that the same total cross section was preserved.
ACTION LLNL; Brown will look at reformatting LANL evaluation.

Be-9:

LANL made a new evaluation that includes RPI experimental data. However, this suffers from the same deficiencies as ENDF/B-VI.8.
ACTION LANL; finalize and submit the evaluation.

O-16:

This new LANL evaluation is based on an R-matrix analysis of reactions in the O-17 system at neutron energies below 7 MeV. Beside the n+O-16 channel, alpha+C-13 configurations were included. Experimental data were included for the reactions 16-O

(n,n)O-16, 16-O(n,alpha)C-13, 13-C(alpha,n)O-16, and 13-C(alpha,alpha)C-13. Most of the new data added to the analysis since the last evaluation were for the alpha+C-13 reactions. Fitting these data required a somewhat different 17-O level structure, especially for the resonances in the 6-7 MeV range. The structure at lower energies remains much the same, but with some minor differences in the positions and widths of the resonances. The results from the analysis were joined smoothly in the 6.5-7.5 MeV region to the previous evaluation. The new cross sections are close to the previous results except for the (n, alpha) cross sections up to 8.9 MeV, which differ by up to ~30%.

Na-23:

BNL made a new evaluation with covariances. Strong fluctuations in the fast neutron range were represented by energy-dependent tuning of the absorption and total cross sections. There are still some issues, e.g. (n,2n) cross section has been adjusted to ENDF/B-VII.0 rather than to the experimental data. However, the evaluation can be completed by the end of CY2010. New evaluation has been developed in the frame of the consistent adjustment project carried out in collaboration with INL.
ACTION BNL; Complete and submit the new evaluation.

Cl-35,37:

Evaluations updated by ORNL by adding resonance parameters (RPs) to File 2, MT=151, and by including the corresponding RP covariance matrices in File 32, MT=151. The Reich-Moore format with LRF=3 and LCOMP=1 was utilized for Cl-37. The Reich-Moore Limited (LRF=7, LCOMP=2) format was used for Cl-35 because the proton exit channel is open.
ACTION LANL; perform data testing of the new ORNL libraries

K-39,41:

New ORNL evaluations of K-39 and K-41 neutron cross sections in the resolved resonance region with the multilevel Reich-Moore R-matrix formalism. The evaluation incorporates recent high-resolution capture and transmission measurements at ORELA to extend the resolved resonance energy range to 1.0 MeV. The Reich-Moore format with LRF=3 and LCOMP=1 was used. Respective covariances are provided.
ACTION LANL; perform data testing of the new ORNL libraries

Ti-isotopes:

ACTION LANL; Ti-48 needs to be resubmitted (it is not included in VII.1beta0).
ACTION ORNL; send to LANL the new Gell measured resonance parameters.
New evaluations of the resonance covariances by ORNL. Preliminary testing of Ti isotopes is good. Leal only changed Ti-48 resonance parameters – other isotopes were produced by LANL.
ACTION LANL/ORNL; Kawano and Leal will submit final files for Ti-46-50.

Ti-50: Current evaluation is missing covariances for (n,3n) reaction that makes NJOY fail.
ACTION LANL; Supplement evaluation with MT=17 MF=33

Mn-55:

MacFarlane reported that the energy balance in the new IAEA evaluation is problematic.
ACTION BNL/IAEA; revise evaluation to improve the energy balance. Ni-58,60:
ACTION LANL; Complete evaluations in the high energy region Y-89:
Capture cross sections has been recalculated by Kawano. The upper energy boundary of the resonance region needs to be decreased. ENDF/A and LANL files should be merged.
ACTION LANL; change resonance range, and merge calculations.

Zr-90:

ACTION BNL; make thermal cross section about 10 mb and remove negative resonance.
The VII.0 uses BROND-2 + a thermal correction. Some changes are needed for VII.1.

Zr-91:

ACTION BNL; consider adopting JENDL3.

Cd-113:

Thermal capture by Mughabghab adopted by BNL. Trkov committed evaluation in the entire resonance region based on the new Geel measurement. New RPI measurement suggests lower thermal cross section.
ACTION BNL; Mughabghab will review new data.

Gd-157:

Discrepancy between VII.0 thermal capture and new measurements by RPI. Some integral experiments support RPI value.
ACTION BNL; Mughabghab will reduce Gd-157 thermal capture by 11%.

Hf-isotopes:

JENDL-3.3 or JEFF-3.1 files modified by RQ Wright in the resonance region to match data in the Atlas of Neutron Resonances.
ACTION KAPL; Check whether RQ update works for KAPLTa-180, 181:
New LLNL evaluations. Ta is important for fusion community.
ACTION LLNL; do more data testing, interact with Sublet on decay heat benchmark for testing Ta data.

W-isotopes:

ACTION LLNL; Summers will send new level schemes to IAEA along with the discrete gammas from EGAF.

Thermal cross sections in fission products:

Mughabghab has reviewed the results from Dean et al's testing, which revealed deficiencies in theVII.0 evaluations for several priority fission products.
Tc-99: we could return to an earlier evaluated value to fix the discrepancy
Rh-103: we could adopt a Japanese measurement that would fix the problem. (Luiz Leal also mentioned new Geel data by Peter Schillebeeck et al.).
Cs-133: Mughabghab still needs to work on this
Nd-145: the discrepancy appears at thermal energy. The JEFF evaluation is lower than ENDF, and adopting the lower one would solve this discrepancy. Said noted a basis for this change.
For the other cases, the discrepancies are within the accuracies of the measurements.
ACTION BNL; Mughabghab will make changes for Mo-95, Tc-99, Rh-103, Cs-133, and Nd-145

U-239:

New evaluation of the fission channel be LLNL taking into account surrogate data by Younes and Britt.
ACTION LLNL; there are practical problems with what was done by LLNL for extending unresolved res region down to very low energies

Pu239:

Resonance parameters were reverted to the ENDF/B-VII.0
ACTION LANL/ORNL; Talou/Leal - double check that VII.1beta0 file is the one they intended. More testing needed.

Pu-240:

New evaluation by LANL and ORNL

Cm isotopes:

KAERI made new evaluations of Cm isotopes using EMPIRE calculations. The covariance data are given. However, the files are not yet ready for testing.

Minor Actinides:

ACTION LANL; replace JENDL/AC files with the JENDL-4.0 evaluations.

SiO2:

Jesse Holmes is working with Luiz Leal on SiO_2 thermal neutron cross section evaluation. Incoherent inelastic and elastic thermal neutron scattering cross sections are considered. Looks at free-gas versus thermal scattering libraries. VASP simulations are being used to create S-alpha-beta data.
ACTION LANL; Kahler will recommend a crit for testing. MacFarlane should test too.

Chi:

Finer energy grid for prompt fission spectra were needed. LANL provided interpolated fission spectra.

Covariances for ENDF/B-VII.1:

BNL and LANL are developing covariances in fast neutron and resonance regions in support of the AFCI program. This effort targets covariance data for 110 materials including 12 light nuclei (coolants and moderators), 78 structural materials and fission products, and 20 actinides. The recently released AFCI-2 covariance library, which uses a 33-energy group structure, is a step towards covariances in the ENDF/B-VII.1. The latter will include covariances for the same set of materials as AFCI-2 but in the ENDF-6 format rather than in a multi-group structure.

In FY2010, LANL contributed new evaluations with covariance data for **241-Am, 238-Pu** and **240-Pu**. LANL also improved several other files. The covariance matrix for the average prompt fission neutron multiplicity for **239-Pu** was revised to eliminate larger than expected uncertainties in the 1-100 keV range. The capture cross-section uncertainties in **235-U** were reviewed. The **241-Pu** neutron-induced fission cross-section was analyzed using experimental data only, and a covariance matrix was produced. More work on this isotope is expected in the next FY.
LANL merged its new evaluation for **240-Pu** with the ORNL file evaluated in the resolved and unresolved resonance ranges.
Note that all new evaluations come with a covariance matrix for the prompt fission neutron multiplicity, as well as spectrum given at 0.5 MeV incident neutron energy. The prompt fission neutron spectra for **235-U, 238-U** and **239-Pu** were also revised on a finer outgoing energy grid above 10 MeV.
LANL completed new R-matrix evaluation for **4-He** and **16-O**.

BNL's new kernel method for covariances in the resonance region was applied to **55-Mn**, to major structural materials **52-Cr, 56-Fe** and **58-Ni**, remaining 5 structural materials in the **Cr-Fe-Ni** range, to 5 materials in the **Pb-Bi** range, as well as to several other materials of some priority (**Mg, Al, Si** and **Zr**).
Full list of covariance estimates performed by BNL in FY2010 covers 40 materials in the region of structural materials and fission products and two actinides. We note that various degree complexity and attention to details was adopted in these evaluations, dictated by the importance of materials for AFCI applications.

1. **24-Mg ; 27-Al**
2. **28-Si, 29-Si, 30-Si**
3. **50-Cr, 52-Cr, 53-Cr**
4. **54-Fe, 56-Fe, 57-Fe**
5. **58-Ni, 60-Ni**
6. **90-Zr, 91-Zr, 92-Zr, 93-Zr, 94-Zr, 95-Zr, 96-Zr**
7. **92-Mo, 94-Mo, 95-Mo, 96-Mo, 97-Mo, 98-Mo, 100-Mo**

8. **109-Ag; 133-Cs, 135-Cs; 141-Pr**
9. **143-Nd, 145-Nd, 146-Nd, 148-Nd**
10. **204-Pb, 206-Pb, 207-Pb, 208-Pb; 209-Bi**
11. **237-Np; 242-Pu**

ACTION BNL; contribute full set of AFCI-2 covariances in the ENDF-6 format.

We believe it is important that the good integral performance of ENDF/B-VII.0 be preserved - and improved upon. The list of actions below represents just a perspective of the highest priority focuses for each Lab, for the coming weeks. (In some cases, if we can't preserve the good VII.0 performance we may need to hold back on a change for VII.1 for certain evaluations).

LANL

- **Delayed neutrons:** Given the negative feedback on VII.0, we may need to revert to VI.8 until a longer term solution is found.
- **16-O**: Keep testing. Initial results appear encouraging, but 16-O is a big deal and we need to ensure no negative surprises for users. Respond in detail to both the calculations requested by Sublet, as well as possible problems noted by Huria Harish.

ORNL

- **240-Pu:** Work on possible changes to address the negative feedback on thermal and criticality testing as noted by McKnight, Kahler, and recently by Huria Harish.

BNL

- **Thermal cross sections**: Implement the handful of modifications recommended by Mughabghab, based on his study of the paper by Dean et al.
- **113-Cd:** Include RPI data and do testing.

LLNL

- Work to get feedback from other Labs on integral performance assessments. E.g., Re isotopes, ask KAPL/Bettis to help; 181-Ta, ask IAEA FENDL project to test and provide feedback.

