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Verification of MCNP6.2 for Nuclear Criticality Safety Applications



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Deja Vu ?

- **You're probably thinking....**

Didn't they give this same talk a year ago?

- **Yes, we did**

**But the release was delayed for over a year,
due to lawyer stuff & approval from non-DOE sponsors**

**Serious, responsible code developers should
repeat & document the verification-validation.**

We did that.

Introduction

- 2017 - 70th anniversary of the first MC code for particle transport
- 2017 - 40th anniversary of the first MCNP release
- 2018 - 70th anniversary of the first MC computer calculations

- 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 – 2018, production version

– Includes Whisper code, benchmarks, & docs

– User Manual is unlimited release, on the web

URL: mcnp.lanl.gov

– ENDF/B-VIII.0 nuclear data released separately on web,

URL: nucleardata.lanl.gov

MCNP6.2 Release – Code Changes

- **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 relevant to NCS, out of 300 total)
 - **Coincident surfaces** for rotated universe/fill (25 year old bug)
 - **S(alpha,beta)** sampling error (rare, due to roundoff)
 - **K-adjoint** first Keff estimate
- **Compiler roundoff & bug-fixes will produce diffs from mcnp6.1**

MCNP6.2 Release – Nuclear Data Changes

- **ENDF/B-VII.1 nuclear data**

- **3 corrections for data errors, with new ACE files:**

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 includes corrected ACE data files**

xmdir_mcnp6.2, 1001.90c – 1001.96c, sio2.10t – sio2.16t, h-zr.28t

- **ENDF/B-VIII.0 nuclear data released on web, nucleardata.lanl.gov**

MCNP6.2 Release – Whisper-1.1

- **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 2019
- **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 S_N) for reactor kinetics parameters
- **KOBAYASHI**
 - 6 void & duct streaming problems, with point detectors, exact solutions
- **Ganapol Benchmarks [in progress]**
 - Exact, semi-analytic benchmarks
 - 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
- **Verification-Validation Suites**
 - All calculations used ENDF/B-VII.1 cross-sections
 - Continuous S(alpha,beta) physics, not old discrete treatment
 - Repeat 2017 verification-validation testing for:
VERIFICATION_KEFF, VALIDATION_CRITICALITY, VALIDATION_CRIT_EXPANDED
- **Running strategy**
 - All calculations performed with OpenMP threading, with 4-18 cpu-cores

Mac Pro:	12-core Xeon,	OS X 10.12.6,	12 MCNP threads
Linux:	18-core Xeon,	Red Hat 7 linux,	18 MCNP threads
Windows laptop:	4-core I7,	Windows 10,	4 MCNP threads
- **Look for possible diffs due to: compiler, S(a,b) fix, coinc-sur fix**

MCNP6.2 Results vs Exact Analytic Results

Case	Name	Analytic keff	MCNP6.2 CE C/E	std
01	PUa-1-0-IN	2.61290	1.00000	0.00000
02	PUa-1-0-SL	1.00000	1.00006	0.00004 *
03	PUa-H2O(1)-1-0-SL	1.00000	1.00001	0.00004
04	PUa-H2O(0.5)-1-0-SL	1.00000	1.00003	0.00004
05	PUB-1-0-IN	2.29032	1.00000	0.00000
06	PUB-1-0-SL	1.00000	1.00003	0.00004
07	PUB-1-0-CY	1.00000	1.00002	0.00003
08	PUB-1-0-SP	1.00000	1.00002	0.00003
09	PUB-H2O(1)-1-0-CY	1.00000	1.00008	0.00003 **
10	PUB-H2O(10)-1-0-CY	1.00000	1.00006	0.00004 *
11	Ua-1-0-IN	2.25000	1.00000	0.00000
12	Ua-1-0-SL	1.00000	1.00000	0.00004
13	Ua-1-0-CY	1.00000	1.00000	0.00003
14	Ua-1-0-SP	1.00000	0.99997	0.00003
15	Ub-1-0-IN	2.33092	1.00000	0.00000
16	Ub-H2O(1)-1-0-SP	1.00000	0.99999	0.00003
17	Uc-1-0-IN	2.25608	1.00000	0.00000
18	Uc-H2O(2)-1-0-SP	1.00000	1.00002	0.00003
19	Ud-1-0-IN	2.23267	1.00000	0.00000
20	Ud-H2O(3)-1-0-SP	1.00000	1.00003	0.00004
21	UD20-1-0-IN	1.13333	1.00000	0.00000
22	UD20-1-0-SL	1.00000	1.00000	0.00002
23	UD20-1-0-CY	1.00000	0.99998	0.00002
24	UD20-1-0-SP	1.00000	1.00000	0.00002
25	UD20-H2O(1)-1-0-SL	1.00000	1.00001	0.00002
26	UD20-H2O(10)-1-0-SL	1.00000	1.00000	0.00002
27	UD20-H2O(1)-1-0-CY	1.00000	0.99999	0.00002
28	UD20-H2O(10)-1-0-CY	1.00000	1.00003	0.00002 *
29	Ue-1-0-IN	2.18067	1.00000	0.00000
30	Ue-Fe-Na-1-0-SL	1.00000	1.00006	0.00004 *
31	PU-1-1-IN	2.50000	1.00000	0.00000
32	PUa-1-1-SL	1.00000	1.00008	0.00004 *
36	Ua-1-1-CY	1.00000	0.99997	0.00003
38	UD20a-1-1-IN	1.20559	1.00000	0.00000
39	UD20a-1-1-SP	1.00000	0.99995	0.00002 **
40	UD20b-1-1-IN	1.22739	1.00000	0.00000
41	UD20b-1-1-SP	1.00000	1.00005	0.00002 **

