

**ANS 2017
Winter Meeting**

Washington DC

Oct 29 – Nov 2, 2017

LA-UR-17-25040

Verification of MCNP6.2 for Nuclear Criticality Safety Applications

Forrest Brown, Michael Rising, Jennifer Alwin

**Monte Carlo Methods, Codes, & Applications (XCP-3)
X Computational Physics Division**



Introduction

- **2017 is the 70th anniversary of the first Monte Carlo code for particle transport**
 - John von Neumann created the first MC code in 1947 for LANL
 - Targeted the Eniac, actually ran in 1948
- **2017 is the 40th anniversary of the MCNP code**
 - The roots of MCNP extend back to von Neumann's original MC code
- **Recent RSICC releases of MCNP**
 - MCNP5 – 2003-2013, R.I.P.
 - MCNP6.1 – 2013, production version
 - MCNP6.1.1 – 2014, **same criticality**, **faster**, beta features for DHS
 - MCNP6.2 – 2017, includes Whisper code & benchmarks**
 - When? Any day. Endless delays in completing documentation.
MCNP User Manual will be unlimited release, on the web,
(not a controlled publication)

MCNP6.2 Code & Data

- **MCNP6.2 Code**
 - **1.5 – 2 times faster** than MCNP6.1 for NCS applications
 - Longer input lines, **128 characters**
 - Longer filenames (256 chars) & command-lines (4096 chars)
 - Analytic Criticality Benchmark Suite – now continuous-energy, not mg
 - **Fortran-2003 standard compliant**, Intel-17 compiler
 - Bug fixes (3 out of 300 relevant to NCS)
 - **Coincident surfaces** for rotated universe/fill (25 year old bug)
 - **S(alpha,beta)** sampling error (rare, due to roundoff)
 - **K-adjoint** first Keff estimate
- **ENDF/B-VII.1 nuclear data**
 - 3 corrections for data errors, with new ACE files:
 - **Hydrogen** (n,g) production data, previously missing
 - **SiO₂ S(alpha,beta)** thermal scattering data
 - **Zirc-Hydride S(alpha,beta)** thermal scattering data at 1200K
- **ENDF/B-VIII.0 nuclear data targeted for release in December 2017**
 - LANL Data Team is investigating web-based distribution in 2018

From the MCNP website, main page at mcnp.lanl.gov

Note on Nuclear Data for MCNP6 (2017-09-28)

As discussed in the references below, previous data released with MCNP6.1 & MCNP6.1.1 had these problems:

- (1) Missing (n,g) production data for hydrogen ACE files, 1001.80c - 1001.86c
- (2) Errors in SiO₂ S(a,b) thermal scattering data, sio2.30t - sio2.36t
- (3) Errors in h-zr.27t S(a,b) thermal scattering data at 1200K

These data issues are discussed in reports on the MCNP website, in the Reference Collection, topic "Release Information for MCNP6.2 Release":

- Release of MCNP6.2 & Whisper-1.1 - Guidance for NCS Users, LA-UR-17-24260
- Whats New with MCNP6.2 & Whisper-1.1, LA-UR-17-27992
- Verification of MCNP6.2 for Nuclear Criticality Safety Applications, LA-UR-17-24406
- Verification of MCNP6.2 for Nuclear Criticality Safety Applications, LA-UR-17-23822.
- Listing of Available ACE Data Tables, LA-UR-17-20709.
- Data Changes for the MCNP6.2 Release, LA-UR-17-21486, LA-UR-17-20703

