Benchmarking ENDF/B-VII.1β3 Using the LANL Validation Suite

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Mini-CSEWG Meeting, Montauk, New York, June 21-23, 2011

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Outline

- Benchmarking tools
- Benchmarking results
- Conclusion

Benchmarking Tools

- LANL Criticality Validation Suite (provided by R. Mosteller, LANL) = 119 benchmarks, subcases permit study of parameter variations

Principal Fuel	Number of Benchmarks			
	Fast	Intermediate	Thermal	Total
^{233}U	10	1	7	18
HEU	29	5	6	40
IEU	10	1	6	17
LEU			8	8
Plutonium	21	1	14	36
Total	70	8	41	119

Reference: Russell D. Mosteller, "An Expanded Criticality Validation Suite for MCNP," Los Alamos National Laboratory report LA-UR-10-06230 (2010).

- MCNP5 v1.40 at 50 million histories/benchmark
- Computing Platform: NNDC Linux Cluster (76 cores)

^{233}U Benchmarks

Case Name:	Benchmark k_{eff}	Calculated k_{eff}		Δk_{eff} [pcm]	
		ENDF/B-VII.1β2	ENDF/B-VII.1β3	ENDF/B-VII.1β2	ENDF/B-VII.1β3
umf1	1.0000 ± 0.0010	0.99962 ± 0.00008	0.99982 ± 0.00008	-38	-18
umf2.1	1.0000 ± 0.0010	0.99895 ± 0.00008	0.99910 ± 0.00008	-105	-90
umf2.2	1.0000 ± 0.0011	1.00041 ± 0.00008	1.00014 ± 0.00009	41	14
umf3.1	1.0000 ± 0.0010	0.99950 ± 0.00009	0.99939 ± 0.00009	-50	-61
umf3.2	1.0000 ± 0.0010	1.00000 ± 0.00009	0.99976 ± 0.00009	0	-24
umf4.1	1.0000 ± 0.0007	0.99870 ± 0.00009	0.99840 ± 0.00009	-130	-160
umf4.2	1.0000 ± 0.0008	0.99584 ± 0.00009	0.99534 ± 0.00009	-416	-466
umf5.1	1.0000 ± 0.0030	0.99643 ± 0.00009	0.99629 ± 0.00009	-357	-371
umf5.2	1.0000 ± 0.0030	0.99584 ± 0.00009	0.99542 ± 0.00009	-416	-458
umf6	1.0000 ± 0.0014	0.99939 ± 0.00010	0.99888 ± 0.00010	-61	-112
usi1.1	1.0000 ± 0.0083	0.98672 ± 0.00015	0.98649 ± 0.00015	-1328	-1351
uct1.3	1.0000 ± 0.0024	1.00456 ± 0.00014	1.00382 ± 0.00014	456	382
ust1.1	1.0000 ± 0.0031	1.00097 ± 0.00008	1.00116 ± 0.00008	97	116
ust1.2	1.0000 ± 0.0033	1.00117 ± 0.00008	1.00138 ± 0.00008	117	138
ust1.3	1.0000 ± 0.0033	1.00054 ± 0.00008	1.00087 ± 0.00008	54	87
ust1.4	1.0000 ± 0.0033	1.00069 ± 0.00008	1.00075 ± 0.00008	69	75
ust1.5	1.0000 ± 0.0033	0.99991 ± 0.00009	0.99994 ± 0.00009	-9	-6
ust8	1.0006 ± 0.0029	1.00076 ± 0.00005	1.00152 ± 0.00005	76	152
			σ :	**368**	**376**

$\sigma < |\Delta k| \leq 2\sigma$ **$|\Delta k| > 2\sigma$**

^{233}U Benchmarks

Russell D. Mosteller, "Some Areas of Concern for ENDF/B-VII.0," Los Alamos National Laboratory report LA-UR-08-06963 (2008).

