Description and use of the SCALE Sampler Parametric Capability for Engineering Analysis and Optimization

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Outline

1. Introduction
2. Sequence input
3. HALEU package design studies
4. Scoping calculations for subcritical limits
5. Conclusion

Introduction

- Sampler was introduced for UQ via random sampling in SCALE 6.2
  - Can sample nuclear data, number densities, and dimensions
- Parametric capability added in 6.2.2 for quantities in input
  - Deterministic sweeps through specified variables
  - Range and number of points both user-specified
  - Provides capability to cover parametric space, including multiple variable sweeps, with no scripting by analyst
- Sampler can also be used to convert between engineering specifications and input parameters
  - Examples: diameters to radii, masses to number densities

Sequence input

- Sampler designed to work with an existing SCALE input
  - CSAS presented here, but Sampler can be used with any sequence
- Each variable to be modified is defined in a variable block
  - Some differences between variable blocks for parametric variables and for random sampling/evaluation variables
  - Variables defined via calculations are evaluated in each parametric input
- New SCALE input written for each parametric case
  - Run within Sampler or normally as standalone SCALE inputs

Sequence input (continued)

- Parametric block provides which variables to sweep and how many points to use
- Multiple variables can be considered in a single calculation
- Sampler generates all combinations of variables
  - Number of cases generated is product of the points for each variable

```
read parametric
  variables= uo2_frac b_content end
  n_samples= 17        5   end
end parametric
```

Sequence input (continued)

- Variable blocks for variables in the parametric block:
  - Set distribution=uniform
  - Provide minimum and maximum
  - Nominal value is ignored but required to be between min and max
- Values used are calculated as:
  - *n_samples*=1 uses just the minimum
  - *n_samples*=2 uses the minimum and maximum
  - *n_samples*= ≥ 3 creates minimum, maximum, and (n-2) equally spaced additional inputs

Sequence input (continued)

Variable block definition

```
read variable[b_content]
   distribution=uniform
   minimum=10.0 value=15 maximum=20
    cases= cask end
end variable
```

CSAS input (placeholders)

```
wtptSAM2X5 6 7.5 8
  6000  3.8   5000  #{b_content}
  24000 18.0  25000 1.9  26000 49.7
  74000 1.6   42000 7.4  14000 2.4
 1.0 end
```

SIREN expressions are also supported to define path to variable without altering SCALE input:

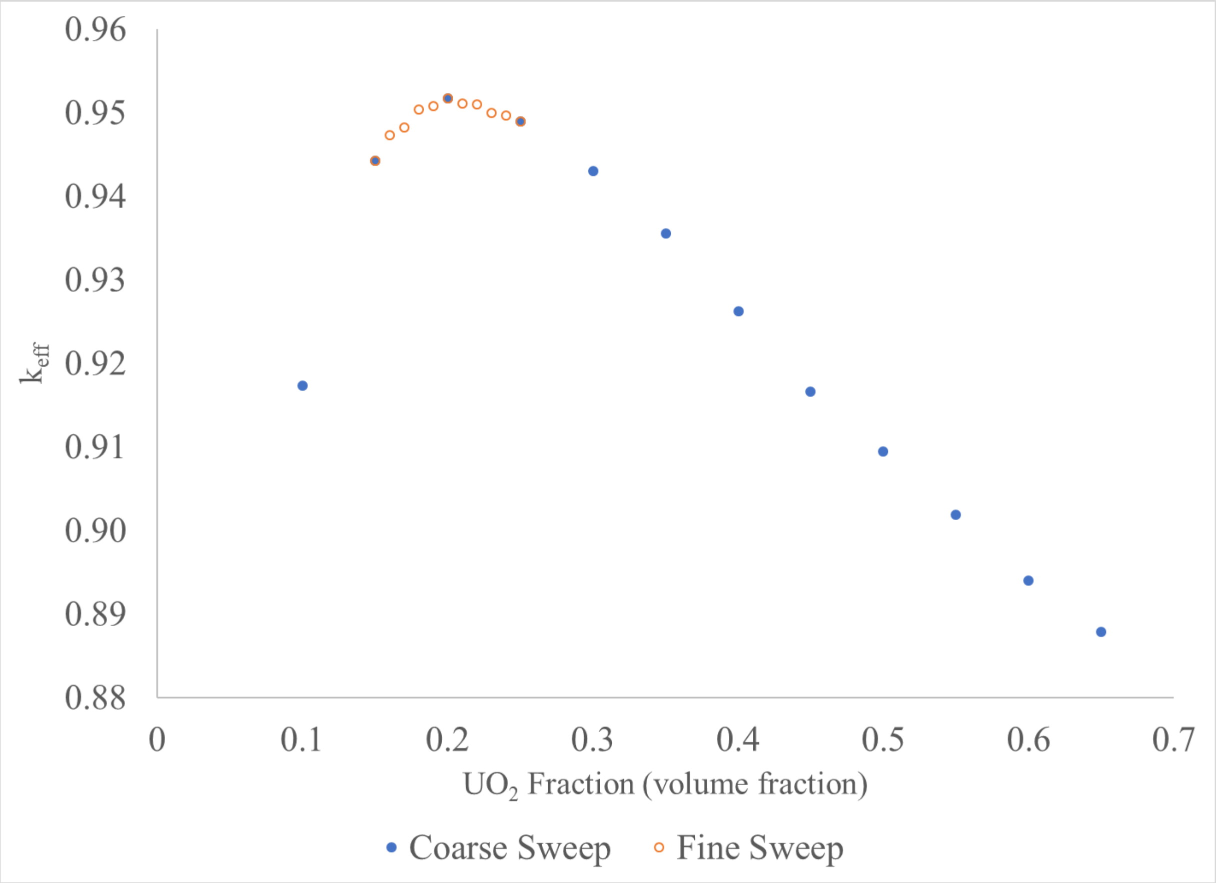
```
siren="/csas6/comps/wtptcomp/atom_wtpt_pair[id='5000']/wtpt"
```

