Summary Record of the 6th Meeting of the WPEC Subgroup 33 on

Methods and issues for the combined use of integral experiments and covariance data

NEA, Issy-les-Moulineaux, France

1-2 December 2011

The subgroup co-ordinators, **M. Salvatores** and **G. Palmiotti**, opened the meeting and welcomed the participants (see Appendix 1). Apologies for absence were received from NNDC (USA), CNDC (China) and NRG (The Netherlands). The proposed agenda was adopted with the addition of two presentations, the first one by **S.-J. Kim** (KAERI) on S/U analysis using DANTSYS/SUSD3D codes and the second one by **I. Hill** (NEA) on the IRPhEP database and analysis tool (IDAT). The final agenda is available in Appendix 2. **M. Salvatores** reviewed the actions from the previous meeting. An updated list of actions is available at the end of this document (see section 8).

1. Further comments on adjustment methodology and covariance matrix

G. Palmiotti mentioned the methodology in use at NRG to search for optimal nuclear data. This random approach was already applied to "adjust" ^{239}Pu nuclear data. The method is radically different from standard adjustment method and it would be worthwhile to have NRG solution contribution to the adjustment exercise.

2. WPNCS EG on Uncertainty Analyses for Criticality Safety Assessment

T. Ivanova reported on progress made in the framework of the WPNCS Expert Group on Uncertainty Analysis for Criticality Safety Assessment (UACSA). She presented the conclusions of the benchmark phase III, which aimed to test techniques and software tools for calculation of k_{eff} sensitivity to neutron cross sections.

3. Experiment analysis – New results

3.a) S. Pelloni presented C/E-values for the proposed benchmark exercise using ERANOS-2.2 in conjunction with different data libraries: ENDF/B-VI.8, JEFF-3.1, JEF-2.2 and ERALIB-1 (adjusted data). In overall, JEFF-3.1 shows good performance, especially in the case of ZPPR9 Na void.

3.b) S.-J. Kim presented preliminary results of benchmark C/E-values and k_{eff} sensitivity to nuclear data uncertainty using the DANTSYS and SUSD3D codes with JENDL-4.0 (incl. covariance data) and ENDF/B-VII.0 data. Future work will include S/U analysis of additional integral parameters and COMMARA-2.0/ENDF/B-VII.1 covariance data.

4. Integral experiment covariance matrix (draft report) and correction factors

M. Ishikawa presented in more details the draft report on *"How to determine error matrix of integral data"* and reminded the participants about the importance to take into account the analytical modelling errors when analysing the result of the adjustment.

M. Salvatores thanked **M. Ishikawa** for this comprehensive report and questioned the separation between common and independent errors, as well as the origin of the 0.3 multiplication factor used to calculate the common error (see draft report, page 13, Fig. A.5). **M. Ishikawa** answered that this value should be arbitrarily set such as 5% or 30%, depending on the evaluator's confidence in the analytical method used. The essential point is to use a fixed multiplication factor according to the sensitivity between the correction values and the analytical modelling error values.

5. Uncertainty analysis – New results

5.a) S. Pelloni presented a detailed S/U analysis of benchmark experiments and target systems using ERANOS with a number of evaluated libraries and associated covariance data: JEFF-3.1 + BOLNA, JEFF-3.1 + COMMARA-2.0, ENDF/B-VI.8 + COMMARA-2.0, JEF-2.2 and ERALIB1 (adjusted library using JEF-2.2 as a prior). The use of COMMARA-2.0 reduces the calculated uncertainties as compared to BOLNA covariance data thanks to improvement in the uncertainty of the ^{237}Np and ^{241}Pu fission cross-sections, the capture of ^{16}O, ^{235}U and ^{238}U, and the elastic scattering of ^{16}O. However, k_{eff} uncertainties are still much larger than experimental uncertainties because of ^{238}U(n,n') uncertainty.

5.b) I. Kodeli presented S/U analysis of selected benchmarks using DANTSYS and SUSD3D codes with covariance data from COMMARA-2.0, SCALE-6 and JENDL-4.0. A reasonably good consistency was observed using these different covariance data. The COMMARA-2.0 data were processed and verified using the ANGELO and LAMBDA codes, respectively. The procedure to interpolate the covariance data to any group structure can be made available to other users if needed.

5.c) M. Ishikawa presented a comparison of adjustment results using JENDL-4.0 and COMMARA-2.0 covariance data. The integral values were calculated using detailed Monte Carlo (MC) simulations (Jezebel, Flattop), simplified MC simulations plus corrective factors (ZPR6-7, ZPPR9 spectral indices, Joyo) and as-built MC simulations (ZPPR-9 k_{eff} and Na voids). The results of three adjustments were compared, (1) case J with JENDL-4.0 covariance data; (2) case B0 with COMMARA-2.0 data complemented by JENDL-4.0 data whenever necessary; (3) case B2 with COMMARA-2.0 data only. The adjusted C/E values were not significantly affected by the difference between JENDL-4.0 and COMMARA-2.0 covariance data. However, the adjusted nuclear data were extremely sensitive to the standard deviation values, which should be carefully assessed in collaboration with nuclear data evaluators.

