Enhancements in SCALE 6.1

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Current Nuclear Data Libraries with Continuous-Energy Resonance Processing

Macroscopic Absorption Cross Sections

Energy (ev)

Energy (ev)

SCALE Overview

SCALE 6.0 Capabilities

- Cross-section processing
- Reactor physics
- Criticality safety
- Radiation shielding
- Sensitivity and uncertainty analysis
- Spent fuel and HLW characterization

Sensitivity and Uncertainty Analysis

High-Resolution Geometry Modeling in Monte Carlo and Deterministic Transport

Depletion and Decay, Radiation Source Terms, and Decay Heat

Radiation Shielding with Automated Variance Reduction
Objective of SCALE 6.1 release is primarily enhancements in two key areas:
    ◦ TSUNAMI Mesh Volumes
    ◦ TRITON Bugs

Other features developed under specific projects are captured in this release
KENO
- Easier mesh specification
- Improved mesh volume calculation
- Improved mesh output edits
- Region mean free paths in CE KENO(s) enabled

Fission source distribution output
- For CAAS or visualization
- MG/CE, KENO V.a/KENO–VI
- Exported in .3dmap format with uncertainties
KENO Mesh Accumulator

- For TSUNAMI, forward and adjoint fluxes are accumulated over same mesh, then multiplied together prior to summing over a region (e.g. all fuel pins).
- Volume of each material within each mesh region is required.
Array Without Automated Mesh

6×6 Array of 4-region cell for 144 regions

4 flux regions
fuel, gap, clad, mod.
Automated Mesh
(1.375 x pitch)
Automated Mesh Fuel Regions
Automated Mesh Moderator Regions
Automated Mesh
Clad Regions
Automated Mesh
Single Fuel Mesh
Automated Mesh
Single Clad Mesh
Automated Mesh
Single Moderator Mesh
Evolution of TSUNAMI Mesh

**SCALE 5.0–5.1**
- Limited uniform mesh
- Analytic volume calculation
  - Applied only to cuboids and cylinders

**SCALE 6.0**
- More flexible planar mesh
- Stochastic volume calculation
  - Applied to generalized geometry
  - Limited volume control

**SCALE 6.1**
- Easier definition of mesh planes
- Improved volume control
- Improved volume defaults

**SCALE 6.2–7.0**
- No mesh required with contribution
Example: PU–SOL–THERM–014

- Pu solution cans (~30 cm)
- Large room (~15 m)
- Desire 3 cm mesh for fissile solution
- Uniform mesh would create ~80,000,000 mesh intervals
- Require ~300 GB of RAM
SCALE 6.0 Planar Mesh

- Mesh refined across fissile solution
- Requires \(~140,000\) mesh intervals
- \(~500\) MB of RAM

![Mesh Grid]

![Bar Chart]

- Direct Perturbation
- TSUNAMI–3D No Mesh
- TSUNAMI–3D SCALE 6.0 Mesh
Planar Mesh

read gridgeometry 1

xplanes
-750 -700 -650 -600 -550 -500 -450 -400 -350 -331 -325 -322 -319
-151 -148 -145 -142 -139 -100 -50 0 50 100 150 200 250 300 350
400 450 500 550 600 650 700 750
end

yplanes
-104 -101 -98 -95 -92 -89 -86 -83 -80 -77 -76 -56 -36 -16 4
24 40 43 44 46 49 52 55 58 61 64 67 70 84 100 150 200 250 300
350 400 450 500 550 585
end

zplanes
-250 -200 -150 -100 -50 0 50 100 150 200 250 300 350 400 450 500
550 570
end
end gridgeometry
To compute sensitivity coefficients, the volume of each region within each mesh interval must be quantified.

Beginning with SCALE 6.0, KENO computes the volume through a stochastic sampling process.

SCALE 6.0 defaults:
- 5000 points per generation for 1000 generations.

SCALE 6.1 defaults:
- 5000 points if volume < 13,600 cm$^3$
- For larger volumes, the number of points is calculated as:

$$points = \frac{volume}{\ln\left(\frac{volume}{5000}\right)}$$
Volume Input

With SCALE 6.1 defaults, PU–SOL–THERM–014 mesh volumes are computed with ~150,000,000 points for 1000 batches.

