LA-UR-16-23111

Approved for public release; distribution is unlimited.

Title: Verification of the Multi-Mesh Capability for MCNP6's Unstructured Mesh Feature

Author(s): Roger L. Martz

Intended For: General Reference / MCNP® Website

Issued: April 2016

This page intentionally left blank.

Verification of the Multi-Mesh Capability for MCNP6's Unstructured Mesh Feature

Roger Martz
Monte Carlo Methods, Codes, and Applications
X-Computational Physics Division
Los Alamos National Laboratory

April 2016

1 Introduction

This report documents the multi-mesh capability that has recently been installed in MCNP6 [1] for use with the unstructured mesh (UM) feature. This capability allows the user to request that the code read any number of Abaqus [2] or mcnpum files for use in separate mesh universes. No new input cards or parameters are required.

2 Verification

Verification of this capability is in two parts, each of which is reflected in two separate test problems in the MCNP6 REGRESSION test suite: #1037 and #1041. Test problem #1037 reads the same UM file multiple times and allows the direct comparison of elemental edits with legacy tallies. Test problem #1041 reads two different mesh files and tests them in a donut arrangement where the smaller UM object is inside the larger one.

2.1 Verification Geometry: 1037

The 1037 verification problem discussed in this document uses a simple geometry that is present in a number of MCNP6's UM test problems appearing in its REGRESSION test suite. This geometry is called the eight-hexagonal cube geometry and is shown in Figure 1. The test configuration for this problem requires three instances of the eight-hexagonal cube geometry where all of the instances are translated and two are rotated so that they are correctly positioned in their respective mesh universes. Figure 2, produced via the MCNP6 plotter, shows this arrangement. This arrangement was modeled with both Constructive Solid Geometry, CSG, and UM in a manner that permits direct comparison (in a manner similar to that of Reference [3]) of cell-based tally results from the CSG version with UM edit results.

For this problem the source particles are started from a spherical surface that surrounds all three universes and are directed inward. This surface is shown in Figure 2. The `VOID` card is used to void out all materials in the problem. Consequently, the pedigree of the cross sections is not important and this problem is then essentially one of ray-tracing through the geometry. When the `WGT` parameter on the `SDEF` card is set to a value corresponding to the surface area of the sphere, this problem becomes one of stochastically estimating the volumes of each cell or UM element as discussed in Reference [4]'s section on Stochastic Volume and Area Calculations. However, in this case the code can calculate the volumes and without a `SD` card or `VOL` card present (where the volumes have been set to a value of 1) the results should approach the value of 1.0 if there is only one source particle type specified with the `PAR` parameter on the `SDEF` card. Since this problem selects equally among 4 particle types, the expected result in each cell / element should be 0.25. Indeed, this can be seen in the results below and more so when a large number of histories are used.

