Guidance Detailing Methods to Calculate CAAS Detector Response and Coverage

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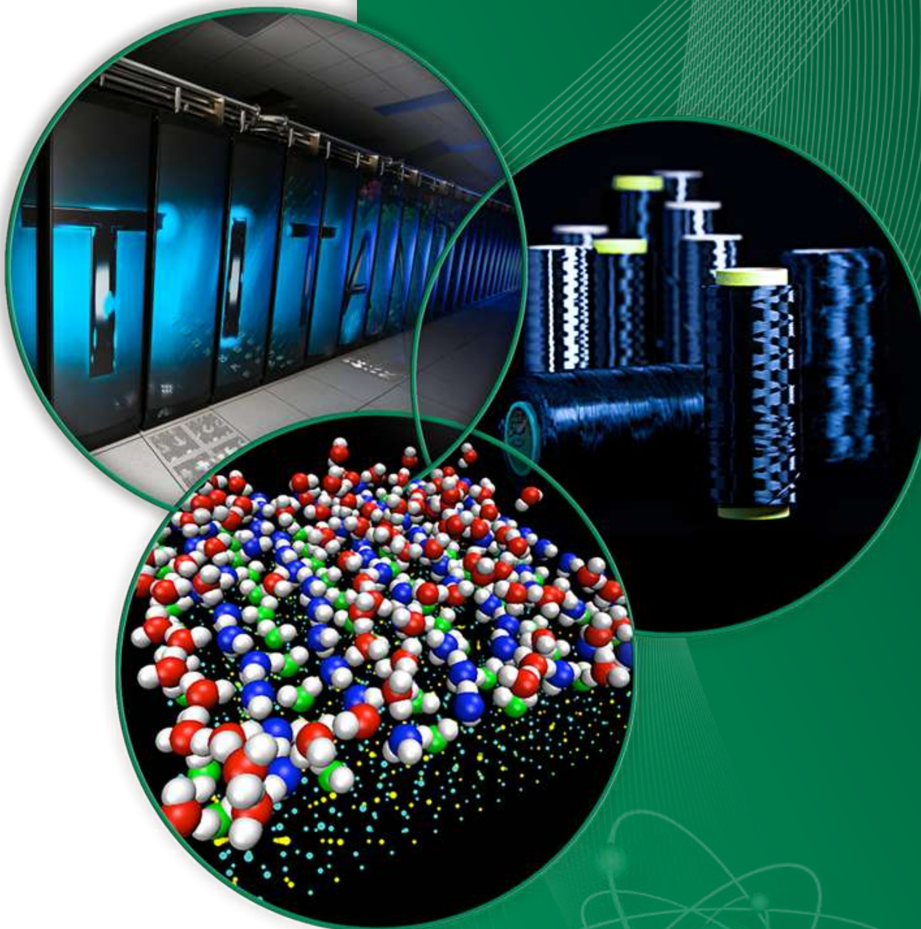

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Motivation and outline

- Motivation
  - Help criticality safety practitioners that have little experience with fixed-source transport calculations perform CAAS analysis
- Outline
  - Introduction
  - Scope and limitations
  - Minimum accident of concern (MAOC)
  - CAAS placement analysis strategy
  - Summary and conclusions

Introduction

- Full document: ORNL/TM-2013/211 http://scale.ornl.gov/caas_input.shtml
  - Brief discussion of ANSI/ANS-8.3
  - Discussion of how CAAS detector response calculations are different from eigenvalue calculations
  - Examples with SCALE and MCNP
    - MAOC, CAAS detector response, CAAS coverage
  - Strategy to determine the optimum placement of the minimum number of CAAS detectors
- This extended summary (conference DVD)
  - MAOC example (using ANSI/ANS-8.3 definition)
  - Strategy to determine the optimum placement of the minimum number of CAAS detectors
  - CAAS coverage example

