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# Visualization Advancements for the MCNP Code (and a Post-processing Wish List)

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Department of Energy Computer Graphics Forum  
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# Outline

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## Overview & Brief History of the MCNP® Code

Constructive Solid Geometry Tutorial & “GUI”

## Recent Visualization Highlights

Four Approaches to Visualization

Examples

Oak Ridge National Laboratory Pool Critical Assembly

Notional Criticality Accident Alarm System (CAAS)

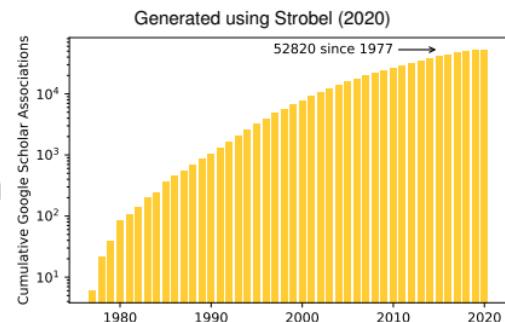
Non-interactive Ray-traced CSG via Radian

Individual History Evolution under Variance Reduction

## Post-processing Wish List for ParaView & XDMF

# Overview & Brief History of the MCNP® Code

- ▶ Monte Carlo particle transport dates back to the Manhattan Project
  - ▶ Richtmyer and von Neumann (1947)
  - ▶ Carter et al. (1975); LASL Group TD-6 (1978, 1979)
- ▶ LANL develops the MCNP code (Goorley et al., 2012), a “gold standard”
  - ▶ The MCNP code has existed in some form for ~40 years
  - ▶ Since 2012: over 11,000 total licenses issued; 1,382 DOE, 917 NNSA
- ▶ Currently undergoing major modernization and modularization work
- ▶ Supports a wide range of DOE analyses and experiment-design studies
  - ▶ Criticality Safety
  - ▶ Experimental Facility Shielding Design
  - ▶ Radiography Experiment Specification
  - ▶ Radiological Protection Planning
  - ▶ Terrestrial & Space Microreactor Design



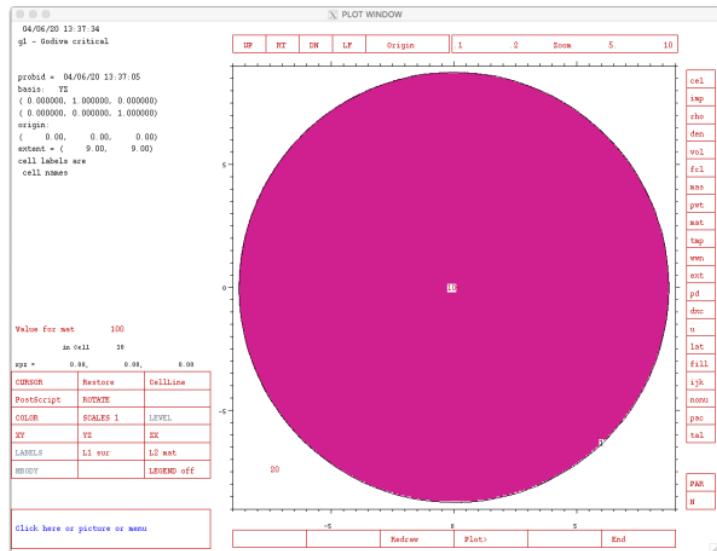
# Overview: MCNP Constructive Solid Geometry (CSG)

- ▶ Boolean combinations of analytic (implicit) surfaces
- ▶ Fast and precise ray tracing
- ▶ Arguably suboptimal geometry specification & visualization experience

```
g1.txt
g1 - Godiva critical
c
c CELL CARDS
10 100 -18.74 -1 imp:n=1
20 0 1 imp:n=0

c SURFACE CARDS
1 so 8.741

c DATA CARDS
kcode 1000 1.0 10 50
ksrc 0.0 0.0 0.0
m100 92235 -.9473
92238 -.0527
~
g1.txt
```