Cross Section Evaluation Working Group

Data Validation Committee Report

A. C. (Skip) Kahler, LANL
Committee chair

The Data Validation Committee received reports from Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Oak Ridge National Laboratory (ORNL), Atomic Energy of Canada, Ltd (AECL) and the University of Wisconsin (UWisc). These reports described continuing work to test ENDF/B-VII.0 cross sections, plus some initial criticality results using the just released ENDF/B-VII.1 β0 file.

A.C. (Skip) Kahler (LANL) presented MCNP eigenvalue calculations for a variety of International Criticality Safety Benchmark Evaluation Project (ICSBEP) benchmarks. These benchmarks have been an important source of criticality information in the past and they will continue to be an important element in future data testing efforts. Gerry Hale's new 16O evaluation was tested with the standard suite of HEU-SOL-THERM benchmarks that have been used over the previous decade. The later versions of ENDF/B-VI have been shown to calculate these benchmarks very accurately; an accuracy level that was retained with ENDF/B-VII.0 cross sections. The latest kcalc values continue to show excellent performance. It was noted from the audience that low-enriched lattice systems might also provide a sensitive test to these cross section revisions as the oxygen present in UO2 molecules may interact with unmoderated fission neutrons. Eigenvalue calculations performed during and subsequent to the meeting for a variety of LEU-COMP-THERM benchmarks exhibit little change, less than 10 pcm, but for the LEU-COMP-THERM-008 (B&W lattices that are particularly favored by the US commercial reactor industry), the calculated eigenvalues change by 90 pcm. The reason for this sensitivity is currently unknown. Calculations were also performed for a suite of benchmarks containing significant quantities of titanium. Previous ENDF libraries, B-VI.8 and B-VII.0 had yielded average kcalc's that on average were several hundred pcm too low to several hundred pcm too high respectively. The latest revisions yield calculated eigenvalues significantly closer to unity.

R. Mosteller (LANL) described a new validation suite for MCNP. Previously there have been validation suites maintained by the Data Team and the MCNP Team. This suite merges and extends those suites, and contains over 100 critical benchmarks encompassing a variety of fuel systems, reflectors (or bare), moderators (or unmoderated). This suite will appear with MCNP6, but can be requested separately from LANL. Having such a suite of tested critical benchmark input decks should allow the broader data testing community to participate in current and future data testing activities.

R.M (Dick) McKnight (ANL) reviewed recent calculations for benchmarks with one or more of 239,240Pu, 55Mn, 52,53Cr and 58,60Ni. The data files for these nuclides had been downloaded a few weeks prior to the meeting and therefore are candidate evaluations for the forthcoming ENDF/B-VII.1 release. Of particular interest, and concern, were the reported results for thermal assemblies with significant quantities of 240Pu. The Pu-SOL-THERM-018.x series in particular contains nearly 50% 240Pu and so is an important thermal test of revised 240Pu cross sections. With ENDF/B-VII.0 the calculated eigenvalues are generally too high; a condition generally observed for all Pu-SOL-THERM benchmarks. With the latest cross sections the calculated eigenvalues are significantly worse, increasing by up to an additional 500 pcm. Previous testing on fast benchmarks had shown little change compared to ENDF/B-VII.0 calculations, but these results (which have been confirmed at LANL subsequent to the meeting) clearly indicate problems with the revised low energy cross sections. In contrast, a ZPR-6/10 calculation, sensitive to 55Mn content, is significantly improved with the latest 55Mn data set.

J. C. Sublet (Culham Centre for Fusion Energy, UK) and L. Leal (ORNL) presented results of Pu-SOL-THERM eigenvalue calculations with revised 239Pu data sets. This is ongoing work that will not be completed in time for ENDF/B-VII.1, but is the subject of a current WPEC study group. They note that calculated eigenvalues are sensitive to both cross section revisions in the resolved resonance region and to revisions in 239Pu's prompt fission neutron spectrum. Their most recent eigenvalue calculations show an improvement of previous results, but it is clear that further work (including the impact of recent oxygen cross section revisions) remains.

Sublet also summarized recent evaluation work that culminated in the latest European Activation File, EAF-2010. Details are available at http://www.ccfe.ac.uk/EASY.aspx. The file contains 66,256 neutron induced reaction cross sections from 10-5 eV to 60 MeV on 816 targets, 66,864 deuteron induced reaction cross sections, 67,925 proton induced cross section, decay data for 2,233 nuclides and uncertainty estimates for all neutron induced reactions. Naturally much of this represents model calculations, but for the neutron induced work, microscopic experimental data are available for 1,728 reactions while integral experimental data are available for 470 reactions. This file is (or will be) available in ENDF-6 format from the NNDC as well as the Nuclear Energy Agency (NEA) in Paris and the nuclear data section of the IAEA in Vienna.

B. Pritychenko (BNL) described recent evaluated file validation efforts at the NNDC. It is impossible to perform detailed benchmark calculations to test every nuclide in a comprehensive library containing hundreds of files, but it is possible to compare the independent evaluation efforts for nuclides that appear in two or more evaluated libraries. The NNDC can compare files from ENDF/B-VII.0, JENDL-4.0, CENDL-3.1, ROSFOND-2010 and JEFF-3.1. Integral quantities to compare for consistency include resonance integrals, thermal and Maxwellian cross sections and Wescott g-factors. Selected comparisons with Mughabghab's Atlas of Neutron Resonances and the neutron cross section standards are also performed. The identification, and elimination, of discrepant data will be an important contribution to the forthcoming ENDF/B-VII.1 library.

Most data validation testing reported is geared toward nuclear criticality. However, an important user of these data are the fusion community, and M. Sawan (U of Wisconsin-Madison) summarized ongoing work to define the next generation fusion evaluated nuclear data library, FENDL-3. A preliminary file, called a "Starter File" and designated FENDF-3/SLIB contains 88 isotopes; 48 of which come from ENDF-VII.0. The FENDL community is closely following ongoing evaluation efforts worldwide as current plans call for the final FENDL-3 library to include approximately 166 isotopes.

K. Kozier (AECL) reviewed recent and ongoing work for deuterium, carbon/graphite and oxygen, and its impact on ZED-2 reactivity. He noted that there is a greater than 1% discrepancy in reported thermal scattering and total cross sections, with the more recent values being smaller than previous measurements. New, well characterized measurements with well understood uncertainties are recommended that might resolve this issue. The impact upon ZED-2 reactivity is estimated to be -0.7 to -2.2 milliK per % decrease in thermal elastic scattering. Deuterium's thermal capture cross section is very small; approximately 0.51 to 0.55 mb. This range has about a -1.0 mK reactivity impact. Potential changes in carbon and oxygen cross sections are also observed to reduce ZED-2 reactivity by several tenths of a mK.

T. Trumbull (KAPL) reviewed recent eigenvalue calculations of the IEU-COMP-THERM-003 (Triga) benchmark. Previous reporting by Andrej Trkov indicated a large eigenvalue sensitivity with varying evaluated zirconium files. In particular, and confirmed by KAPL, the calculated eigenvalue was observed to change from 1.0003(3) with ENDF/B-VI.8 cross sections, to 1.0061(3) with ENDF/B-VII.0 and back to ~1.0010 when JENDL-4 91Zr was inserted into an otherwise ENDF/B-VII.0 based model. While additional study of these results is warranted, an initial assessment is that the JENDL-4.0 zirconium evaluation be considered for ENDF/B.

R. Brewer and M. White (LANL) reported on recent studies to develop a detailed geometric model of the historical LANL Jezebel experiment. For decades this experiment has been modeled as a simple sphere, even though the actual experiment consisted of a number of discrete components that only crudely a sphere-like. This work has also lead to a new, considerably larger estimate of the experimental uncertainty of almost 500 pcm (a value that is needs to undergo further internal review at LANL). Initial calculations of historical reaction rate data with this new model yield C/E values closer to unity.

D. Heinrichs (LLNL) reported on continuing Livermore work to define delayed fission gamma data. This was a new data type for ENDF/B-VII.0 (MT=460) and by volume represents a significant fraction of the data contained in the 235U file. LLNL's most recent work in this area suggests that significant revisions may be needed to the original ENDF/B-VII.0 data. They also proposed a new format for future work; a proposal that was not expected and therefore had not been reviewed by the CSEWG community and so no action was taken.

Cross Section Evaluation Working Group

Covariance Committee Report

D. Smith, ANL
Committee chair

A four-hour meeting of the CSEWG Covariance Committee (hereafter referred to as CovCom for convenience) was held on Tuesday, 2 November. There were 11 individual presentations. These presentations addressed various topics including the ongoing evaluation of covariances, processing of these covariances, quality assurance requirements for ENDF/B-VII.1 covariances, user experience in testing the new covariance evaluations, sources of experimental uncertainty information that impact on the evaluation of covariance data, and a report on the recent technical meeting held by the IAEA on the topic of neutron cross section covariances. Of particular importance is the fact that explicit comparisons are being made between different evaluations as well as between the results obtained from processing these evaluations with both the NJOY and PUFF processing code systems. The identification of discrepancies and differences in these various results is leading to improvements in the data libraries. A synopsis of each presentation made at the present session of CovCom is given below in the order of their appearance in the session agenda, as posted on the Web (see the URL below). The complete presentations can be found through links provided on the CSEWG-2010 meeting agenda Web page as follows: http://www.nndc.bnl.gov/meetings/csewg2010.

D. Smith (ANL) – Quality assurance requirements for ENDF/B-VII.1 covariances

Considerable effort has been devoted by the CSEWG community during the past year to discussing and reaching an agreement on a set of minimal quality assurance (QA) requirements for the covariances that will be included in ENDF/B-VII.1. Many compromises were needed to arrive at a practical set of requirements that could be put in place prior to the release of this library. These requirements, which were approved by the CSEWG Executive Committee at its meeting on 1 November 2010, were presented to the wider CSEWG community in this talk. It was mentioned that the complete QA document would soon be posted on the NNDC CSEWG website for all to examine.

S. Mughabghab (BNL) – Kernel approximation and 52Cr, 56Fe, 58Ni covariances in the resonance region

Under the AFCI covariance project plan, the NNDC is responsible for structural materials, of which 56-Fe, 52-Cr and 58-Ni represent a top priority. The resonance region is of primary importance since it extends up to 0.8 - 1 MeV. During FY2008-2009

several strategies to meet this obligation were tried, but AFCI (fast reactor) users at INL and ANL suggested that the uncertainties that were originally obtained appeared to be far too small. To resolve this issue it was decided to invoke the Kernel Approximation that was first proposed by J.D. Smith in a Master thesis. It is employed by PUFF and NJOY to process MF32 capture and fission into cross section covariances, and has been advocated by F. Fröhner (FZK) for estimating covariances using statistical model of neutron resonance reactions (Hauser-Feshbach with width fluctuation corrections). The detailed formalism for capture and elastic scattering was developed by the NNDC in FY2010 and applied to 55-Mn, 52-Cr, 56-Fe and 58-Ni.