Fast Be cross sections should be re-examined prior to the next interim release of ENDF/B-VII

Case	Benchmark k_{eff}	Calculated k_{eff}			
		ENDF/B-VII.0	ENDF/B-VI	JEFF-3.1	JENDL-3.3
Jezebel-233	1.0000 ± 0.0010	0.9995 ± 0.0003	0.9926 ± 0.0003	1.0038 ± 0.0003	1.0041 ± 0.0003
Flattop-23	1.0000 ± 0.0014	0.9994 ± 0.0003	1.0003 ± 0.0003	1.0062 ± 0.0003	0.9985 ± 0.0003
U233-MF-05	1.0000 ± 0.0030	0.9929 ± 0.0003	0.9972 ± 0.0003	1.0004 ± 0.0003	1.0019 ± 0.0003

umf5.1-5.2

Case	Benchmark k_{eff}	Calculated k_{eff} (ENDF/B-VII.0 + Indicated Be)		
		ENDF/B-VII β-3	ENDF/B-VII β-2	ENDF/B-VII β-1
U233-MF-05	1.0000 ± 0.0030	0.9925 ± 0.0003	0.9925 ± 0.0003	0.9977 ± 0.0003

$|\Delta k| > 2\sigma$

U233-MF-05 is a ^{233}U sphere encased in Be

Deficiency addressed in VII.1β2 and VII.1β3

^{233}U Benchmarks

Russell D. Mosteller, "Some Areas of Concern for ENDF/B-VII.0," Los Alamos National Laboratory report LA-UR-08-06963 (2008).

Thermal ^{233}U cross sections should be re-examined prior to release of the next interim version of ENDF/B-VII

Case	Benchmark k_{eff}	Calculated k_{eff}			
		ENDF/B-VII.0	ENDF/B-VI	JEFF-3.1	JENDL-3.3
ORNL-11	1.0006 ± 0.0029	1.0015 ± 0.0002	0.9974 ± 0.0002	0.9975 ± 0.0002	0.9989 ± 0.0002
SB-2½	1.0000 ± 0.0024	1.0038 ± 0.0005	0.9977 ± 0.0005	0.9966 ± 0.0005	0.9980 ± 0.0005
SB-6	0.9995 ± 0.0027	1.0033 ± 0.0004	1.0000 ± 0.0005	0.9971 ± 0.0004	1.0033 ± 0.0004

uct1.3

$\sigma < |\Delta k| \leq 2\sigma$

ENDF/B-VII.0 value for k_{eff} is reasonable for ORNL-11 (water solution), but its values for the thermal lattices of fuel pins in water are high

SB-2½ and SB-6 have harder spectra than ORNL-11

Deficiencies still exist in VII.1β2 and VII.1β3

HEU Benchmarks, Part I

Case Name	Benchmark k_{eff}	Calculated k_{eff}		Δk_{eff} [pcm]	
		ENDF/B-VII.1β2	ENDF/B-VII.1β3	ENDF/B-VII.1β2	ENDF/B-VII.1β3
hmf1	1.0000 ± 0.0010	0.99988 ± 0.00008	1.00007 ± 0.00009	-12	7
hmf3.1	1.0000 ± 0.0050	0.99496 ± 0.00009	0.99492 ± 0.00009	-504	-508
hmf3.2	1.0000 ± 0.0050	0.99442 ± 0.00009	0.99437 ± 0.00009	-558	-563
hmf3.3	1.0000 ± 0.0050	0.99924 ± 0.00009	0.99912 ± 0.00009	-76	-88
hmf3.4	1.0000 ± 0.0030	0.99735 ± 0.00009	0.99732 ± 0.00009	-265	-268
hmf3.5	1.0000 ± 0.0030	1.00149 ± 0.00009	1.00147 ± 0.00009	149	147
hmf3.6	1.0000 ± 0.0030	1.00170 ± 0.00009	1.00169 ± 0.00009	170	169
hmf3.7	1.0000 ± 0.0030	1.00195 ± 0.00009	1.00196 ± 0.00009	195	196
hmf3.8	1.0000 ± 0.0050	1.00141 ± 0.00009	1.00146 ± 0.00009	141	146
hmf3.9	1.0000 ± 0.0050	1.00191 ± 0.00009	1.00191 ± 0.00009	191	191
hmf3.10	1.0000 ± 0.0050	1.00520 ± 0.00009	1.00529 ± 0.00009	520	529
hmf3.11	1.0000 ± 0.0050	1.00986 ± 0.00009	1.01002 ± 0.00009	986	1002
hmf3.12	1.0000 ± 0.0030	1.00846 ± 0.00009	1.00838 ± 0.00009	846	838
hmf4.1	1.0020 ± 0.0010	1.00358 ± 0.00011	1.00326 ± 0.00011	158	126
hmf8	0.9989 ± 0.0016	0.99559 ± 0.00009	0.99572 ± 0.00009	-331	-318
hmf9.1	0.9992 ± 0.0015	0.99752 ± 0.00009	0.99752 ± 0.00009	-168	-168
hmf9.2	0.9992 ± 0.0015	0.99690 ± 0.00009	0.99644 ± 0.00009	-230	-276
hmf11	0.9989 ± 0.0015	0.99888 ± 0.00011	0.99888 ± 0.00011	-2	-2
hmf12	0.9992 ± 0.0018	0.99805 ± 0.00009	0.99818 ± 0.00009	-115	-102
hmf13	0.9990 ± 0.0015	0.99748 ± 0.00009	0.99750 ± 0.00009	-152	-150
hmf14	0.9989 ± 0.0017	0.99780 ± 0.00009	0.99778 ± 0.00009	-110	-112
hmf15	0.9996 ± 0.0017	0.99451 ± 0.00009	0.99455 ± 0.00009	-509	-505
			σ :	**394**	**397**