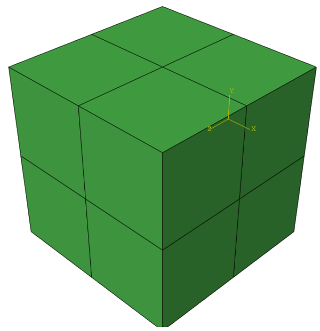

Figure 1: The Eight-Hexagonal Cube Geometry

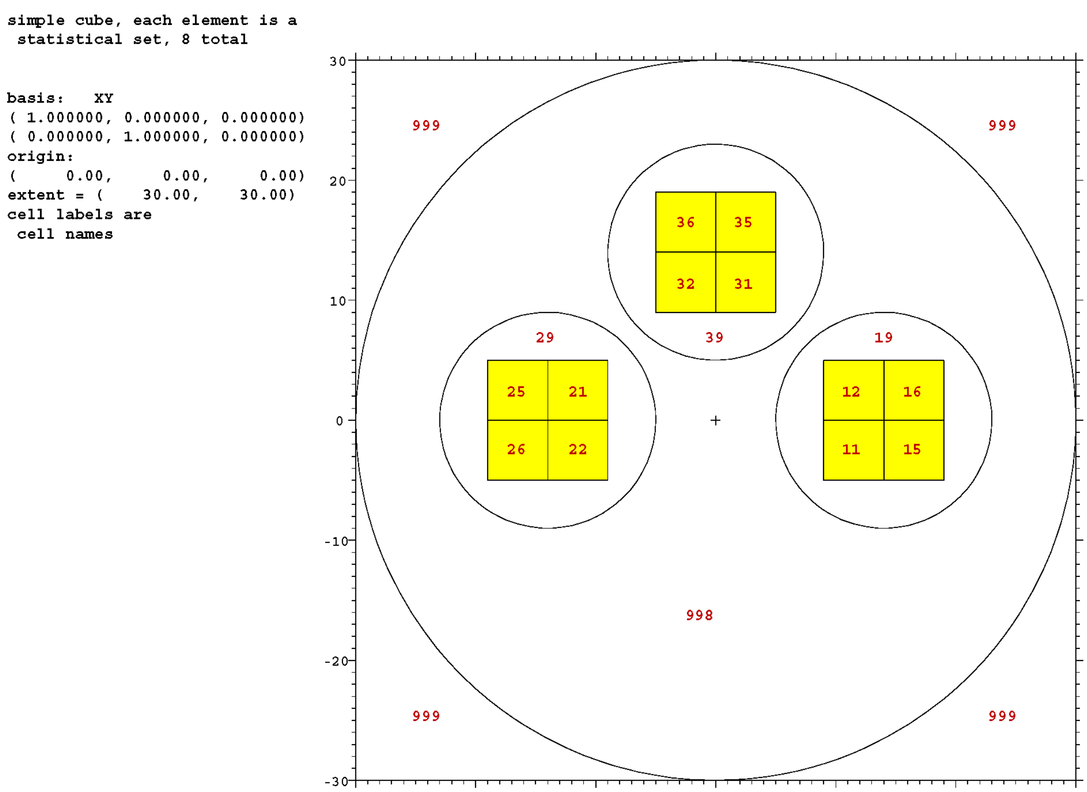

Figure 2: CSG representation of inp1037 geometry arrangement

2.2 Test Case Inputs: 1037

The following two sections provide the MCNP6 input for the CSG and UM calculations.

The CSG Input

```
simple cube, each element is a statistical set, 8 total
c
c  8 1st order hex elements (simulated w/ cells); 1 per octant
c  each element is a statistical set, 8 total
c  fixed source, ray tracing from inward directed surface source.
c  Tally and edit results should be the element volume * source fraction.
c  Tests 4 particles & 3 tracking loops:
c    neutral particle low energy (neutrons & photons)
c    low mass charged (electrons)
c    heavy mass charged (protons)
c
c ---cell cards---
11   1  4.7984e-02  10 -11 20 -21 31 -32  u=2
12   1  4.7984e-02  10 -11 21 -22 31 -32  u=2
13   1  4.7984e-02  10 -11 20 -21 30 -31  u=2
14   1  4.7984e-02  10 -11 21 -22 30 -31  u=2
15   1  4.7984e-02  11 -12 20 -21 31 -32  u=2
16   1  4.7984e-02  11 -12 21 -22 31 -32  u=2
17   1  4.7984e-02  11 -12 20 -21 30 -31  u=2
18   1  4.7984e-02  11 -12 21 -22 30 -31  u=2
19   0              300 -50  u=2
121  0             -41  fill=2(1)
c
21   1  4.7984e-02  10 -11 20 -21 31 -32  u=4
22   1  4.7984e-02  10 -11 21 -22 31 -32  u=4
23   1  4.7984e-02  10 -11 20 -21 30 -31  u=4
24   1  4.7984e-02  10 -11 21 -22 30 -31  u=4
25   1  4.7984e-02  11 -12 20 -21 31 -32  u=4
26   1  4.7984e-02  11 -12 21 -22 31 -32  u=4
27   1  4.7984e-02  11 -12 20 -21 30 -31  u=4
28   1  4.7984e-02  11 -12 21 -22 30 -31  u=4
29   0              300 -50  u=4
221  0             -42  fill=4(2)
c
31   1  4.7984e-02  10 -11 20 -21 31 -32  u=6
32   1  4.7984e-02  10 -11 21 -22 31 -32  u=6