Scope and limitations

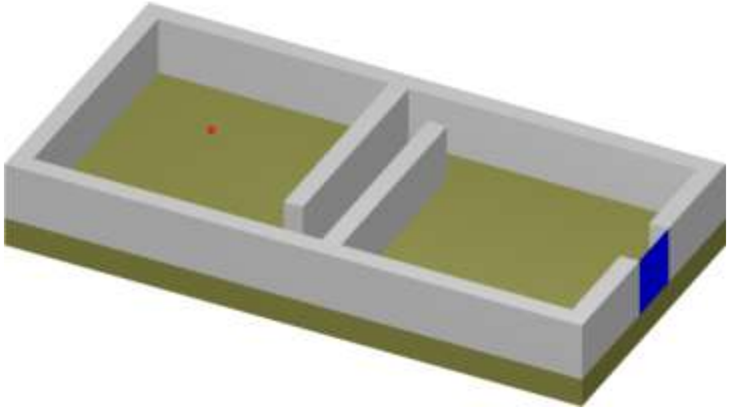
- The guidance provided covers just the detector response calculations, not several other important aspects of CAAS analysis
  – Determination of credible accidents & accident locations
  – Minimum accidents of concern other than that prescribed in ANSI/ANS-8.3
  – What set of flux-to-dose-rate conversion factors are appropriate for your analysis
  – Kinetic behavior of a criticality accident & excursion shutdown mechanisms
  – Initial evacuation zones
    - However, the methods used to determine CAAS detector responses over a larger area using mesh tallies can be applied to initial evacuation zones

Minimum accident of concern (MAOC)

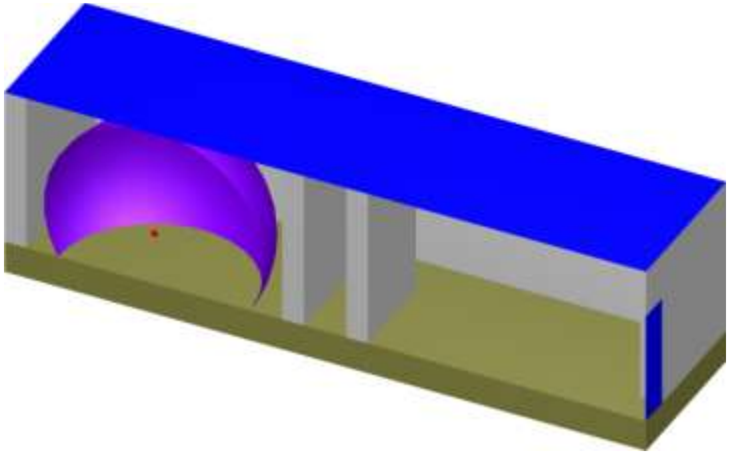
- According to ANSI/ANS-8.3
  - *A CAAS shall respond immediately to the minimum accident of concern, which may be assumed to deliver the equivalent of an absorbed dose rate in free air of 0.2 Gy/min at 2 meters.*
- First, model the credible accident and location and calculate the dose rate per fission rate 2 meters from the accident ($D_N + D_P$)
- Use the the calculated dose rate per fission rate and the minimum accident dose rate to determine the MAOC fission rate

