IER 602: AFRRI International Dosimetry Intercomparison Exercise

NCSP Technical Program Review

Wednesday, December 4, 2024

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Nuclear Criticality Safety Division

Prepared by LLNL under Contract DE-AC52-07NA27344.

Purpose

- Test participants ability to meet ANSI/HPS N13.3

American National Standard

ANSI/HPS N13.3-2013 (R2019)

Dosimetry for
Criticality Accidents

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4.1.2 Preliminary Total Absorbed Dose Information. Preliminary total absorbed dose information (neutron plus photon) shall be provided within 24 h of dosimeter retrieval and may be revised as more information becomes available. Preliminary doses are primarily intended to guide the follow-on treatment of exposed individuals.

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6.0 Performance Criteria

6.1 Verification and Testing

Performance of the System shall be verified in a mixed neutron and photon field. The field should have characteristics similar to a criticality accident. Important characteristics include delivered absorbed dose over the range of 0.1 to 10 Gy (10–1,000 rad) to a phantom. The energy spectra shall be well characterized. Performance testing shall replicate the configuration of normal use, e.g., on phantom or free-in-air.

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6.2 Frequency of Verification and Testing

Performance of the System, as identified in the STBD, shall be conducted at least every 3 y.

6.3 Performance Testing Criteria

During performance testing the System shall provide total absorbed dose results within the criteria given in Table 1. The performance statistic, *B*, is calculated using equation (1):

$$B = \frac{(\text{Measured Dose} - \text{Delivered Dose})}{\text{Delivered Dose}} \times 100. \qquad (1)$$

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Table 1. Performance testing criteria for criticality accident dosimeter systems.

Total absorbed dose range	*B*
0.1 to 1 Gy (10 to 100 rad)	±50%
1 to 10 Gy (100 to 1,000 rad)	±25%
>10 Gy (1,000 rad)	Must give positive indication of >10 Gy (1,000 rad)

Recent Intercomparisons

- Prior to IER: Intercomparisons in France (2009-2014)
- IER 148 (2016) – Godiva Intercomparison
- IER 253 (2018) – Flattop Intercomparison
- IER 538 (2022) – Godiva Intercomparison
- IER 602 (2024) – This work, Intercomparison at AFRRI

Why AFRRI?

- DAF (at NNSS)
  - Godiva
  - Flattop
  - Slow turnaround time (>4 hr)