The MCNP6.2 release will include corrected data files

Whisper-1.1 Release

- **Whisper-1.1 code**
 - Upgrade: Whisper-1.0 (2014) to Whisper-1.1 (2016), Total, thorough line-by-line code review - no bugs found
 - **Portable to Linux, Mac, Windows**
- **Utility scripts for ease-of-use (Linux, Mac, Windows)**
 - `whisper_mcnpl` – setup & run MCNP6 for sensitivity-profile
 - `whisper_usl.pl` – run Whisper to get baseline USLs
- **Covariance data files**
 - Low-fidelity BLO 44-group data, in new ACE format
 - Improved covariance data planned for 2018
- **1101 ICSBEP benchmark cases**
 - MCNP input files
 - Catalog of sensitivity-profiles for every benchmark
- **Documentation - 70 reports**
 - overview, theory, user manual, release notes, applications, nuclear covariance data, SQA, MCNP6 verification-validation, general references on adjoints/perturbation/sensitivity-analysis

MCNP Verification & Validation Suites for Criticality

Verification Suites

- **REGRESSION**
 - 161 code test problems
 - Run by developers for QA checking
- **VERIFICATION_KEFF**
 - 75 analytic benchmarks (0-D and 1-D)
 - Exact solutions for k_{eff}
 - Past – multigroup,
New – continuous-energy
- **VERIFICATION_GENTIME**
 - 10 benchmarks (analytic or comparisons to Partisn) for reactor kinetics parameters
- **KOBAYASHI**
 - 6 void & duct streaming problems, with point detectors, exact solutions
- **Ganapol Benchmarks [in progress]**
 - Exact, semi-analytic benchmark problems
 - Fixed source, not criticality
- **Gonzales Benchmark [in progress]**
 - Exact analytic benchmark with elastic scatter, including free-gas scatter

Validation Suites

- **VALIDATION_CRITICALITY**
 - 31 ICSBEP Cases
 - Too small a suite for serious V&V
 - Today, used for
 - Code-to-code verification, with real problems & data
 - Compiler-to-compiler verification, with real problems & data
 - Timing tests for optimizing MCNP coding & threading
- **VALIDATION_CRIT_EXPANDED**
 - 119 ICSBEP Cases
 - Broad-range validation, for developers
- **VALIDATION_CRIT_WHISPER**
 - 1101 ICSBEP Cases
 - Used with Whisper methodology for serious validation
 - Will be expanded, as time permits

Testing Methodology

- **Fortran Compilers**

- Intel-12 - MCNP6.1 & MCNP6.1.1, Intel-17 - MCNP6.2
- Using different compilers always leads to minor differences due to roundoff
- Roundoff differences are not errors, but must be examined in detail

- **Validation Suites**

- All calculations used ENDF/B-VII.1 cross-sections
- Continuous S(alpha,beta) physics, not old discrete treatment
 - MCNP6.1 had a small, rare error in dealing with the continuous S(α,β) data:
 - Fixed in MCNP6.1.1 & fixed better in MCNP6.2
 - Very minor roundoff differences for a few problems between MCNP6.1 & later versions

- **Running strategy**

- All calculations performed with OpenMP threading, with 8-16 cpu-cores
- Mac Pro, 12-core Xeon, 2 HT/core, OS X 10.9.5, 14 MCNP threads
- Linux, 1 HPC node, 8 dual-core Xeons, Chaos linux, 16 MCNP threads
- Calculations run with & without new coincident-surface fix

