Verification of MCS particle transport calculations using the Sky-shine experiment in the SINBAD benchmark

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- Calculation results
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Part I. Introduction
Introduction

Skyshine Benchmark

- Ra-Reactor
- Tokamak Fusion Test Reactor

MCS Code

MCS code is a particle transport simulation program developed by UNIST.

Validation Method

The validation methodology for MCS code features is the so-called V&V process (verification and validation—MCNP and Benchmark). Evaluation of experimental configuration and material data was made based on calculations performed mainly with MCNP6, using ENDF/B-VII.1 continuous-energy cross sections.

All the measurement uncertainties are assumed to be at 3 standard deviations (3σ) since it is not clearly stated in the benchmark documentation.
Part II. Skyshine Model
Skyshine RA-reactor
This experiment was carried out in the RA reactor in Kazakhstan. The position of the detector is 1m above the ground and 50, 100, 200, 300, 400, 500, 600, 800 and 1000m from the axis. The statistical data in the experiment are Neutron Flux, Neutron Dose Rate, and Neutron Spectra. Uncertainties (1σ) of the on-site measurements: (10-20%)
## RA reactor experimental detector type

<table>
<thead>
<tr>
<th>Detector</th>
<th>Characteristics of the Detector</th>
<th>Approximate Energy Range</th>
<th>Function obtained from Measurements</th>
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<tbody>
<tr>
<td>Scintillation counter with a LiF+ZnS(Ag) pellet</td>
<td>⌀25 × 2mm pellet (⌀40 × 200mm counter)</td>
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<td>Thermal neutron flux</td>
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<td>0.5eV – 10MeV</td>
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<td>0.5 – 10MeV</td>
<td>Neutron dose rate</td>
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<tr>
<td>Plastic+ZnS(Ag)</td>
<td>⌀80 × 6mm pellet</td>
<td>1 – 10MeV</td>
<td>Fast neutron flux</td>
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<tr>
<td>H counter</td>
<td>⌀32 × 150mm; 3atm (H₂-90%, CH₄-9.4%, ³He-0.4%)</td>
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Skyshine Model

Skyshine RA-reactor
The size of the simulation model is the same as the size of the actual reactor. Detector geometry is not modelled. **Neutron source** modelled as cylinder source with energy distribution and run in **fixed-source mode**.
Skyshine TFTR (Tokamak Fusion Test Reactor)
The experiment was conducted at the Tokamak Fusion Test Reactor in the Princeton Plasma Physics Laboratory. The D-T neutron source is used as the source information. The neutron dose rate was measured. The measurement uncertainty of the neutron dose rate is within 30%. Detector: $^3$He proportional detector, Fuji Electric NSN10002.

Model figure of TFTR and detector locations.
Skyshine TFTR (Tokamak Fusion Test Reactor)

The actual reactor model is simplified. The source is located at a height of 1.8 meters from the horizontal. The shape of the reactor is a cylinder with a height of 13 meters, a radius of 11.5 meters, and a thickness of about 3 meters. The main shielding material is concrete. Detector geometry is not modelled. Neutron source modelled as point source with energy & angular distribution and run in fixed-source neutron-photon mode.
Part III. Calculation results
In order to facilitate observation, the Y-axis uses a logarithmic scale.
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Calculation results

Skyshine RA-reactor

**Neutron Dose Rate** at different Distances from the RA Reactor

$D_n$, [$\mu$Sv/h]

- **Experiment**
- **MCS**
- **MCNP**

In order to facilitate observation, the Y-axis uses a logarithmic scale.
Skyshine RA-reactor

Differential Neutron Spectra at 100m from the RA Reactor, $\Phi(E), [1/(cm^2\cdot s\cdot MeV)]$. 

- Experiment
- MCS
- MCNP

Differential Neutron Spectra at 200m from the RA Reactor, $\Phi(E), [1/(cm^2\cdot s\cdot MeV)]$. 

- Experiment
- MCS
- MCNP

In order to facilitate observation, the Y-axis uses a logarithmic scale.
Calculation results

Skyshine RA-reactor

Differential Neutron Spectra at 400m from the RA Reactor, $\Phi(E), [1/(\text{cm}^2 \cdot \text{s} \cdot \text{MeV})]$.

Differential Neutron Spectra at 600m from the RA Reactor, $\Phi(E), [1/(\text{cm}^2 \cdot \text{s} \cdot \text{MeV})]$.

In order to facilitate observation, the Y-axis uses a logarithmic scale.
Calculation results

Skyshine RA-reactor

Differential Neutron Spectra at 800m from the RA Reactor, $\Phi(E), \text{[1/(cm}^2 \cdot \text{s} \cdot \text{MeV})].$

Differential Neutron Spectra at 1000m from the RA Reactor, $\Phi(E), \text{[1/(cm}^2 \cdot \text{s} \cdot \text{MeV})].$

In order to facilitate observation, the Y-axis uses a logarithmic scale.
Skyshine TFTR (Tokamak Fusion Test Reactor)

Calculated & measured **neutron dose rate** distribution.

$D_n$, [$\mu$Sv/h]

In order to facilitate observation, the Y-axis uses a logarithmic scale.
Part IV. Conclusion
Conclusion

**Skyshine Benchmark**

The computational capability of the MCS code neutron-photon coupled transport simulation is verified by the sky-shine benchmark experiment of the SINBAD shielding benchmark. The two experimental models are one for fission source reactor experiment and one for fusion source test reactor experiment; the calculation results show good overall agreement with the experimental results, although there are some errors.

Next, other SINBAD Benchmark models will be used to verify the MCS code shielding calculations in fixed source mode.
Thank you 😊