

Criticality Accident Alarm System (CAAS) modeling with SCALE

SCALE 6.3.1

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Learning goals

- Introduce attendees to the SCALE Criticality Accident Alarm System (CAAS) analysis capability
- Identify the input syntax and where additional input is required in the KENO-VI/CSAS6 and Monaco/MAVRIC input files to use the CAAS analysis capability

CAAS model components

- Criticality problem
 - Fission neutron source distribution (space, energy)
 - Average number of neutrons per fission
- Shielding problem
 - Source neutrons contribute to neutron dose
 - Source neutrons scatter and create secondary photons, which contribute to photon dose
 - Source neutron absorption produces no fission neutrons (`fissionMult=0`), but fission photons are produced (`secondaryMult=2`), which contribute photon dose
 - Usually, a deep-penetration problem requiring variance reduction

CAAS modeling in SCALE

- KENO-VI (through CSAS6 sequence, MG, or CE)
 - Calculates k_{eff}
 - Calculates $\bar{\nu}$
 - Creates “*fission_source.3dmap*” (previously “*fissionSource.3dmap*”)
- MAVRIC Utility: *mt2msm* converts mesh tally (*.3dmap) to mesh source (*.msm)
 - e.g., “*fissionSource.msm*”
- MAVRIC
 - Uses the fission mesh source, “*fissionSource.msm*”, as a source
 - Transports neutrons and photons
 - Region tallies, point detector tallies, mesh tallies
 - Can use CADIS and FW-CADIS variance reduction

KENO-VI criticality calculation

Tell KENO-VI to store fission_source.3dmap

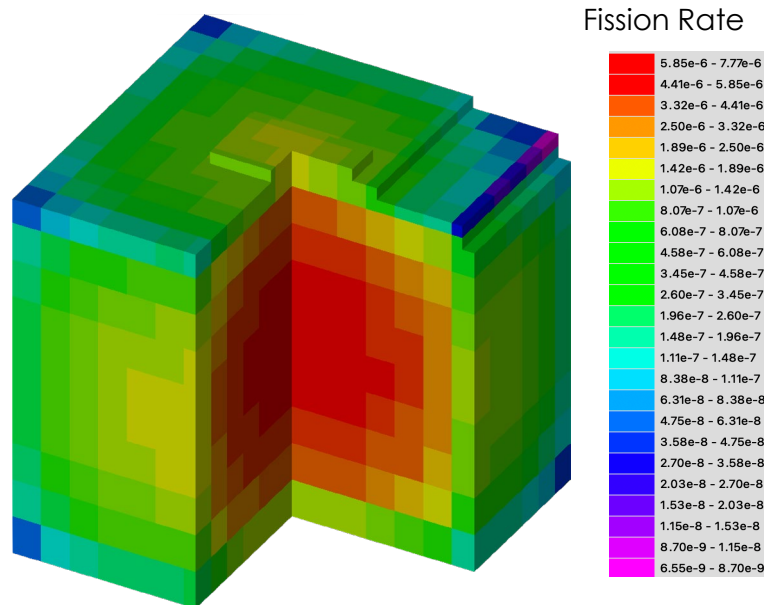
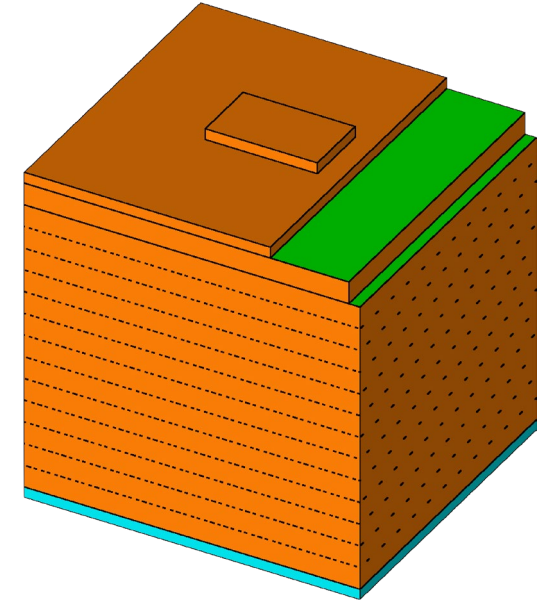
```
'-----  
' Parameters Block  
'-----  
read parameters  
    ...  
    cds=yes  **or**  cds=1  
'           cds=# if you specify more than one grid geometry  
end parameters
```

