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Proposed Guidance and Specification for a Process-Specific Minimum Accident of Concern

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Y-12 National Security Complex

The Analogy for a Hazard in the Near Field

"The Luckiest Man"

The near field represents the closest distance to an imminent hazard with "acceptable outcome".

A criticality hazard in the near field will most likely be greater than the MAC

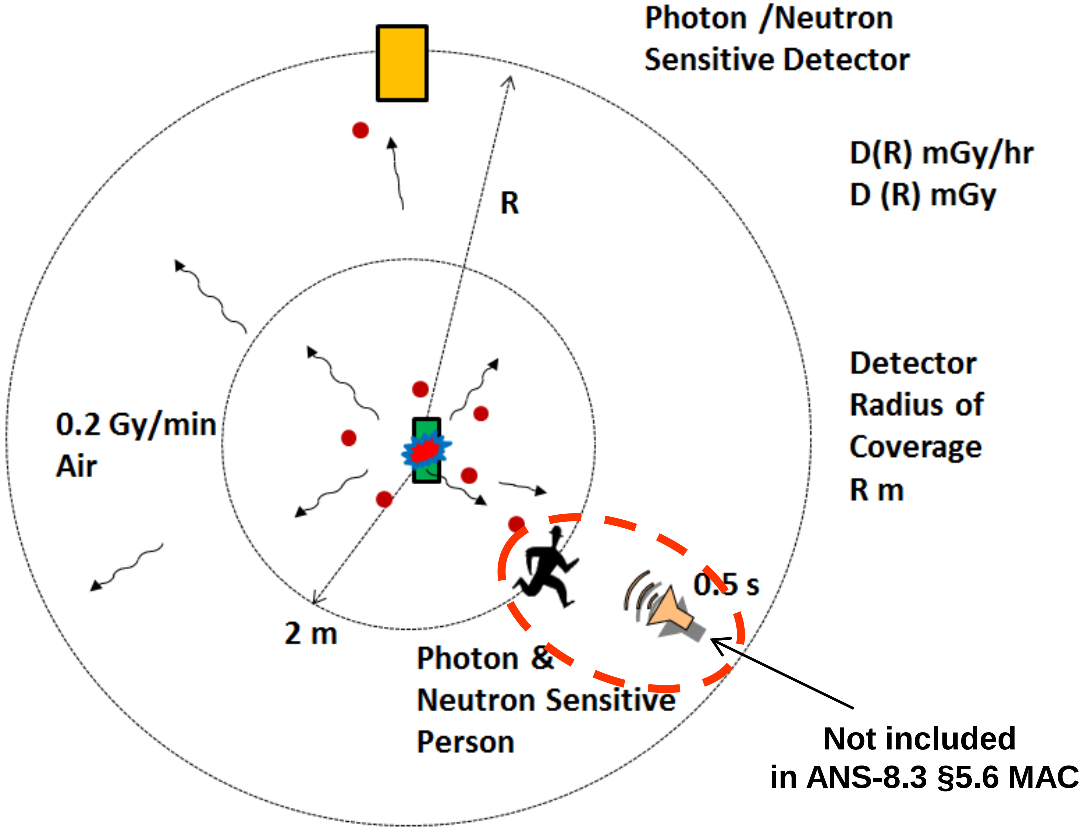
The Main Ideas

1. Significant background from past ANS papers provides **timeline** for process specific MAC
2. Proposed excursion thresholds are derived from recent kinetic and past experiment evaluations
3. The near field excursions encapsulate the **"Time Period of Interest"**
4. Existing ANS-8.3 Appendix B guidance for detector radius of coverage can be **AUGMENTED**
5. **Apply specific guidance to HEU scenarios**
6. Risk Informed Insight **– 'deterministic wiggle room'**

Timeline for Considerations

- NCSD 1993 – "Ground Zero" – **Malenfant/Barbry**
- ICNC 1995 – Distribution of fissions and CDF (upper bound)
- NS&E 1999, 2001 – **Nomura** papers, **SRS MAC**
- ANS 2004 – **Barbry** "most credible minimum accident"
- **NCSD 2005** – 2 papers on process-specific MAC
- ANS 2007 – Adjoint MC and CAAS MAC contours
- ANS 2009 – Dose in **air**, tissue **D*(10),** effective dose **H*(10)**
- NCSD 2009 – "Realism and Risk acceptance, "minimum spike excursion"
- **ICNC2011 -** ANS-8.3 Appendix B ***Sustained Reaction***, MAC comparison to experiments (**Duluc**)
- **NCSD2013 –** ANS-8.3 Appendix B ***Rapid Transient***, "adequate protection" for near field