- **Look for possible diffs due to: compiler, S(a,b) fix, coinc-sur fix**

MCNP6 Criticality Results vs Exact Analytic Results

Case	Name	Analytic	MCNP_Multigroup		MCNP Continuous Energy	
		keff	C/E-1	std	C/E-1	std
01	PUa-1-0-IN	2.61290	-0 pcm	0	-0 pcm	0
02	PUa-1-0-SL	1.00000	0	5	6	5
03	PUa-H2O(1)-1-0-SL	1.00000	8	5 *	1	5
04	PUa-H2O(0.5)-1-0-SL	1.00000	2	5	3	5
05	PUB-1-0-IN	2.29032	-0	0	-0	0
06	PUB-1-0-SL	1.00000	4	4	0	4
07	PUB-1-0-CY	1.00000	-4	4 *	3	4
08	PUB-1-0-SP	1.00000	6	4 *	6	4 *
09	PUB-H2O(1)-1-0-CY	1.00000	-3	4	5	4
10	PUB-H2O(10)-1-0-CY	1.00000	5	4	5	5
11	Ua-1-0-IN	2.25000	0	0	0	0
12	Ua-1-0-SL	1.00000	6	4 *	-3	4
13	Ua-1-0-CY	1.00000	4	4	3	4
14	Ua-1-0-SP	1.00000	1	4	-5	4 *
15	Ub-1-0-IN	2.33092	0	0	0	0
16	Ub-H2O(1)-1-0-SP	1.00000	-2	4	-1	4
17	Uc-1-0-IN	2.25608	0	0	0	0
18	Uc-H2O(2)-1-0-SP	1.00000	-1	4	0	4
19	Ud-1-0-IN	2.23267	-0	0	-0	0
20	Ud-H2O(3)-1-0-SP	1.00000	4	4	7	4 *
21	UD20-1-0-IN	1.13333	-0	0	-0	0
22	UD20-1-0-SL	1.00000	3	2	0	2
23	UD20-1-0-CY	1.00000	-1	2	-5	2 **
24	UD20-1-0-SP	1.00000	1	3	-4	2 **
25	UD20-H2O(1)-1-0-SL	1.00000	2	2	-2	2 *
26	UD20-H2O(10)-1-0-SL	1.00000	-5	2 **	1	2
27	UD20-H2O(1)-1-0-CY	1.00000	4	2 *	-1	2
28	UD20-H2O(10)-1-0-CY	1.00000	0	2	3	2
29	Ue-1-0-IN	2.18067	0	0	0	0
30	Ue-Fe-Na-1-0-SL	1.00000	-1	5	7	4 *
31	PU-1-1-IN	2.50000	0	0	0	0
32	PUa-1-1-SL	1.00000	8	5 *	7	5 *
36	Ua-1-1-CY	1.00000	2	4	-3	4
38	UD20a-1-1-IN	1.20559	0	0	0	0
39	UD20a-1-1-SP	1.00000	-2	3	2	3
40	UD20b-1-1-IN	1.22739	-0	0	-0	0
41	UD20b-1-1-SP	1.00000	8	3 **	6	3 *

1 pcm = 0.00001

RMS Differences

3 pcm ±3 pcm

3 pcm ±3 pcm

Validation Rossi Alpha Test Suite Results

	Benchmark		MCNP6.1 & MCNP6.2							
			MCNP5 1.60 ENDF/B-VII.0		MCNP6.1 ENDF/B-VII.0		MCNP6.1.1 ENDF/B-VII.1		MCNP6.2 ENDF/B-VII.1	
	rossi- α	std	rossi- α	std	rossi- α	std	rossi- α	std	rossi- α	std
U233 Benchmarks										
Jezebel-233	-100	(1)	-108	(1)	-108	(1)	-107	(1)	-107	(1)
Flattop-23	-26.7	(5)	-30.2	(4)	-30.2	(4)	-29.8	(4)	-29.8	(4)
HEU Benchmarks										
Godiva	-111	(2)	-113	(1)	-113	(1)	-113	(1)	-113	(1)
Flattop-25	-38.2	(2)	-39.7	(2)	-39.5	(2)	-39.6	(2)	-39.5	(2)
Zeus-1	-0.338	(7)	-0.363	(2)	-0.363	(2)	-0.360	(2)*	-0.360	(2)
Zeus-5	-14.8	(1)	-10.8	(1)	-10.8	(1)	-10.7	(1)	-10.7	(1)
Zeus-6	-3.73	(5)	-4.14	(3)	-4.16	(3)	-4.11	(3)*	-4.10	(3)
IEU Benchmarks										
BIG TEN	-11.7	(1)	-11.8	(1)	-11.8	(1)	-11.7	(1)	-11.7	(1)
STACY-30	-0.0127	(3)	-0.0133	(3)	-0.0133	(3)	-0.0121	(3)***	-0.0121	(3)
STACY-46	-0.0106	(4)	-0.0104	(2)	-0.0104	(2)	-0.0106	(2)	-0.0106	(2)
Pu Benchmarks										
Jezebel	-64.0	(10)	-65	(1)	-65.1	(8)	-63.2	(7)**	-63.2	(7)
Flattop-Pu	-21.4	(5)	-21.0	(3)	-21.0	(3)	-20.2	(3)**	-20.2	(3)
THOR	-19.7	(10)	-20	(1)	-19.7	(7)	-20.6	(7)*	-20.6	(7)