33   1  4.7984e-02  10 -11 20 -21 30 -31  u=6
34   1  4.7984e-02  10 -11 21 -22 30 -31  u=6
35   1  4.7984e-02  11 -12 20 -21 31 -32  u=6
36   1  4.7984e-02  11 -12 21 -22 31 -32  u=6
37   1  4.7984e-02  11 -12 20 -21 30 -31  u=6
38   1  4.7984e-02  11 -12 21 -22 30 -31  u=6
39   0              300 -50  u=6
321  0             -43  fill=6(3)
c
998  0              41  42 43 -100
999  0              100
```

```
c ---surface cards---
10   px -5.0
11   px  0.0
12   px  5.0
c
20   py -5.0
21   py  0.0
22   py  5.0
c
30   pz  0.0
31   pz  5.0
32   pz  10.0
c
41   sx  14 9
42   sx -14 9
43   sy  14 9
c
50   so 55.0
100  so 30.0
300  rpp -5 5  -5 5  0 10

c --- DATA CARDS ---
c
c  Transformations
 tr1   14  0 -5
*tr2  -14  0 -5   180 -90 90   90 180 90  90 90 0
*tr3    0 14 -5   270   0 90  180 270 90  90 90 0
c
c ---material cards---
c   Material 1: HEU (Godiva)
c   atom density:  4.7984e-02 at/b-cm
m1   92235  4.4994e-02
     92238  2.4984e-03
     92234  4.9184e-04
c
c ---tally cards---
f14:n 11 12 13 14 15 16 17 18 T
c
f24:n 21 22 23 24 25 26 27 28 T
c
f34:n 31 32 33 34 35 36 37 38 T
c
f114:p 11 12 13 14 15 16 17 18 T
c
f124:p 21 22 23 24 25 26 27 28 T
c
f134:p 31 32 33 34 35 36 37 38 T
c
f214:e 11 12 13 14 15 16 17 18 T
c
f224:e 21 22 23 24 25 26 27 28 T
```

```
c
f234:e 31 32 33 34 35 36 37 38 T
c
f314:h 11 12 13 14 15 16 17 18 T
c
f324:h 21 22 23 24 25 26 27 28 T
c
f334:h 31 32 33 34 35 36 37 38 T
c
c ---source, etc cards---
sdef pos= 0 0 0  erg=14   nrm= -1  par= d1       rad= 30     sur=100  wgt= 2827.4334
c
si1 L  1    2     3     h
sp1   0.25 0.25  0.25  0.25
c
totnu no
c
nps 10000
prdmp J 10000000  -1  j 8000
c
mode n p e h
imp:n 1 30r 0
imp:p 1 30r 0
c
print -85 -86  -130
c
void  11 12 13 14 15 16 17 18
      21 22 23 24 25 26 27 28
      31 32 33 34 35 36 37 38
```

