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Revised C/E-values and S/U analysis of benchmark experiments using ERANOS with JEFF-3.1 and ENDF/B-VI.8 evaluated libraries and associated COMMARA-2.0 covariance data

Methodology, objective and achievement

Methodology:
Deterministic ERANOS (Version 2.2-N) in conjunction with the following basic/covariance data pairs:
JEFF-3.1/COMMARA2.0 (unadjusted).
ENDF/B-VI.8/COMMARA2.0 (unadjusted): COMMARA2.0 to be used in conjunction with ENDF/B-VII.0 (no ENDF/B-VII.0 based library available with this edition of ERANOS).

ERANOS format for COMMARA-2.0: Gerardo Aliberti's work + Small in house program for generating all data available, based on the dedicated format kindly provided by NEA to the to SG33 members shortly after the May 2011 meeting. In this study: **Only the 11 nuclides specified in the benchmark (no ^{237}Np).**

Objective: Explain different results
of PSI with INL (but also JAEA and ANL) especially noticeable as regards data uncertainties for
1) k_{eff} in the case of JEZEBEL-Pu239 (~0.4% versus ~0.6%) and, quite significant,
2) Na void (Step 3 and Step 5) in the case of ZPPR-9 (~60% and ~80% versus ~8% and ~10%).

Achievement (main causes of the differences found)**:** At PSI, use was made of
1) the same ERANOS input option which is particularly suitable for decomposing a reactivity effect, also for determining the sensitivity coefficients;
2) An uncertainty calculation path just for reactivity effects which is apparently incompatible with the sensitivity coefficient file format. Namely, good agreement had been noticed also in the earlier studies between the PSI and INL sensitivity coefficients.

C/E values with their uncertainties

Reactor	Parameter	C/E-1 (%)		C/E uncertainty (%)[a]
		JEFF-3.1	ENDF/B-VI.8	
JEZEBEL_Pu239	k_{eff}	-0.06	-0.29	0.22
JEZEBEL_Pu239	F28/F25	-1.76	-3.89	1.49
JEZEBEL_Pu239	F49/F25	-1.52	-2.49	1.35
JEZEBEL_Pu239	F37/F25	0.01	-3.73	1.72
JEZEBEL_Pu240	k_{eff}	0.37	-0.24	0.22
FLATTOP_Pu239	k_{eff}	-0.07	-0.23	0.32
FLATTOP_Pu239	F28/F25	-1.37	-2.43	1.49
FLATTOP_Pu239	F37/F25	0.70	-1.99	1.72
ZPR6_7	k_{eff}	0.14	0.40	0.25
ZPR6_7	F28/F25	0.44	4.08	3.16
ZPR6_7	F49/F25	-4.07	-3.21	2.33
ZPR6_7	C28/F25	0.47	0.76	2.60
ZPR6_7_Pu240	k_{eff}	0.09	0.32	0.24
ZPPR9	k_{eff}	0.00	0.55	0.15
ZPPR9	F28/F25	-3.94	1.23	2.88
ZPPR9	F49/F25	-2.42	-1.40	2.24
ZPPR9	C28/F25	0.37	0.66	2.15
ZPPR9	VOID_STEP3	2.88	10.48	4.23
ZPPR9	VOID_STEP5	-2.68	8.22	4.13
JOYO	k_{eff}	-0.06	-0.48	0.21

[a] $C = C_0 f$, where C_0 is the computed value using a simplified deterministic model, assumed without uncertainty;
f is the estimated correction factor by means of a heterogeneous Monte Carlo calculation, uncorrelated with *E*, with a standard deviation *df*. Then,

$$\frac{d(C/E)}{C/E} = \frac{d(fC_0/E)}{fC_0/E} = \left(\frac{C_0}{E}df - \frac{fC_0}{E^2}dE\right)(E/fC_0) = \frac{df}{f} + \frac{dE}{E}$$