M. Salvatores stressed that these concluding remarks were very important and that we need to organise our results before sending feedback to the nuclear data community.

6. Phase I of the benchmark adjustment exercise

6.a) C. de Saint Jean presented different adjustment results obtained using different covariance data (in-house, COMMARA-2.0, JENDL-4.0), with/without adjusting Chi and Nu-bar, and with/without integral correlations. Covariance matrices are quite different, but similar trends were observed using JENDL and COMMARA data except for sodium. Further analysis is ongoing to confirm trends and review covariance data.

M. Salvatores recommended reporting adjusted cross-sections (not trends) in order to facilitate the comparison between participants using different nuclear data. **M. Ishikawa** reminded that benchmark results should be sent to the NEA. **C. de Saint Jean** said that final results will be available shortly.

6.b) R. McKnight presented the results of preliminary cross-section adjustments using the GMADJ code primarily developed at ANL by W.P. Poenitz in the 80s. The sensitivity and C/E values were calculated by INL using VARI3D (diffusion) or ERANOS (transport) with ENDF/B-VII.0 and COMMARA-2.0 data. The adjustment results were similar whether neglecting or taking into account the correlation between experimental data. The adjusted C/E-values and associated uncertainties were compared with INL results for the 20 integral parameters used in the benchmark exercise. Moreover, adjusted cross-section and covariance data were used to calculate C/E-values and associated uncertainties for 14 additional integral parameters.

M. Salvatores thanks the speaker and noted that reporting C/E and associated uncertainties before and after adjustment was very useful to assess the performance of the adjustment. **M. Ishikawa** recommended sending benchmark results to the NEA as soon as possible. **M. Salvatores** stressed that partial results are welcome as well if available and that IPPE and ORNL should also contribute to the benchmark exercise.

6.c) G. Palmiotti presented revised adjustment results based on ENDF/B-VII.0 and COMMARA-2.0 data. With respect to the previous report, the Chi variable is now adjusted and the new experiment and calculation covariance matrices have been used. The most significant nuclear data adjustments are observed for ^{238}U and ^{239}Pu inelastic cross sections, as well as for the ^{235}U and ^{239}Pu capture. All the adjustments on cross sections are within the 1 sigma standard deviation range. The inclusion of integral experiment correlations, at least in this specific case, does not seem to have any significant impact. The uncertainty evaluation performed on target systems shows significant reductions (mostly related to correlations) for k_{eff}, but not as significant for Na voids.

6.d) I. Hill presented the IRPhEP database and analysis tool (IDAT). He highlighted the differences between ICSBEP/DICE (for criticality safety) and IRPhE/IDAT (for reactor physics), which contains less evaluations but more types of measurements (e.g. buckling, reactivity coefficient, power distribution). He presented new functionalities available in IDAT to visualize map of neutron flux, spectra and reaction rates in a 3-D geometry, to present summary plots of C/E for various quantities, to search for experiments with similar spectrum or neutron balance or sensitivity profile, etc. Members of subgroup 33 were invited to provide the IRPhE/IDAT project with their numerical results, especially C/E-values and sensitivity coefficients.

6.e) R. McKnight presented ANL ZPR-3 assemblies 53 (MIX-MET-INTER-004[*]), 54 (MIX-MET-INTER-003[*]) and ZPR-6 assembly 10 (PU-MET-INTER-002[*]). For these experiments, with large iron or stainless steel content, the k_{eff} value calculated with ENDF/B-VII data and the measurements differ by $1\% \div 3\%$, which is unusually large for this type of integral parameter. One of these experiments could be introduced in the benchmark exercise as a "stress" test of the adjustment methods.

Some participants questioned the relevance of these experiments as stress test due to the difficulty to model the transport of neutrons in the core/reflector transition zone and due to the presence of carbon and manganese, which are not considered in the benchmark adjustment exercise. **G. Palmiotti** proposed ZPR-9/34 (HEU-MET-INTER-001[*]) as an alternative solution. This is a ^{235}U(93%)/Fe assembly reflected by stainless steel with clean configuration and geometry very close to a cylindrical one. Participants agreed to look into more details at the various sensitivity profiles before taking a decision on which configuration to adopt for the stress test.

[*] International Handbook of Evaluated Criticality Safety Benchmark Experiments, NEA/NSC/DOC(95)03, DVD edition, OECD NEA, September 2011.

7. Discussion on next steps

M. Salvatores summarizes the results to be sent to the NEA for the phase I of the benchmark exercise:

- Cross-sections and associated uncertainties before and after adjustment,
- C/E and associated uncertainties (data, method, experimental) before and after adjustment (and split by isotope/reaction),
- Correlation matrices of nuclear data before and after adjustment,
- Sensitivity coefficients.

Participants agreed to send their result to the NEA (in SG33 format) by the end of March 2012 in order for the NEA secretariat to prepare and distribute a comparison of the results by the end of April 2012, one month before the next meeting.