This approach involves the following three step procedure: 1) Replace the detailed resonance shape with an average cross section. 2) Compute uncertainties of these averages by propagating parameter uncertainties from the Atlas Handbook. 3) Combine these uncertainties into a covariance matrix by adding suitable level-level correlations. This approach offers several advantages. It is transparent since the formalism is analytical, the results are easy to reproduce, and they are easy to explain. It addresses several MF32 issues: a) the lack of systematic uncertainties (level-level correlations), b) the lack of potential scattering uncertainty, c) it avoids dubious adjustment of the thermal region with RRR, and d) it does not rely on processing codes. The disadvantages are that it is approximate, i.e., the covariances are produced in broad energy bins and there is a relatively crude treatment of interferences.

The method described in this presentation was applied to the major structural materials. It was shown that neutron capture strongly depends on level-level correlations, while elastic scattering is driven by potential scattering. Basic QA was performed on the results obtained and no major deficiencies were identified. Comparison with MF32 data (from ENDF/A) found fairly good agreement in the thermal region, but sharp discrepancies were observed particularly at the high end of the resonance region. The obtained results suggest that MF32 data suffer from the lack of highly correlated systematic uncertainties including potential scattering uncertainty.

M. Pigni (BNL) – Covariances for lead isotopes and 209-Bi

This presentation began with an overview of the evaluation methods used at the NNDC, and it traced progression of the evaluation process that led most recently to version AFCI-2.0β, and ultimately will produce the files to be contributed to ENDF/B-VII.1. Representative results were presented graphically for 204,206-208Pb and 209-Bi. It was pointed out that further improvements, e.g., inclusion of cross-reaction covariances, and covariances for additional reaction channels, will be tasks for the future. They will not appear in ENDF/B-VII.1.

L. Leal (ORNL) – Resonance region covariance data for 233U, 235U, 238U, and 239Pu

This presentation focused on the methodology used at ORNL for RRR evaluations, with particular emphasis on the indicated U and Pu isotopes and covariance issues.

The main tool for this work is the computer code SAMMY which is used for analysis of neutron and charged-particle cross- section data. It employs the Bayes' method (generalized least squares) to find parameter values and R-matrix theory, in the Reich-Moore approximation (default) or multi- or single-level Breit-Wigner formalism. It generates covariance and sensitivity parameters for the resonance region. There exist two possible scenarios for generating covariance data in SAMMY: 1) direct results from the SAMMY data evaluation which are automatically generated by every SAMMY fit of the experimental data, or 2) retroactively constructed covariance data.

The ENDF Covariance representation for the RRR is based on detailed uncertainties for the resonance parameters. The information is provided in File (MF) 2, Section (MT) 151. The parameters considered in the standard Reich-Moore formalism are: E_r , Γ_γ , Γ_n , Γ_{f1} , Γ_{f2} , etc. Covariances of the group cross sections ultimately are derived from the covariances for the resonance parameters p, i.e., $<\delta p_i \delta p_j>$. These quantities are calculated in SAMMY and they are stored in the ENDF library (FILE32). Alternatively, the group covariance cross section covariances can be obtained from the derived point cross section covariances, i.e., in the File 33 representation. An issue discussed in this talk was how to establish some equivalence to these two different approaches.

The first issue discussed was FILE32 to FILE33 conversion. The procedure developed at ORNL allows converting FILE32 covariance representation into FILE33 according to the following three steps using ORNL codes:

First Step: The task is to find an energy mesh that can be used to represent the point covariance matrix, *COV(σ),* such that the uncertainty in the group cross section reproduces that using the FILE32 representation.

Second Step: Generate FILE32 Covariance into the COVERX format using the PUFF-IV code.

Third Step: Use the COVCON code to convert COVERX into FILE33.

The remainder of this presentation focused on numerical details for the above mentioned U and Pu isotopes. Particular attention was given to space considerations for storing covariance information in the various representations. The following table was provided.

RPCM	Isotope	CSCM
100 megabytes	^{233}U	3 megabytes
1.76 gigabytes	^{235}U	30 megabytes
800 megabytes	^{238}U	200 kilobytes
2.5 megabytes	^{239}Pu	140 kilobytes

The key point is that a substantial reduction of storage space requirements can be achieved by transformation from the resonance parameter covariance matrices (RPCM) to cross-section covariance matrices (CSCM). For many applications the loss of detailed information is of minimal consequence. However, in applications where resonance self shielding effects need to be considered, questions remain as to whether use of CSCM information alone will be adequate. This point needs further study.

P. Talou (LANL) – LANL covariance work

This presentation described two broad areas of current LANL investigation as summarized by the following bullets:

Contemporary Evaluations and methodologies

- Covariance Evaluations
- Complete new evaluations + UQ for 238,240Pu, 241Am (ORNL at low energies)
- New light nuclei R-matrix evaluations for 4He, 9Be, and 16O
- Covariance evaluation of pulsed fast neutron spectra (PFNS) for n(0.5 MeV) +238,239,240Pu
- Systematic study of minor actinides PFNS
- "AFCI-2.0 Covariance Library: BNL & LANL Report FY2010", M.Herman et al. (BNL) and P.Talou et al. (LANL), Oct. 14, 2010.

Advanced Uncertainty Quantification (UQ) methodologies

- Develop PFNS evaluation and UQ toolkit
- Advanced statistical tools
- Testing covariance matrices

Examples of results from recent work in these areas were shown in the form of several plots.

Considerable attention is being devoted to issues related to the PFNS evaluation work, including the determination of covariances, because it has been determined that calculated integral results are extremely sensitive to this information. This work complements experimental studies now being carried out at LANL, and it also builds on earlier work on PFNS by Madland and Nix and their collaborators at LANL.

Finally, it is planned to investigate new approaches to cross-section and neutron spectrum evaluations at LANL that involve both deterministic and Monte Carlo techniques. The planned projects and goals were described briefly in this presentation.

S. Hoblit (BNL) – AFCI-2.0β covariance library

This library is being developed for the purpose of data adjustment. That is, it will be used as a starting point to generate an AFCI user library that is adjusted relative to the original library using a suite of accurate integral data for representative conceptual fast reactor system. This presentation provided an overview of the steps leading to the development of the AFCI 2.0β library and a glimpse into its content.

The objective was to provide neutron cross-section covariances for 110 materials relevant to fast reactor R&D, including 12 light nuclei (LANL), 78 structural materials (BNL), and 20 (major and minor) actinides (LANL + BNL). This library is coupled to ENDF/B-VII.0 for the central values of the cross sections, etc.. Thus, most of the recent work has been devoted to the development of covariance information. It is intended that these AFCI covariances will ultimately be adopted for ENDF/B-VII.1. The approach and content of the covariance information in the ACFI-2.0β library has been driven largely by AFCI community data adjustment requirements as follows:

- Requires neutron cross sections (ENDF/B-VII.0 based) with associated covariances.
- The preference is for multi-group (processed) covariances with uniform lethargy energy groups (33 group, 1/E Flux).
- The reaction channels of interest are: (n,el), (n,inl), (n,2n), (n,γ), (n,f), plus nu-bar. Also some mu-bar and prompt fission neutron spectra (PFNS).

The covariance evaluation methodology used for specific isotopes has been determined by user stated priorities as follows:

- Most important materials (~30) treated individually.
- Medium importance materials (~40) treated with simplified methods.

- Low priority materials (~40, mostly fission products) treated with low-fidelity type approach.

The contents of the ACFI-2.0β library covariances, expressed according to origin of the components, are as follows:

- Major actinides covariances were produced by LANL/ORNL, i.e., 233,235,238U and 239Pu, in a simultaneous evaluation.
- Structural materials covariances were produced by BNL, i.e., 23Na, 52Cr, 56Fe, 58Ni, Zr, Pb, Bi, etc.
- Light nuclei covariances came from LANL (from R-matrix analyses, but also low-fi).
- Minor actinides partly based on data from V. Maslov (Minsk).
- Miscellaneous isotopes, partly based on BNL and LANL efforts.
- Fission products isotopes mostly based on low-fidelity covariance estimates.

The evolutionary timeline for development of the AFCI library is as follows:

- Initial version under Global Nuclear Energy Partnership (GNEP) released Oct 2008.
- Name changed to Advanced Fuel Cycle Initiative (AFCI) at version 1.2.
- Ver. 1.3 release in Apr 2010 included many improved structural & actinide evaluations.
- AFCI 2.0βreleased Oct 2010, final release scheduled for Dec 2010.

Key changes for AFCI-2.0β relative to earlier versions are:

- Many structural materials updated at NNDC using Kernel approach in RRR and Empire code in fast region.
- New actinide evaluations from LANL (238,239,240Pu and 241Am).
- New evaluations for minor actinides from BNL (242Pu and 237Np).

New structural materials included (from BNL)

- 23-Na
- 24-Mg, 27-Al
- 28,29,30-Si
- 50,52,53-Cr
- 55-Mn
- 54,56,57-Fe
- 58,60-Ni
- 90,91,92,94-Zr
- 92-Mo

- 109-Ag
- 143,145,146,148-Nd
- 141-Pr
- 204,206,207,208-Pb
- 209-Bi

The remainder of the presentation provided some details on the covariance evaluation procedures, gave some examples in the form of plots, and discussed various QA measures taken to eliminate errors and identify potentially unrealistic values for variances and correlations.

D. Brown (LLNL) – Covariance work at LLNL

In recognition that nuclear data covariance matrices can be huge and unwieldy, some recent work has been undertaken at Livermore to explore ways of achieving what is required by users in the way of data uncertainty quantification at a level that is manageable. The following observations were made related to the above mentioned statement that the full covariance matrix of an evaluation is way too big to be used:

- Most channels have ~2 outgoing particles (usu. γ & n).
- Assume isotropic, but each channel has ~ 10 outgoing E' points, so one has 10 x (number of points in σ); this comes out to ~ 1.5 x 10^5 points/evaluation (neglecting fission)!
  Note: this neglects cross-isotope correlations.
- When considering the reaction model, and the common parameters in modeling, one adds considerable further information to deal with.
- Experimentally, one adds ratio data (e.g., 239Pu(n,f)/235U(n,f)), 3 big σ's: (n,tot), (n,el), (n,γ), etc., leading to 5000 points each.
- Then add ~ 10 discrete level excitation σ's: (n,n') 100 pts each and ~ 5 threshold σ's: (n,2n), (n,p), (n,3n), etc. with 100 points each.
- If fissions, then have fission σ also with 5000 points each.