$$N_{MAOC} = \frac{0.2\ Gy/min}{D_N + D_P}$$

MAOC example with Jezebel



Block building with Jezebel, top half removed



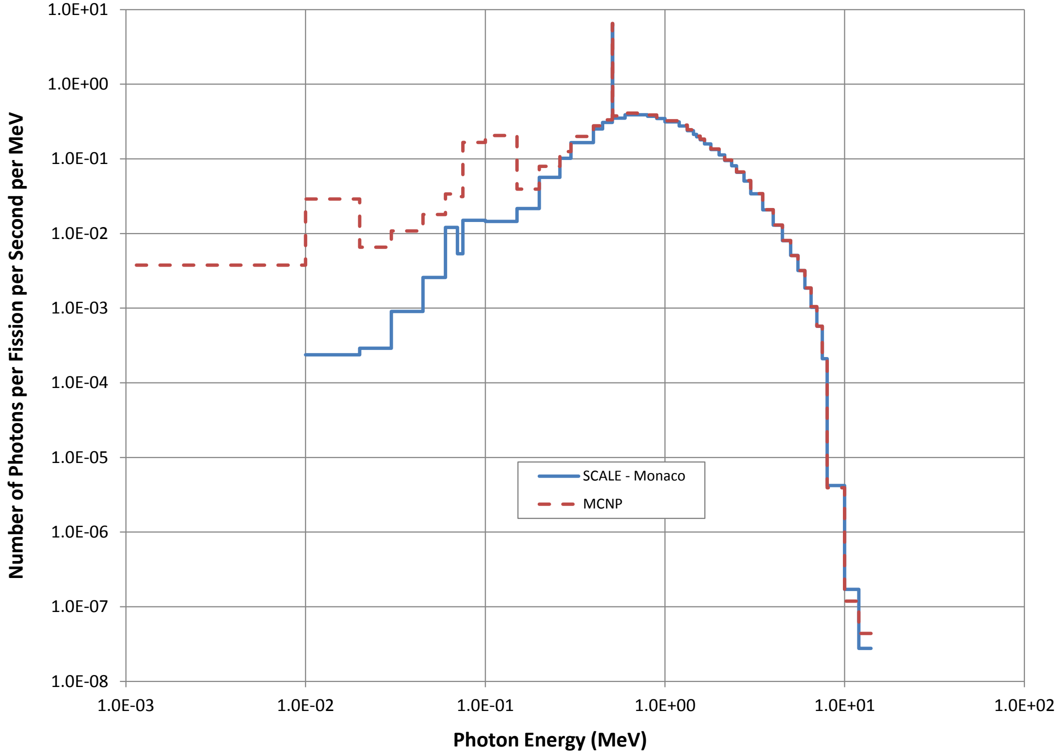
Block building with Jezebel and 2 meter tally sphere, front half removed

- Differences between MCNP and SCALE
  - MCNP: easily calculate detector response with eigenvalue calculation
  - SCALE: easily create fixed source & perform automated variance reduction for heavily shielded / loosely coupled critical source & detector
  - MCNP: more detailed physics for low energy photons (even CE Monaco)

MAOC example with Jezebel

Determination of the minimum accident of concern for Jezebel in a simple block building

Result	MAVRIC/Monaco	MCNP
Neutron air kerma (Gy/min per fission/sec)	1.83133E-15 ± 0.074%	1.8352E-15 ± 0.02%
Photon air kerma (Gy/min per fission/sec)	5.85128E-16 ± 0.183%	6.6624E-16 ± 0.05%
Minimum accident of concern (fissions/sec)	8.2766E+13	7.9954E+13



CAAS placement strategy

- **Different approaches for CAAS detector placement studies**
  - Based on comparison between number of accident sites and detector locations
  - Adjoint approaches are not all available with SCALE or MCNP

Detector locations *D* and Accident sites *A*			Geometry	Approach			
Comparison	*A*	*D*			Direction	Biasing	Tallies
$A<D$	small	small	sparse	1.	forward	analog	standard tallies
$A<D$	small	large	sparse	2.	forward	analog	mesh tally
$A<D$	small	small	dense	3.	forward	CADIS	standard tallies
$A<D$	small	large	dense	4.	forward	FW-CADIS	mesh tally
$D<A$	small	small	sparse	5.	adjoint	analog	standard tallies
$D<A$	large	small	sparse	6.	adjoint	analog	mesh tally
$D<A$	small	small	dense	7.	adjoint	CADIS	standard tallies
$D<A$	large	small	dense	8.	adjoint	FW-CADIS	mesh tally