Specify the grid geometry for fission_source.3dmap

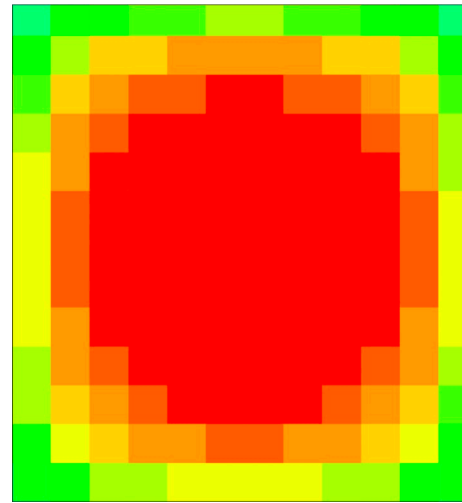
```
'-----  
' Grid Block - mesh grid for source  
'-----  
read grid 1  
    xLinear 10  -10.0 10.0  
    yLinear 10  -10.0 10.0  
    zPlanes -10.0 -8 -6 -4 -2 0 2 4 6 8 10 end  
    title="easy grid"  
end grid
```

KENO-VI results

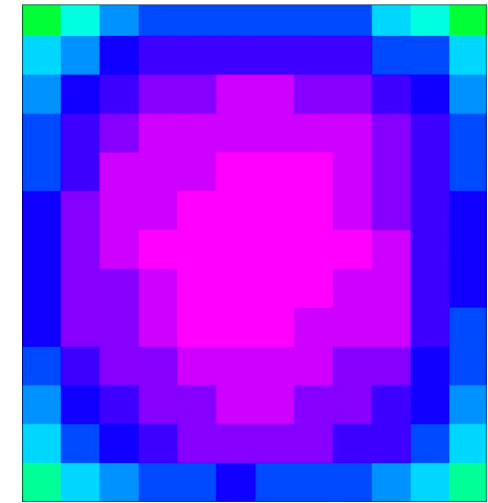
- KENO-VI calculates $\bar{\nu}$ and stores in it a file `kenoNuBar.txt`
- Use Fulcrum to visualize the fission source neutron distribution *.3dmap