Notes

- All results in 10^4 generations/second
- Color indicates type of diff, * indicates magnitude of diff:

compiler/hardware
nuclear data
minor k-adjoint bug fix

* = diff > 1 std
 ** = diff > 2 std
 *** = diff > 3 std

Validation Suite Diffs - Summary

Look for possible diffs due to: **S(a,b) fix**, **coinc-sur fix**, **compiler**

VALIDATION_CRITICALITY – 31 ICSBEP cases

	Mac OS X				Linux		
	match	Sab-fix	coinc r/o	compiler	match	Sab-fix	coinc r/o
mcnp6.1 (reference)							
mcnp6.1.1	30	1	-	-	30	1	-
mcnp6.2 old coinc sur	29	1	-	1	30	1	-
mcnp6.2 new coinc sur	27	1	2	1	28	1	2

VALIDATION_CRIT_EXPANDED – 119 ICSBEP cases

	Mac OS X – 12 cores			Linux – 16 cores		
	match	coinc r/o	speedup	match	coinc r/o	speedup
mcnp6.1 (reference)						
mcnp6.1.1	119	-	1.9	119	-	2.0
mcnp6.2 old coinc sur	119	-	1.9	119	-	2.2
mcnp6.2 new coinc sur	108	11	1.9	108	11	2.2

VALIDATION_CRITICALITY – Mac OS X - 2017-03-28

610_12_71 – 2013, mcnp6.1, Intel-12, endf/b-vii.1
 611_12_71 – 2014, mcnp6.1.1, Intel-12, endf/b-vii.1
 621_17_71 – 2017, mcnp6.2, Intel-17, endf/b-vii.1, with old coincident-surface treatment
 620_17_71 – 2017, mcnp6.2, Intel-17, endf/b-vii.1, with new coincident-surface treatment

	610_12_71_mac		611_12_71_mac		621_17_71_mac		620_17_71_mac		Reason for diffs
	keff	std	deltak	std	deltak	std	deltak	std	
U233 Benchmarks									
JEZ233	1.0000	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
FLAT23	0.9974	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
UMF5C2	0.9960	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
FLSTF1	0.9845	(11)	0.0000	(15)	0.0000	(15)	0.0000	(15)	
SB25	0.9997	(10)	0.0000	(14)	0.0000	(14)	0.0009	(14)	roundoff, coinc-sur
ORNL11	1.0018	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
HEU Benchmarks									
GODIVA	0.9988	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
TT2C11	1.0009	(8)	0.0000	(11)	0.0000	(11)	0.0000	(11)	
FLAT25	1.0034	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
GODIVR	0.9989	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
UH3C6	0.9957	(8)	0.0000	(11)	0.0000	(11)	0.0000	(11)	
ZEUS2	0.9976	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
SB5RN3	0.9945	(13)	0.0000	(18)	0.0000	(18)	0.0000	(18)	
ORNL10	1.0001	(4)	0.0000	(5)	0.0000	(5)	0.0000	(5)	
IEU Benchmarks									
IMF03	1.0019	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
BIGTEN	0.9952	(5)	0.0000	(7)	0.0000	(7)	0.0000	(7)	
IMF04	1.0082	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
ZEBR8H	1.0193	(5)	0.0000	(8)	-0.0011	(8)*	-0.0011	(8)*	roundoff, compiler
ICT2C3	1.0023	(7)	0.0012	(9)*	0.0012	(9)*	0.0012	(9)*	Sab-fix
STACY36	0.9981	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
LEU Benchmarks									
BAWXI2	1.0025	(5)	0.0000	(8)	0.0000	(8)	-0.0004	(8)	roundoff, coinc-sur
LST2C2	0.9960	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
Pu Benchmarks									
JEZPU	0.9990	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
JEZ240	0.9999	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
PUBTNS	0.9980	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
FLATPU	1.0004	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
THOR	0.9976	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
PUSH20	1.0013	(8)	0.0000	(11)	0.0000	(11)	0.0000	(11)	
HISHPG	1.0121	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
PNL2	1.0050	(10)	0.0000	(14)	0.0000	(14)	0.0000	(14)	
PNL33	1.0068	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
Wall-clock:	19.6 min		11.8 min		11.8 min		11.7 min		
Threads:	12		12		12		12		
Rel. Speed:	1.00		1.66		1.66		1.67		