The UM Input

```
simple cube, each element is a statistical set, 8 total
c
c  8 1st order hex elements; 1 per octant
c  each element is a statistical set, 8 total
c  fixed source, ray tracing from inward directed surface source.
c  Tally and edit results should be the element volume * source fraction.
c  Tests 4 particles & 3 tracking loops:
c    neutral particle low energy (neutrons & photons)
c    low mass charged (electrons)
c    heavy mass charged (protons)
c
c ---cell cards---
11   1  4.7984e-02   0        u=2
12   1  4.7984e-02   0        u=2
13   1  4.7984e-02   0        u=2
14   1  4.7984e-02   0        u=2
15   1  4.7984e-02   0        u=2
16   1  4.7984e-02   0        u=2
17   1  4.7984e-02   0        u=2
18   1  4.7984e-02   0        u=2
19   0               0        u=2
```

```
121  0             -41     fill=2(1)
c
21   1  4.7984e-02   0        u=4
22   1  4.7984e-02   0        u=4
23   1  4.7984e-02   0        u=4
24   1  4.7984e-02   0        u=4
25   1  4.7984e-02   0        u=4
26   1  4.7984e-02   0        u=4
27   1  4.7984e-02   0        u=4
28   1  4.7984e-02   0        u=4
29   0               0        u=4
221  0             -42     fill=4(2)
c
31   1  4.7984e-02   0        u=6
32   1  4.7984e-02   0        u=6
33   1  4.7984e-02   0        u=6
34   1  4.7984e-02   0        u=6
35   1  4.7984e-02   0        u=6
36   1  4.7984e-02   0        u=6
37   1  4.7984e-02   0        u=6
38   1  4.7984e-02   0        u=6
39   0               0        u=6
321  0             -43     fill=6(3)
c
998  0          41 42 43 -100
999  0                   100

c ---surface cards---
c
41   sx  14 9
42   sx -14 9
43   sy  14 9
c
50   so 55.0
100  so 30.0

c --- DATA CARDS ---
c
c  Transformations
 tr1   14  0 -5
*tr2  -14  0 -5   180 -90 90   90 180 90  90 90 0
*tr3    0 14 -5   270   0 90  180 270 90  90 90 0
c
c ---material cards---
c   Material 1: HEU (Godiva)
c   atom density:  4.7984e-02 at/b-cm
m1   92235  4.4994e-02
     92238  2.4984e-03
     92234  4.9184e-04
c
c ---tally cards---
f14:n 11 12 13 14 15 16 17 18 T
```

```
c
f24:n 21 22 23 24 25 26 27 28 T
c
f34:n 31 32 33 34 35 36 37 38 T
c
f114:p 11 12 13 14 15 16 17 18 T
c
f124:p 21 22 23 24 25 26 27 28 T
c
f134:p 31 32 33 34 35 36 37 38 T
c
f214:e 11 12 13 14 15 16 17 18 T
c
f224:e 21 22 23 24 25 26 27 28 T
c
f234:e 31 32 33 34 35 36 37 38 T
c
f314:h 11 12 13 14 15 16 17 18 T
c
f324:h 21 22 23 24 25 26 27 28 T
c
f334:h 31 32 33 34 35 36 37 38 T
c
embee14:n   embed=2  errors=yes
            comment= neutron flux in universe 2
c
embee24:n   embed=4  errors=yes
            comment= neutron flux in universe 4
c
embee34:n   embed=6  errors=yes
            comment= neutron flux in universe 6
c
embee114:p  embed=2  errors=yes
            comment= photon flux in universe 2
c
embee124:p  embed=4  errors=yes
            comment= photon flux in universe 4
c
embee134:p  embed=6  errors=yes
            comment= photon flux in universe 6
c
embee214:e  embed=2  errors=yes
            comment= electron flux in universe 2
c
embee224:e  embed=4  errors=yes
            comment= electron flux in universe 4
c
embee234:e  embed=6  errors=yes
            comment= electron flux in universe 6
c
embee314:h  embed=2  errors=yes
            comment= proton flux in universe 2
```

```
c
embee324:h  embed=4  errors=yes
            comment= proton flux in universe 4
c
embee334:h  embed=6  errors=yes
            comment= proton flux in universe 6
c
sdef pos= 0 0 0  erg=14   nrm= -1  par= d1
     rad= 30     sur=100  wgt= 2827.4334
c
si1 L  1    2     3     h
sp1   0.25 0.25  0.25  0.25
c
totnu no
c
nps 10000
prdmp J 10000000  -1  j 8000
c
mode n p e h
imp:n 1 30r 0
imp:p 1 30r 0
c
print -85 -86  -130
c
embed2 meshgeo=abaqus
       mgeoin=um1007.inp
       meeout=inp1037u
       filetype=ascii
       background= 19
       matcell= 1 11  2 12  3 13  4 14  5 15  6 16  7 17  8 18
c
embed4 meshgeo=abaqus
       mgeoin=um1007.inp
       meeout=inp1037u2
       filetype=ascii
       background= 29
       matcell= 1 21  2 22  3 23  4 24  5 25  6 26  7 27  8 28
c
embed6 meshgeo=abaqus
       mgeoin=um1007.inp
       meeout=inp1037u3
       filetype=ascii
       background= 39
       matcell= 1 31  2 32  3 33  4 34  5 35  6 36  7 37  8 38
c
void  11 12 13 14 15 16 17 18
      21 22 23 24 25 26 27 28
      31 32 33 34 35 36 37 38
```