Source and Target in Near and Far Field



$D(R) \sim D(2m) \bullet (2/R)^2 \bullet t_{air}$

Source and Target Relationships

Near Field – Reference MAC   Far Field – Detector Response

“Marginal Utility” of Dose Rate in Air, SR and RT

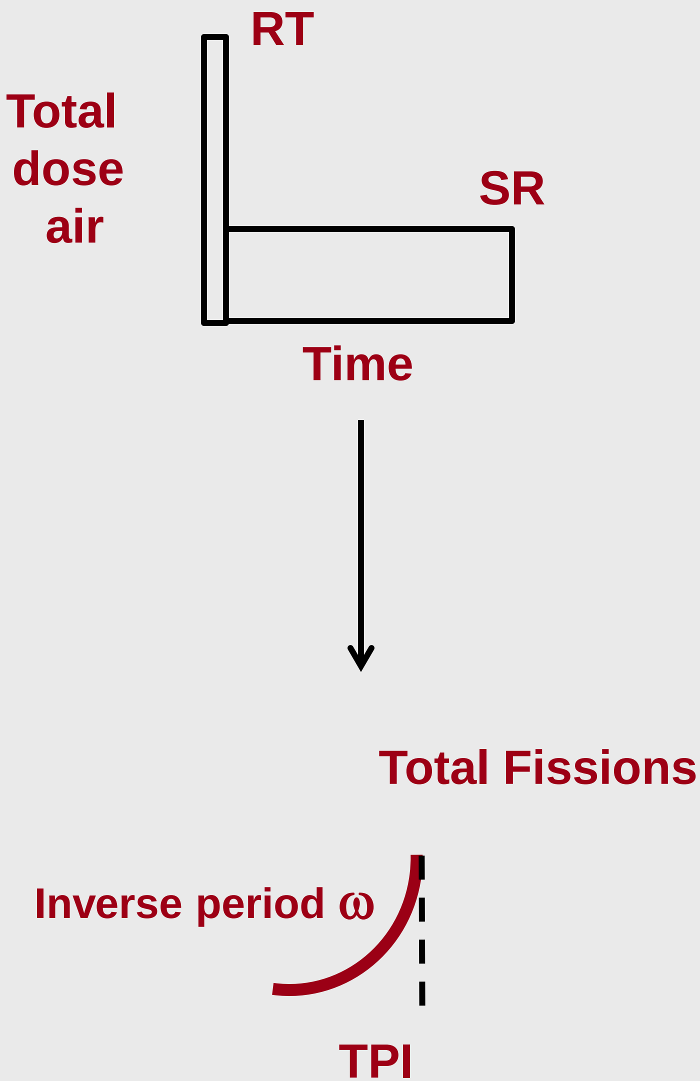
- ***Sustained Reaction*** – **Non responsive rate based CAAS** below a minimum reactivity value ~ 1/3 the delayed critical range. Large D*(10) 1-2 Gy if 60 s delay– (ICNC2011)

- ***Rapid Transient*** - **Non responsive rate based CAAS** for excursions extending into prompt critical range. (NCSD 2013)

- **Above $0.75** delayed critical, D*(10) > 0.2 Gy, H*(10) > 15 Sv unmoderated

- **Below $0.35** delayed critical D*(10) 0.2 > Gy, H*(10) > 5 Sv for a poorly moderated system.