Fission Rate



Rel. Uncertainty



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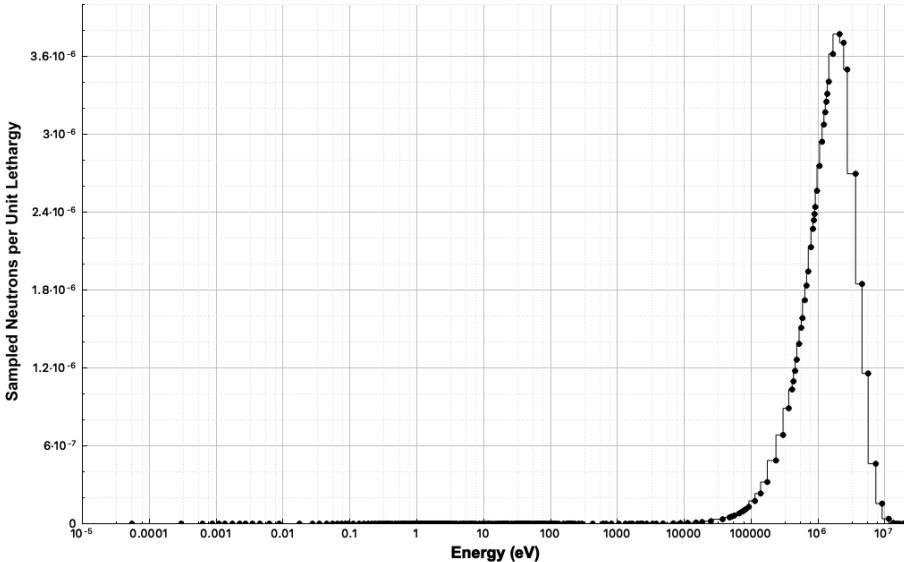
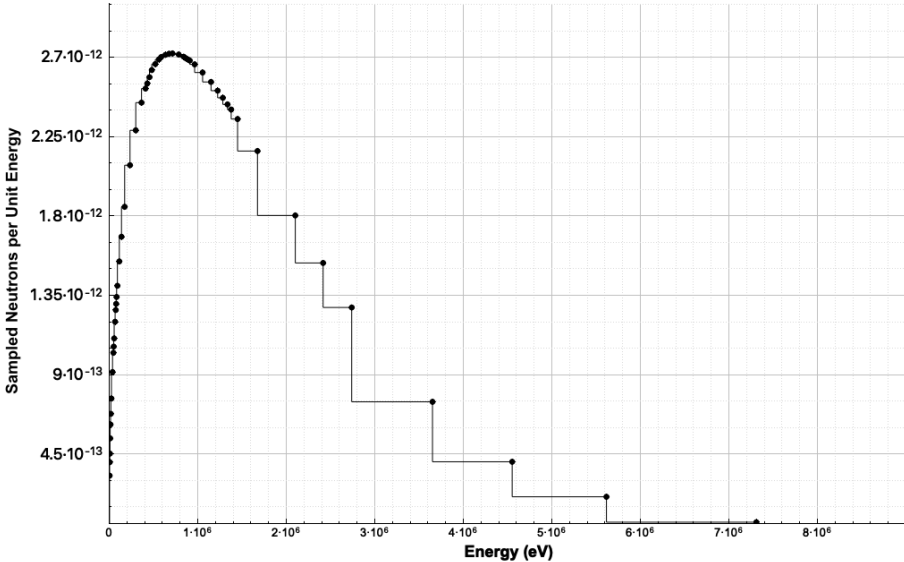
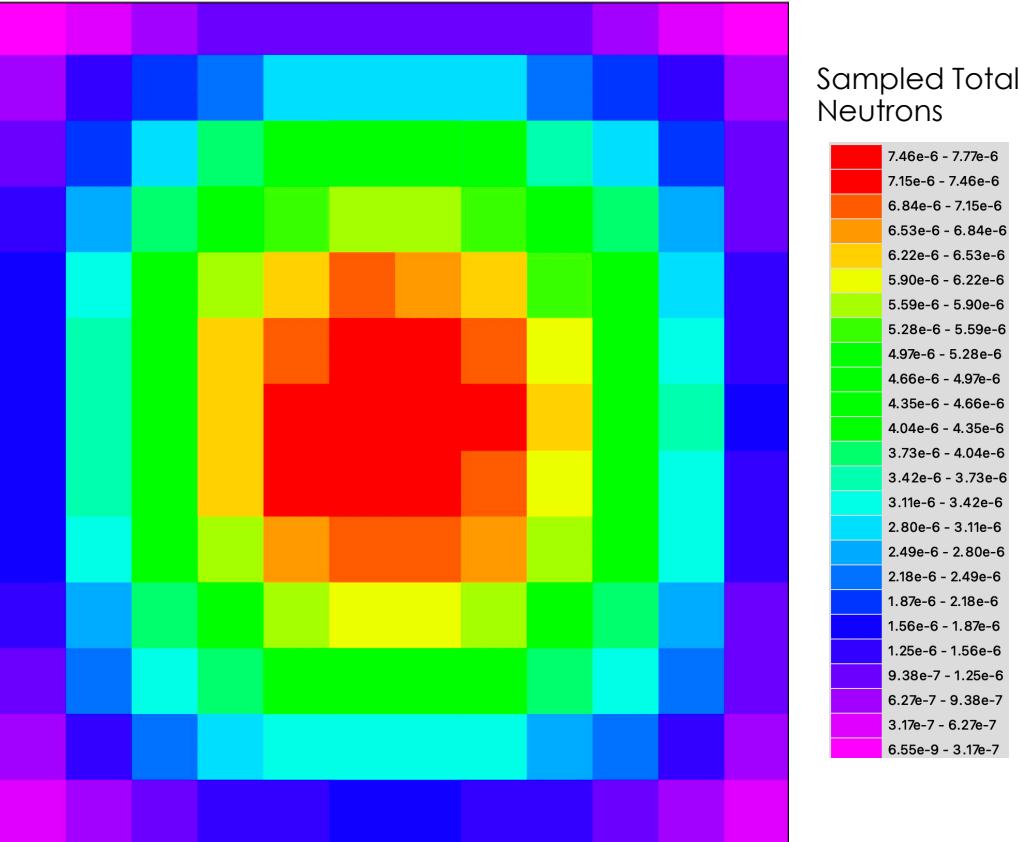
MAVRIC utility: mt2msm

- Convert a *.3dmap into a *.msm file

```
'=====
' Convert the mesh tally into a mesh source
'=====
=mt2msm
'C:\documents\fission_source.3dmap'    ! Mesh tally name
1                                     ! Family 1 of mesh tally
-1                                    ! -1 use all energy groups
1                                     ! Source: 1-neutron, 2-photon
'C:\documents\fissionSource.msm'      ! Mesh source map name
end
```

- Use version-specific mt2msm to prevent misinterpretation of data

Mesh source map



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 - Calculates $\bar{v}$
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MAVRIC shielding example

Use the fissionSource.msm

```
'-----  
' Source Block - for 1e18 fissions  
'-----  
read sources  
  src 1  
    meshSourceFile="fissionSource.msm"  
    origin x=280 y=300 z=100  
    fissions=1.0e18  
    nu-bar=2.6  
  end src  
end sources  
read parameters  
  ...  
' turn off neutron multiplication, turn on photon production  
  fissionMult=0 secondaryMult=2  
end parameters
```

Use importance maps block for biasing. MAVRIC will create an importance map and biased source using its cross section library group structure.