So, the full covariance matrix (for just one evaluation) would require consideration of uncertainties, and correlations, for ~ 1010 parameter entries. It would appear to be impractical to use the entire thing without taking some shortcuts. The nuclear data community has discussed, and in some cases implemented, various ad hoc approaches to try and reduce the dimensionality of the problem. Among these are:

- Convert to group the covariance information. (But, this lowers the resolution.)
- Throw out (or avoid determining) cross correlations. (But, what if the application is sensitive to those correlations?)
- Guess which sub-spaces data users are likely need and throw out the rest. (But, what if the project turns out to be sensitive to something that was thrown out? Or,

alternatively, what if the project is indeed insensitive to something that was kept and storage space was wasted)
- Use compressed formats. (This lowers precision of entries and can lead to numerical artifacts, e.g., non-positive eigenvalues.)
- Reject double precision arithmetic and use single precision. (This lowers precision of entries and for sure leads to numerical artifacts, e.g., non-positive eigenvalues.)

Although on the surface the situation seems almost hopeless, LLNL will continue to "live" with the situation as it is for now. But, LLNL is also looking into ways to streamline the data handling procedures. For example, new data structure and format possibilities are being investigated that will, hopefully, simplify data interfaces between various applications software, and simplify the QA process for new nuclear data libraries. Another approach might be to avoid using covariances altogether and morph in a direction along the lines of the Total Monte Carlo (TMC) scheme.

The remainder of this presentation offered an outline to the approach which LLNL is exploring and illustrated its application to a simple example (the Jezebel benchmark).

O. Buss (AREVA) – Use of covariances at AREVA

AREVA is a large international company that provides a wide variety of services to the nuclear power industry. This presentation focused on contract work it does in the area of nuclear criticality safety. It was mentioned that only in the U.S. and France are uncertainty information required for nuclear data used in criticality safety assessments. All other countries rely on the use of wide safety margins to avoid confronting directly the issue of nuclear data uncertainties.

AREVA has been working on developing its own approach to actually include consideration of nuclear data uncertainties in its analyses. The method is quite different from methods which are generally discussed within the CSEWG community. The idea is somewhat related to the Total Monte Carlo concept. However, instead of changing nuclear model parameters to generate alternative libraries, an approach to randomly varying the cross section data found in actual evaluations such as ENDF, JEFF, etc., is employed. This approach takes evaluated nuclear data correlations and uncertainties, as reflected in provided covariance matrices, into account. The relationship between this approach and those utilized within the SCALE package was discussed, and some examples were given. AREVA is most interested in obtaining ENDF/B-VII.1 when it becomes available, and in utilizing the uncertainty information it will contain.

H. Kim (KAERI) – Preliminary evaluations including covariances for 237Np, 240Pu, and 144Cm above the resonance region

KAERI has participated in producing evaluated nuclear data with covariance matrices for two minor actinide isotopes needed for future applications such as the Advance Fuel Cycle (AFCI), Safeguards, Fast reactor physics, etc. This collaboration (with ORNL) has been carried out under the auspices of an International Nuclear Energy Research Initiative (INERI) program. The nuclides considered are: ^{237}Np, ^{240}Pu, and ^{144}Cm. Work is planned for the future for other isotopes in the range $^{240\text{-}250}$Cm. ORNL addressed the low energy region, while KAERI worked on the fast region. This project involved producing the evaluated files with covariance data, and then testing them through sensitivity/uncertainty calculations for some very simple, integral, "pseudo" (bare sphere) benchmark configurations.

The evaluation procedure, including determination of covariances, was described in this presentation. Calculations in the fast-neutron region were carried out using the EMPIRE code. The following features were invoked in these calculations:

- OMP: An isospin-dependent coupled-channels optical model potential containing the dispersive term (DCCOMP) suggested by Capote et al. (RIPL # 2408).
- Hauser-Feshbach.
- DEGAS for gamma and PCROSS for others in pre-equilibrium with HRTW.
- Empire specific level densities.
- Gamma strength function given by Plujiko (MLO1).
- Double-humped fission barrier with OMPs for fission, as suggested, were modified in order to reproduce the measurements of fission cross section.

Covariances were generated using the EMPIRE-KALMAN code package. Covariances above the resonance region were generated using the following considerations:

- Sensitivity matrices from 3 ~ 5 % variations of model parameters around optimal values.
- Using uncertainties from measurements if available.
- Using pseudo data with 10% uncertainty for the cross section results from model calculation if no measurements were available.

The list of covariance data generated by KAERI for the indicated isotopes are: MT = 1, 2, 4, 16, 17, 18, 22, 24, (51-91), 102, 103 and 107. MF=32 files were obtained from ORNL for ^{237}Np, ^{240}Pu, and ^{244}Cm. The information taken from JENDL-4 are for nu-bar, fission neutron spectra, and MF = 31.

Several plots of results from this work were presented. These showed error bands on plots of experimental data, plots of standard deviations, and plots of correlation patterns. In addition, simple integral calculations were performed for bare sphere configurations to test these data. The following table gives the critical radii for these "pseudo" benchmarks. These simple one-element benchmarks were chosen in order to avoid bringing in additional materials that would complicate interpretation of the results.

No.	Actinide	Critical Radius (cm)
1	92-U-233	5.72
2	92-U-235	8.25
3	93-Np-237	9.20
4	94-Pu-239	4.95
5	94-Pu-240	7.24
6	94-Pu-241	5.20
7	95-Am-241	11.33
8	95-Am-243	15.54

Further work to be carried out during this collaboration is as follows:

- Covariances for angular distributions and nu-bar values will be added.
- The "too small uncertainties" issue that was encountered in this work will be rectified through analyzing the measurements more carefully.
- Finally, in the future, covariance files for all curium isotopes will be generated.

S. Mughabghab (BNL) – Uncertainty treatment in the unresolved resonance region

Several motivations for the present investigation were offered:

- An uncertainty analysis of total, capture and scattering cross sections in the Unresolved Energy Region (URR) was required. (However, the fission process was not considered.)
- It was desired to test and validate the average resonance parameters, particularly the R' as well as the s- and p-wave strength functions, in the Atlas of Neutron Resonances (S. F. Mughabghab, Elsevier, 2006) which were derived in the resolved resonance region.

- An approach was needed to supplement information required for the AFCI covariance library in cases where there is a lack of explicit experimental data regarding these quantities in certain mass regions.

In the description of URR and calculations of covariances, reliable values of R' and average resonance parameters are needed, and such information is mandatory for all materials in a complete library. R' values for particular isotopes can be derived to a high degree of accuracy from measured precise coherent scattering lengths provided that the available resonance information is complete. However, when this situation is not satisfied, as is frequently the case, it is necessary to resort to systematics. The average resonance parameters, S_0, S_1, G_0, and G_1, can be obtained from the RRR, as was achieved in the Atlas. However, the accuracy of these parameters is largely dependent on the numbers and parity assignments of these resonances. For the latter part, a Bayesian analysis was carried out which is based on the strength of resonances. This introduces some uncertainty in these determinations, particularly in the mass region around mass 90. The resonances of ^{98}Mo are a prime example.

The methodology of the present approach was described in this talk. One adopts, as a starting point, the average resonance parameters derived on the basis of resolved resonance parameters from the Atlas. One then carries out a least-squares fit to the total cross section to derive R', the s- and p-wave strength functions. Next, one calculates within the framework of Lane and Lynn, the capture cross section in URR. The scattering cross section is then obtained from the difference of these computed values. Finally, the uncertainties of the cross sections are generated from the information. When no data are available, as in the case of unstable nuclei, then average parameters and their uncertainties are obtained from the systematic trends.

This methodology was used to determine and test uncertainties of s_t , s_s , and s_g for 90 isotopes and elements. In the process, R', S_0 and S_1 were derived from s_t and compared against the Atlas recommended values. Good agreement for R' within 6% was obtained. Some new results for a few R' were derived for the first time. Some examples from this work were shown by means of plots and tables. A new finding is the observation of the splitting of S_1 into two peaks located at A = 90 and 112. This finding is correlated with the splitting of the ratio of $\Gamma_{\gamma p} / \Gamma_{\gamma s}$ revealed in a previously reported study (ND2010). With this information and procedures, the uncertainties for s_t , s_s , and s_g were computed for the AFCI materials at 3 keV and 100 keV. This detailed work also revealed unanticipated structures in plots of the ratio of $\Gamma_{\gamma p} / \Gamma_{\gamma s}$ at A = 92, 112, 124, and 230.

D. Muir (ANL) – Summary of the IAEA Technical Meeting on Neutron Cross-Section Covariances

The Technical Meeting on Neutron Cross-Section Covariances, which was held at the IAEA in Vienna, Austria, on 27-30 September, was organized by the IAEA Nuclear Data Section. This meeting brought together 26 covariance specialists, representing the fields of cross section measurement, modeling, and evaluation, as well as key data user communities. This presentation provides an overview of that meeting.

The objective of the meeting was to promote the generation of reliable covariance data and to facilitate their use in practical applications, especially in the field of nuclear power production. The discussions were organized around three major themes: 1) The resolved and unresolved resonance region, 2) The fast neutron region, and 3) User requirements for covariance data. Some highlights of the discussions follow:

Stimulated by recent major technical advancements, the area of generating covariances from nuclear modeling area is becoming increasingly important in the fast neutron energy range. A. Koning (NRG) gave a detailed progress report on the Total Monte Carlo (TMC) method. The value of TMC in studying the importance in applications of aspects of data uncertainties commonly neglected in current evaluations, such as material-material correlations and uncertainties of emission spectra, was emphasized. R. Capote (IAEA) introduced a new formulation of the Unified Monte Carlo method in which each randomly-sampled set of parameters is assigned a weight that depends on the quality of the fit of the experimental data, including correlations. These and other model-based approaches were discussed, and some of the advantages of each were mentioned. There was agreement that such comparisons should continue.

In view of the strong need for input from experimentalists in the evaluation of data covariances, the group reaffirmed the need for nuclear data measurers to pay more attention to the documentation of experimental uncertainties. The group also noted that this topic is not adequately addressed in the training of nuclear scientists. This fact is compounded by the pressures to publish results in archival journals and the limitations on the content that can be included in such publications. To remedy the situation, the group recommended that: 1) Future experimenters keep better records of details governing measurement uncertainties. 2) Future compilers exert greater efforts in seeking out and compiling such information, going, where necessary, beyond the information given in archival journal articles. V. Zerkin (IAEA) reported on the IAEA effort to create a new, Web-accessible library of experimental nuclear data, based on EXFOR but including corrections and additions, and presented in Computational Format (C4). The attendees strongly endorsed this initiative, and several evaluation groups indicated that they are planning to integrate this C4 library into their future developments. The group also recognized that these “reforms” will take time to bear fruit, so that present-day evaluators will continue to need to supplement compilations such as EXFOR with their own rough

estimates of systematic uncertainties. For traceability, it is important that evaluators clearly document any use of such estimates.