**VERIFICATION_KEFF
Suite**

**Max C/E diff
= 0.00008**

**Overall RMS diffs
= 0.003%**

* = differ by 1-2 std
** = differ by 2-3 std
*** = differ by >3 std

400 M neutrons per case

VALIDATION_CRITICALITY Suite, 2018

```

610_mac    = mcnp6.1 + Intel-12 + endf/b-vii.1 + macos
611_mac    = mcnp6.1.1 + Intel-12 + endf/b-vii.1 + macos
620_mac    = mcnp6.2.0 + Intel-17 + endf/b-vii.1 + macos
620_lin    = mcnp6.2.0 + Intel-17 + endf/b-vii.1 + linux
620_win    = mcnp6.2.0 + Intel-17 + endf/b-vii.1 + windows
    
```

	610_mac		611_mac		620_mac		620_lin		620_win		
	keff	std	deltak	std	deltak	std	deltak	std	deltak	std	Reason for diffs
U233 Benchmarks											
JEZ233	1.0000	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
FLAT23	0.9974	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
UMF5C2	0.9960	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
FLSTF1	0.9845	(11)	0.0000	(15)	0.0000	(15)	0.0000	(15)	0.0000	(15)	
SB25	0.9997	(10)	0.0000	(14)	0.0010	(14)	0.0009	(14)	0.0010	(14)	coinc-sur roundoff diffs
ORNL11	1.0018	(2)	0.0000	(4)	0.0000	(4)	0.0000	(4)	0.0000	(4)	
HEU Benchmarks											
GODIVA	0.9988	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
TT2C11	1.0009	(8)	0.0000	(11)	0.0000	(11)	0.0000	(11)	0.0000	(11)	
FLAT25	1.0034	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
GODIVR	0.9989	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
UH3C6	0.9957	(8)	0.0000	(11)	0.0000	(11)	0.0000	(11)	0.0000	(11)	
ZEUS2	0.9976	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
SB5RN3	0.9945	(13)	0.0000	(18)	0.0000	(18)	0.0000	(18)	0.0000	(18)	
ORNL10	1.0001	(4)	0.0000	(5)	0.0000	(5)	0.0000	(5)	0.0000	(5)	
IEU Benchmarks											
IMF03	1.0019	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
BIGTEN	0.9952	(5)	0.0000	(7)	0.0000	(7)	0.0000	(7)	0.0000	(7)	
IMF04	1.0082	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
ZEBR8H	1.0193	(5)	0.0000	(8)	-0.0011	(8)*	-0.0007	(7)	-0.0007	(7)	compiler roundoff diffs
ICT2C3	1.0023	(7)	0.0012	(9)*	0.0012	(9)*	0.0012	(9)*	0.0012	(9)*	S(a,b) fixes
STACY36	0.9981	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
LEU Benchmarks											
BAWXI2	1.0025	(5)	0.0000	(8)	-0.0004	(8)	-0.0004	(8)	-0.0004	(8)	coinc-sur roundoff diffs
LST2C2	0.9960	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
Pu Benchmarks											
JEZPU	0.9990	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
JEZ240	0.9999	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
PUBTNS	0.9980	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
FLATPU	1.0004	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
THOR	0.9976	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
PUSH20	1.0013	(8)	0.0000	(11)	0.0000	(11)	0.0000	(11)	0.0000	(11)	
HISHPG	1.0121	(5)	0.0000	(8)	0.0000	(8)	0.0000	(8)	0.0000	(8)	
PNL2	1.0050	(10)	0.0000	(14)	0.0000	(14)	0.0000	(14)	0.0000	(14)	
PNL33	1.0068	(7)	0.0000	(9)	0.0000	(9)	0.0000	(9)	0.0000	(9)	
Summary											
Wall-clock:	18.6 min		11.5 min		11.6 min		7.7 min		41 min		1 M neutrons per case
Threads:	12		12		12		18		4		Continuous S(a,b)
Rel. Speed:	1.00		1.62		1.61		1.62		1.36		