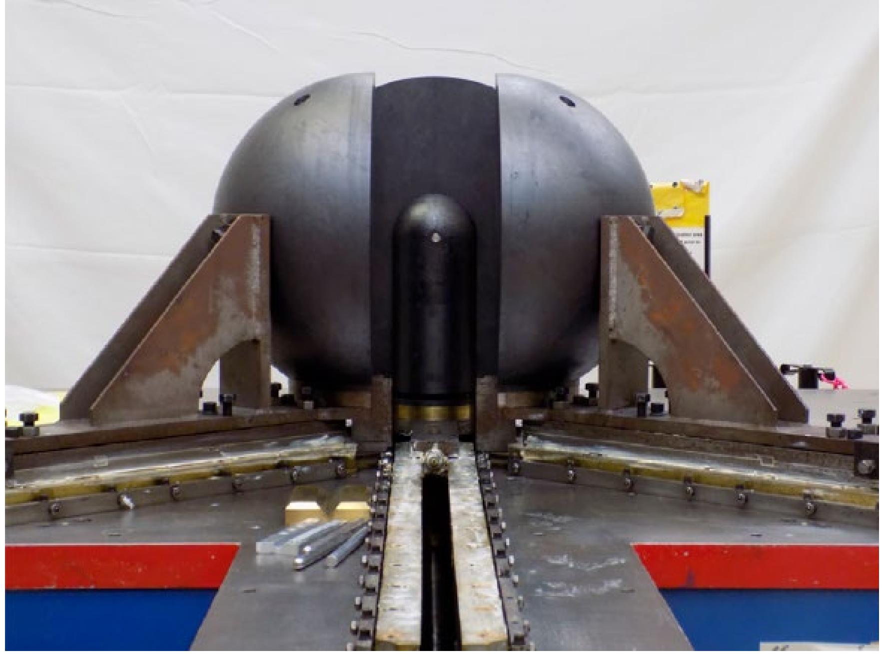
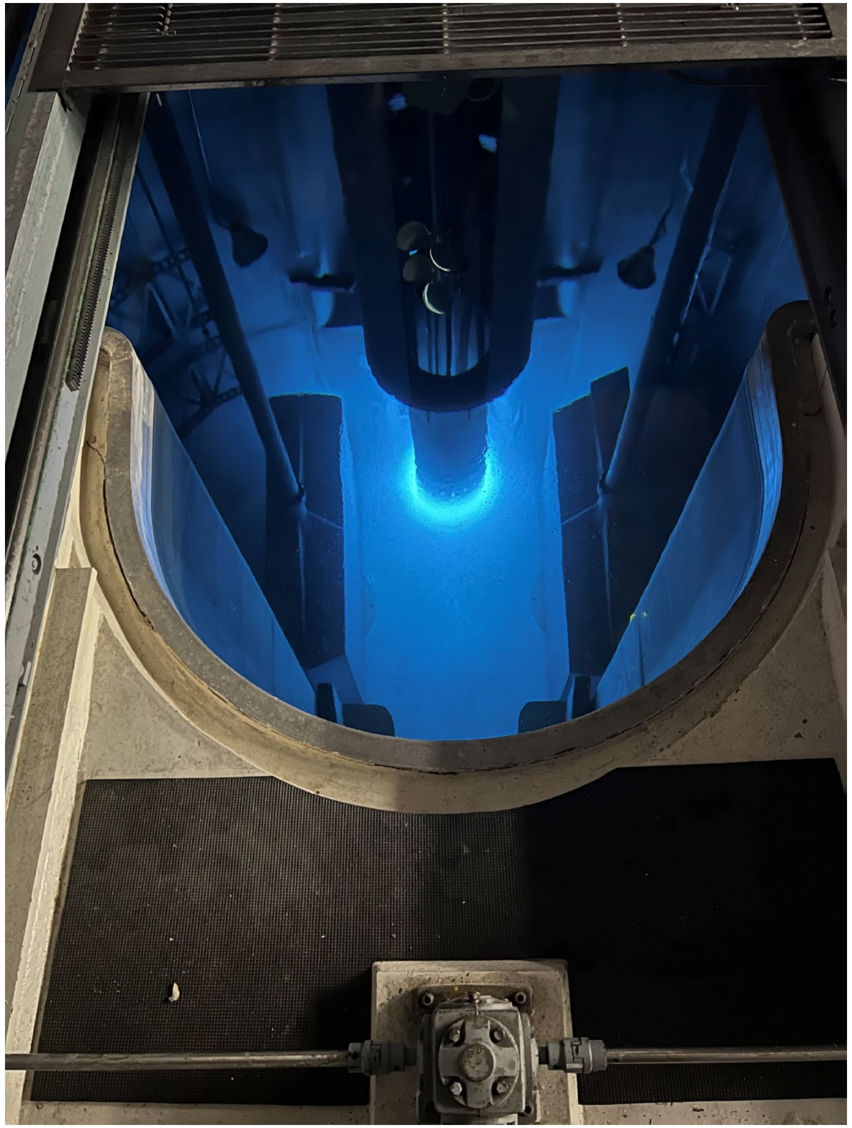


Image Source: DOI 10.3389/fenrg.2022.1082389

Why AFRRI?

- DAF (at NNSS)
  - Godiva
  - Flattop
  - Slow turnaround time (>4 hr)
- TRIGA (at AFRRI)
  - < 1 hr turnaround time