CAAS placement strategy

- **Different approaches for CAAS detector placement studies**

Detector locations D and Accident sites A			Geometry	Approach			
Comparison	A	D			Direction	Biasing	Tallies
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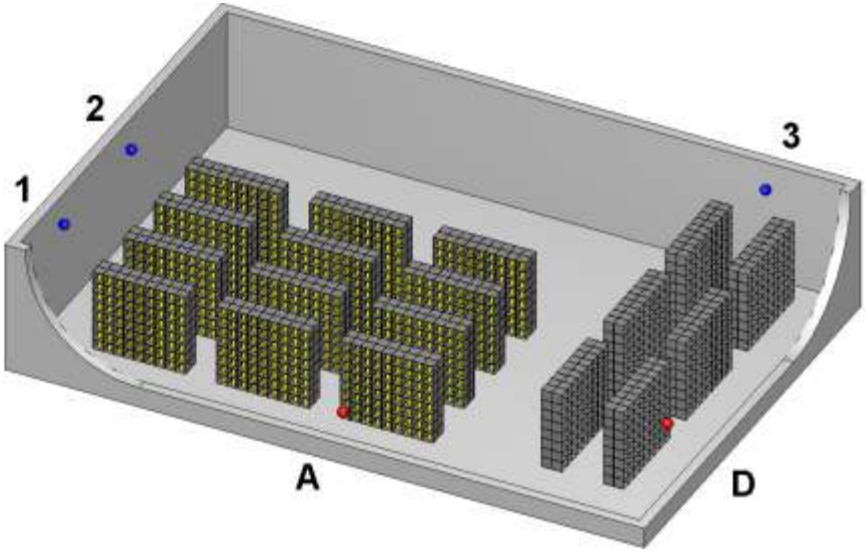
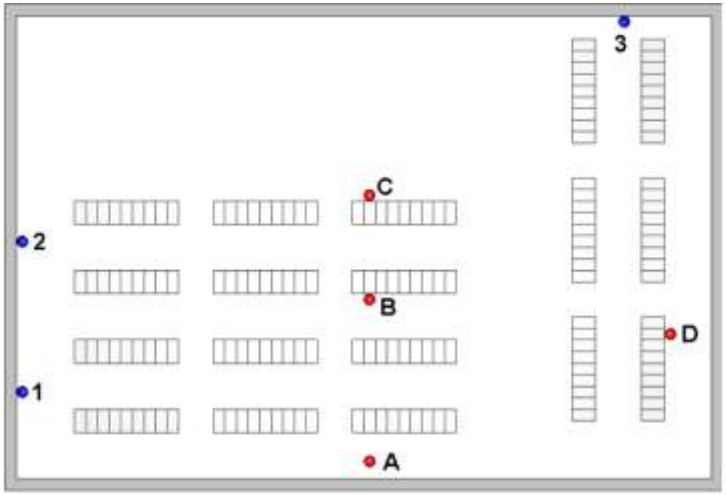
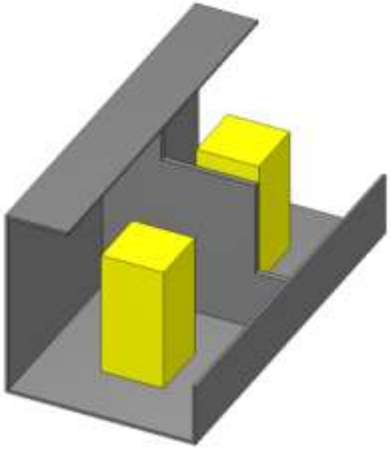
Forward Placement Analysis Approach 4: Forward Simulation, FW-CADIS, Mesh Tallies





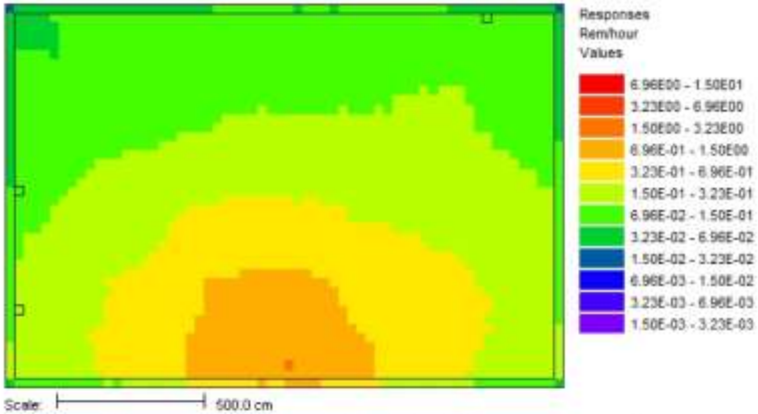


Direct comparison of dose rates at detector locations (rem)