VALIDATION_CRITICALITY – Linux - 2017-04-07

610_12_71 – 2013, mcnp6.1, Intel-12, endf/b-vii.1
 611_12_71 – 2014, mcnp6.1.1, Intel-12, endf/b-vii.1
 621_17_71 – 2017, mcnp6.2, Intel-17, endf/b-vii.1, with old coincident-surface treatment
 620_17_71 – 2017, mcnp6.2, Intel-17, endf/b-vii.1, with new coincident-surface treatment

	610_12_71_lin		611_12_71_lin		621_17_71_lin		620_17_71_lin		Reason for diffs
	keff	std	deltak	std	deltak	std	deltak	std	
U233 Benchmarks									
JEZ233	1.0000	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
FLAT23	0.9974	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
UMF5C2	0.9960	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
FLSTF1	0.9845	(11)	0.0000	(15)	0.0000	(15)	0.0000	(15)	
SB25	0.9997	(10)	0.0000	(14)	0.0000	(14)	0.0009	(14)	roundoff, coinc-sur
ORNL11	1.0018	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
HEU Benchmarks									
GODIVA	0.9988	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
TT2C11	1.0009	(8)	0.0000	(11)	0.0000	(11)	0.0000	(11)	
FLAT25	1.0034	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
GODIVR	0.9989	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
UH3C6	0.9957	(8)	0.0000	(11)	0.0000	(11)	0.0000	(11)	
ZEUS2	0.9976	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
SB5RN3	0.9945	(13)	0.0000	(18)	0.0000	(18)	0.0000	(18)	
ORNL10	1.0001	(4)	0.0000	(5)	0.0000	(5)	0.0000	(5)	
IEU Benchmarks									
IMF03	1.0019	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
BIGTEN	0.9952	(5)	0.0000	(7)	0.0000	(7)	0.0000	(7)	
IMF04	1.0082	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
ZEBR8H	1.0182	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
ICT2C3	1.0023	(7)	0.0012	(9)*	0.0012	(9)*	0.0012	(9)*	Sab-fix
STACY36	0.9981	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
LEU Benchmarks									
BAWXI2	1.0025	(5)	0.0000	(8)	0.0000	(8)	-0.0004	(8)	roundoff, coinc-sur
LST2C2	0.9960	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
Pu Benchmarks									
JEZPU	0.9990	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
JEZ240	0.9999	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
PUBTNS	0.9980	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
FLATPU	1.0004	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
THOR	0.9976	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
PUSH20	1.0013	(8)	0.0000	(11)	0.0000	(11)	0.0000	(11)	
HISHPG	1.0121	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
PNL2	1.0050	(10)	0.0000	(14)	0.0000	(14)	0.0000	(14)	
PNL33	1.0068	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
Wall-clock:	18.9 min		10.2 min		9.6 min		9.6 min		
Threads:	16		16		16		16		
Rel. Speed:	1.00		1.86		1.97		1.97		