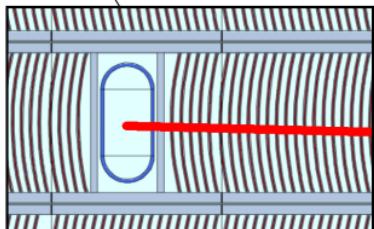
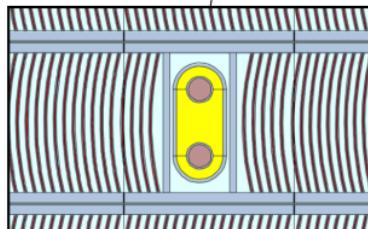
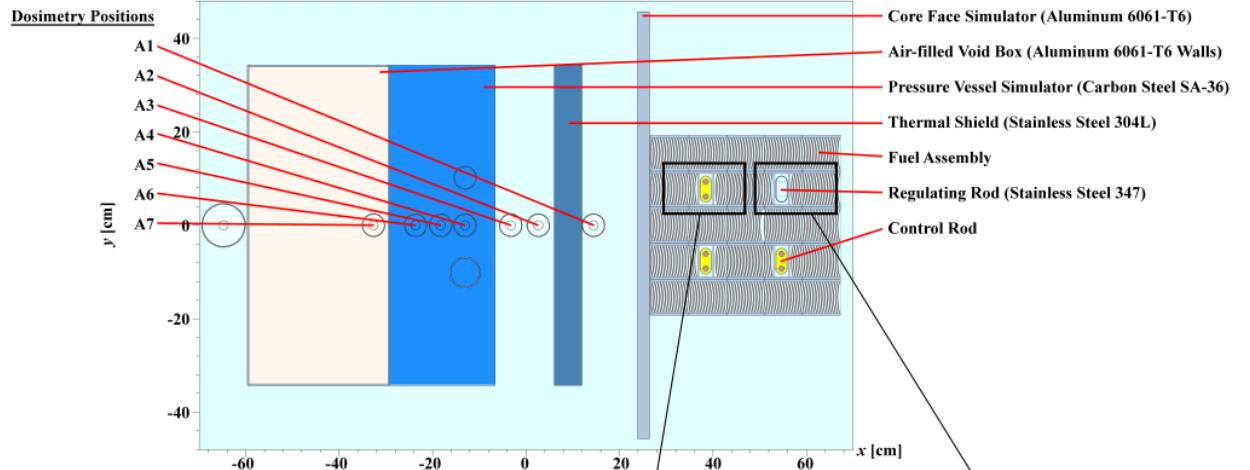


## Recent Highlights

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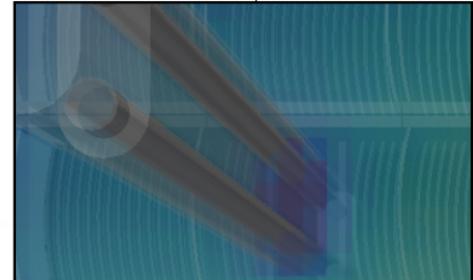
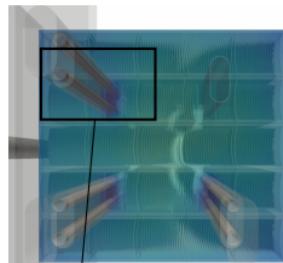
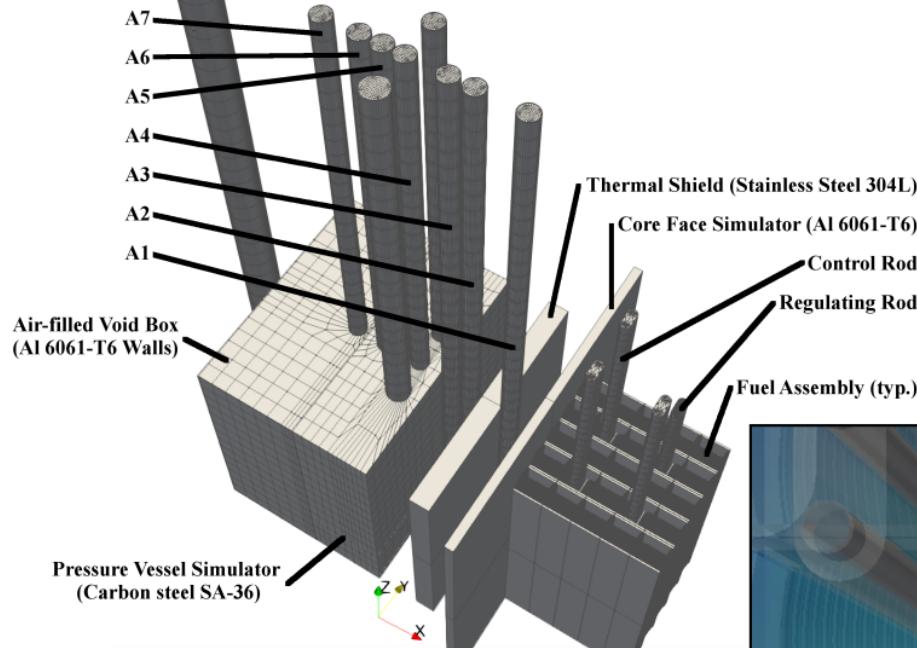
1. MCNP unstructured mesh (UM) geometry since ~2012
  - ▶ Finite-element based; linear & quadratic 4-, 5-, and 6-sided elements
  - ▶ Results historically output in an MCNP-specific format (EEOUT)
  - ▶ Results now\* available optionally as HDF5+XDMF version 2 files
2. MCNP superimposed track-length mesh tallies since ~2003
  - ▶ Structured Cartesian or cylindrical mesh; arbitrary orientation
  - ▶ Other extensions since introduction, e.g., spherical structured mesh
  - ▶ Results now\* available optionally as HDF5+XDMF version 2 files
3. Non-interactive ray-traced MCNP CSG via Radiant (RSICC, 2019)
  - ▶ 3-D, shaded, view of geometry with slicing
4. MCNP discrete particle tracks since ~1990s
  - ▶ Understanding individual statistical samples can be useful