2.3 Results: 1037

Tables 1-12 compare the tally and edit means and errors for the problem described in this document; 1E+04 histories were run. Tables 1-4 are for the geometry of universe 2. Tables 5-8 are for the geometry of universe 4. Tables 9-12 are for the geometry of universe 6. The traditional tally information was extracted from the outp file while the edit results were extracted from the eeout file. All means agree to 6 significant figures. Errors in the outp file are provided to 4 significant figures while the errors in the eeout file are provided to 6 significant digits. The edit errors are in agreement with the traditional tally errors.

Table 1: Neutron Results in Universe 2

Cell/Element	CSG Mean	CSG Error	UM Mean	UM Error
11	1.75594E-01	0.2332	1.75594E-01	2.33191E-01
12	2.35498E-01	0.2124	2.35498E-01	2.12428E-01
13	1.65573E-01	0.2426	1.65573E-01	2.43570E-01
14	2.72658E-01	0.1939	2.72658E-01	1.93922E-01
15	1.58603E-01	0.2564	1.58603E-01	2.56409E-01
16	2.37966E-01	0.2064	2.37966E-01	2.06416E-01
17	2.80468E-01	0.1968	2.80468E-01	1.96776E-01
18	2.38811E-01	0.2138	2.38811E-01	2.13798E-01

Table 2: Photon Results in Universe 2

Cell/Element	CSG Mean	CSG Error	UM Mean	UM Error
11	1.67386E-01	0.2517	1.67386E-01	2.51690E-01
12	2.00426E-01	0.2093	2.00426E-01	2.09334E-01
13	2.05550E-01	0.2135	2.05550E-01	2.13482E-01
14	2.95999E-01	0.1782	2.95999E-01	1.78200E-01
15	2.55613E-01	0.1929	2.55613E-01	1.92861E-01
16	2.91322E-01	0.1771	2.91322E-01	1.77113E-01
17	2.51364E-01	0.1943	2.51364E-01	1.94260E-01
18	3.42210E-01	0.1713	3.42210E-01	1.71272E-01

Table 3: Electron Results in Universe 2

Cell/Element	CSG Mean	CSG Error	UM Mean	UM Error
11	2.01596E-01	0.2238	2.01596E-01	2.23850E-01
12	2.23202E-01	0.2082	2.23202E-01	2.08169E-01
13	2.35835E-01	0.2047	2.35835E-01	2.04723E-01
14	2.62840E-01	0.1938	2.62840E-01	1.93812E-01
15	1.89324E-01	0.2340	1.89324E-01	2.33989E-01
16	2.73384E-01	0.1924	2.73384E-01	1.92358E-01
17	2.84696E-01	0.1943	2.84696E-01	1.94327E-01
18	2.56171E-01	0.1969	2.56171E-01	1.96940E-01

Table 4: Proton Results in Universe 2

Cell/Element	CSG Mean	CSG Error	UM Mean	UM Error
11	8.79893E-02	0.3058	8.79893E-02	3.05831E-01
12	2.41750E-01	0.2031	2.41750E-01	2.03085E-01
13	1.72152E-01	0.2367	1.72152E-01	2.36663E-01
14	1.93261E-01	0.2334	1.93261E-01	2.33421E-01
15	2.05339E-01	0.2239	2.05339E-01	2.23916E-01
16	3.14019E-01	0.1782	3.14019E-01	1.78167E-01
17	2.08343E-01	0.2299	2.08343E-01	2.29944E-01
18	2.15372E-01	0.2088	2.15372E-01	2.08839E-01

Table 5: Neutron Results in Universe 4

Cell/Element	CSG Mean	CSG Error	UM Mean	UM Error
21	3.06134E-01	0.1715	3.06134E-01	1.71517E-01
22	2.19582E-01	0.2156	2.19582E-01	2.15602E-01
23	2.40042E-01	0.1994	2.40042E-01	1.99357E-01
24	2.31284E-01	0.2029	2.31284E-01	2.02886E-01
25	2.74912E-01	0.1858	2.74912E-01	1.85837E-01
26	2.40872E-01	0.2096	2.40872E-01	2.09617E-01
27	3.06473E-01	0.1824	3.06473E-01	1.82362E-01
28	2.13513E-01	0.2131	2.13513E-01	2.13064E-01

Table 6: Photon Results in Universe 4

Cell/Element	CSG Mean	CSG Error	UM Mean	UM Error
21	1.53706E-01	0.2514	1.53706E-01	2.51351E-01
22	2.91934E-01	0.1833	2.91934E-01	1.83288E-01
23	2.55864E-01	0.1969	2.55864E-01	1.96857E-01
24	1.73943E-01	0.2380	1.73943E-01	2.38033E-01
25	2.00879E-01	0.2234	2.00879E-01	2.23449E-01
26	2.18473E-01	0.2296	2.18473E-01	2.29612E-01
27	2.32873E-01	0.2051	2.32873E-01	2.05137E-01
28	1.47109E-01	0.2708	1.47109E-01	2.70764E-01