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 Suite, 2018 (1)

5 M active neutrons per case
Continuous S(a,b)

610_lin = mcnp6.1 + Intel-12 + endf/b-vii.1 + linux
611_lin = mcnp6.1.1 + Intel-12 + endf/b-vii.1 + linux
620_lin = mcnp6.2.0 + Intel-17 + endf/b-vii.1 + **linux**
620_mac = mcnp6.2.0 + Intel-17 + endf/b-vii.1 + **macos**
620_win = mcnp6.2.0 + Intel-17 + endf/b-vii.1 + **windows**

Differences are relative to reference case: 620_lin

*'s indicate differences > 1, 2, or 3 std

	610_lin		611_lin		620_lin		620_mac		620_win		
	deltak	std	deltak	std	keff	std	deltak	std	deltak	std	
U233 Benchmarks											
u233-met-fast-001	0.0000	(4)	0.0000	(4)	1.0000	(2)	0.0000	(4)	0.0000	(4)	
u233-met-fast-002-case-1	0.0000	(4)	0.0000	(4)	0.9983	(2)	0.0000	(4)	0.0000	(4)	
u233-met-fast-002-case-2	0.0000	(4)	0.0000	(4)	1.0003	(2)	0.0000	(4)	0.0000	(4)	
u233-met-fast-003-case-1	0.0000	(4)	0.0000	(4)	0.9995	(2)	0.0000	(4)	0.0000	(4)	
u233-met-fast-003-case-2	0.0000	(4)	0.0000	(4)	0.9995	(2)	0.0000	(4)	0.0000	(4)	
u233-met-fast-006	0.0000	(4)	0.0000	(4)	0.9984	(2)	0.0000	(4)	0.0000	(4)	
u233-met-fast-004-case-1	0.0000	(4)	0.0000	(4)	0.9988	(2)	0.0000	(4)	0.0000	(4)	
u233-met-fast-004-case-2	0.0000	(4)	0.0000	(4)	0.9956	(2)	0.0000	(4)	0.0000	(4)	
u233-met-fast-005-case-1	0.0000	(4)	0.0000	(4)	0.9959	(2)	0.0000	(4)	0.0000	(4)	
u233-met-fast-005-case-2	0.0000	(4)	0.0000	(4)	0.9952	(2)	0.0000	(4)	0.0000	(4)	
u233-sol-inter-001-case-1	0.0000	(7)	0.0000	(7)	0.9845	(5)	0.0000	(7)	0.0000	(7)	
u233-comp-therm-001-case-3	0.0006	(5)*	0.0006	(5)*	1.0028	(4)	0.0006	(5)*	0.0006	(5)*	coinc r/o
u233-sol-therm-001-case-1	0.0000	(4)	0.0000	(4)	1.0010	(2)	0.0000	(4)	0.0000	(4)	
u233-sol-therm-001-case-2	0.0000	(4)	0.0000	(4)	1.0010	(2)	0.0000	(4)	0.0000	(4)	
u233-sol-therm-001-case-3	0.0000	(4)	0.0000	(4)	1.0007	(2)	0.0000	(4)	0.0000	(4)	
u233-sol-therm-001-case-4	0.0000	(4)	0.0000	(4)	1.0007	(2)	0.0000	(4)	0.0000	(4)	
u233-sol-therm-001-case-5	0.0000	(4)	0.0000	(4)	0.9996	(2)	0.0000	(4)	0.0000	(4)	
u233-sol-therm-008	0.0000	(2)	0.0000	(2)	1.0016	(2)	0.0000	(2)	0.0000	(2)	
LEU Benchmarks											
leu-comp-therm-008-case-1	0.0005	(4)*	0.0005	(4)*	1.0001	(2)	0.0006	(4)*	0.0006	(4)*	coinc r/o
leu-comp-therm-008-case-2	-0.0002	(4)	-0.0002	(4)	1.0007	(2)	0.0000	(4)	0.0000	(4)	coinc r/o
leu-comp-therm-008-case-5	-0.0004	(4)	-0.0004	(4)	1.0010	(2)	0.0000	(4)	0.0000	(4)	coinc r/o
leu-comp-therm-008-case-7	0.0004	(4)	0.0004	(4)	1.0000	(2)	0.0003	(4)	0.0003	(4)	coinc r/o
leu-comp-therm-008-case-8	0.0000	(4)	0.0000	(4)	0.9997	(2)	-0.0002	(4)	-0.0002	(4)	coinc r/o
leu-comp-therm-008-case-11	-0.0003	(4)	-0.0003	(4)	1.0010	(2)	0.0002	(4)	0.0002	(4)	coinc r/o
leu-sol-therm-002-case-1	0.0000	(4)	0.0000	(4)	0.9994	(2)	0.0000	(4)	0.0000	(4)	
leu-sol-therm-002-case-2	0.0000	(4)	0.0000	(4)	0.9964	(2)	0.0000	(4)	0.0000	(4)	