This technical meeting generated the following formal recommendations, in the order in which they appear in the draft report of the meeting:

1. Evaluated covariances must be reasonable, which implies that they must at least be positive semi-definite and be consistent with relevant experimental information. Other aspects of "reasonableness" depend on details of the intended application.
2. Covariances should be provided for energy-dependent unresolved resonance parameters.
3. Time-of-flight spectra should be archived directly in EXFOR.
4. The IAEA should consider an activity to further elaborate the comparison of proposed evaluation methods.
5. Covariances should be provided in ENDF for thermal scattering data in MF7.
6. The IAEA should continue to support activities to correct errors in EXFOR, along the lines of WPEC Subgroup 30.
7. The IAEA should monitor user requirements for reactor dosimetry data and continue to maintain IRDF.
8. Information (e.g., documentation, instructions, and specific examples) on techniques for the preparation and recording of uncertainty information should be provided to experimenters, for example on the IAEA website.
9. The EXFOR formats should be made flexible enough to accommodate information as provided by experimenters.
10. Authors of experimental data are urged to provide the full energy-to-energy covariance matrix or, alternatively, to provide components of this matrix together with instructions for combining them to create the full matrix.
11. Authors of experimental data are urged to provide explicitly in EXFOR the data actually measured, especially ratios.
12. The NRDC compilers should be instructed that is its mandatory, for each data set compiled, to seek and compile relevant covariance information in computer-retrievable form.
13. The activity to assess systematic uncertainties for existing entries in EXFOR, and to add them to the compilation, should continue.
14. The present Computational Format (C4) should be extended to accommodate partial uncertainty information stored in EXFOR.
15. Cross-reaction and cross-material correlations should be addressed in MF40 (covariances of activation cross sections).
16. Evaluators should consider evaluating MF35 for angle-integrated particle- and recoil-emission spectra (for DPA).

Cross Section Evaluation Working Group

Formats and Processing Committee Report

Michael E. Dunn, ORNL
Committee Chair

The Formats and Processing Committee meeting was convened on November 3, 2010 in Santa Fe, NM. The initial part of the meeting was devoted to format related issues. Jean-Christophe Sublet (UKAEA) submitted an activation reaction format proposal. In addition, Mike Dunn presented a previous resonance parameter uncertainty format (MF=32) proposal (circa 1994) by F. Fröhner for discussion by the CSEWG. Subsequently, Goran Arbanas (ORNL) provided a presentation concerning temperature-dependent scattering kernels for non-thermal moderators, and Jean-Christophe Sublet provided a presentation concerning the unresolved resonance region (URR). After a review and discussion of the format proposals and formatting issues, status reports on the major processing codes were presented. The Formats and Processing meeting concluded with a status report from BNL concerning NNDC activities related to the ENDF-102 Manual and checking codes. The following are the minutes from the Formats and Processing Committee meeting.

Formats and Related Issues

Activation Reaction Format Proposal (Jean-Christophe Sublet, UKAEA)

Jean-Christophe Sublet submitted a proposal to add MT numbers to completely specify the reaction mechanism for activation-transmutation analyses (i.e., in similar format to activation files). The proposal is co-authored by A Koning (NRG-Petten), R. A. Forrest (IAEA), and J Kopecky. Note this proposal was submitted for consideration by the CSEWG in 2009; however, no representative for the proposal was present at the November 2009 CSEWG meeting to present the proposal for review and approval (i.e., per the CSEWG Formats and Processing Committee expectations for new format proposals). At the 2009 meeting, Dunn brought the proposal before the CSEWG for discussion in order to identify possible concerns/issues with the proposal. During the November 2010 meeting, Sublet presented the proposal to the CSEWG for consideration as a new format, and the previous concerns were identified and addressed by Sublet.

The proposal requests the addition of more defined MT numbers in Appendix B of the ENDF-102 Manual. The additional MT numbers would make any reaction description complete (+/- 10 mb) up to an incident energy of 60 MeV for all foreseeable light and

heavy target nuclides. Moreover, the format change would enable consistency with the European Activation File (EAF) format. In addition, Sublet provided a revised addition to the ENDF-102 manual in order to support the proposed format change. As a minor suggestion, the CSEWG recommended that the reaction ordering be organized such that the neutron reactions would be grouped toward the front of the list thereby keeping the neutron reactions organized together for implementation in the processing codes. Subsequently, the activation reaction format proposal was approved by the CSEWG, and Sublet agreed to look at the reaction reordering before finalizing the format for implementation in the manual.

F. Fröhner MF=32 Proposal (circa 1994 – presented by Mike Dunn, ORNL)

In correspondence prior to the November 2010 CSEWG meeting, there was discussion among the CSEWG community to reassess the MF=32 format proposal that was submitted by F. Fröhner to the CSEWG in 1994. During the November 2010 CSEWG meeting, Dunn presented the proposal to the CSEWG to determine whether the format or elements of the format be adopted in the current ENDF formats.

At the time of the original proposal, Fröhner noted the following deficiencies in the ENDF formats:

No provisions for uncertainties of effective radii for s-, p-, and d-wave potential scattering
Variances and covariance data are not only needed for partial widths but total widths
No location for second fission or other residual width (e.g., inelastic) needed for the 3-channel Reich-Moore format that has been used for 235U, 239Pu, etc.

In 1994, Fröhner proposed a more general, user-friendly format where the covariance data would be stored as standard deviations and correlations thereby enabling the processing codes to reconstruct the covariance matrices from the standard deviations and correlations. Fröhner proposed to represent the standard deviations in the MF=2 resonance parameter format. Specifically, standard deviations would be provided for all resonance parameters in the same sequence and same format as the MF=2 parameters. Moreover, the evaluator would be permitted to enter relative standard deviations. From a practical standpoint, the evaluator would be able to copy their resonance parameter tables from MF=2 to MF=32 and replace the resonance parameters with the standard deviations thereby providing a one-to-one correspondence between MF=2 and MF=32. Regarding the correlation data, correlation tables would be represented in a new, general format. Because of symmetry and unit values on the diagonal, the evaluator would only need to store values above the diagonal. In addition, correlation matrices can be sparse; so, the evaluator would only need to store the nonzero values. Furthermore, Fröhner proposed a compression scheme in the original proposal; however, it should be noted that the compression scheme would no longer be needed as the CSEWG subsequently adopted

the Compact Resonance Format by Nancy Larson in the ENDF-6 format years after the Fröhner proposal.

The CSEWG reviewed the original Fröhner proposal and determined that many of the technical issues have been addressed by subsequent MF=32 format revisions; however, there is still a need to represent the scattering radius uncertainty and correlations. A format revision was approved at the 2009 CSEWG meeting allowing the scattering radius uncertainty to be provided by the evaluator; however, additional work will be needed to implement the scattering radius correlation data, and there are efforts in progress to address the correlation data format issue. Based on the discussion, the CSEWG determined that no further action should be taken with the previous Fröhner MF=32 proposal.

Temperature Dependent Scattering Kernel Discussion (Goran Arbanas, ORNL)

Arbanas provided a presentation discussing the need to address temperature-dependent scattering kernels for non-thermal moderators. Ron Dagan (IRS) and Bjorn Becker (RPI) have performed significant research related to resonance scattering theory and temperature dependent scattering kernel impacts on nuclear reactor applications. Recently ORNL has collaborated with Dagan and Becker to implement the Doppler Broadened Rejection Correction (DBRC) methodology in the ORNL Monte Carlo and deterministic codes. The objective of the Arbanas presentation is to highlight the importance of temperature-dependent scattering kernels for non-thermal moderators and determine whether the ENDF formats should be revised to permit evaluators to provide such scattering kernels or whether the processing codes should be updated to provide temperature-dependent scattering kernels for the radiation transport codes. Arbanas presented the theory along with the pros and cons of both approaches, and the CSEWG agreed that the burden should be placed on the processing codes to provide temperature-dependent scattering kernels as opposed to using the ENDF files to transmit the temperature dependence. No further action should be taken to revise the ENDF formats to provide temperature-dependent scattering kernels for non-thermal moderators.

Unresolved Resonance Region (URR) Issues (Jean-Christophe Sublet, UKAEA)

Jean-Christophe Sublet gave a presentation on the URR formats and interpretation of the formalism for calculating cross-sections. The ENDF URR format is limited to the Single Level Breit Wigner (SLBW) formalism for the URR. As a result, the SLBW format does not account for resonance-resonance interference, and only one single-channel inelastic competitive reaction is allowed. Sublet noted that an inconsistency is obtained in URR cross-section results among the different processing codes if the competitive reaction width, Γx, is given (e.g., LRF=2 238U evaluation). Sublet presented results for NJOY-

PURR, CALENDF, AUROX, and PURM for six different URR evaluations. The isotope evaluations were selected to encompass most cases encountered in the URR of any ENDF/B-VII.0 or JEFF-3.1.1 evaluation. Based on the study, the primary conclusion is that the noted processing codes usually agree within a target accuracy of 1% for both infinitely dilute and 1-barn self-shielded effective cross sections with the exception of PURM when the parameter files and ENDF-102 rules have been properly and consistently interpreted by both evaluators and those who processed the data. Sublet further noted that the processing codes have to palliate the data format deficiencies, either because the format rules have not been well defined, have been interpreted differently, or are inconsistent/unphysical. Sublet provided the following recommendations for future ENDF format revisions:

Implement the CALENDF procedures for the URR and a new format will need to be defined
Allow for other resonance formalisms in the URR: Multi-level Breit Wigner (MLBW) and Reich-Moore Limited (RML)
Account for the effect of multiple fission channels
Allow all competition channels to be open in URR (e.g., inelastic levels, direct components, charge particle emissions)
Enforce LSSF=1 formalism (self-shielding factors from MF=2 and infinite dilution cross-sections from MF=3) if the evaluator can be sure that the self-shielding factors can be correctly predicted and applied; otherwise LSSF should be 0.
Make the URR format and specifications unambiguous.

Further, Sublet recommended a possible improvement could be obtained through the insertion of some large resolved resonances in the URR. In addition, one should add local descriptions of the average cross sections with INT=1 (linear-linear interpolation) from selected random sampling. Moreover, these two modifications would improve the description of the URR and are possible within the existing ENDF format. No format proposals were presented for the URR. In addition, it should be noted that improvements to the URR are being investigated within the context of WPEC Subgroup (SG) 32, and format proposals could be submitted following the completion of the work of SG 32.

Status of Processing Codes

NJOY (Skip Kahler, LANL)

NJOY99.336 was released April 2010, and LANL has a new version (99.347) that is being used internally and will be released later in November 2010. LANL is continuing to work on NJOY2010, and the new code package is undergoing final testing and debugging. Efforts are in progress to complete a new NJOY manual. The final draft of the manual has 26 chapters, is 737 pages long, contains 580 equations, and has 128 citations. In addition, LANL has developed a paper titled “Processing ENDF/B-VII.0

with NJOY" that has been accepted for publication in the December 2010 issue of Nuclear Data Sheets. Kahler also presented a detailed report on recent revisions to the NJOY software. A detailed listing of the NJOY code updates is available in the presentation by Kahler at the November 2010 CSEWG. The presentation can be downloaded from the NNDC website.