# CSG: Oak Ridge National Lab. Pool Critical Assembly

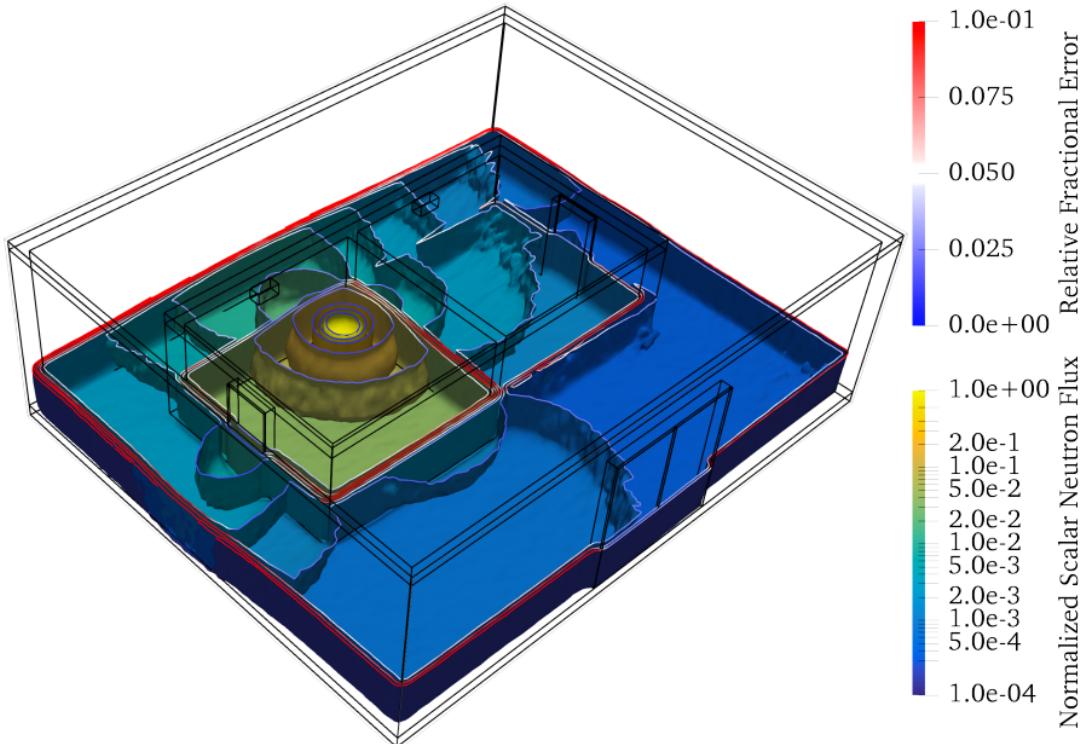


# UM & Mesh Tally: ORNL PCA via ParaView (Ayachit, 2018)