M. Salvatores estimated that one more year will be necessary to finalise and conclude on SG33 activities. He asked participants to think about two options that should be further discussed before the next WPEC meeting, where a request to extend the SG33 mandate could be made (option 1) or a new subgroup could be proposed (option 2). The subgroup extension could be justified by involvement of new participants in the benchmark exercise and/or by a specific study on the importance of the role of correlation. The new subgroup activities could focus on the adjustment of nuclear reaction model parameters and/or on feedbacks to evaluators.

The next meeting will be held at the NEA Headquarters, Issy-les-Moulineaux, France on May 22-23, 2012, in conjunction with the WPEC meeting.

8. Actions

1.	E. Dupont All	To compile a list of the most useful references related to S/U methods.
2.	All	To send to the NEA, by the end of March 2012, the results of the phase I of the benchmark adjustment exercise.
3.	E. Dupont	To prepare and distribute, by the end of April 2012, a comparison of participant results for the phase I of the benchmark exercise.
4.	E. Dupont	To update the subgroup web page with materials from this meeting and other participant contributions.

Appendix 1

Participants to the 6th meeting of WPEC subgroup 33

NEA, Issy-les-Moulineaux, France

1-2 December 2011

A. Blokhin	IPPE, Russian Federation	
E. Dupont	NEA, OECD	(Secretary)
C.-S. Gil	KAERI, Korea	
I. Hill	NEA, OECD	
M. Ishikawa	JAEA, Japan	
T. Ivanova	IRSN, France	
S.-J. Kim	KAERI, Korea	
I. Kodeli	IJS, Slovenia	
L. Leal	ORNL, USA	
R. McKnight	ANL, USA	(Monitor)
E. Mitenkova	NSI/RAS, Russian Federation	
G. Palmiotti	INL, USA	(Coordinator)
S. Pelloni	PSI, Switzerland	
C. de Saint Jean	CEA, France	
M. Salvatores	INL, USA – CEA, France	(Coordinator)

Appendix 2

Agenda of the 6th meeting of WPEC subgroup 33

NEA, Issy-les-Moulineaux, France

1-2 December 2011

1 December 2011

14:15-14:30 **Introduction**

- Welcome, approval of agenda, action items from last meeting. (M. Salvatores)

1. 14:30-14:50 **Further comments on adjustment methodology and covariance matrix**

2. 14:50-15:10 **WPNCS EG on Uncertainty Analyses for Criticality Safety Assessment**

- Overview of the progress made at the WPNCS (T. Ivanova, IRSN)

3. 15:10-16:00 **Experiment analysis – New results**

It is expected that all the Subgroup members present their C/E (e.g. based on the simplified MCNP or deterministic models and the correction factors distributed by G. Palmiotti). Please remember that this is the minimum contribution expected from each member.

- C/E-values using ERANOS in conjunction with different data libraries (S. Pelloni, PSI)
- Preliminary results of nuclear data S/U analysis using DANTSYS/SUSD3D (S.-J. Kim, KAERI)

4. 16:20-17:20 **Integral experiment covariance matrix (draft report) and correction factors**

Under this item, it is expected to discuss members' comments on the report draft by M. Ishikawa: "Appendix A: How to Determine Error Matrix of Integral Data"

2 December 2011

5. 8:45-10:10 **Uncertainty analysis – New results**

- Data uncertainty analysis for the proposed benchmark exercise using ERANOS by comparing COMMARA-2.0 and BOLNA covariance libraries (S. Pelloni, PSI)
- S/U analysis of selected benchmarks and COMMARA-2 processing with ANGELO (I. Kodeli, IJS)
- Comparison of adjustment results using covariances of JENDL-4.0 and COMMARA-2.0 (M. Ishikawa, JAEA)

6. 10:10-12:30 **Phase I of the benchmark adjustment exercise**

Results and discussion on lessons learned

- Status of CEA Activities in SG33 (C. de Saint Jean, CEA)
- Status of ANL adjustment (R. McKnight, ANL)
- Adjustment results based on ENDF/B-VII and COMMARA 2.0 (G. Palmiotti, INL)

Under this item, we could also discuss:

How to compare results of the different adjustments: the number of parameters is in principle very large and we should propose practical approaches (e.g. select specific important data, as U-238 inelastic, Pu-239 fission etc.)
Role of anti-correlations in the adjustment and their interpretations
Possible need of a kind of "stress" tests on the adjustment methods (e.g. including a few experiments where very large C/E are expected, maybe experiments with very large iron or SS content as ZPR6/10 (Pu/C/SS) or ZPR9/34 (U/Fe))

- IRPhEP database and analysis tool: IDAT (I. Hill, NEA)
- ZPR-3 assemblies for testing the adjustment methods (R. McKnight, ANL)

7. 13:45-15:30 **Discussion on next steps**

Next steps (e.g. use of unique set of covariance data), schedule, reporting to WPEC and next meeting (All)