THE NATION'S
URANIUM PROCESSING FACILITY

"Swapped Source": A Forward Calculation Technique to Help Establish the Worst-Case Accident Location for CAAS Detectors in Fixed Locations

Presented at the Philadelphia ANS Summer Meeting June 17-21, 2018

Kevin H. Reynolds
Consolidated Nuclear Security – Y-12 National Security Complex

Demonstrating Coverage

- Demonstrating coverage can be a challenge for small events, such as the Minimum Accident of Concern
- Frequently the CAAS detectors are in a fixed location
- Accident location can be anywhere
  - In transport over open floor space
  - Inside equipment
  - Inside containers
  - Shielded by walls
  - Shielded by equipment
  - Any combination of the above
- **Need to prove that the detector will "see" the accident even if it is in the worst-possible location.**

Typical methods for finding worst-case accident location

- Engineering judgement:
  - In many cases the worst-case location may be obvious.
- Repeated forward calculations:
  - Repeated calculations can be performed for a fixed detector and varying source locations to map out detector response.
- Adjoint transport: An adjoint calculation can transport adjoint particle throughout geometry to map out detector response.

Another Option: Swapped-source

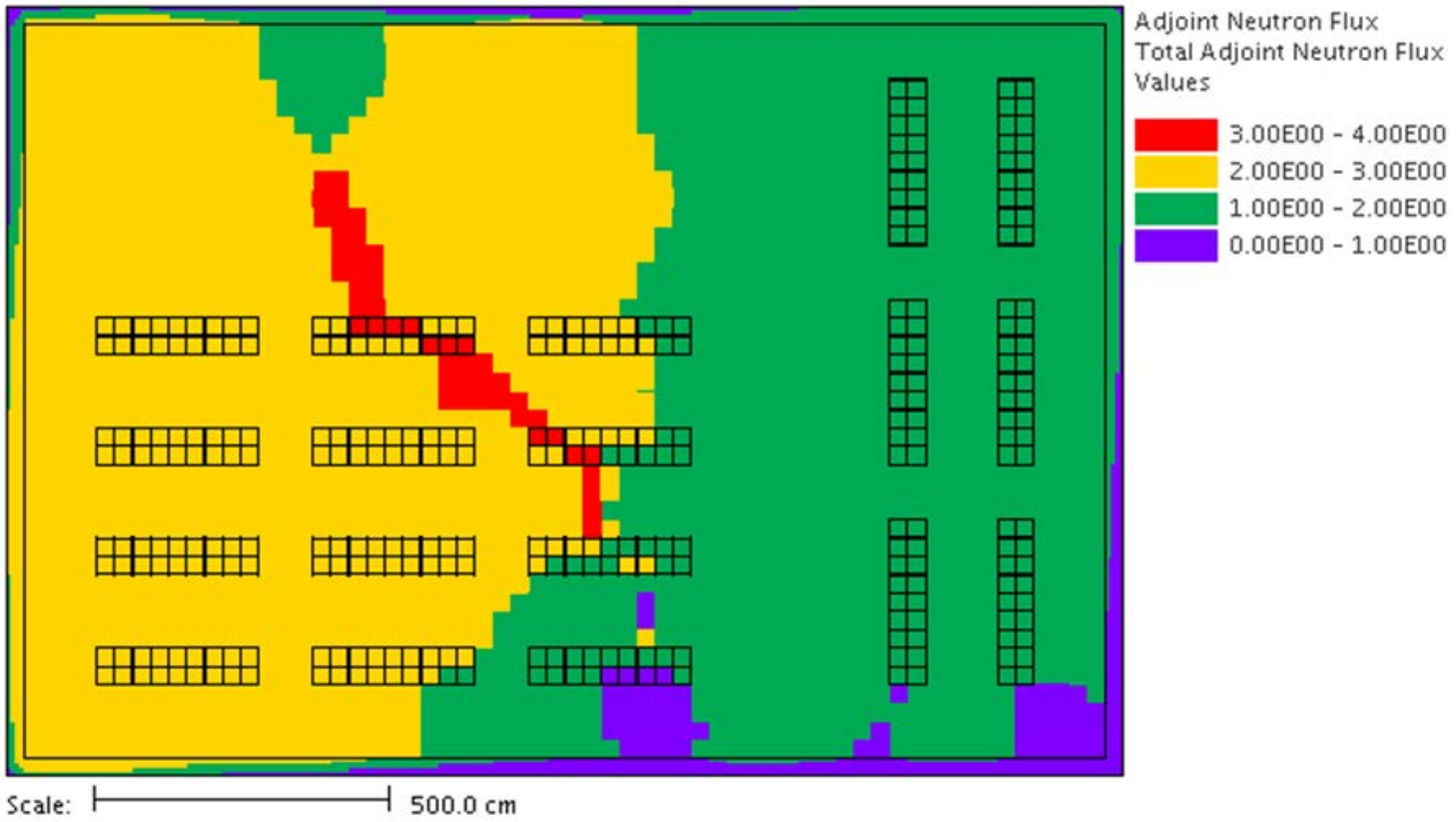
- What is swapped source?
  - A hybrid method used to support engineering judgement with a simple forward calculation.
  - A single calculation where the source is moved to the CAAS cluster detector locations
  - All tallies are replaced with a mesh tally (e.g. FMESH) to observe transport from the cluster throughout the geometry.