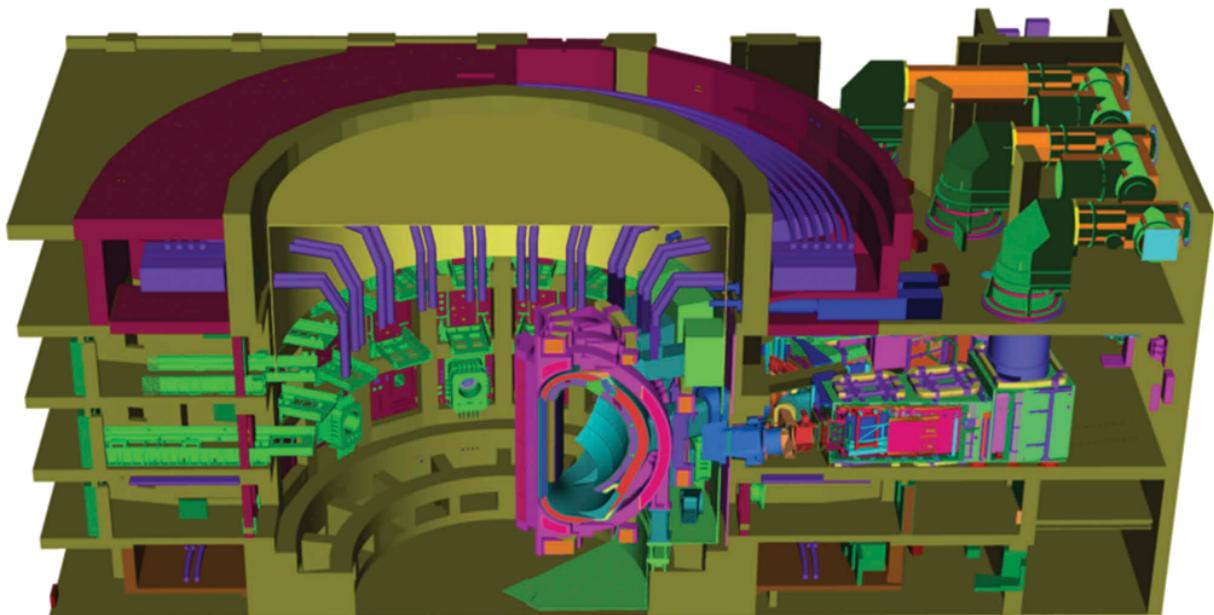
Dosimetry Positions



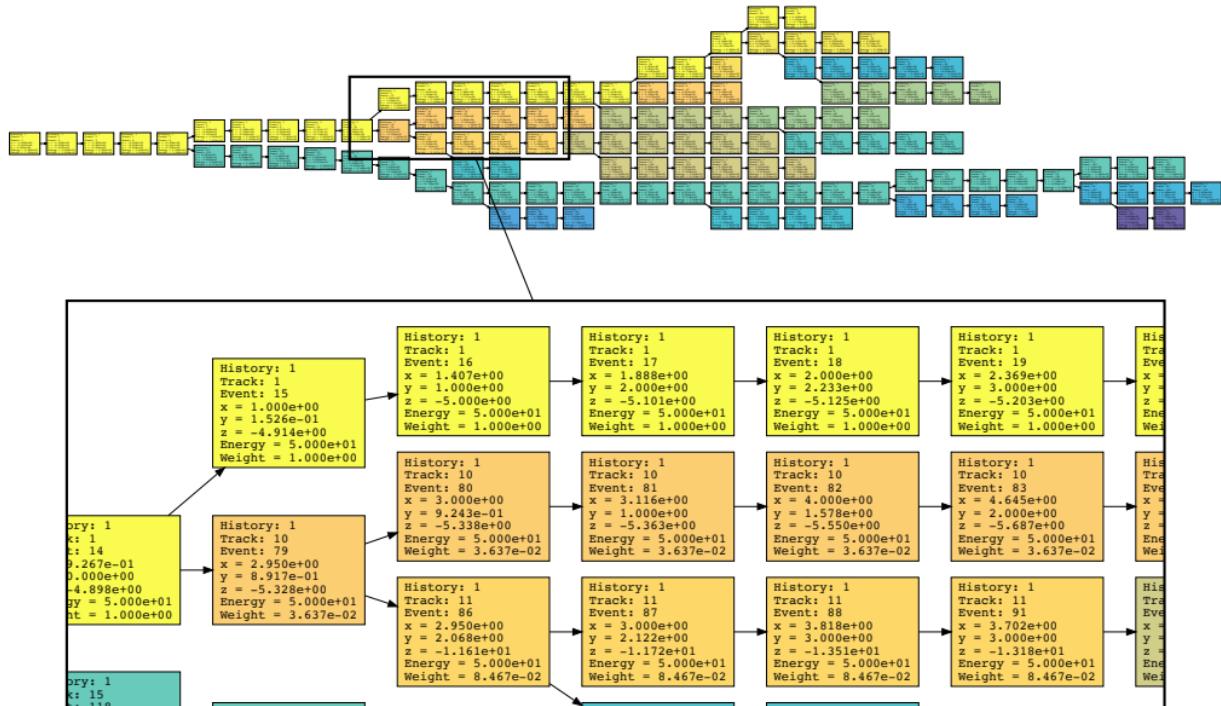
# Criticality Accident Alarm System via ParaView