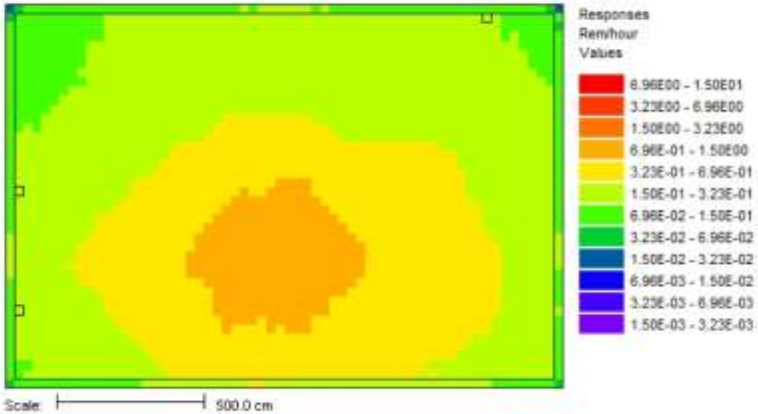
Source or Accident Site	Detector	MAVRIC/Monaco	MCNP	Ratio: MAVRIC / MCNP
A	1	1.81E-1 ± 2.55%	2.40E-1 ± 0.49%	0.75 ± 0.02
A	2	1.06E-1 ± 2.00%	1.50E-1 ± 0.46%	0.71 ± 0.01
A	3	9.55E-2 ± 2.45%	1.22E-1 ± 0.48%	0.78 ± 0.02
B	1	1.91E-1 ± 2.38%	2.43E-1 ± 0.51%	0.78 ± 0.02
B	2	1.77E-1 ± 2.26%	2.35E-1 ± 0.48%	0.75 ± 0.02
B	3	1.59E-1 ± 2.46%	2.01E-1 ± 0.52%	0.79 ± 0.02
C	1	1.12E-1 ± 2.24%	1.46E-1 ± 0.47%	0.77 ± 0.02
C	2	1.93E-1 ± 2.25%	2.64E-1 ± 0.45%	0.73 ± 0.02
C	3	2.99E-1 ± 2.36%	3.89E-1 ± 0.50%	0.77 ± 0.02
D	1	4.78E-2 ± 3.06%	6.29E-2 ± 0.68%	0.76 ± 0.02
D	2	5.72E-2 ± 4.22%	7.17E-2 ± 0.83%	0.80 ± 0.03
D	3	2.44E-1 ± 2.15%	3.25E-1 ± 0.52%	0.75 ± 0.02

- Differences due to neutron only source, i.e. photons only born from inelastic scattering and neutron capture
- Course photon group structure, 47 photon groups
- Agreement between MCNP and continuous energy MAVRIC/Monaco (SCALE 6.2 beta) much improved, ~6% different