Transforming the MAC "Coordinate System"



- Transform from "square waves" (SR and RT) to "**inverse period**" and **upper bound total fissions** over **Time Period of Interest (TPI)**
- **Same** threshold units (**fissions/sec**)
- **Independent of air response, no 60 sec delay assumed**
- Based on experiments, accident history, kinetics evaluations
- Initial human recognition of alarm
- "Acceptable near field outcome"

Proposed Excursion Thresholds

- **Excursion Threshold I** -
  - ***Credible Slow Excursions*** –
  - bounded by 2- 4 × 10^{15} fissions over the slowest CRAC
  - Inverse period 0.1 s^{-1} (ICNC 2011) (no slow cookers), 5 sec TPI
  - $0.35 -$0.75

- **Excursion Threshold II** -
  - ***Credible Fast Excursions***
  - bounded by 1-2 × 10^{15} fissions , 3-5 Sec TPI
  - Inverse period of 1 s^{-1} (NCSD 2013)
  - $0.75-$1.0

- **Excursion Threshold III** -
  - ***Credible Spike Excursions*** –
  - bounded by 1 × 10^{14} fissions over a 1000-s^{-1} inverse period.
  - (NCSD 2009)
  - greater than $1 reactivity.

- **Consistent with Delafield and Clifton SRD R309**

Tying Excursion to Detector Radius of Coverage

$$D_r(R) = D_{2m} \times \left(\frac{2}{R}\right)^2 \times T_{air} \times \varepsilon \qquad \text{Eq. (1)}$$

$$D_{tot}(R, t_{tot}) = [E_{Tot}]_{2m} \cdot f\left(\frac{D}{E}\right)_{2m} \cdot \left(\frac{2}{R}\right)^2 \cdot T_{air} \qquad \text{Eq. (2)}$$

$$E_{Tot} = E_{Thresh\,(I,II,II)} + E_{TPI} \qquad \text{Eq. (3)}$$

$$t_{Tot} = t_{Thresh\,(I,II,II)} + \text{TPI} \qquad \text{Eq. (4)}$$

$$P_{Thresh} \sim E_{Thresh\,(I,II,II)} \cdot \omega(t_{thresh}) \qquad \text{Eq. (5)}$$

$$D_{TPI} = f\left(\frac{D}{E}\right)_{2m} \cdot P_{thresh} \cdot \int_{t_{thresh}}^{TPI} exp^{\omega(t) \cdot t} dt \qquad \text{Eq. (6)}$$

Application to CIDAS Detector Radius of Coverage

1. **Determine/Choose** reactivity insertion

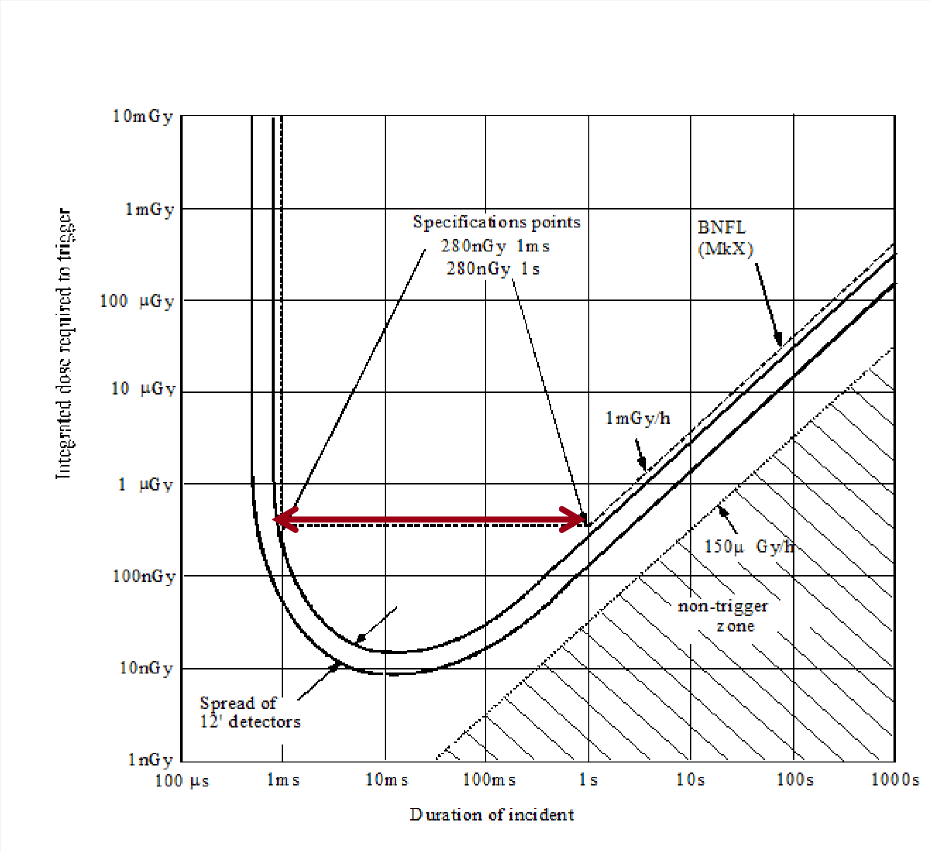
(Exploit time dependent kinetics information)