$\sigma < |\Delta k| \leq 2\sigma$ **$|\Delta k| > 2\sigma$**

HEU Benchmarks, Part II

Case Name	Benchmark k_{eff}	Calculated k_{eff}		Δk_{eff} [pcm]	
		ENDF/B-VII.1β2	ENDF/B-VII.1β3	ENDF/B-VII.1β2	ENDF/B-VII.1β3
hmf18.2	1.0000 ± 0.0014	0.99958 ± 0.00008	0.99951 ± 0.00008	-42	-49
hmf19.2	1.0000 ± 0.0028	1.00711 ± 0.00009	1.00720 ± 0.00009	711	720
hmf20.2	1.0000 ± 0.0028	1.00070 ± 0.00010	1.00085 ± 0.00009	70	85
hmf21.2	1.0000 ± 0.0024	0.99753 ± 0.00009	0.99748 ± 0.00009	-247	-252
hmf22.2	1.0000 ± 0.0019	0.99755 ± 0.00009	0.99770 ± 0.00009	-245	-230
hmf26.c11	1.0000 ± 0.0038	1.00314 ± 0.00011	1.00306 ± 0.00011	314	306
hmf28	1.0000 ± 0.003	1.00278 ± 0.00009	1.00285 ± 0.00009	278	285
hci3.6	1.0000 ± 0.0047	0.99538 ± 0.00011	0.99536 ± 0.00011	-462	-464
hmi6.1	0.9977 ± 0.0008	0.99328 ± 0.00011	0.99316 ± 0.00011	-443	-455
hmi6.2	0.9997 ± 0.0008	0.99685 ± 0.00011	0.99714 ± 0.00011	-285	-256
hmi6.3	1.0015 ± 0.0009	1.00082 ± 0.00011	1.00102 ± 0.00011	-68	-48
hmi6.4	1.0016 ± 0.0008	1.00726 ± 0.00010	1.00728 ± 0.00010	565	567
uct1.6	1.0015 ± 0.0028	1.00091 ± 0.00013	1.00041 ± 0.00013	-59	-109
hst13.1	1.0012 ± 0.0026	0.99833 ± 0.00008	0.99863 ± 0.00008	-287	-257
hst13.2	1.0007 ± 0.0036	0.99760 ± 0.00009	0.99781 ± 0.00008	-310	-289
hst13.3	1.0009 ± 0.0036	0.99393 ± 0.00009	0.99415 ± 0.00009	-696	-674
hst13.4	1.0003 ± 0.0036	0.99577 ± 0.00009	0.99544 ± 0.00009	-453	-486
hst32	1.0015 ± 0.0026	0.99861 ± 0.00005	0.99937 ± 0.00005	-289	-213
σ :				**373**	**371**