AMPX (Dorothea Wiarda, ORNL)

Dorothea (Doro) Wiarda provided a detailed status report on the AMPX development and maintenance activities since the November 2009 CSEWG meeting. During the past year, PUFF-IV has been used to process all of the ENDF/A evaluation files containing covariance matrices, and a report was provided in the presentation concerning the processing results and comparisons with NJOY.

In addition, AMPX is used to provide nuclear data libraries for the ORNL-developed SCALE radiation transport package. With regard to new library generation efforts, updated ENDF/B-VI.8 and ENDF/B-VII.0 CE and multi-group criticality libraries have been produced for SCALE and will be released with SCALE 6.1. Furthermore, ORNL has been working to develop an ENDF/B-VII.0 broad-group reactor physics cross-section library for HTGR applications. The HTGR library is currently undergoing testing for release with SCALE. ORNL has developed ENDF/B-VII.0 versions of the VITAMIN and BUGLE cross-section libraries for supporting reactor pressure vessel fluence analyses.

In addition, Wiarda also reported on ORNL work to develop capabilities to propagate cross-section data uncertainty for depletion calculations. Specifically, an adjoint solver has recently been integrated into the SCALE/ORIGEN software, and a sensitivity module has been developed to calculate sensitivities of concentrations (and other responses) to nuclear data. Furthermore, ORNL has been working to develop a continuous-energy neutron/gamma shielding package in SCALE (i.e., CE-Monaco). ORNL has recently updated the CE gamma processing capabilities in AMPX. Wiarda presented results of the new gamma processing capability in AMPX and showed CE transport results for a shielding problem using the new SCALE/CE-Monaco capability.

With regard to the AMPX code package, all of the modules have been converted to double precision. The Y12 module (code to create pointwise collision kinematics files) has been updated to improve the treatment of gamma production matrices from MF=6. In addition, the processing of MF=12, 13, 14 and 15 has been improved. As noted in the previous report, ORNL has developed a new Java-based graphical user interface (GUI) tool named ExSite that can be used for SCALE and AMPX. During the past year, the supporting template for generating multi-group and continuous-energy libraries has been finalized for release with the AMPX code package. The AMPX code package has been

finalized and sent to RSICC in September 2010. Efforts are currently in progress to finalize the documentation for publication with the code package.

ANL (Dick McKnight, ANL)

Dick McKnight provided the status report on the ANL codes and noted that ANL has been working to keep the processing codes current with the ENDF formats to support MC2-3.

LLNL (Caleb Mattoon, LLNL)

Caleb Mattoon provided an update on the LLNL processing codes. LLNL converts the ENDF files to the ENDL format then processes the files to produce libraries for the LLNL transport codes. The LLNL codes historically are based on C, C++, and FORTRAN, and the LLNL efforts have been focused on converting the coding to the FUDGE (For Updating Data and Generating ENDL)/Python package. LLNL has developed a new Generalized Nuclear Data (GND) Format, and the new format can take advantage of the object-oriented tools that are available. A beta version of the GND Format will be released soon and will include: the ability to convert ENDF-6 to Python classes (supports writing out to XML or ENDF-6 format); and XML 'schema' (i.e., xml rules) defining the format; conversion from XML to HDF5. In addition, the GND beta version currently supports cross section, energy and angular distributions, multiplicities corresponding to MF =1,3,4-6, and 8-10. LLNL plans to add support for resonances and emitted photons corresponding to MF=2 and 12-15.

ENDF-6 manual and checking codes (Mike Herman, BNL)

ENDF-102 Manual

The ENDF-102 Manual has been updated during the past year, and BNL plans to send the manual to OSTI once per year as new updates are made to the manual. The LaTeX source for the manual will be updated more frequently and maintained under GForge (public access). The latest version of the manual can be downloaded from the NNDC website. The manual was last updated on July 2010 and includes format changes that were approved at the CSEWG 2009 meeting. Mike Zerkle (BAPL) requested that previous releases of the ENDF manual also be placed on the NNDC website to support regulator requests and reviews. After some discussion, BNL agreed to take an action item to comply with the request to post the previous versions of the manual on the website.

Checking Codes

A status report was provided for the ENDF-6 checking codes (submitted by A. Trkov and presented by M. Herman).

CHECKR Version 8.06:
The ENDF-6 format extensions for the scattering radius uncertainty in MF=32 have been implemented as approved at the November 2009 CSEWG Meeting.
CHECKR test for STA and NST in decay libraries.

FIZCON Version 8.04
The ENDF-6 format extensions for the scattering radius uncertainty in MF=32 have been implemented as approved at the November 2009 CSEWG Meeting.
The changes proposed by M. Kellett have not been included yet.

STANEF Version 8.02
The ENDF-6 format extensions for the scattering radius uncertainty in MF=32 have been implemented as approved at the November 2009 CSEWG Meeting.

PSYCHE Version 8.01
Small cosmetic corrections to the code have been made.
The code is not sensitive to the Format extensions regarding the scattering radius uncertainty in MF=32.

Current versions of the ENDF-6 checking codes are maintained under GForge as part of the EMPIRE code. In addition, only the FORTRAN source is posted on the NNDC website, and current versions can be compiled on any system with standard compilers. Currently, NNDC is considering the possibility of having users run ENDF-6 checking codes on the NNDC servers.

Cross Section Evaluation Working Group

Measurements Committee Report

Yaron Danon, RPI
Committee chair

The measurement committee session was held on the morning of November 2, 2010. Eight presentations from representatives of experimental programs at LANL, Rutgers ORNL, RPI, Duke (TUNL), NIST, LLNL and NIF were given. The presentations provided an overview of current research and measurement performed at the different US laboratories. The full presentations can be found on the CSEWG web site.

The Agenda

1. Nuclear Data Experiments at LANSCE: Highlights 2010, Haight, 25'
2. Developing a surrogate for the (n,γ) reaction on short-lived nuclei, Cizewski, 15'
3. Neutron Cross-Section Measurements Activities at ORNL, Dunn, 15'
4. Nuclear Data at Rensselaer, Danon, 15'
5. Recent results from precision neutron and photon induced cross section measurements, Tonchev, 15'
6. NIST Measurements and Standards Related Work at Other Facilities, Carlson, 15'
7. Review of the Experimental Nuclear Physics Work at LLNL, Burke, 15'
8. Nuclear Data needs for NIF-based cross section measurements, Bernstein, 30'

U.S. Laboratories Measurement Programs

Nuclear Data Experiments at LANSCE: Highlights 2010 (Robert C. Haight, LANL)

Total Cross Sections – Reported total cross section measurement for ^{48}Ca in the energy range from 10-300 MeV, R. Shane et al., NIM A 614, 468 (2010).
Chi-Nu - Development of a system to measure fission neutrons spectrum below 1 MeV using LiGlass neutron detectors. There were issues due to background from room return; a new flight path is planned. LANL Obtained first results with the LLNL PPAC fission chamber and ^{235}U. A tagged neutron system (using proton recoil) to measure the absolute efficiency of neutron detectors was developed.
GEANIE – data is taken for incident neutron energies in the range 1 MeV $<E_n<$200 MeV.

^{103}Rh(n,xnγ) analysis finalized, internal report written, cross sections obtained for 140 γ-rays in 15 reaction channels.
^{56}Fe(n, γ γ) published result on the first 3- state of ^{56}Fe: PRC 81, 037304 (2010)
^{191,193}Ir and ^{197}Au isomer production published: PRC 80, 044612 (2009)
From Gammasphere experiments: High spin states observed for the 1st time in ^{96,97}Nb (Fotiades et al., PRC 82, 044306, 2010)
Capture measurement with DANCE – ^{89}Y, ^{157}Gd summarized in PhD thesis of Andrii Chyzh (NCSU/LANL), ^{152,154,155,156,158}Gd and ^{94,95}Mo, summarized in PhD thesis of Bayarbadrakh Baramsai (NCSU/LANL). Analysis is in progress for ^{97}Mo.
Planned measurements: capture ^{63}Ni, capture to fission ratio ^{233,235}U and ^{239,241}Pu,
Fission gamma-ray multiplicity and spectra $^{239, 241}$Pu
Fission cross section measurements - (0.2 eV to 200 MeV)
Completed Np-237, Pu-239, Pu-240, (t1/2 =6600 a), Pu-241, (t1/2 =14 a), Pu-242, U-238, U-233, Am-243. To be completed in FY 2011: U-236 U-234.
LANL presented future plans for experimental fission physics studies:
A TPC for high accuracy fission cross section measurements is developed by a collaboration of LANL, LLNL, INL and several universities. A prototype detector was constructed and is now being tested at LANL.
A new Spectrometer for Ion Detection in Fission Experiments (SPIDER) is considered in order to provide high fission fragment mass resolution for fast neutron fission.

Developing a surrogate for the (n,γ) reaction on short-lived nuclei (Cizewski, Rutgers)

A method for reliable (n,γ) measurements using the surrogate reaction is developed. It has advantages for rare and short lived isotopes that cannot be measured directly. A method to use the (d,pγ) reaction was presented. This method will work under the assumption that the same compound nucleus is produced and that the decay is independent of spin and parity of states. The dependence CN spin distributions prompted a measurement of ^{95}Mo spin states at FP12 at LANSCE.

Neutron Cross-Section Measurements Activities at ORNL (Dunn, ORNL)

ORNL completed data analysis of capture data for ^{182,183,184,186}W and transmission data for ^{184,186}W. The for ^{186}W the data show new resonances above 10 keV. Neutron capture and transmission measurements for ^{63,65}Cu were performed at GELINA, new evaluation will include old ORELA data. The ^{63}Cu data show resonance structure up to 400 keV.

Nuclear Data at Rensselaer (Danon, RPI)

Transmission: In preparation for transmission measurements (~1 eV~400 keV) for ^{95,96,98,100}Mo samples, a D_2O moderated and cooled neutron target was produced in order

to reduce gamma background from neutron capture in hydrogen. Preliminary data for ^{95}Mo was presented and show many new resonances above 2 keV.
Transmission and Capture: Preliminary SAMMY fits for transmission and capture measurements for Eu-nat and Eu-153 samples were presented. The new analysis extends the upper energy limit of the resolved resonance region from 100 eV to ~300 eV.
Neutron scattering data and analysis for Zr-nat samples were presented. The data in the energy range of 0.5 MeV to 20 MeV show discrepancies when compared to current ENDF/BVII and JEFF 3.1 evaluations in the energy range from 10-20 MeV.
Capture and Fission: RPI is developing a method for simultaneous capture and fission measurements using the RPI multiplicity detector the goal is to measure the capture of in U-235 in the unresolved region up to 10 keV. Preliminary results were presented showing resonance structure above 2.2 keV (the current end of unresolved resonance region).