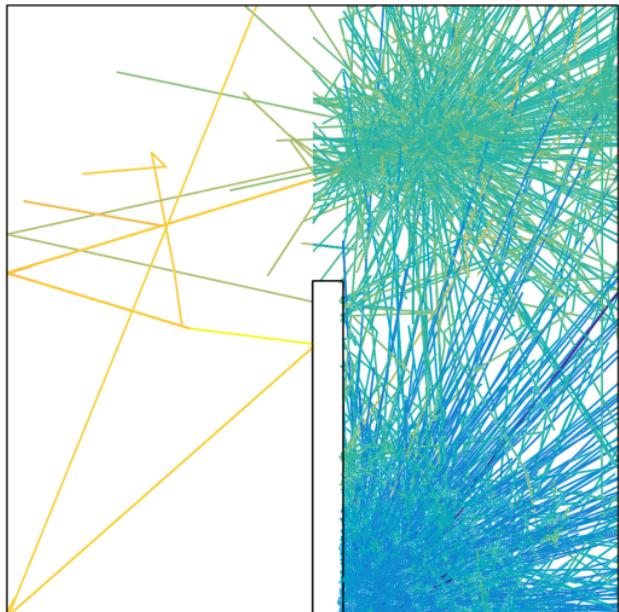
# Non-interactive Ray-traced CSG via Radiant



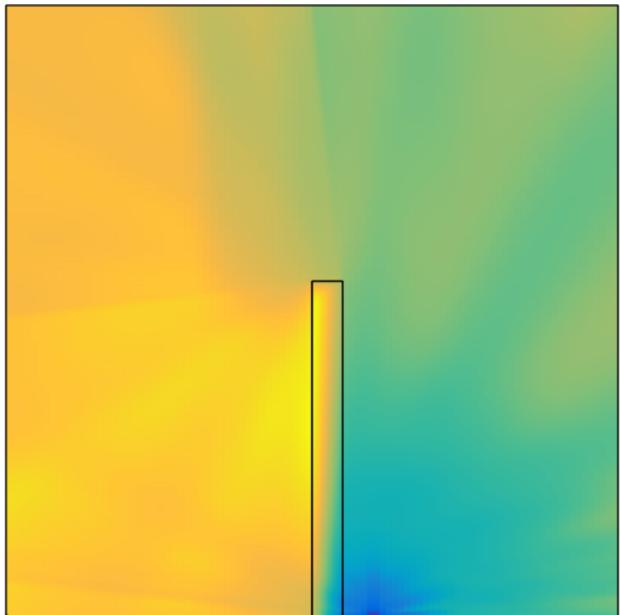
# Particle History Evolution via Graphviz (Ellson et al., 2001)