MCNP6 – Performance History

Run Times for VALIDATION_CRITICALITY Suite on Various Computers

Computer	CPU Speed (GHz)	Mem. Speed (GHz)	Processors, Cores	MCNP Threads used	MCNP Version	Total Time (minutes)
MacBook 2010	2.7	1.1	1 - i7, 2 x 2 HT	4	mcnp6.1.1	88
MacBook 2013	3.0	1.6	1 - i7, 2 x 2 HT	4	mcnp6.1	62
				4	mcnp6.1.1	42
Mac Pro 2010	3.0	0.67	2 - Xeon, 4	8	mcnp6.1	44
				8	mcnp6.1.1	28
Windows 2012	2.7	1.3	2 - Xeon, 6	10	mcnp6.1.1	19
Mac Pro 2012	2.4	1.07	2 - Xeon, 4 x 2 HT	16	mcnp6.1.1	22
Mac Pro 2014	2.7	1.6	1 - Xeon, 12 x 2 HT	12	mcnp5-1.60	14
				12	mcnp6.1.1	14
				12	mcnp6.1.1	12
				12	mcnp6.2	12
HP Linux 2016	3.1	2.4	2 - Xeon, 12 x 2 HT	24	mcnp6.2	8

MCNP6.2 preserves all performance improvements from MCNP6.1.1, and is much faster than MCNP6.1 & slightly faster than MCNP5

Runtimes are wall-clock for the entire suite of 31 problems, including cross-section I/O & output

VALIDATION_CRIT_EXPANDED – Mac OS X – 2017-04-11 (1)

610_12_71_mac = mcnp6.1 + Intel 12 + endf/b-vii.1 + macosx
 611_12_71_mac = mcnp6.1.1 + Intel 12 + endf/b-vii.1 + macosx
 621_17_71_mac = mcnp6.2.0 + Intel 17 + endf/b-vii.1 + macosx, with old coincident-surface treatment
 620_17_71_mac = mcnp6.2.0 + Intel 17 + endf/b-vii.1 + macosx, with new coincident-surface treatment

	610_12_71_mac		611_12_71_mac		621_17_71_mac		620_17_71_mac		
	keff	std	deltak	std	deltak	std	deltak	std	
U233 Benchmarks									
u233-met-fast-001	1.0000	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
u233-met-fast-002-case-1	0.9983	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
u233-met-fast-002-case-2	1.0003	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
u233-met-fast-003-case-1	0.9995	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
u233-met-fast-003-case-2	0.9995	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
u233-met-fast-006	0.9984	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
u233-met-fast-004-case-1	0.9988	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
u233-met-fast-004-case-2	0.9956	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
u233-met-fast-005-case-1	0.9959	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
u233-met-fast-005-case-2	0.9952	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
u233-sol-inter-001-case-1	0.9845	(5)	0.0000	(7)	0.0000	(7)	0.0000	(7)	
u233-comp-therm-001-case-3	1.0034	(4)	0.0000	(5)	0.0000	(5)	-0.0006	(5)*	coinc r/o
u233-sol-therm-001-case-1	1.0010	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
u233-sol-therm-001-case-2	1.0010	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
u233-sol-therm-001-case-3	1.0007	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
u233-sol-therm-001-case-4	1.0007	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
u233-sol-therm-001-case-5	0.9996	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
u233-sol-therm-008	1.0016	(2)	0.0000	(2)	0.0000	(2)	0.0000	(2)	
LEU Benchmarks									
leu-comp-therm-008-case-1	1.0006	(2)	0.0000	(4)	0.0000	(4)	-0.0005	(4)*	coinc r/o
leu-comp-therm-008-case-2	1.0005	(2)	0.0000	(4)	0.0000	(4)	0.0002	(4)	coinc r/o
leu-comp-therm-008-case-5	1.0006	(2)	0.0000	(4)	0.0000	(4)	0.0004	(4)	coinc r/o
leu-comp-therm-008-case-7	1.0004	(2)	0.0000	(4)	0.0000	(4)	-0.0004	(4)	coinc r/o
leu-comp-therm-008-case-8	0.9997	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
leu-comp-therm-008-case-11	1.0007	(2)	0.0000	(4)	0.0000	(4)	0.0003	(4)	coinc r/o
leu-sol-therm-002-case-1	0.9994	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
leu-sol-therm-002-case-2	0.9964	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	