Recent Results from Precision Neutron And Photon Induced Cross Section Measurements (Tonchev, Duke)

Measurements were done at TUNL using mono energetic neutrons (4-18 MeV). Cross section for ^{241}Am(n,2n) were presented and show very good agreement with the ENDF/B-VI evaluations up to 15 MeV. The data is in good agreement with newer a IRMM measurement. Measurements of ^{241}Am(γ,n) cross section in the gamma energy range from 9 to 16 MeV showed a peak cross section of ~200mb, the shape of the cross section as a function of energy supports a single lorentzian model.
Measurements of ^{69}Ga(n,2n)^{68}Ga, ^{69}Ga(n,p)^{69m}Zn, ^{71}Ga(n,p)^{17m}Zn were presented and show good agreement with TALYS calculations in the energy range of 8 to 16 MeV. Similar measurements were presented for ^{75}As(n,2n)^{74}As, ^{75}As(n,p)^{75}Ge and ^{75}As(n,α)^{72}Ga.
A method to measure ^{239}Pu Fission product yields by using mono energetic beam followed by gamma measurements is under development, preliminary results for ^{147}Nd were given.

NIST Measurements and Standards Related Work at Other Facilities (Carlson, NIST)

H(n,n) – angular distribution measurements are in progress at Ohio University, preliminary results at 14.9 MeV are in good agreement with ENDF/B-7.1. New data at 194 MeV indicated a discrepancy in recent angular distribution (Uppsala University and Indiana) measurements.
^{3}He(n,p) – Analysis of NIST polarized neutrons scattering measurements and total cross section both with small errors resulted in conversion problem of R-matrix formalism used for evaluations.
^{6}Li(n,t) - Measurements are now underway at the NIST of the ^{6}Li(n,t) cross section standard at ~4 meV neutron energy, total uncertainty is expected to be about 0.3%.
^{10}B(n,α) – The NIST setup for the ^{6}Li(n,t) will be used for the ^{10}B(n,α) reaction.

C(n,n) - New measurements at low energies for C(n,n) disagree with the evaluation.

Recent experiment indicate that Additional work should be done in the high energy region on the ^{235}U(n,f), ^{238}U(n,f) and ^{239}Pu(n,f) cross sections to support of the needs for better standards in that energy region

Review of the Experimental Nuclear Physics Work at LLNL (Burke, LLNL)

Use the experimental apparatus - STARS-LiBerACE now located in Cave 2 experimental hall @ 88Inch Cyclotron LBNL.
Capture - Progress on ^{88,89}Y cross section measurements using the surrogate reactions with ^{3}He incident beam on ^{89}Y was presented. Results for surrogate measurements of ^{175}Lu(n,γ) were presented and are significantly higher than previous measurements and evaluations.
Fission - Surrogate fission measurements on ^{241}were presented and show good agreement with direct measurements in the energy range of 0.4 MeV- 10 MeV.
For the first time, the ^{242}Cm fission XS has been determined up to the onset of second chance fission. New data ^{243}Cm show discrepancies with Fursov data but good agreement with Formushkin data.
Surrogate measurement of ^{238}Pu fission cross section was used for a new evaluation, which is about 5-20% higher than ENDF/B-7 in the energy rang of 10-20 MeV.
New Surrogate measurement of ^{239}U fission cross section in the energy range from 0.5 MeV to 20 MeV is lower than then ENDF/B-7 evaluation above 8 MeV.
A new fission chamber was developed and was used for measurements at LANL. Measurements of the fission cross section of ^{239}Pu and ^{241}Pu were completed but results were not presented.

Nuclear Data needs for NIF-based cross section measurements (Bernstein, LLNL)

A general description of the NIF facility and the conditions of the NIF fuel capsule were given. Loading the NIF capsule with sample material provides unique opportunities to perform cross section measurements. Examples of (n,α) and (n,x) were given.

Summary of the 13th U.S. Nuclear Data Program Meeting

Held at
Eldorado Hotel, Santa Fe, New Mexico

November 2 - 3, 2010

US Nuclear Data Program

Chairman's Summary

M. Herman
National Nuclear Data Center, BNL

The 13th Annual Meeting of the United States Nuclear Data Program was held on November 2-3, 2010 and attended by 48 registered participants. The meeting was held adjacent to the CSEWG Annual Meeting, with a common USNDP-CSEWG session on nuclear reaction modeling.

Nuclear Structure Working Group

The status of basic nuclear structure databases NSR, XUNDL and ENSDF was reviewed. The ENSDF evaluation productivity maintains moderated growth. The NSR compilation has improved radically, recovering lat years loss related to the change of the NSR management. Innovative approach to NSR compilation, based on semantic analysis of the nuclear physics publications and automatic NSR keyword generation is being developed, with a potential of largely facilitating the compilation in the future.

It has been noted a worldwide improvement of the manpower situation in the NSDD, with several new evaluators entering the network in Eastern Europe and Asia. Also in the US there are positive indications of stabilizing the number of structure evaluators. The danger of shutting down in a few years nuclear data activities at Berkley seems to be over. There remains, however, a concern regarding future of the McMaster data program once Balraj Singh retires.

The size of Nuclear Data Sheet publications continues to grow, which is a matter of concern. It has been realized that this trend must be reversed. A new format of the mass-chain publications has been proposed that would leave certain part of the paper in the electronic version only. An important initiative of forming the Format and Procedures Committee has been undertaken. This Committee should initiate and then coordinate work on the modernization of the evaluation methodology and publication layout. The USNDP Chairman strongly believes that technical aspects of setting up NDS publications should be modernized and that it is essential for the NDS to maintain a space for non-mass-chain papers, which enrich NDS contents and improve impact factor of the journal. It has been noted that impact factor has fallen from a respectable value of 3.4 to 1.1 when ENDF/B-VII paper stopped to be counted because the two-year counting period has expired.

Nuclear Reaction Working Group

A common CSEWG-USNDP session was devoted to recent advances in development of nuclear reaction model codes in several US laboratories. Progress has been made in R-matrix approach to fission (LANL), parametrization of optical model approach to fission (BNL), fission prompt neutron spectra (LLNL), covariance methodology (BNL), exclusive spectra in the DDHMS preequilibrium model (BNL), calculations of neutron scattering on excited states (LLNL), and calculations of Legendre moments of Doppler broadened resonance elastic scattering (ORNL).

User Discussion Forum

This activity, established in 2005 and aimed to strengthen interaction between the user community and USNDP, has been suspended in 2010 due to logistical difficulties to organize it off-site. The user's forum should resume during the 2011 Autumn Week that will return to BNL.

Task Forces

The two task forces (Nuclear Data for Astrophysics and Nuclear Data for Homeland Security) continue their activity and presented their reports.

Planning and Reporting

- Summary of the present Annual Meeting should be issued in January 2011,
- Annual Report for FY10 in January 2011, and
- Workplan FY13 in February 2011.

The next budget briefing will be held at the DOE Headquarters on February 16, 2011. The USNDP team will include USNDP Chairman, WG chairmen and two who have specific issues to bring to the meeting. We should stress, on one side, the positive development in the ENSDF staff, and difficulties in hiring reaction evaluators on the other side.

Next Meeting

The next Nuclear Data Week will be held at BNL Nov. 14 through 18, 2011. This period was chosen instead of the traditional first week of November to avoid conflict with the ANS meeting. Tentatively, the USNDP annual meeting will be held on Nov. 14-16 (Mon – Wed).

USNDP Coordinating Committee Meeting

The Coordinating Committee met at working lunchtime on Wednesday, November 3, 2010. Nine members attended the meeting, including M. Herman, R. Firestone, A.

Carlson, T. Kawano, J. Kelley, F. Kondev, N. Summers, B. Singh, and C. Nasaraja. The meeting was also attended by Ted Barnes, DOE-SC.

Agenda

- M. Herman reported on the preparations to the Conference on Nuclear Data for Science and Technology in 2013 organized by the NNDC. The venue and the dates have been fixed. The Conference will take place in the New York City Sheraton Hotel, March 4-8, 2013. The contract with the Sheraton has already been signed. Ted Barnes informed that it will be possible to seek financial support from DOE-SC.

- **USNDP Status**: An overall personnel and funding situation at the USNDP laboratories was discussed. The overall funding in FY10 continued to be good due to the influx of the ARRA money. By the same token it continued to be difficult to recruit new staff, especially in reaction evaluation, because of the general shortage of qualified candidates. There has been very positive news from LBNL which successfully expanded (with the help of non-SC funding) eliminating imminent threat of closing nuclear data activities at Berkeley. ANL has hired two PostDocs while LLNL has hired one. Caleb Mattoon, BNL PostDoc promoted to staff, has moved to LLNL in August 2010. BNL lost also S. Tandel who did not return to US from India for personal reasons. The funding of C. Nesaraja, continues to be precarious. LANL and NIST report no significant change in manpower.

- **Annual Report FY10 and Workplan FY13**: See above.

- **Budget Briefing FY13**: See above.

- **Next Meeting**: See above.

US Nuclear Data Program

Structure and Decay Data Working Group

R. Firestone (LBNL),
Working Group Chair

Databases

ENSDF/Nuclear Data Sheets (Tuli): The numbers of datasets, nuclides, and file size have continued to grow by 1-2% over the past year. On average there have been 26 mass chains in the publication pipeline. Ten issues of mass chain evaluations and one issue of non-ENSDF material were published in *Nuclear Data Sheets*. The average published mass chain is now 183 pages, a 6% growth over last year and 70% more than four years ago. On-line paid downloads of mass chains through Elsevier remain high. The *Nuclear Data Sheet* impact factor dropped dramatically from 3.4 in 2008 to 1.1 in 2009, partially due to the covariance workshop proceedings in 2008 containing large number of papers, and partially because the highly cited ENDF/B-VII.0 paper is older than two years and is not counted any more. Interest in the printed copy of *Nuclear Data Sheets* has dwindled dramatically compared to electronic access and Elsevier will soon provide access by nuclide/datasets. Considerable discussion ensued about what to print in the electronic copy with a strong consensus in favor of Adopted Levels, Gammas and Decay datasets.

NSR (Pritychenko): The NSR database continues to grow with nearly 5% more nuclides referenced last year. Scanning efforts are divided between the NNDC, IAEA, McMaster and Bratislava. Work is ongoing with XSB, Inc. on semantic analysis of the nuclear physics publications and automatic NSR keyword generation. A call for missing NSR references of special importance was given in 2009 and several USNDP members responded.