Table 7: Electron Results in Universe 4

Cell/Element	CSG Mean	CSG Error	UM Mean	UM Error
21	1.83227E-01	0.2294	1.83227E-01	2.29370E-01
22	2.25810E-01	0.2142	2.25810E-01	2.14209E-01
23	2.15668E-01	0.2336	2.15668E-01	2.33626E-01
24	2.09972E-01	0.2255	2.09972E-01	2.25472E-01
25	1.69702E-01	0.2378	1.69702E-01	2.37822E-01
26	2.03477E-01	0.2232	2.03477E-01	2.23189E-01
27	2.15466E-01	0.2208	2.15466E-01	2.20839E-01
28	2.50951E-01	0.2046	2.50951E-01	2.04638E-01

Table 8: Proton Results in Universe 4

Cell/Element	CSG Mean	CSG Error	UM Mean	UM Error
21	2.59593E-01	0.2005	2.59593E-01	2.00523E-01
22	2.47234E-01	0.2098	2.47234E-01	2.09809E-01
23	3.01722E-01	0.1858	3.01722E-01	1.85843E-01
24	3.00017E-01	0.1827	3.00017E-01	1.82714E-01
25	1.42855E-01	0.2503	1.42855E-01	2.50294E-01
26	2.19488E-01	0.2270	2.19488E-01	2.26981E-01
27	1.73957E-01	0.2371	1.73957E-01	2.37088E-01
28	2.20192E-01	0.2156	2.20192E-01	2.15611E-01

Table 9: Neutron Results in Universe 6

Cell/Element	CSG Mean	CSG Error	UM Mean	UM Error
31	2.16313E-01	0.2070	2.16313E-01	2.06955E-01
32	2.61078E-01	0.1949	2.61078E-01	1.94896E-01
33	2.23949E-01	0.2267	2.23949E-01	2.26688E-01
34	2.22879E-01	0.2110	2.22879E-01	2.11010E-01
35	2.45996E-01	0.2028	2.45996E-01	2.02815E-01
36	2.98583E-01	0.1889	2.98583E-01	1.88900E-01
37	2.10629E-01	0.2210	2.10629E-01	2.20991E-01
38	2.47133E-01	0.2034	2.47133E-01	2.03390E-01

Table 10: Photon Results in Universe 6

Cell/Element	CSG Mean	CSG Error	UM Mean	UM Error
31	2.64066E-01	0.1971	2.64066E-01	1.97128E-01
32	3.28124E-01	0.1721	3.28124E-01	1.72130E-01
33	2.30670E-01	0.2019	2.30670E-01	2.01892E-01
34	2.17576E-01	0.2068	2.17576E-01	2.06836E-01
35	3.17368E-01	0.1751	3.17368E-01	1.75068E-01
36	3.57643E-01	0.1761	3.57643E-01	1.76121E-01
37	3.48064E-01	0.1711	3.48064E-01	1.71126E-01
38	3.04599E-01	0.1831	3.04599E-01	1.83086E-01

Table 11: Electron Results in Universe 6

Cell/Element	CSG Mean	CSG Error	UM Mean	UM Error
31	2.46853E-01	0.1972	2.46853E-01	1.97224E-01
32	2.49132E-01	0.1962	2.49132E-01	1.96204E-01
33	2.17944E-01	0.2103	2.17944E-01	2.10263E-01
34	2.29267E-01	0.2086	2.29267E-01	2.08649E-01
35	3.01593E-01	0.1841	3.01593E-01	1.84058E-01
36	2.78340E-01	0.2048	2.78340E-01	2.04840E-01
37	2.02769E-01	0.2188	2.02769E-01	2.18836E-01
38	2.13960E-01	0.2182	2.13960E-01	2.18174E-01

Table 12: Proton Results in Universe 6

Cell/Element	CSG Mean	CSG Error	UM Mean	UM Error
31	2.73975E-01	0.1920	2.73975E-01	1.92017E-01
32	3.21960E-01	0.1791	3.21960E-01	1.79061E-01
33	2.90469E-01	0.1927	2.90469E-01	1.92700E-01
34	1.97153E-01	0.2093	1.97153E-01	2.09268E-01
35	3.21997E-01	0.1808	3.21997E-01	1.80751E-01
36	2.88884E-01	0.1860	2.88884E-01	1.86046E-01
37	2.26382E-01	0.2060	2.26382E-01	2.06030E-01
38	2.98200E-01	0.1917	2.98200E-01	1.91700E-01

2.4 Verification Geometry: 1041

The 1041 verification problem discussed in this document uses two separate UM objects in a donut configuration. The donut configuration has one mesh universe, containing a peg of triangular cross section, inside the hole of another mesh universe that contains a thick, square shell. Both UM objects use 1st order tetrahedra with 448 elements in the peg and 1206 elements in the shell. A CSG equivalent of this has been created so that cell tallies from the two geometries can be compared. A cross section of the CSG geometry is shown in Figure 3. Surface numbers are shown in this Figure. Everything inside surface 98 belongs to the mesh universe containing the wedge with the triangular cross section while everything outside of surface 98 and inside surface99 belongs to the square shell universe. Additionally, the flux tallies across surface 99 can be compared.