Revised nuclear data uncertainties

Reactor	Parameter	Data uncertainty (%)[a]	
		JEFF-3.1	ENDF/B-VI.8
JEZEBEL_Pu239	k_{eff}	**0.51**	**0.61**
JEZEBEL_Pu239	F28/F25	2.43	2.89
JEZEBEL_Pu239	F49/F25	0.72	0.79
JEZEBEL_Pu239	F37/F25	1.60	2.08
JEZEBEL_Pu240	k_{eff}	0.58	0.62
FLATTOP_Pu239	k_{eff}	0.83	0.77
FLATTOP_Pu239	F28/F25	1.95	2.27
FLATTOP_Pu239	F37/F25	1.42	1.79
ZPR6_7	k_{eff}	0.97	0.92
ZPR6_7	F28/F25	6.40	5.62
ZPR6_7	F49/F25	0.83	0.80
ZPR6_7	C28/F25	1.49	1.49
ZPR6_7_Pu240	k_{eff}	0.97	0.92
ZPPR9	k_{eff}	1.20	1.10
ZPPR9	F28/F25	7.74	6.88
ZPPR9	F49/F25	0.85	0.81
ZPPR9	C28/F25	1.52	1.52
ZPPR9	VOID_STEP3	**7.23**	**7.03**
ZPPR9	VOID_STEP5	**9.16**	**8.83**
JOYO	k_{eff}	0.88	0.87

[a]Does not include contributions due to the fission spectrum.

Experiment correlation matrix with original COMMARA-2.0 covariance matrices (JEFF-3.1)

Nr	Core	Nr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	JEZEBEL_ Pu239	k_{eff}	1																			
2		F28/F25	-0.60	1																		
3		F49/F25	-0.18	0.52	1																	
4		F37/F25	-0.57	0.94	0.60	1																
5	JEZEBEL_ Pu240	k_{eff}	0.77	-0.32	0.20	-0.30	1															
6	FLATTOP_ Pu239	k_{eff}	0.38	-0.11	0.17	-0.12	0.33	1														
7		F28/F25	-0.53	0.95	0.54	0.89	-0.28	-0.37	1													
8		F37/F25	-0.47	0.82	0.60	0.92	-0.24	-0.43	0.91	1												
9	ZPR6_7	k_{eff}	0.14	0.05	0.12	0.05	0.16	-0.53	0.26	0.30	1											
10		F28/F25	-0.04	0.09	0.06	0.07	-0.02	-0.85	0.37	0.41	0.73	1										
11		F49/F25	0.15	0.13	0.46	0.18	0.12	-0.37	0.32	0.40	0.43	0.62	1									
12		C28/F25	0.01	0.01	0.09	0.02	0.00	0.19	-0.04	-0.04	-0.51	-0.18	0.10	1								
13	ZPR6_7 _Pu240	k_{eff}	0.14	0.05	0.12	0.05	0.18	-0.54	0.27	0.31	1.00	0.74	0.43	-0.51	1							
14	ZPPR9	k_{eff}	0.11	0.05	0.10	0.05	0.12	-0.64	0.29	0.33	0.99	0.82	0.49	-0.50	0.99	1						
15		F28/F25	-0.03	0.06	0.05	0.05	-0.02	-0.86	0.35	0.40	0.74	1.00	0.60	-0.18	0.75	0.83	1					
16		F49/F25	0.15	0.12	0.44	0.16	0.12	-0.41	0.33	0.41	0.48	0.66	0.99	0.10	0.48	0.53	0.64	1				
17		C28/F25	0.00	0.02	0.10	0.03	0.00	0.21	-0.04	-0.04	-0.53	-0.18	0.11	1.00	-0.52	-0.52	-0.19	0.11	1			
18		VOID_ STEP3	-0.01	0.06	0.05	0.07	0.01	-0.72	0.30	0.37	0.60	0.87	0.58	-0.06	0.61	0.69	0.87	0.61	-0.06	1		
19		VOID_ STEP5	-0.00	0.06	0.06	0.07	0.02	-0.72	0.31	0.37	0.62	0.87	0.57	-0.06	0.63	0.71	0.87	0.60	-0.06	1.00	1	
20	JOYO	k_{eff}	0.12	-0.01	0.00	-0.03	0.16	0.01	0.00	-0.01	0.37	0.07	-0.12	-0.21	0.37	0.32	0.09	-0.08	-0.23	0.00	0.04	1

Experiment correlation matrix with original COMMARA-2.0 covariance matrices (ENDF/B-VI.8)