Common items: KENO-VI and MAVRIC

- Cross section library
 - Can be the same or different
 - KENO-VI fission source group structure is converted when loaded by MAVRIC
- Materials
 - Can be the same or different
- Geometry
 - Can be the same or different
 - Origins can be offset but not rotated
- Mesh grid
 - Can be the same or different
 - KENO-VI fission source grid geometry is converted when loaded by MAVRIC

Optional fission photons

- To model fission photons, the following are required
 - Keyword `secondaryMult>0` in the parameters block
 - If specifying the `strength=` of the neutron source, then the value of $\bar{\nu}$ needs to be known; if the file `kenoNuBar.txt` doesn't exist, then the user can supply with keyword `nu-bar=  $\bar{\nu}$`

Format

```
read sources
  src 1
    meshSourceFile="fissionSource.msm"
    fissions=num_fissions -or- strength=num_neutrons
    nu-bar=nu_bar_from_keno
  end src
end sources
```

Avoid “duplicate” neutron multiplication

- The `fissionMult=0` keyword must be included in the parameters block to turn off the production of fission neutrons when a neutron is absorbed by fissile material in the MAVRIC calculation (fission photons are still produced)
- Because the fission neutrons are already accounted for in the KENO-VI mesh source file, failure to use the `fissionMult=0` keyword in MAVRIC will, at a minimum, result in incorrect results
- For systems at or near critical, without `fissionMult=0` the MAVRIC calculation may never end, since neutrons will be added to the particle bank at essentially the same rate at which they leave the system or get killed

Input file – One file

```
'=====
' KENO-VI Criticality Calculation
'=====

=csas6
A problem title line goes here
xn238
. . .
. . .
end

'=====
' Convert mesh tally into mesh source
'=====

=mt2msm
'fission_source.3dmap'
1
-1
1
'fissionSource.msm'
end

'=====
' MAVRIC Shielding Calculation
'=====

=mavric
Another problem title line goes here
V7.1-28n19g
. . .
. . .
read sources
    src 1
        meshSourceFile="fissionSource.msm"
        fissions=1.0e+15
    end src
end sources
. . .
. . .
end data
end
```

Input file – Multiple files

C:\documents\work\today1.inp

```
'=====
' KENO-VI Criticality Calculation
'=====
=csas6
A problem title line goes here
xn238
. . .
. . .
end
```

Creates: today1.kenoNuBar.txt,
today1.fission_source.3dmap

C:\documents\work\today2.inp

```
'=====
' Convert mesh tally into mesh source
'=====
=mt2msm
'c:\documents\work\today1.fission_source.3dmap'
1
-1
1
'c:\documents\work\today2.fissionSource.msm'
end
```

Creates: today2.fissionSource.msm

When using multiple input files, these files must be copied to the temp directory for MAVRIC calculation

C:\documents\work\today3.inp

```
=shell
cp c:\documents\work\today1.kenoNuBar.txt kenoNuBar.txt
cp c:\documents\work\today2.fissionSource.msm fissionSource.msm
end

'=====
' MAVRIC Shielding Calculation
'=====
=mavric
Another problem title line goes here
V7.1-28n19g
. . .
. . .
read sources
  src 1
    meshSourceFile="fissionSource.msm"
    fissions=1.0e+15
  end src
end sources
. . .
. . .
end data
end
```

Output file – fission source

```
Source specification: 1
  title:
  fissions: 1.0000000E+00 fissions/sec
  strength: 3.1539270E+00 particles/sec
  sample: 1.0000000E+00
  Mesh Source specification:
    total strength          3.1539270E+00
    biased strength         9.9990763E-01
    Number of cells         2744
      in x dimension        14
      in y dimension        14
      in z dimension        14
    Number of spectra       1472
    Number of groups        252
    Energy weights for biasing F
    Volume amounts          T
    Volume weights for biasing F
    Number of cells with source 1472
    Sum(this%amounts)       3.1539270E+00
    Sum(this%vweights)      2.7440000E+03
    Total mesh volume       2.7440082E+03
    Source voxels volume    1.4720010E+03
    Limited to mixture      1
  Energy Structure
  Neutron
    Energy Groups 252 from 2.00000E+07 eV to 1.00000E-05 eV
  Photon
    None
  geometry limited by:
    mixture limited to mixture 1
  directional dependence:
    isotropic (default)
```

CAAS modeling summary

- Two-step modeling
 - Generate fission source distribution with CSAS
 - Import fission source to MAVRIC to perform CAAS analysis
- Important things to remember
 - CSAS models can be simple enough to only cover the fissile materials
 - MAVRIC models should include more detail for the CAAS
 - The fission source has spatial and energy distributions
 - no angular information and assumed to be isotropic
 - Disable fission neutrons (`fissionMult=0`) and enable fission photons (`secondaryMult=2`) in MAVRIC
 - Most analyses require variance reduction methods