# Particle History Evolution via VisIt (Childs et al., 2012)



Single History Behavior, 13276 Tracks



Weight Windows,  $6.4 \leq E [\text{MeV}] \leq 20$

# ParaView & XDMF Wish List

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## ParaView

1. **Implicit surface handling & clipping/slicing (CSG visualization)**
2. Proper & adaptive mesh curvature representation (visual accuracy)
  - ▶ Second-order finite elements & structured curvilinear mesh
3. Extensible phase-space organization/querying (e.g.,  $(\underline{x}, \underline{\Omega}, E, t)$ )
4. Mesh element overlap finder (mesh quality metric)
5. ParaView material boundary handling (easier interrogation; cf. VisIt)
6. Easier ParaView camera path definition (UI improvement)

## XDMF

1. Documentation of XDMF specification (supplement/replace xdmf.org)
2. XDMF 1-D function representation (results storage/visualization)
3. Merge XDMF and HDF5 (eliminate two-file paradigm; multi-file?)

# Questions?

Overview & Brief History of the MCNP® Code  
Constructive Solid Geometry Tutorial & “GUI”

## Contact Information

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## Recent Visualization Highlights

Four Approaches to Visualization

Examples

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Non-interactive Ray-traced CSG via Radianit

Individual History Evolution under Variance Reduction

## Post-processing Wish List for ParaView & XDMF

# Backup Slides

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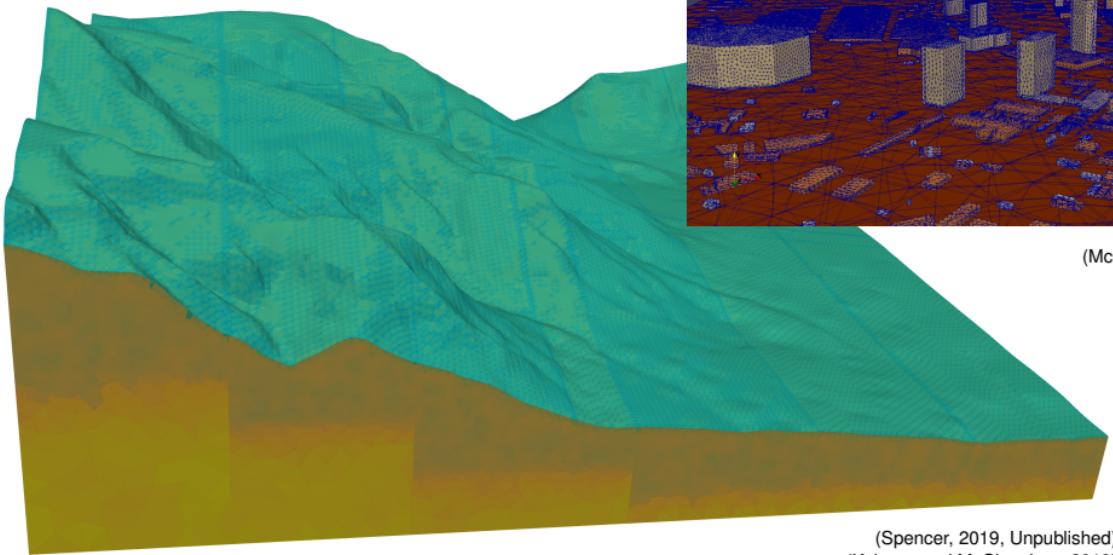
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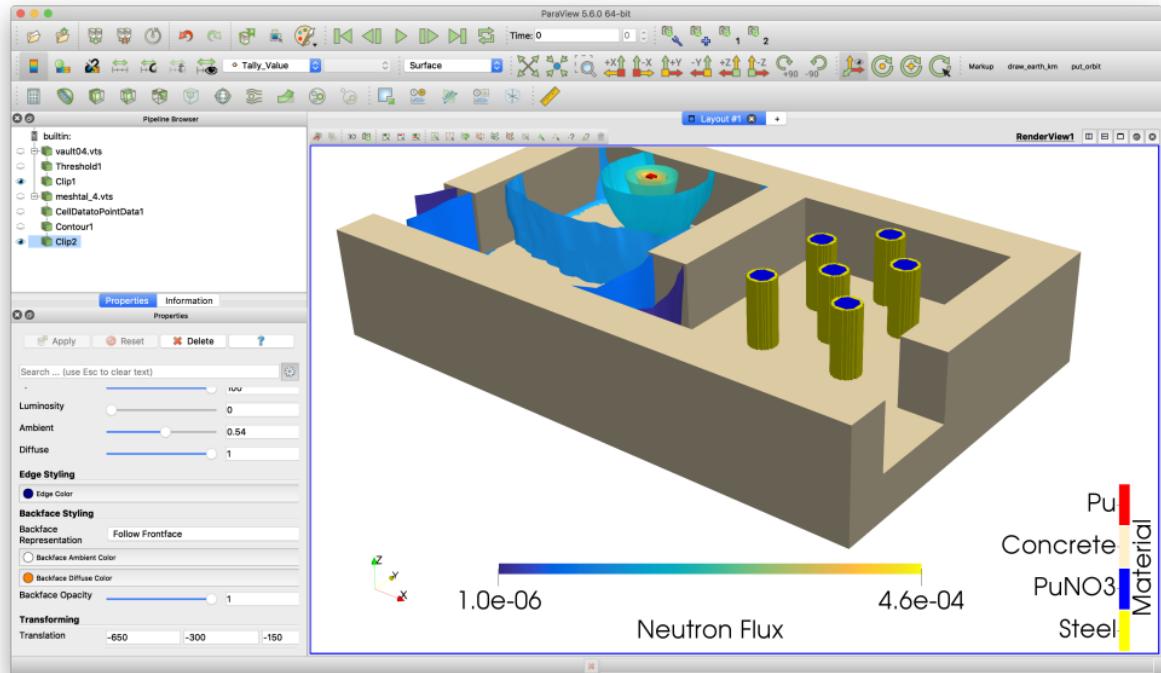
# Terrain and Urban Centers via ParaView