Nr	Core	Nr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	JEZEBEL_ Pu239	k_{eff}	1																			
2		F28/F25	-0.74	1																		
3		F49/F25	-0.11	0.62	1																	
4		F37/F25	-0.75	0.95	0.69	1																
5	JEZEBEL_ Pu240	k_{eff}	0.80	-0.47	-0.01	-0.48	1															
6	FLATTOP_ Pu239	k_{eff}	0.42	-0.18	0.10	-0.20	0.37	1														
7		F28/F25	-0.69	0.97	0.63	0.92	-0.44	-0.35	1													
8		F37/F25	-0.70	0.88	0.69	0.96	-0.44	-0.41	0.92	1												
9	ZPPR6_7	k_{eff}	0.09	0.07	0.14	0.07	0.13	-0.46	0.22	0.24	1											
10		F28/F25	-0.06	0.11	0.08	0.09	-0.04	-0.80	0.31	0.32	0.69	1										
11		F49/F25	0.08	0.17	0.49	0.21	0.08	-0.28	0.30	0.36	0.37	0.57	1									
12		C28/F25	0.03	-0.01	0.07	-0.01	0.02	0.16	-0.04	-0.04	-0.50	-0.13	0.13	1								
13	ZPPR_6_7 _Pu240	k_{eff}	0.09	0.07	0.14	0.07	0.15	-0.47	0.22	0.24	1.00	0.69	0.37	-0.49	1							
14	ZPPR9	k_{eff}	0.06	0.08	0.13	0.07	0.10	-0.56	0.24	0.26	0.99	0.78	0.42	-0.50	0.99	1						
15		F28/F25	-0.04	0.08	0.06	0.06	-0.03	-0.82	0.28	0.30	0.70	0.99	0.54	-0.14	0.71	0.79	1					
16		F49/F25	0.09	0.15	0.46	0.18	0.09	-0.34	0.29	0.35	0.43	0.62	0.99	0.14	0.43	0.48	0.60	1				
17		C28/F25	0.02	-0.00	0.08	0.01	0.01	0.18	-0.03	-0.04	-0.53	-0.15	0.14	1.00	-0.52	-0.52	-0.16	0.14	1			
18		VOID_ STEP3	-0.07	0.09	0.08	0.11	-0.03	-0.71	0.27	0.32	0.57	0.88	0.53	-0.03	0.58	0.67	0.87	0.57	-0.04	1		
19		VOID_ STEP5	-0.06	0.09	0.08	0.10	-0.02	-0.71	0.27	0.32	0.60	0.88	0.52	-0.03	0.61	0.69	0.88	0.57	-0.05	1.00	1	
20	JOYO	k_{eff}	0.01	-0.02	-0.00	-0.03	0.16	0.06	-0.01	-0.03	0.36	0.03	-0.15	-0.20	0.36	0.30	0.05	-0.11	-0.22	-0.02	0.01	1

Similar correlations as with JEFF-3.1 data.

Also rather similar values as compared to INL, except mainly for F28/F25.

Correlation between JEFF-3.1 and ENDF/B-VI.8

Reactor	Parameter	Correlation factor
JEZEBEL_Pu239	k_{eff}	*0.949*
JEZEBEL_Pu239	F28/F25	0.993
JEZEBEL_Pu239	F49/F25	0.987
JEZEBEL_Pu239	F37/F25	0.992
JEZEBEL_Pu240	k_{eff}	*0.966*
FLATTOP_Pu239	k_{eff}	0.990
FLATTOP_Pu239	F28/F25	0.991
FLATTOP_Pu239	F37/F25	0.987
ZPR6_7	k_{eff}	0.997
ZPR6_7	F28/F25	0.997
ZPR6_7	F49/F25	0.994
ZPR6_7	C28/F25	0.999
ZPR6_7_Pu240	k_{eff}	0.997
ZPPR9	k_{eff}	0.997
ZPPR9	F28/F25	0.998
ZPPR9	F49/F25	0.996
ZPPR9	C28/F25	0.999
ZPPR9	VOID_STEP3	0.997
ZPPR9	VOID_STEP5	0.997
JOYO	k_{eff}	0.999