$\sigma < |\Delta k| \leq 2\sigma$ **$|\Delta k| > 2\sigma$**

IEU Benchmarks

Case Name	Benchmark k_{eff}	Calculated k_{eff}		Δk_{eff} [pcm]	
		ENDF/B-VII.1β2	ENDF/B-VII.1β3	ENDF/B-VII.1β2	ENDF/B-VII.1β3
imf1.1	0.9989 ± 0.0010	1.00039 ± 0.00009	1.00048 ± 0.00009	149	158
imf1.2	0.9997 ± 0.0010	1.00071 ± 0.00009	1.00047 ± 0.00009	101	77
imf1.3	0.9993 ± 0.0005	1.00095 ± 0.00009	1.00099 ± 0.00009	165	169
imf1.4	1.0002 ± 0.0005	1.00146 ± 0.00009	1.00159 ± 0.00009	126	139
imf2	1.0000 ± 0.0030	0.99895 ± 0.00008	0.99902 ± 0.00008	-105	-98
imf3.2	1.0000 ± 0.0017	1.00259 ± 0.00009	1.00247 ± 0.00009	259	247
imf4.2	1.0000 ± 0.0030	1.00739 ± 0.00009	1.00755 ± 0.00009	739	755
imf5.2	1.0000 ± 0.0021	1.00172 ± 0.00009	1.00172 ± 0.00009	172	172
imf6.2	1.0000 ± 0.0023	0.99648 ± 0.00009	0.99611 ± 0.00009	-352	-389
imf7.4	1.0049 ± 0.0008	1.00467 ± 0.00007	1.00468 ± 0.00007	23	22
mmf8.7	1.0030 ± 0.0025	1.01924 ± 0.00006	1.01902 ± 0.00006	1619	1597
ict2.3	1.0017 ± 0.0044	1.00500 ± 0.00010	1.00466 ± 0.00010	329	295
lst7.14	0.9961 ± 0.0009	0.99511 ± 0.00010	0.99500 ± 0.00010	-99	-110
lst7.30	0.9973 ± 0.0009	0.99735 ± 0.00010	0.99772 ± 0.00010	5	42
lst7.32	0.9985 ± 0.0010	0.99640 ± 0.00009	0.99631 ± 0.00009	-210	-219
lst7.36	0.9988 ± 0.0011	0.99861 ± 0.00009	0.99896 ± 0.00009	-19	16
lst7.49	0.9983 ± 0.0011	0.99749 ± 0.00008	0.99766 ± 0.00009	-81	-64
			σ :	**447**	**444**

$\sigma < |\Delta k| \leq 2\sigma$ **$|\Delta k| > 2\sigma$**

LEU Benchmarks

Case Name	Benchmark k_{eff}	Calculated k_{eff}		Δk_{eff} [pcm]	
		ENDF/B-VII.1β2	ENDF/B-VII.1β3	ENDF/B-VII.1β2	ENDF/B-VII.1β3
lct8.1	1.0007 ± 0.0016	1.00033 ± 0.00009	1.00122 ± 0.00010	-37	52
lct8.2	1.0007 ± 0.0016	1.00078 ± 0.00009	1.00150 ± 0.00009	8	80
lct8.5	1.0007 ± 0.0016	1.00004 ± 0.00009	1.00114 ± 0.00009	-66	44
lct8.7	1.0007 ± 0.0016	0.99995 ± 0.00009	1.00093 ± 0.00009	-75	23
lct8.8	1.0007 ± 0.0016	0.99973 ± 0.00010	1.00046 ± 0.00010	-97	-24
lct8.11	1.0007 ± 0.0016	1.00101 ± 0.00009	1.00195 ± 0.00009	31	125
lst2.1	1.0038 ± 0.0040	1.00515 ± 0.00008	1.00562 ± 0.00008	134	181
lst2.2	1.0024 ± 0.0037	0.99603 ± 0.00009	0.99632 ±0.00009	-635	-607
			σ :	**232**	**247**