VALIDATION_CRIT_EXPANDED – Mac OS X – 2017-04-11 (2)

	610_12_71_mac		611_12_71_mac		621_17_71_mac		620_17_71_mac	
	keff	std	deltak	std	deltak	std	deltak	std
HEU Benchmarks								
heu-met-fast-001	0.9994	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-008	0.9962	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-018-case-2	0.9995	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-003-case-1	0.9949	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-003-case-2	0.9945	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-003-case-3	0.9989	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-003-case-4	0.9974	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-003-case-5	1.0012	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-003-case-6	1.0020	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-003-case-7	1.0019	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-028	1.0027	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-014	0.9977	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-003-case-8	1.0023	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-003-case-9	1.0023	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-003-case-10	1.0052	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-003-case-11	1.0094	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-003-case-12	1.0087	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-013	0.9975	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-021-case-2	0.9979	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-022-case-2	0.9976	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-012	0.9984	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-019-case-2	1.0069	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-009-case-2	0.9966	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-009-case-1	0.9977	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-011	0.9985	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-020-case-2	1.0006	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-004-case-1	1.0034	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-015	0.9947	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-fast-026-case-c-11	1.0032	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-comp-inter-003-case-6	0.9948	(4)	0.0000	(5)	0.0000	(5)	0.0000	(5)
heu-met-inter-006-case-1	0.9929	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-inter-006-case-2	0.9968	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-inter-006-case-3	1.0008	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-met-inter-006-case-4	1.0072	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
u233-comp-therm-001-case-6	0.9988	(4)	0.0000	(5)	0.0000	(5)	0.0000	(5)
heu-sol-therm-013-case-1	0.9985	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-sol-therm-013-case-2	0.9969	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-sol-therm-013-case-3	0.9939	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-sol-therm-013-case-4	0.9953	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
heu-sol-therm-032	0.9992	(2)	0.0000	(2)	0.0000	(2)	0.0000	(2)

VALIDATION_CRIT_EXPANDED – Mac OS X – 2017-04-11 (3)