2. **Increment** 1 s interval for 280 nGy.

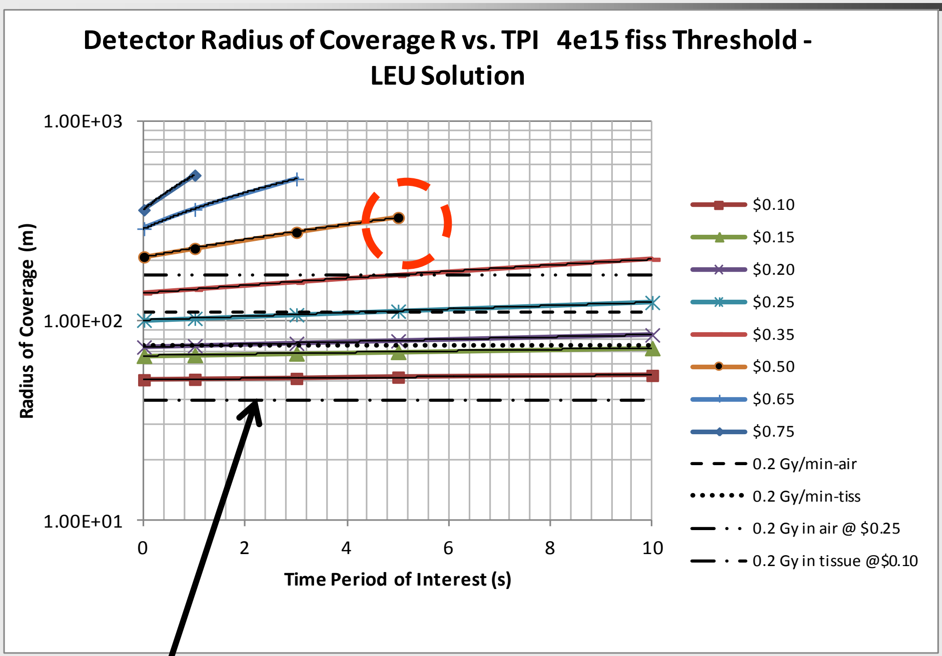
3. **Note** threshold P, E, ω, time

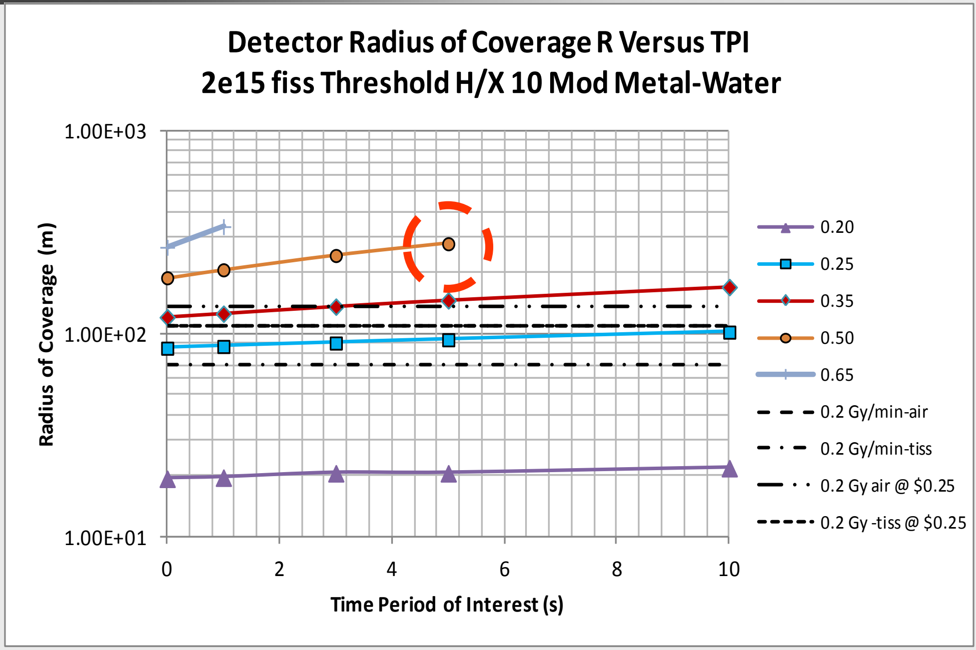
4. **Determine** total fissions for TPI

5. **Solve** Eq. 1-6 for Radius of Coverage



Detector Radius of Coverage



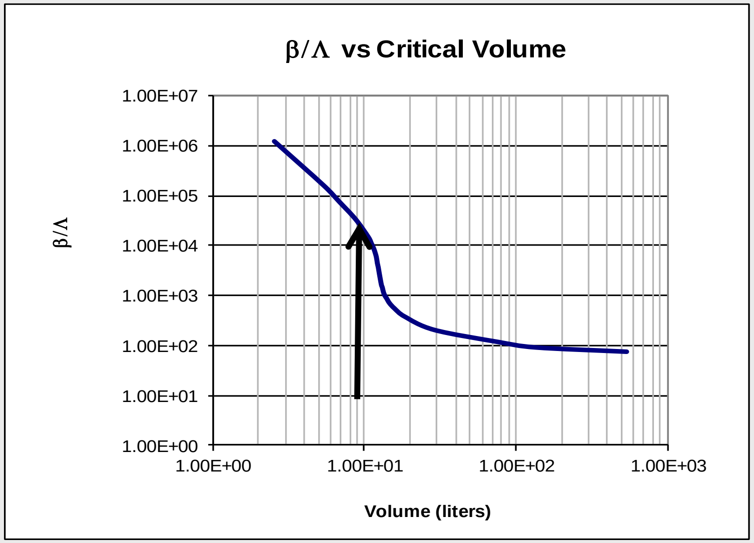


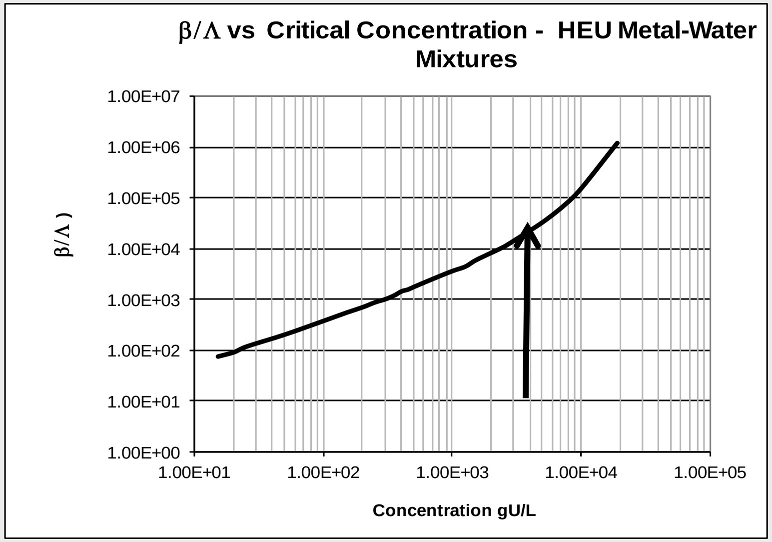
40 m default
1e15 over 60 s

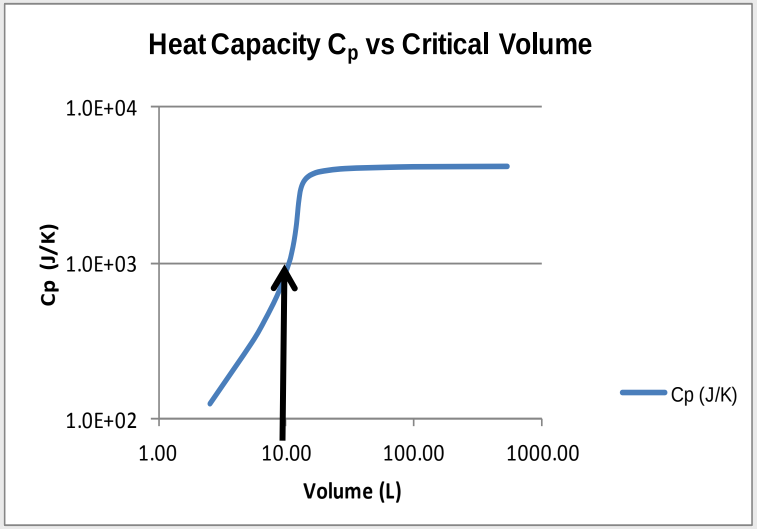
Radius of detector coverage increases over 0.2 Gy/min in air with $0.5 (best est.) 5 sec TPI

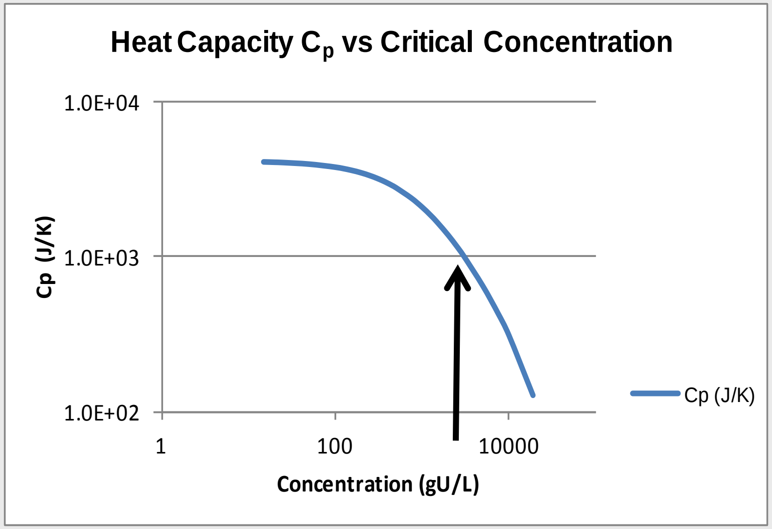
310 m Solution, 270 m Mod metal-water

Application to Uranium Systems – 10 L Volume









Integrate Excursions Thresholds with Uranium System

- **Process Specific Scenario 1:** 2-4e15 fissions/sec **TPI 5 s**