$\sigma < |\Delta k| \leq 2\sigma$ $|\Delta k| > 2\sigma$

Plutonium Benchmarks, Part I

Case Name	Benchmark k_{eff}	Calculated k_{eff}		Δk_{eff} [pcm]	
		ENDF/B-VII.1β2	ENDF/B-VII.1β3	ENDF/B-VII.1β2	ENDF/B-VII.1β3
pmf1	1.0000 ± 0.0020	0.99988 ± 0.00008	0.99988 ± 0.00008	-12	-12
pmf2	1.0000 ± 0.0020	0.99995 ± 0.00008	0.99995 ± 0.00008	-5	-5
pmf3.103	1.0000 ± 0.0030	0.99878 ± 0.00009	0.99878 ± 0.00009	-122	-122
pmf5	1.0000 ± 0.0013	1.00094 ± 0.00009	1.00121 ± 0.00009	94	121
pmf6	1.0000 ± 0.0030	1.00020 ± 0.00010	1.00010 ± 0.00010	20	10
pmf8.2	1.0000 ± 0.0006	0.99772 ± 0.00009	0.99772 ± 0.00009	-228	-228
pmf9	1.0000 ± 0.0027	1.00493 ± 0.00009	1.00493 ± 0.00009	493	493
pmf10	1.0000 ± 0.0018	0.99953 ± 0.00009	0.99970 ± 0.00009	-47	-30
pmf11	1.0000 ± 0.0010	1.00074 ± 0.00011	1.00012 ± 0.00010	74	12
pmf18	1.0000 ± 0.0030	0.99944 ± 0.00009	0.99932 ± 0.00009	-56	-68
pmf19	0.9992 ± 0.0015	1.00061 ± 0.00009	1.00084 ± 0.00009	141	164
pmf20	0.9993 ± 0.0017	0.99807 ± 0.00009	0.99794 ± 0.00009	-123	-136
pmf21.1	1.0000 ± 0.0026	1.00472 ± 0.00009	1.00446 ± 0.00009	472	446
pmf21.2	1.0000 ± 0.0026	0.99378 ± 0.00009	0.99321 ± 0.00009	-622	-679
pmf22.2	1.0000 ± 0.0021	0.99864 ± 0.00008	0.99864 ± 0.00008	-136	-136
pmf23.2	1.0000 ± 0.0020	1.00004 ± 0.00009	0.99998 ± 0.00009	4	-2
pmf24.2	1.0000 ± 0.0020	1.00174 ± 0.00009	1.00183 ± 0.00009	174	183
pmf25.2	1.0000 ± 0.0020	0.99874 ± 0.00009	0.99897 ± 0.00009	-126	-103
pmf26.2	1.0000 ± 0.0024	0.99864 ± 0.00009	0.99877 ± 0.00009	-136	-123
mmf1	1.0000 ± 0.0016	0.99967 ± 0.00008	0.99943 ± 0.00008	-33	-57
mmf3	0.9993 ± 0.0016	1.00083 ± 0.00009	1.00075 ± 0.00009	153	145
pci1	1.0000 ± 0.0110	1.01096 ± 0.00008	1.01094 ± 0.00008	1096	1094
			σ :	**326**	**330**

$\sigma < |\Delta k| \leq 2\sigma$ **$|\Delta k| > 2\sigma$**

Plutonium Benchmarks, Part I

Russell D. Mosteller, "Some Areas of Concern for ENDF/B-VII.0," Los Alamos National Laboratory report LA-UR-08-06963 (2008).

Fast cross sections for thorium should be re-examined prior to the next interim release of ENDF/B-VII

Case	Benchmark k_{eff}	Calculated k_{eff}			
		ENDF/B-VII.0	ENDF/B-VI	JEFF-3.1	JENDL-3.3
Jezebel	1.0000 ± 0.0020	1.0002 ± 0.0003	0.9971 ± 0.0003	1.0000 ± 0.0003	0.9966 ± 0.0004
Jezebel-240	1.0000 ± 0.0020	0.9998 ± 0.0003	0.9980 ± 0.0003	1.0043 ± 0.0003	1.0009 ± 0.0004
Pu Buttons	1.0000 ± 0.0030	0.9984 ± 0.0003	0.9962 ± 0.0003	0.9996 ± 0.0003	0.9958 ± 0.0004
Flattop-Pu	1.0000 ± 0.0030	1.0003 ± 0.0003	1.0016 ± 0.0003	1.0019 ± 0.0003	0.9904 ± 0.0003
THOR	1.0000 ± 0.0006	0.9977 ± 0.0003	1.0057 ± 0.0003	1.0020 ± 0.0003	1.0066 ± 0.0003
Pu-MF-11	1.0000 ± 0.0010	1.0005 ± 0.0004	0.9966 ± 0.0004	0.9970 ± 0.0003	0.9982 ± 0.0003