VALIDATION_CRIT_EXPANDED Suite, 2018 (2)

	610_lin deltak std	611_lin deltak std	620_lin keff std	620_mac deltak std	620_win deltak std	
HEU Benchmarks						
heu-met-fast-001	0.0000 (4)	0.0000 (4)	0.9994 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-008	0.0000 (4)	0.0000 (4)	0.9962 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-018-case-2	0.0000 (4)	0.0000 (4)	0.9995 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-003-case-1	0.0000 (4)	0.0000 (4)	0.9949 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-003-case-2	0.0000 (4)	0.0000 (4)	0.9945 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-003-case-3	0.0000 (4)	0.0000 (4)	0.9989 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-003-case-4	0.0000 (4)	0.0000 (4)	0.9974 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-003-case-5	0.0000 (4)	0.0000 (4)	1.0012 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-003-case-6	0.0000 (4)	0.0000 (4)	1.0020 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-003-case-7	0.0000 (4)	0.0000 (4)	1.0019 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-028	0.0000 (4)	0.0000 (4)	1.0027 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-014	0.0000 (4)	0.0000 (4)	0.9977 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-003-case-8	0.0000 (4)	0.0000 (4)	1.0023 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-003-case-9	0.0000 (4)	0.0000 (4)	1.0023 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-003-case-10	0.0000 (4)	0.0000 (4)	1.0052 (2)	0.0000 (4)	0.0001 (4)	
heu-met-fast-003-case-11	0.0000 (4)	0.0000 (4)	1.0094 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-003-case-12	0.0000 (4)	0.0000 (4)	1.0087 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-013	0.0000 (4)	0.0000 (4)	0.9975 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-021-case-2	0.0000 (4)	0.0000 (4)	0.9979 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-022-case-2	0.0000 (4)	0.0000 (4)	0.9976 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-012	0.0000 (4)	0.0000 (4)	0.9984 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-019-case-2	0.0000 (4)	0.0000 (4)	1.0069 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-009-case-2	0.0000 (4)	0.0000 (4)	0.9966 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-009-case-1	0.0000 (4)	0.0000 (4)	0.9977 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-011	0.0000 (4)	0.0000 (4)	0.9985 (2)	0.0000 (4)	0.0000 (5)	
heu-met-fast-020-case-2	0.0000 (4)	0.0000 (4)	1.0006 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-004-case-1	0.0000 (4)	0.0000 (4)	1.0034 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-015	0.0000 (4)	0.0000 (4)	0.9947 (2)	0.0000 (4)	0.0000 (4)	
heu-met-fast-026-case-c-11	0.0000 (4)	0.0000 (4)	1.0032 (2)	0.0000 (4)	0.0000 (5)	
heu-comp-inter-003-case-6	0.0000 (5)	0.0000 (5)	0.9948 (4)	0.0000 (5)	0.0000 (5)	
heu-met-inter-006-case-1	0.0000 (4)	0.0000 (4)	0.9929 (2)	0.0000 (4)	0.0000 (4)	
heu-met-inter-006-case-2	0.0003 (4)	0.0003 (4)	0.9965 (2)	0.0003 (4)	0.0000 (4)	compiler
heu-met-inter-006-case-3	0.0000 (4)	0.0000 (4)	1.0008 (2)	0.0000 (4)	0.0000 (4)	
heu-met-inter-006-case-4	0.0000 (4)	0.0000 (4)	1.0072 (2)	0.0000 (4)	0.0000 (4)	
u233-comp-therm-001-case-6	-0.0002 (5)	-0.0002 (5)	0.9990 (4)	0.0001 (5)	-0.0003 (5)	compiler
heu-sol-therm-013-case-1	0.0000 (4)	0.0000 (4)	0.9985 (2)	0.0000 (4)	0.0000 (4)	
heu-sol-therm-013-case-2	0.0000 (4)	0.0000 (4)	0.9969 (2)	0.0000 (4)	0.0000 (4)	
heu-sol-therm-013-case-3	0.0000 (4)	0.0000 (4)	0.9939 (2)	0.0000 (4)	0.0000 (4)	
heu-sol-therm-013-case-4	0.0000 (4)	0.0000 (4)	0.9953 (2)	0.0000 (4)	0.0000 (4)	
heu-sol-therm-032	0.0000 (2)	0.0000 (2)	0.9992 (2)	0.0000 (2)	0.0000 (2)	

