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MCNP6 documentation

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**ANS 2018  
Winter Meeting**

Orlando, FL  
Nov 11-15, 2018

LA-UR-18-

# Verification of MCNP6.2 for Nuclear Criticality Safety Applications



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## Deja Vu ?

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- **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

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- 2017 - 70<sup>th</sup> anniversary of the first MC code for particle transport
- 2017 - 40<sup>th</sup> anniversary of the first MCNP release
- 2018 - 70<sup>th</sup> 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](http://mcnp.lanl.gov)

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

URL: [nucleardata.lanl.gov](http://nucleardata.lanl.gov)

# MCNP6.2 Release – Code Changes

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- **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

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- **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](http://nucleardata.lanl.gov)**

# MCNP6.2 Release – Whisper-1.1

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- **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_mcnp.pl` – 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  $k_{\text{eff}}$
  - 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

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- **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	<u>Reason for diffs</u>
<b>U233 Benchmarks</b>											
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)	
<b>HEU Benchmarks</b>											
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)	
<b>IEU Benchmarks</b>											
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)	
<b>LEU Benchmarks</b>											
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)	
<b>Pu Benchmarks</b>											
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)	
<b>Summary</b>											
Wall-clock:	18.6 min		11.5 min		11.6 min		7.7 min		41 min		
Threads:	12		12		12		18		4		
Rel. Speed:	1.00		1.62		1.61		1.62		1.36		

1 M neutrons per case  
Continuous S(a,b)

# 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)

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**

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

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	
<b>U233 Benchmarks</b>											
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)	
<b>LEU Benchmarks</b>											
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	
<b>HEU Benchmarks</b>						
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	
<b>Pu Benchmarks</b>											
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 deltak std	611_lin deltak std	620_lin keff std	620_mac deltak std	620_win deltak std
<b>IEU Benchmarks</b>					
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)
<b>Wall-clock:</b>	<b>264.2 min</b>	<b>131.6 min</b>	<b>102.4 min</b>	<b>156.4 min</b>	<b>-</b>
<b>Threads:</b>	<b>16</b>	<b>16</b>	<b>18</b>	<b>12</b>	<b>4</b>
<b>Rel. Speed:</b>	<b>0.44</b>	<b>0.88</b>	<b>1.00</b>	<b>0.98</b>	<b>-</b>

# Conclusions

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- **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 ?**