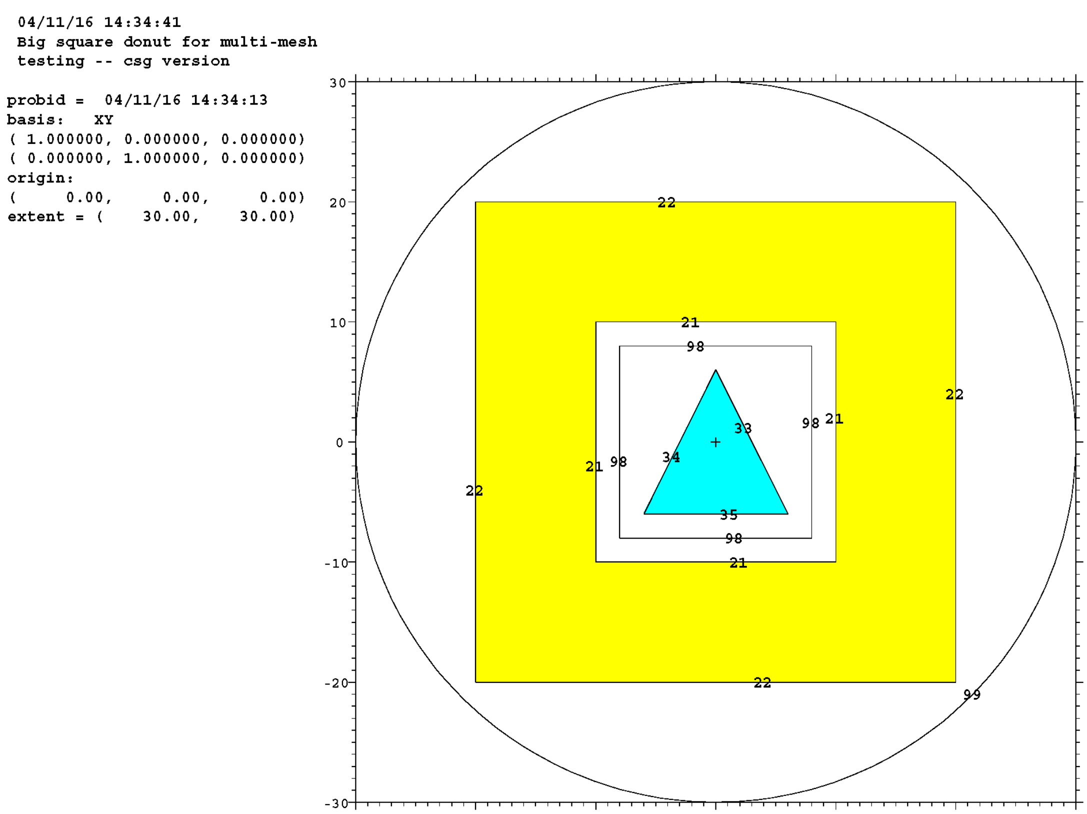

Figure 3: Cross section of equivalent CSG geometry for regression problem 1041.

2.5 Test Case Inputs: 1041

The following two sections provide the MCNP6 input for the CSG and UM calculations.