Trieste Workshop/IAEA Activities (Abriola): A total of six nuclear data CRP's were completed in the past year, four are in progress, and two more are planned. Ten data development projects remain active. The IAEA published 2 mass chain evaluations and one is in progress. They are responsible for the keywords of European journal publications that account for about 20-25% of recent NSR effort. New mass chain evaluation contracts were issued to seven centers in Eastern Europe and Asia. Contracts were extended to Nick Stone (USA) for a new nuclear moment evaluation and Wang Meng for atomic mass evaluation. The IAEA coordinates the NSDD, supported a DDEP workshop in Madrid, June 2010, and held a successful Nuclear Structure and Decay Data evaluation workshop in Trieste, 11-15 Oct. 2010. The NSDD provides the *LiveChart of*

Nuclides on their website providing basic nuclear data. The next NSDD evaluators meeting will be in Vienna, 4-8 April, 2011.

XUNDL/Mass Compilations (Singh): XUNDL contributions were provided by evaluators at McMaster, TUNL, ANL, LBNL, Poland, Jordan, and the NNDC. XUNDL contains 3805 datasets for 1860 nuclides and 483 new entries were provided last year. All mass measurement references for the past year have been placed on-line at www.nuclearmasses.org.

DDEP (Kondev): A total of 170 of 322 decay data evaluations scheduled for completion have been completed and 20 are in review. Publication in a special issue of *Applied Radiation & Isotopes* is being explored. The ICRM has formally approved the adoption of DDEP data in future nuclear data studies.

EGAF/RIPL (Firestone): EGAF γ-ray cross section measurements are continuing at the Budapest Reactor and new measurements are planned at the Munich Reactor. Surrogate reaction cross section measurements have started with the STARS-Liberace facility in LBNL. EGAF will be expanded to provide updated RIPL data for nuclei produced by neutron capture on stable and selected radioactive targets. Evaluation of EGAF 2.0 is currently in progress with updated (n,γ) evaluations, an improved activation file, and new σ_0 measurements. A comparison of EGAF and IUPAC k_0 values was completed as part of and IAEA Research Project on a *"Reference Database for NAA"*.

Manpower/Outreach (Tuli/all): New evaluators, supported by the IAEA, have been identified in Bulgaria, Romania, Poland, Hungary, Ukraine, France, Germany, Finland, IAEA, and India. Long-term participation by these evaluators will require the support of their host institutions.

Compilations/NDS Publications

Analysis Codes (Johnson): Analysis codes continue to be maintained by the NNDC. Improved tracking of code development is being developed. Greatly improved web access to nuclear data is under development.

B(E2) evaluation (Pritychenko/Singh): A new evaluation of B(E2) values for Cr, Fe, Ni and Zn isotopes has been performed by collaboration of BNL, McMaster and Central Michigan Universities. It provides an update for the Z~N~28 region of nuclei and includes shell model calculations. Results will be submitted to Atomic Data and Nuclear Data Tables journal.

EADL (Sonzogni): The EADL atomic data library from LLNL was presented. The goal is to provide more detailed atomic data for RADLST and NuDat. Minor discrepancies with earlier work are under investigation.

DDEP Publication (All): No effort is recommended to publish DDEP evaluations in NDS at this time. Concern was expressed about the proliferation of slightly different evaluated decay data in ENSDF and DDEP publications.

EGAF Publication (Firestone): An example of a new EGAF publication in NDS was presented. The publication was well received by the NNDC and could potentially occupy one issue per year. The new publication would only occur after new EGAF data measured at the Budapest Reactor was published in peer-reviewed literature.

Charged Particle/Neutron Resonance Evaluation (Singh): It was proposed that absolute charged particle resonance level energies, not e.g. S_p+E(p), and other level properties be given in reaction and Adopted data sets. It also was proposed that neutron resonance data remain optional in ENSDF and S_n+E(n) be given the reaction dataset only.

Evaluation Topics

Half-life Evaluation Guidelines (Singh/all): Clear guidelines for averaging discrepant half-life value are missing from ENSDF. Other evaluation efforts have taken various approaches. It was recommended that ENSDF develop clear guidelines for half-life averaging.

High Spin Multipolarity/J^{π} Adoption (Singh/all): Rules for adoption of low-spin and high-spin J^{π} and multipolarity values appear to be inconsistent. It was suggested that rules for adoption of high spin data need to be improved.

JAVA-NSR Editor (Choquette/Singh): A JAVA based helper application for generating NSR keywords has been developed at McMaster and is being implemented at the NNDC.

Physics Evaluations/Research Discussions

Tungsten Capture γ-ray Analysis (Hurst): The preliminary analysis of EGAF data for the tungsten isotopes using DICEBOX calculations was discussed. Nuclear structure evaluation problems uncovered in this analysis were discussed.

Europium Capture γ-ray Analysis (Basunia): The preliminary analysis of EGAF data for the europium isotopes using DICEBOX calculations was discussed. Nuclear structure evaluation problems uncovered in this analysis were discussed. Planned experiments to investigate possible K dependence in the statistical model for ^{168}Er were discussed.

^{119m}Sn Internal Conversion (Nica): Ongoing precise measurements of the 65.66-keV transition conversion coefficient from ^{119m}Sn IT decay were discussed. The measurement is complicated by the weak intensity of the low-energy transition. Preliminary results cannot yet discriminate between the hole and no-hole assumptions.

Light Element Cross Sections (Firestone): Results of the analysis of σ_0 for Z=1-19 from EGAF are discussed. The decays schemes from these isotopes are essentially completely measured. Possible problems due to changes in high energy γ-ray efficiency standards were discussed. Most measurements showed significant discrepancies from values in the Atlas of Neutron Resonances (Elsevier, 2006).

How to Draw a Level Scheme (Nica): The average level energy spacings in large detector array coincidence rays show regular energy patterns. No method of displaying this kind of level scheme information currently exists.

JAVA-NDS (Choquette/Singh): A JAVA based program for the layout and publication of NDS was developed at McMaster. The code is being developed in collaboration with the NNDC and will be handed over to the NNDC in 2011.

Discussion

Several topics of general interest were discussed in this meeting. There are very few new IAEA Coordinated Research Projects (CRP) related to nuclear structure and decay currently being proposed. Members of the USNDP are strongly encouraged to get involved in proposing new CRPs. The XUNDL project has been very successful but faces a near term crisis if new leadership isn't found to take over some of McMaster's responsibilities pending Balraj Singh's retirement. USNDP members are urged to look for new candidates. Significant changes in the NDS production format are coming and a consensus must be reached as to what to include in future publications.

NDS no longer publishes only mass chain data. Recent publications on EMPIRE and RIPL have proven very successful. EGAF may provide yet another publication for NDS. It has become clear that the large growth in the size of mass chain publications must be reversed to make room for other topics.

A persistent problem continues to be finding a mechanism for changing ENSDF policies. It was suggested that the Formats and Procedures Subcommittee, formerly chaired by Murray Martin, should be reconstituted. This committee would work with the NNDC to implement changes in how we evaluate and publish nuclear data. It was recognized that this committee should be small including the head of the USNDP Nuclear Structure Working Group, the editor of Nuclear Data Sheets, and 1-2 other evaluators. Each year format and procedure proposals would be sent to the Subcommittee which would provide formal recommendations for the appropriate action. The Subcommittee would present these actions at the annual USNDP meeting for further discussion and final recommendations. The results of these actions would be presented at the next NSDD meeting for final ratification and the NNDC would then implement any necessary changes. Richard Firestone, chair of the USNDP Nuclear Structure Working Group was asked to begin forming the Formats and Procedures Committee.

The next meeting of the USNDP has been scheduled for November 14-18 at Brookhaven National Laboratory.

US Nuclear Data Program

Nuclear Reaction Working Group

T. Kawano, LANL
Working Group Chair

Model code development

Herman of BNL presented the status of the EMPIRE code development, from both physics and software sides. The updates include the DDHMS preequilibrium model with exclusive spectra, KERCEN code for estimating covariances in the resonance region, and modifications to accomodate primary gamma-rays from EGAF. New fission parametrizations have been developed, which give similar cross sections to those in JENDL/AC. In the software development part, EMPIRE is now managed under GForge and Subversion.

Talou of LANL gave a talk on recent fission modeling development. The model is based on the R-matrix approach, including recent nuclear structure studies of Moller's potential energy surface calculations and/or a more microscopic theories. The coupling between class-I and class-II states is explicitly taken into account . A code written in Fortran95, which is an updated version of AVXSF by E. Lynn, applied to Pu isotopes. They plan to combine the code with other reaction codes to perform complete nuclear data evaluations.

Thompson of LLNL presented theoretical calculations of neutron scattering on excited states, using the coupled-channels method. Comparing compound formation cross sections to the ground and first excited states of Pu-239, it was shown that a large number of coupled states is needed to obtain convergence. The adiabatic limit was considered, in which the target does not rotate during interaction, and it was shown that the adiabatic approximation works very well. Further research will be made by looking into the spin dependence, oscillation behavior of convergence, and convergence on the total cross sections.

Vogt of LLNL gave a talk on the application of the event-by-event fission simulation code, FREYA, to the prompt fission neutron spectrum (PFNS). The FREYA simulation of 239-Pu(n,f) was extended into the higher energy region, where multi-chance fission and preequilibrium emission need to be included. A statistical method was applied to obtain fit parameters needed for the evaluation of the PFNS, also yielding covariances between the outgoing neutron energies. They further looked into the correlations between model input parameters as well as the correlation between the calculated fission

neutron spectra, outgoing energies, and average number of prompt fission neutrons at different energies. The obtained fission spectra were applied to calculate the eigenvalue k_effective in critical assemblies, yielding good agreement. There was improved agreement with the pulsed sphere experiments.

Arbanas of ORNL presented calculations of Legendre moments of Doppler broadened resonance elastic scattering. The history of temperature-dependent method was reviewed. Starting with a complicated three-fold integrals derived by Ouisloumen and Sanchez in 1991, by recursive application of integration by parts Arbanas obtained a single integral formula that is very fast to compute. Their deterministic method was validated by comparison to the Mote Carlo method. A very good agreement between the two methods was obtained fo Legendre moments of effective scattering kernel as well as the Doppler broadened cross section of U-238 at T=1000K. It was noted that there will be 10% effect on the Legendre moments caused by the Blatt-Biedenharn angular distribution at 10keV. The uncertainties of the double differential cross section were shown to be a functional of the elastic scattering cross sections covariance matrix.

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USNDP Reports

A. Sonzogni, BNL
Session Chair

The reporting session started with the talk on the USNDP web services by Pritychenko who discussed improvements in the retrieval interfaces for the major NNDC products: Nudat, NSR, Sigma, and EXFOR.

The two Task Force reports were delivered by the respective chairmen: Nuclear Data for Astrophysics by C. Nesaraja, and Nuclear Data for Homeland Security by Brown.

Nine laboratory reports were given:

1. BNL Report, Herman
2. ANL Report, Kondev
3. LANL Report, Kawano
4. LBNL Report, Firestone
5. LLNL Report, Summers
6. McMaster Report, Singh
7. NIST Report, Carlson
8. ORNL Report, Smith
9. TUNL Report, Kelley