VALIDATION_CRIT_EXPANDED Suite, 2018 (3)

	610_lin		611_lin		620_lin		620_mac		620_win		
	deltak	std	deltak	std	keff	std	deltak	std	deltak	std	
Pu Benchmarks											
pu-met-fast-001	0.0000	(4)	0.0000	(4)	0.9993	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-002	0.0000	(4)	0.0000	(4)	1.0003	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-022-case-2	0.0000	(4)	0.0000	(4)	0.9984	(2)	0.0000	(4)	0.0000	(4)	
mix-met-fast-001	0.0000	(4)	0.0000	(4)	0.9998	(2)	0.0000	(4)	0.0000	(4)	
mix-met-fast-003	0.0000	(4)	0.0000	(4)	1.0004	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-006	0.0000	(4)	0.0000	(4)	1.0001	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-010	0.0000	(4)	0.0000	(4)	0.9996	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-020	0.0000	(4)	0.0000	(4)	0.9983	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-008-case-2	0.0000	(4)	0.0000	(4)	0.9977	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-005	0.0000	(4)	0.0000	(4)	1.0019	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-025-case-2	0.0000	(4)	0.0000	(4)	0.9991	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-026-case-2	0.0000	(4)	0.0000	(4)	0.9987	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-009	0.0000	(4)	0.0000	(4)	1.0048	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-023-case-2	0.0000	(4)	0.0000	(4)	0.9994	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-018	0.0000	(4)	0.0000	(4)	0.9993	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-019	0.0000	(4)	0.0000	(4)	1.0004	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-024-case-2	0.0000	(4)	0.0000	(4)	1.0025	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-011	0.0000	(4)	0.0000	(4)	1.0000	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-021-case-2	0.0000	(4)	0.0000	(4)	0.9935	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-021-case-1	0.0000	(4)	0.0000	(4)	1.0047	(2)	0.0000	(4)	0.0000	(4)	
pu-met-fast-003-case-103	0.0000	(4)	0.0000	(4)	0.9990	(2)	0.0000	(4)	0.0000	(4)	
pu-comp-inter-001	0.0000	(4)	0.0000	(4)	1.0116	(2)	0.0000	(4)	0.0000	(4)	
mix-comp-therm-002-case-pn130	0.0000	(4)	0.0000	(4)	1.0002	(2)	0.0003	(4)	0.0003	(4)	coinc r/o
mix-comp-therm-002-case-pn131	0.0006	(5)*	0.0006	(5)*	1.0012	(2)	0.0000	(4)	0.0000	(4)	coinc r/o
mix-comp-therm-002-case-pn132	0.0003	(4)	0.0003	(4)	1.0017	(2)	0.0003	(4)	0.0003	(4)	coinc r/o
mix-comp-therm-002-case-pn133	0.0001	(4)	0.0001	(4)	1.0062	(2)	0.0002	(4)	0.0002	(4)	coinc r/o
mix-comp-therm-002-case-pn134	-0.0001	(4)	-0.0001	(4)	1.0046	(2)	0.0000	(4)	0.0000	(4)	coinc r/o
mix-comp-therm-002-case-pn135	0.0004	(4)	0.0004	(4)	1.0059	(2)	-0.0002	(4)	-0.0002	(4)	coinc r/o
pu-sol-therm-009-case-3a	0.0000	(2)	0.0000	(2)	1.0191	(2)	0.0000	(2)	0.0000	(2)	
pu-sol-therm-011-case-16-5	0.0000	(5)	0.0000	(5)	1.0054	(4)	0.0000	(5)	0.0000	(5)	
pu-sol-therm-011-case-18-1	0.0000	(4)	0.0000	(4)	0.9941	(2)	0.0000	(4)	0.0000	(5)	
pu-sol-therm-011-case-18-6	0.0000	(5)	0.0000	(5)	1.0005	(4)	0.0000	(5)	0.0000	(5)	
pu-sol-therm-021-case-1	0.0000	(5)	0.0000	(5)	1.0053	(4)	0.0000	(5)	0.0000	(5)	
pu-sol-therm-021-case-3	0.0000	(5)	0.0000	(5)	1.0043	(4)	0.0000	(5)	0.0000	(5)	
pu-sol-therm-018-case-9	0.0000	(4)	0.0000	(4)	1.0026	(2)	0.0000	(4)	0.0000	(4)	
pu-sol-therm-034-case-1	0.0000	(5)	0.0000	(5)	1.0007	(4)	0.0000	(5)	0.0000	(5)	