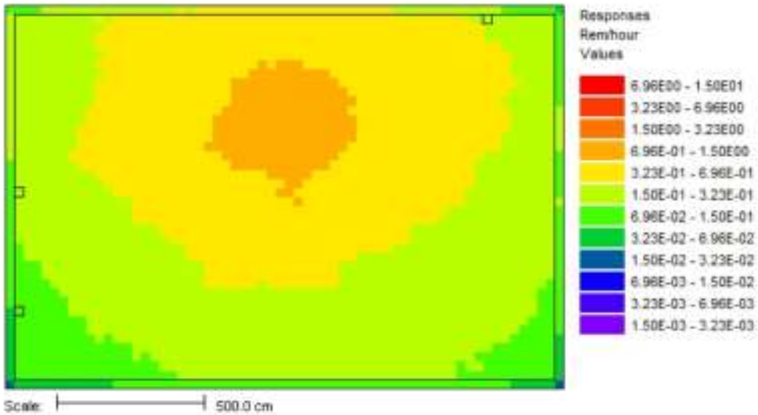
Dose contours



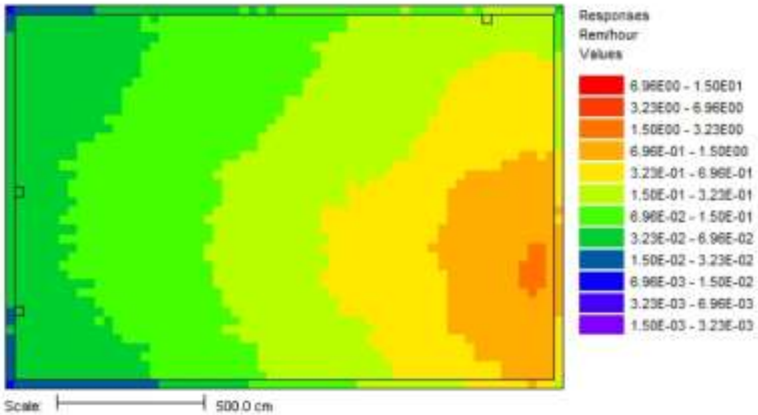
Gamma dose mesh tally from source A



Gamma dose mesh tally from source B

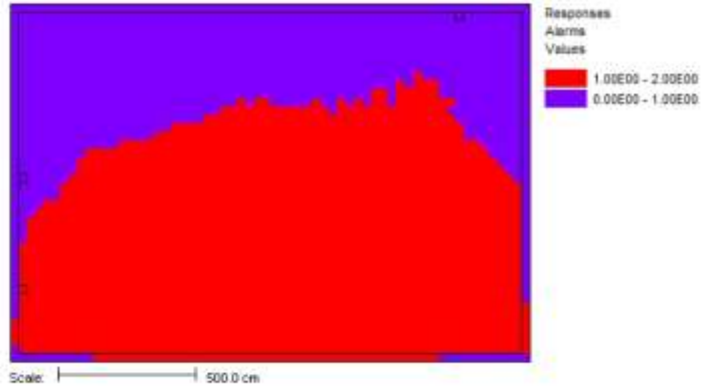


Gamma dose mesh tally from source C

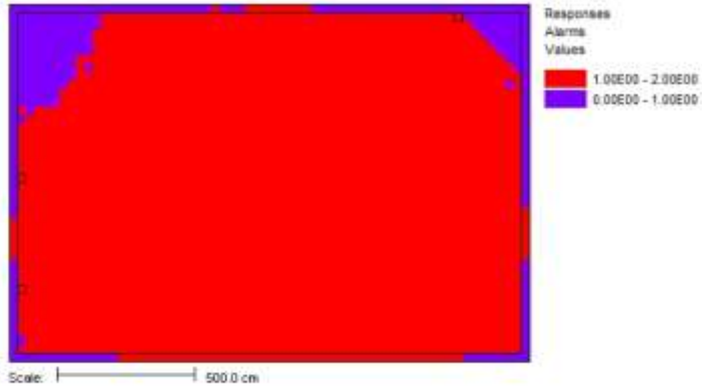


Gamma dose mesh tally from source D

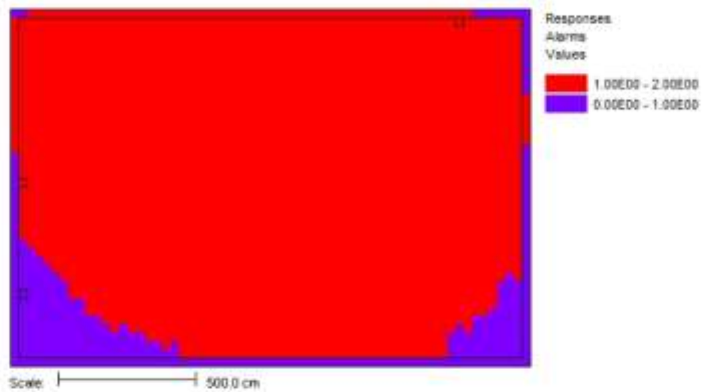
Contours filtered:
Red – dose above 0.15 rem (alarm)
Purple – dose below 0.15 rem (no alarm)



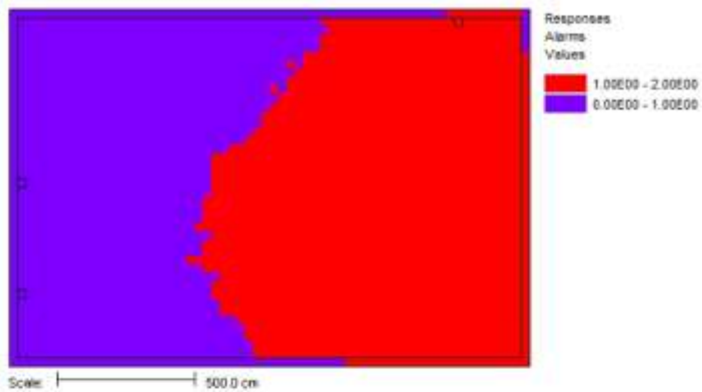
Areas that would alarm for accident site A