- Input sampling directly:
  - read volume
  - points=25000
  - batches=4000
  - end volume

- Input sampling density:
  - read volume
  - sample_den=0.1
  - batches=4000
  - end volume
Fission Source Viewing
Fission Source Uncertainty
Shielding Analysis – MAVRIC

- Multiple sources
- Spatial variation of sources
- Energy distributions from ORIGEN or AMPX
- Macro materials for Denovo calculation
- Cylindrical mesh grids
- MAVRIC Utilities
Cylindrical Mesh Tally

Dose (rem/hr)
Depletion and Decay

- Arbitrary group structures for COUPLE/ORIGEN
- Support for ENDF/B–VII decay libraries
- Energy–dependent fission yields
- Cross section transitions from multiple sources
  - JEFF–3.0/A based AMPX libraries
  - AMPX library from SCALE
  - Input from user
Reactor Physics

- TRITON bug fixes as documented newsletter
  - KMART updates to correct mixture power distributions
  - KENO blocks START, VOLUME, and PLOT now work
- TRITON enhancements
  - Greatly improved runtime for large models
  - Speedup in cell data and reaction rate calculations
- Parallel capabilities
  - Threaded NEWT with OpenMP
  - Parallel branch cases with RUNNER (MPI)
- NEWT improvements
  - HTGR prismatic geometry
  - n–gamma libraries
  - CMFD
  - Better grid generation
  - Better few–group cross section generation
  - Improved output edits
Sensitivity and Uncertainty

- Improved KENO mesh and mesh volume greatly benefits TSUNAMI-3D
- TSUNAMI-2D based on NEWT is introduced
- Generalized perturbation theory calculations in 1D and 2D provide sensitivities/uncertainties due to cross sections for:
  - Flux ratios
  - Reaction rate ratios
  - Few group cross sections, etc
- TSURFER
  - Additional uncertainty edits
  - Additional plots
  - Improved output
TSURFER Output

TSURFER - Adjust and Initial $k_{eff}$ Plot
tsurfer sample problem

Plot of Adjusted and Initial $k_{eff}$ C/E

Double-click an item on right side of window to plot, or select multiple items and right click to plot.

keff Bias and Uncertainty

<table>
<thead>
<tr>
<th>Response File</th>
<th>Adjusted keff C/E</th>
<th>Initial keff C/E</th>
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Nuclear Data

- Improved probability table data for unresolved resonance region for U and Pu
- 238-group neutron libraries
  - New weighting spectrum with modified tie-in of fission spectrum – better VHTR performance
  - Use of double-precision in AMPX routines
- ORIGEN Library
  - ENDF/B-VII decay and fission libraries with JEFF multigroup cross sections in many group structures
  - Decay libraries with 2227 nuclides
    - 174 actinides
    - 1149 fission products
    - 904 structural activation materials
- Coupled n-gamma libraries
  - Many improvements in gamma yield data
Graphical User Interfaces

- GeeWiz
  - Substantial improvement in functionality and stability
  - Added code support
    - STARBUCS
    - TRITON
    - MAVRIC enhancements
    - TSUNAMI–GPT

- Javapeño
  - CE KENO cross section plotting
  - OPUS plotting (replaces PlotOPUS)
  - NEWT contour plots
  - Custom installer
Continuous-energy Plot

[Graph showing continuous-energy plot with energy in eV on the x-axis and microscopic cross-section in barns on the y-axis. The plot includes lines for various cross-sections and fission processes, with annotations for U-238 n,gamma and Pu-239 fission at T=293.0K.]
Infrastructure Moderization

- **GForge**
  - Collaborative development environment with web interface.
  - All issues can be identified and tracked.
  - SCALE QA now conducted and tracked within GForge
  - SCALE development ideas and issues are easily tracked to resolution
  - SCALE Help migrated to GForge
Build system

- CMake build system
- Same code and build system will be used on all platforms, Linux, Mac, Windows
- 64-bit Windows build for first time

Supported platforms:

- Linux 32- and 64-bit
- Mac 32- and 64-bit
- Windows 32- and 64-bit
New Installer

- Consistent experience on Linux, Mac, Windows
Schedule

- SCALE 6.1 beta sent to limited distribution
- Delivery to RSICC by end of November
- Distribution to end-users after a few weeks of testing at RSICC
  - Likely late 2010 or early 2011