pmf8.2

Case	Benchmark k_{eff}	Calculated k_{eff} (ENDF/B-VII.0 + Indicated Th)		
		ENDF/B-VII β-3	ENDF/B-VII β-2	ENDF/B-VII β-1
THOR	1.0000 ± 0.0006	0.9979 ± 0.0003	0.9979 ± 0.0003	0.9995 ± 0.0003

$\sigma < |\Delta k| \leq 2\sigma$ $|\Delta k| > 2\sigma$

Deficiency addressed in VII.1β2 and VII.1β3

Plutonium Benchmarks, Part II

Case Name	Benchmark k_{eff}	Calculated k_{eff}		Δk_{eff} [pcm]	
		ENDF/B-VII.1β2	ENDF/B-VII.1β3	ENDF/B-VII.1β2	ENDF/B-VII.1β3
mct2.p30	1.0024 ± 0.0060	1.0013 ± 0.00010	1.00146 ± 0.00011	-114	-94
mct2.p31	1.0009 ± 0.0047	1.0025 ± 0.00011	1.00292 ± 0.00011	161	202
mct2.p32	1.0042 ± 0.0031	1.0031 ± 0.00010	1.00299 ± 0.00011	-114	-120
mct2.p33	1.0024 ± 0.0021	1.0061 ± 0.00011	1.00692 ± 0.00010	370	451
mct2.p34	1.0038 ± 0.0025	1.0042 ± 0.00010	1.00433 ± 0.00010	41	53
mct2.p35	1.0029 ± 0.0027	1.0060 ± 0.00010	1.00640 ± 0.00010	309	349
pst9.3a	1.0000 ± 0.0033	1.0183 ± 0.00006	1.01887 ± 0.00006	1832	1887
pst11.16-5	1.0000 ± 0.0052	1.0068 ± 0.00013	1.00638 ± 0.00013	684	638
pst11.18-1	1.0000 ± 0.0052	0.9946 ± 0.00011	0.99441 ± 0.00011	-539	-559
pst11.18-6	1.0000 ± 0.0052	1.0003 ± 0.00012	1.00034 ± 0.00012	34	34
pst18.9	1.0000 ± 0.0034	1.0029 ± 0.00010	1.00337 ± 0.00010	288	337
pst21.1	1.0000 ± 0.0032	1.0057 ± 0.00013	1.00526 ± 0.00013	571	526
pst21.3	1.0000 ± 0.0065	1.0057 ± 0.00014	1.00511 ± 0.00014	566	511
pst34.1	1.0000 ± 0.0062	1.0009 ± 0.00013	1.00050 ± 0.00013	92	50
			σ :	**547**	**557**

$\sigma < |\Delta k| \leq 2\sigma$ **$|\Delta k| > 2\sigma$**

Conclusion

- VII.1beta2 vs. VII.1beta3:
  - Overall Assessment: No significant difference in performance. Changes made in VII.1beta3 had no impact on data validation.

- VII.0 vs. VII.1beta2/beta3:
  - VII.0 deficiencies in Be-9 and Th-232 fast cross sections have been addressed in VII.1beta2/beta3.
  - VII.0 deficiencies in U-233 thermal cross sections still exist in VII.1beta2/VII.1beta3.

Acknowledgment

I would like to express my sincere gratitude to:

- Russell D. Mosteller (LANL) for providing documentation and the associated MCNP input files of the LANL Expanded Criticality Validation Suite

- Skip Kahler (LANL) for the advice on benchmarking techniques

- Andrej Trkov (JSI) for the advice on benchmark results analyses