	610_12_71_mac		611_12_71_mac		621_17_71_mac		620_17_71_mac		
	keff	std	deltak	std	deltak	std	deltak	std	
Pu Benchmarks									
pu-met-fast-001	0.9993	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-002	1.0003	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-022-case-2	0.9984	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
mix-met-fast-001	0.9998	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
mix-met-fast-003	1.0004	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-006	1.0001	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-010	0.9996	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-020	0.9983	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-008-case-2	0.9977	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-005	1.0019	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-025-case-2	0.9991	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-026-case-2	0.9987	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-009	1.0048	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-023-case-2	0.9994	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-018	0.9993	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-019	1.0004	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-024-case-2	1.0025	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-011	1.0000	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-021-case-2	0.9935	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-021-case-1	1.0047	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-met-fast-003-case-103	0.9990	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-comp-inter-001	1.0116	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
mix-comp-therm-002-case-pn130	1.0002	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
mix-comp-therm-002-case-pn131	1.0018	(4)	0.0000	(5)	0.0000	(5)	-0.0006	(5)*	coinc r/o
mix-comp-therm-002-case-pn132	1.0020	(2)	0.0000	(4)	0.0000	(4)	-0.0003	(4)	coinc r/o
mix-comp-therm-002-case-pn133	1.0063	(2)	0.0000	(4)	0.0000	(4)	-0.0001	(4)	coinc r/o
mix-comp-therm-002-case-pn134	1.0045	(2)	0.0000	(4)	0.0000	(4)	0.0001	(4)	coinc r/o
mix-comp-therm-002-case-pn135	1.0063	(2)	0.0000	(4)	0.0000	(4)	-0.0004	(4)	coinc r/o
pu-sol-therm-009-case-3a	1.0191	(2)	0.0000	(2)	0.0000	(2)	0.0000	(2)	
pu-sol-therm-011-case-16-5	1.0054	(4)	0.0000	(5)	0.0000	(5)	0.0000	(5)	
pu-sol-therm-011-case-18-1	0.9941	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-sol-therm-011-case-18-6	1.0005	(4)	0.0000	(5)	0.0000	(5)	0.0000	(5)	
pu-sol-therm-021-case-1	1.0053	(4)	0.0000	(5)	0.0000	(5)	0.0000	(5)	
pu-sol-therm-021-case-3	1.0043	(4)	0.0000	(5)	0.0000	(5)	0.0000	(5)	
pu-sol-therm-018-case-9	1.0026	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
pu-sol-therm-034-case-1	1.0007	(4)	0.0000	(5)	0.0000	(5)	0.0000	(5)	

VALIDATION_CRIT_EXPANDED – Mac OS X – 2017-04-11 (4)

	610_12_71_mac		611_12_71_mac		621_17_71_mac		620_17_71_mac	
	keff	std	deltak	std	deltak	std	deltak	std
IEU Benchmarks								
ieu-met-fast-003-case-2	1.0028	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
ieu-met-fast-005-case-2	1.0024	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
ieu-met-fast-006-case-2	0.9958	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
ieu-met-fast-004-case-2	1.0075	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
ieu-met-fast-001-case-1	1.0009	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
ieu-met-fast-001-case-2	0.9999	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
ieu-met-fast-001-case-3	1.0011	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
ieu-met-fast-001-case-4	1.0015	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
ieu-met-fast-002	0.9991	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
ieu-met-fast-007-case-4	1.0045	(2)	0.0000	(2)	0.0000	(2)	0.0000	(2)
mix-met-fast-008-case-7	1.0192	(2)	0.0000	(2)	0.0000	(2)	0.0000	(2)
ieu-comp-therm-002-case-3	1.0038	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
leu-sol-therm-007-case-14	0.9947	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
leu-sol-therm-007-case-30	0.9971	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
leu-sol-therm-007-case-32	0.9959	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
leu-sol-therm-007-case-36	0.9990	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
leu-sol-therm-007-case-49	0.9972	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)
Wall-clock:	301.2 min		158.7 min		156.0 min		156.4 min	
Threads:	12		12		12		12	
Rel. Speed:	1.00		1.90		1.93		1.93	

Conclusions

- **All current versions of MCNP6 – 6.1, 6.1.1, 6.2 – perform correctly for the 3 suites of analytic benchmarks & ICSBEP problems**
- **MCNP6 testing is performed very frequently for criticality problems during all MCNP code development**
 - New features for non-criticality problems are disallowed if they affect criticality results
 - Because it only takes 12 minutes to run the VALIDATION_CRITICALITY suite using threading, it is run daily or weekly during development
 - MCNP6 performance is also monitored, with corrections or optimization if criticality performance changes
- **There are no technical or correctness issues to delay switching to the latest version of MCNP6**
 - MCNP5 is no longer supported
 - Newer versions – can use continuous S(a,b) data (MCNP5 cannot)
 - Newer versions – better performance & use of computer resources
 - Newer versions – bug fixes (few, since neutronics is mature)
 - Newer versions – better support from developers

**This work was supported by the
DOE-NNSA Nuclear Criticality Safety Program.**

Questions ?