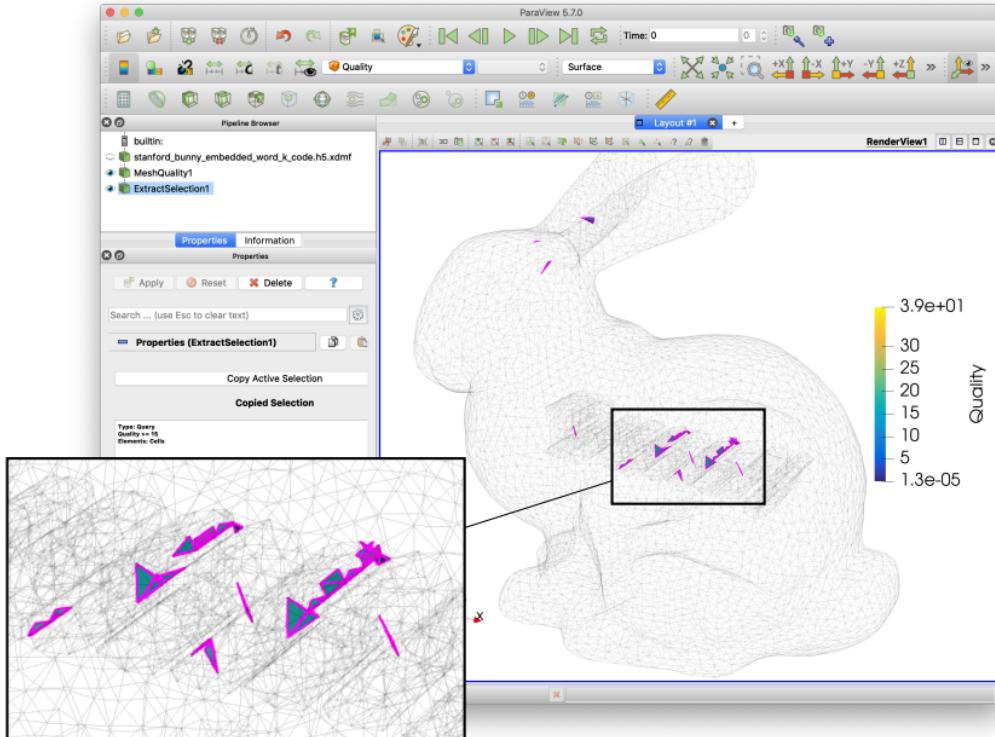
(McClanahan, 2020)

(Spencer, 2019, Unpublished)  
(Kulesza and McClanahan, 2019)

# Fissionable Material Vault Teaching Example via ParaView



# Extracting Low-quality Elements via ParaView



# Stanford Bunny Animation Frames via ParaView