Concept is akin to turning on the lights and looking for the darkest shadow.

Swapped Source

- Very simple:
  1. Use the same fission source that will be used for final detector dose calculations.
  2. Position the fission source at the CAAS cluster position(s).
  3. If more than one fixed CAAS cluster location is known, then split the source with equal probability among each CAAS cluster position.
  4. Introduce a mesh tally near the floor (most distant from detectors), such as FMESH or TMESH in MCNP.
  5. Run the case and review the mesh results.
     - The mesh results will be related to the degree of intervening shielding along each path from any point on the mesh to each cluster location.
     - **Areas with the lowest mesh dose/flux will be the accident locations that are the most difficult to detect in a normal forward detector dose calculation.**

Comparison to reference case Adjoint Neutron Flux results: Figure 43 from ORNL-TM-2013-211



Thomas M. Miller, Douglas E. Peplow, ORNL/TM-2013-211, "*Guide to Performing Computational Analysis of Criticality Accident Alarm Systems*," Oak Ridge National Laboratory, August 30, 2013.

Reference Case modified for Swapped source

- ORNL-TM-2013/211 identifies three detector locations, and evaluates response to four different source locations.
- Swapped source used Source A specification from the ORNL reference and located the source at all three detector locations, each with equal probability.

Original Source :

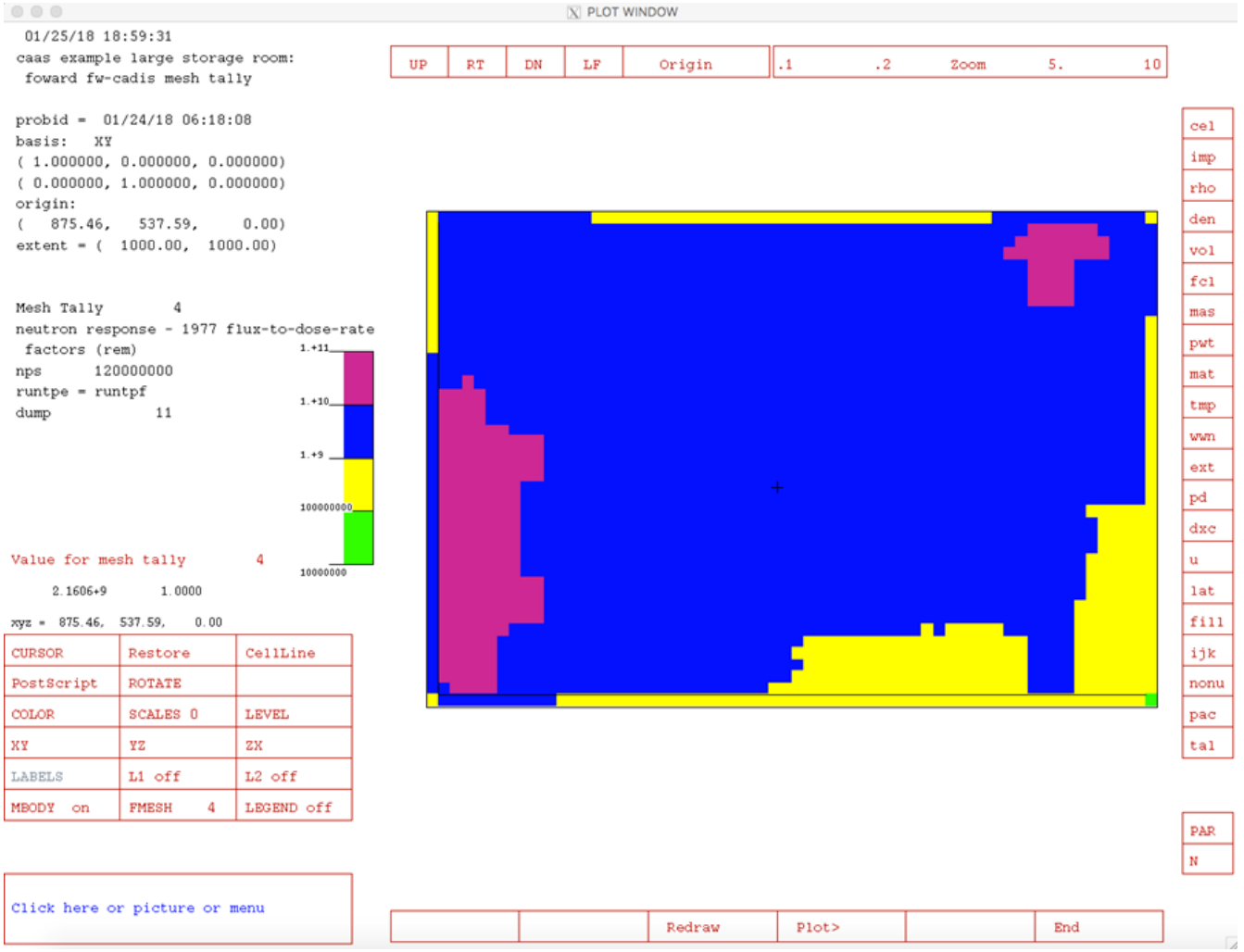
```
sdef erg=d1 pos=929.64 45.72 76.2 par=n
```

Swapped Source changes:

```
sdef erg=d1 pos=d2 par=n
.
.
.
si2 L   15.24   228.60  289.56
        15.24   624.85  289.56
      1600.20  1203.96  289.56
sp2      0.333 0.333 0.334
```

FMESH added in Swapped Source case to monitor flux near the floor.

Swapped source output near the floor



Although plot resolution is poor, lowest tally is bottom-center, and bottom right, just as in the case of the adjoint results.

Swapped-source example for UPF: Main Processing Building West, First Floor with 6 detectors/swapped source locations.