The CSG Input

```
 Big square donut for multi-mesh testing -- csg version
c
01       1     -1.00000  21 -22     u=1     imp:n=1
02       0               -21     u=1     imp:n=1
03       0                22     u=1     imp:n=1
c
11       2     -2.00000  31 -32 -33 -34 -35  u=2       imp:n=1
12       0               #11              u=2       imp:n=1
13       0                          -98  fill=2    imp:n=1
c
22       0              -99  98   fill=1 imp:n=1
24       0               99             imp:n=0

c -------------------------------------------------------------
c SURFACES
11  so    5
21  rpp  -10 10  -10 10  -10 10
22  rpp  -20 20  -20 20  -20 20
c
31  pz  -6 32  pz   6
33  p   0  6 -6   6 -6 -6   6 -6 6
34  p   0  6 -6  -6 -6 -6  -6 -6 6
35  p   6 -6 -6  -6 -6 -6   6 -6 6
c
98  rpp  -8 8  -8 8  -8 8
99  sph   0.00000E+00   0.00000E+00   0.00000E+00   42.0

c ------------------------------------------------------------
c  DATA CARDS
c
c  the following is pseudo-concrete
m1   1001.62c -0.02  8016.62c -0.60  14000.60c -0.38
c
c   Material 1: HEU (Godiva)
c   atom density:  4.7984e-02 at/b-cm
m2   92235.69c  4.4994e-02
     92238.69c  2.4984e-03
     92234.69c  4.9184e-04
c
f2:n  99
f14:n 1
f24:n 11
c
mode n
sdef pos= 0 0 0
nps 1e6
```

The UM Input

```
 Big square donut for multi-mesh testing
c
c  Created from file    : um_multipart_big_donut.inp
c  Created on           :  7- 9-2015 @ 16:16: 6
c
c
c PSEUDO CELLS
01       1     -1.00000      0      u=1     imp:n=1
02       0                   0      u=1     imp:n=1
c
c PSEUDO CELLS
11       2     -2.00000      0  u=2         imp:n=1
12       0                   0  u=2         imp:n=1
13       0                 -98  fill=2      imp:n=1
c
22       0                 -99  98   fill=1 imp:n=1
24       0                  99              imp:n=0

c ------------------------------------------------------------
c SURFACES
c
98  rpp  -8 8  -8 8  -8 8
99  sph   0.00000E+00   0.00000E+00   0.00000E+00   42.0

c -----------------------------------------------------------
c  DATA CARDS
c
c  the following is pseudo-concrete
m1   1001.62c -0.02  8016.62c -0.60  14000.60c -0.38
c
c   Material 1: HEU (Godiva)
c   atom density:  4.7984e-02 at/b-cm
m2   92235.69c  4.4994e-02
     92238.69c  2.4984e-03
     92234.69c  4.9184e-04
c
embed1 meshgeo=abaqus
       mgeoin= um_multipart_big_donut.inp
       meeout= um_multipart_big_donut.eeout
       length= 1.00000E+00
       background= 2
       matcell=  1  1
c
embed2 meshgeo=abaqus
       mgeoin= um_multipart_inner_peg.inp
       meeout= um_multipart_inner_peg.eeout
       length= 1.00000E+00
       background= 12
       matcell=  1  11
c
f2:n  99
```

```
f14:n 1
f24:n 11
c
mode n
sdef pos= 0 0 0
nps 1e6
```

2.6 Results: 1041

The geometry for this problem was designed without curved surfaces so that the tally results would match exactly between the CSG and UM calculations; that is exactly the outcome. Table 13 provides the tally results that appear in each outp file.

Table 13: Tally Results for Problem 1041

Tally	Mean	Rel. Error
2	5.2913E-05	0.0008
14	3.8483E-04	0.0013
24	7.7904E-03	0.0009

3 Summary

This document provides verification that the UM multi-mesh capability is functioning as expected. In one-to-one comparisons with results calculated by traditional cell-based tallies, the results are identical. Comparison of the relative errors showed that the tally errors and edit errors are in agreement as well. Additionally, a donut configuration was modeled with both CSG and UM geometries and all tally results between the two calculations displayed exact agreement. The multi-mesh capability is working as expected.

Provided here within are the MCNP6 input listings used in this verification. The problems described is this documents are regression problems 1037 and 1041 in the MCNP6 REGRESSION test suite.

References

[1] “MCNP6 User’s Manual: Code Version 6.1.1 beta,” Denise B. Pelowitz, Andrew J. Fallgren, and Garrett E. McMath (editors), Los Alamos National Laboratory manual LA-CP-00745, Rev. 0 (June 2014).

[2] “ABAQUS USER MANUALS, Version 6.14,” Dessault Systemes Simulia, Inc., Providence, RI (2014).

[3] Roger L. Martz, “Flux Multiplier Capability for MCNP6’s Unstructured Mesh Feature,” Los Alamos National Laboratory, LA-UR-16-22004 (April 2014).

[4] ”MCNP - A General Monte Carlo N-Particle Transport Code, Version 5, Volume I: Overview and Theory,” X-5 Monte Carlo Team, Los Alamos National Laboratory manual LA-UR-03-1987 (2008).