HALEU package design studies

- Preconceptual design studies for a HALEU UO_2 shipping package undertaken by INL, PNNL, and ORNL
  – Criticality analysis led by ORNL
- Sampler parametric capability used extensively
  – Parametric sweeps for design variables
  – Coarse sweeps followed by more detailed sweeps with higher precision calculations
  – Sweeps in design variable space with calculations in Sampler to convert those parameters to KENO inputs

HALEU package design studies (continued)

- Optimum mixture of UO_2 and H_2O in package:



HALEU package design studies (continued)

- Optimum UO_2/H_2O with different boron loadings:

UO_2 Fraction	Boron Areal Density (g $^{10}B/cm^2$)		
	0.0017	0.0228	0.0439
	k_{eff} values		
0.10	1.0267	0.9585	0.9339
0.11	1.0285	0.9615	0.9365
0.12	1.0302	0.9621	0.9379
0.13	1.0318	0.9633	0.9398
0.14	1.0321	0.9650	0.9408
0.15	1.0310	0.9645	0.9413
0.16	1.0311	0.9645	0.9404
0.17	1.0327	0.9644	0.9409
0.18	1.0324	0.9649	0.9401
0.19	1.0296	0.9632	0.9390
0.20	1.0294	0.9622	0.9375

Scoping calculations for subcritical limits

- Example 1: SCL for UO_2F_2 solution in spherical tank
- Different concentrations studied with a fixed mass
- Concentration calculated for each radius generated in the parametric sweep

```
read variable[r_inner]
   distribution=uniform
   minimum=10.0 value=15 maximum=20
end variable
```

```
read variable[conc]
    distribution=expression
   expression="10700/((4/3)*3.1415927
       *r_inner^3)/1000)"
end variable
```

Recall that the number of radii generated is set in the parametric block

Scoping calculations for subcritical limits (continued)

- Example 2: SCL for lattices
- Multiple parameter sweeps on fuel rod radius and fuel rod pitch

Rod Separation (cm)	Radius (cm)		
	7.3222	8.4333	9.5444
	k_{eff} values		
1.000	1.0035	0.9736	0.9432
1.333	1.0080	0.9753	0.9485
1.667	1.0066	0.9735	0.9485
2.000	0.9990	0.9683	0.9384
2.333	0.9818	0.9525	0.9306
2.667	0.9606	0.9374	0.9150
3.000	0.9373	0.9176	0.8959
3.333	0.9147	0.8931	0.8785
3.667	0.8875	0.8707	0.8562
4.000	0.8632	0.8476	0.8365

Conclusion

- Parametric capability added to Sampler in SCALE 6.2.2
- Useful for establishing system behavior with respect to several variables and their ranges
- Useful capability for parametric studies necessary for NCS evaluations

Questions?

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