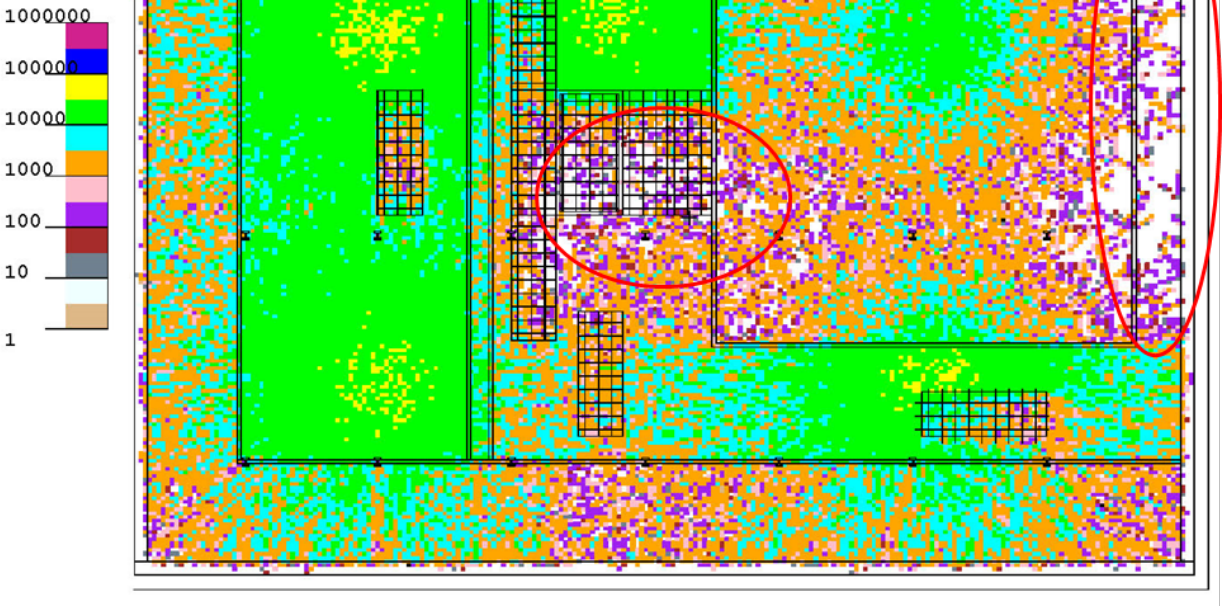
```
 01/12/17 17:41:01
MPB West Prompt Gamma Model


probid =  01/12/17 17:21:52
basis:   XY
( 1.000000, 0.000000, 0.000000)
( 0.000000, 1.000000, 0.000000)
origin:
(  3700.00, -2500.00,    30.48)
extent = (  3800.00,  3800.00)


Mesh Tally        14
nps          1000000
runtpe = caasrun
dump              1
```

Sources placed at each detector location.
Map is composite near the floor.

- Circled regions near center and right side show areas most difficult to detect.
- Those are worst-case accident locations for detection.



Observations

- Swapped source used only as a tool to help identify worst-case locations for accident detection.
- Final detection always based on forward calculation of dose at detector from accident positioned at worst-case location.
- When worst-location identified by swapped source obvious by basic engineering judgement, the position was confirmed by varying the source location of several forward calculations.
- No case was found where a more limiting accident location could be chosen than the one identified by swapped source.

Limitations

- **Transport is not simply reversible!**
- Scattering, solid angle, and energy spectrum can be different in one direction than in the opposite.
  - Neutron dose transported through a low-Z material then through a high-Z material will be different than if transported in the opposite order.
  - Solid angle and scattering would be different for particle transported through a nearby object to a distant detector, than if transported a long distance through an object that is near the detector.
- Swapped source should only be used to shows regions of reduced particle transport (akin to shadows).
  - Even with proper flux-to-dose and unit conversion, the dose transported from a detector location to a some point in the geometry would not necessarily be the same magnitude if the detector and source locations were switched.
- In many cases, transport through a glovebox, or through a sheetrock wall is similar in distance, and in order of similar materials, when transported from either direction. If that is not the case then the method may be less effective.

Summary of Effort

- Swapped source is a semi-qualitative method to identify worst-case accident location for a set of fixed detectors.
- Used effectively in the UPF CAAS analysis to identify worst-case locations for accident detection.
- Found to identify several difficult accident locations to detect that were not otherwise obvious.
- Used effectively for neutron transport and for photon transport in UPF CAAS analyses.
- Method has clear limitations based on the non-reversible nature of flux transmission between two points:
  - i.e. dose transported in one direction is not necessarily equal to the dose transported in the opposite direction.

Disclaimer