VALIDATION_CRIT_EXPANDED Suite, 2018 (4)

	610_lin		611_lin		620_lin		620_mac		620_win	
	deltak	std	deltak	std	keff	std	deltak	std	deltak	std
IEU Benchmarks										
ieu-met-fast-003-case-2	0.0000	(4)	0.0000	(4)	1.0028	(2)	0.0000	(4)	0.0000	(4)
ieu-met-fast-005-case-2	0.0000	(4)	0.0000	(4)	1.0024	(2)	0.0000	(4)	0.0000	(4)
ieu-met-fast-006-case-2	0.0000	(4)	0.0000	(4)	0.9958	(2)	0.0000	(4)	0.0000	(4)
ieu-met-fast-004-case-2	0.0000	(4)	0.0000	(4)	1.0075	(2)	0.0000	(4)	0.0000	(4)
ieu-met-fast-001-case-1	0.0000	(4)	0.0000	(4)	1.0009	(2)	0.0000	(4)	0.0000	(4)
ieu-met-fast-001-case-2	0.0000	(4)	0.0000	(4)	0.9999	(2)	0.0000	(4)	0.0000	(4)
ieu-met-fast-001-case-3	0.0000	(4)	0.0000	(4)	1.0011	(2)	0.0000	(4)	0.0000	(4)
ieu-met-fast-001-case-4	0.0000	(4)	0.0000	(4)	1.0015	(2)	0.0000	(4)	0.0000	(4)
ieu-met-fast-002	0.0000	(4)	0.0000	(4)	0.9991	(2)	0.0000	(4)	0.0000	(4)
ieu-met-fast-007-case-4	0.0000	(2)	0.0000	(2)	1.0045	(2)	0.0000	(2)	0.0000	(2)
mix-met-fast-008-case-7	0.0000	(2)	0.0000	(2)	1.0192	(2)	0.0000	(2)	0.0001	(2)
ieu-comp-therm-002-case-3	0.0000	(4)	0.0000	(4)	1.0038	(2)	0.0000	(4)	0.0000	(4)
leu-sol-therm-007-case-14	0.0000	(4)	0.0000	(4)	0.9947	(2)	0.0000	(4)	0.0000	(4)
leu-sol-therm-007-case-30	0.0000	(4)	0.0000	(4)	0.9971	(2)	0.0000	(4)	0.0000	(4)
leu-sol-therm-007-case-32	0.0000	(4)	0.0000	(4)	0.9959	(2)	0.0000	(4)	0.0000	(4)
leu-sol-therm-007-case-36	0.0000	(4)	0.0000	(4)	0.9990	(2)	0.0000	(4)	0.0000	(4)
leu-sol-therm-007-case-49	0.0000	(4)	0.0000	(4)	0.9972	(2)	0.0000	(4)	0.0000	(4)
Wall-clock:	264.2 min		131.6 min		102.4 min		156.4 min		-	
Threads:	16		16		18		12		4	
Rel. Speed:	0.44		0.88		1.00		0.98		-	

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**

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Questions ?