Areas that would alarm for accident site B

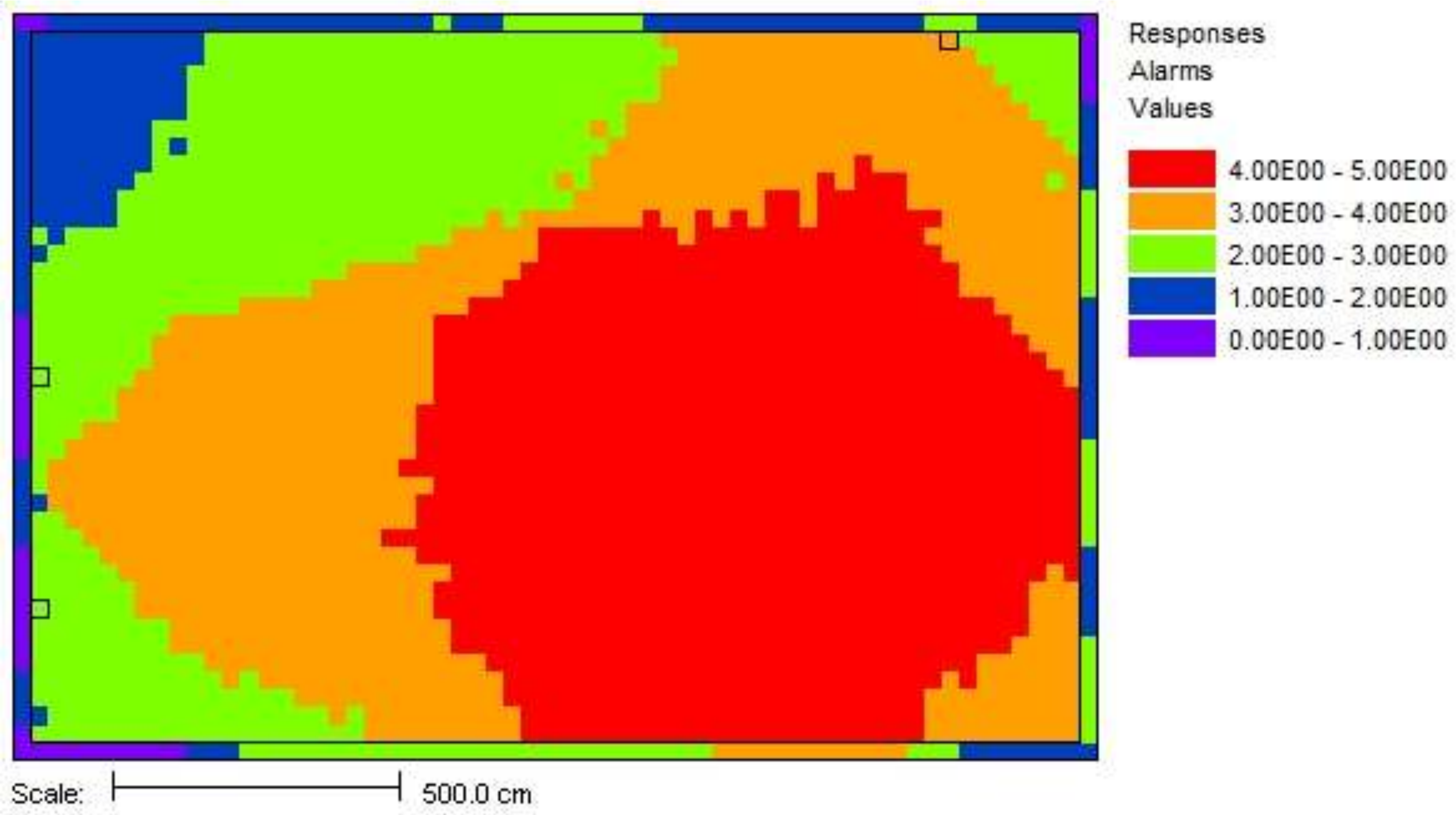


Areas that would alarm for accident site C



Areas that would alarm for accident site D

Sum previous filtered plots: Number of detectors providing coverage



Summary and conclusions

- Summary of ORNL/TM-2013/211, see the full report for more details and more examples
  - Download the report and example input files **http://scale.ornl.gov/caas_input.shtml**
- Two points to remember
  - All stakeholders should help determine credible accidents, locations, and appropriate flux-to-dose-rate conversion factors
  - To select the most efficient analysis methodology, consider the number of detectors versus accidents