  - Excursion Threshold I – inverse period 0.1 s-1
  - HEU Solutions/fully moderated (homogenous) mixtures
  - **(critical volume >10 L):**

- **Process Specific Scenario 2:** 1-2 e 15 fissions/sec **TPI 3 s**
  - Excursion Threshold II – inverse period 1 s-1
  - HEU Poorly Moderated H/X ~10
  - **(critical volume <10 L):**

- **Process Specific Scenario 3**: 1e17 fissions/sec
  - Excursion Threshold III – inverse period 1000 s-1
  - HEU unmoderated metal

Risk Informed Insight into Decision Making

Risk Informed Insight noted by ***ANS Standards Board Policy Manual*** as an initiative to better apply standards

"Probabilistic" or "Heuristic" input into a **deterministic** value (e.g. MAC). **NOT RISK-BASED**

Substantiation of Numeric Values – ASB Policy Manual

"reference to **another** (ANSI) standard"

ANSI/ASEE/ ISO 31000 – *Risk Management Principles and Guidance*

Complimentary view of risk (ANSI/ISO 31000):

"Risk is the effect of uncertainties on objectives"

Summary and Conclusions

- **Proposed guidance and specification requires stakeholder involvement, concurrence**
- **Transform** ANS-8.3 Appendix B guidance (SR, RT) to realistic exponential excursion guidance
- **Couple** ANS-8.3 Appendix B Radius of Coverage equation to excursion kinetics
- **Evaluate** for a specific material form and type (e.g. HEU)
- Risk informed insight– **input into final decision making**
- **Identify Objectives** and “Effect of Uncertainties on Objectives”