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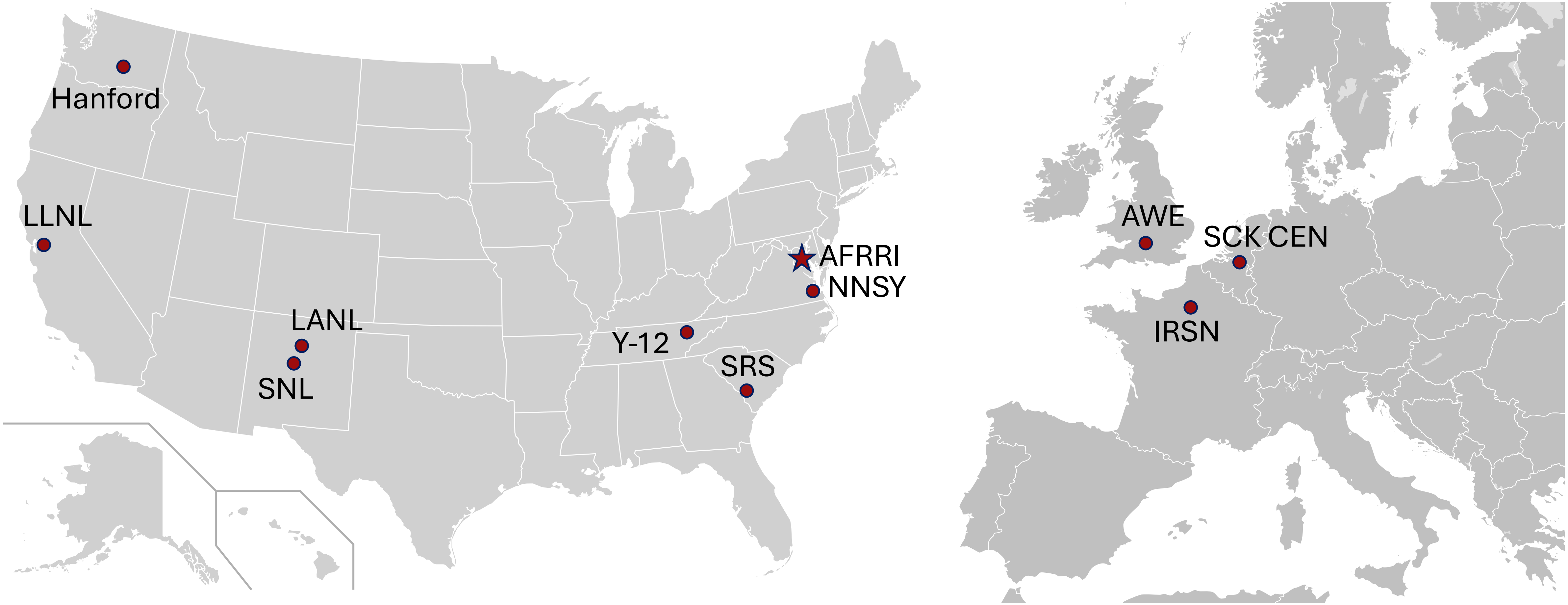
IER 602 Participants



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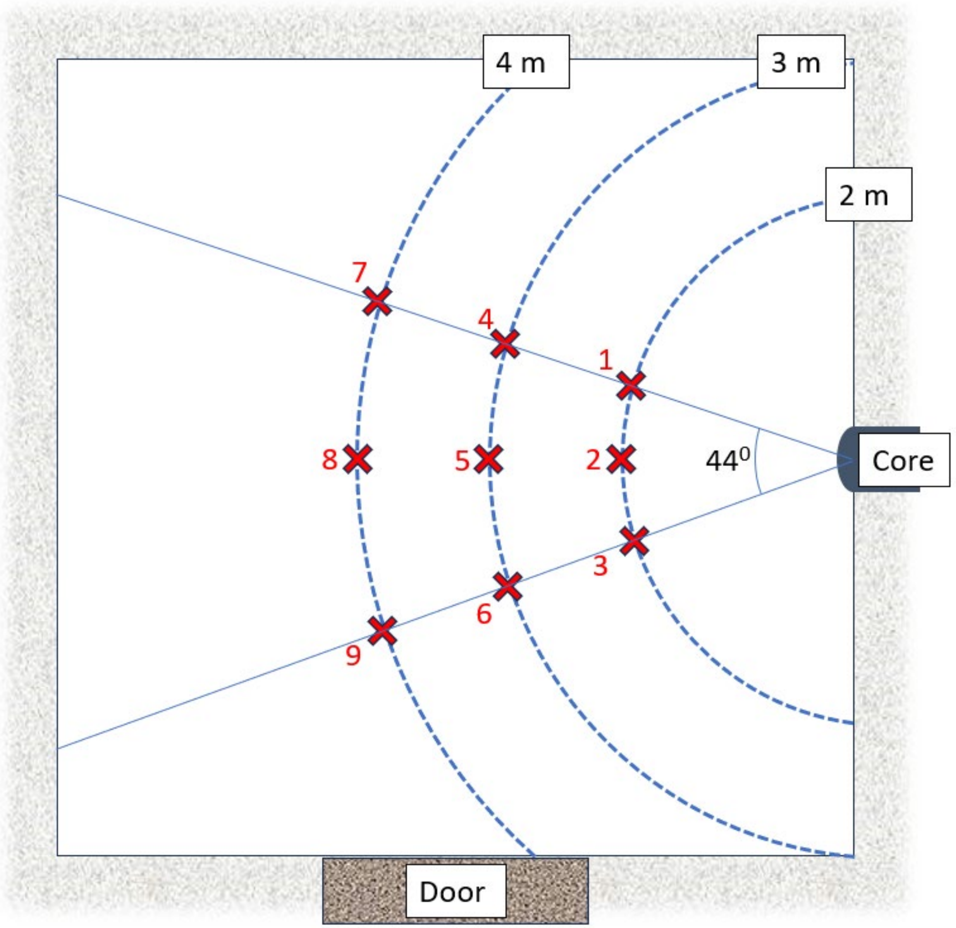
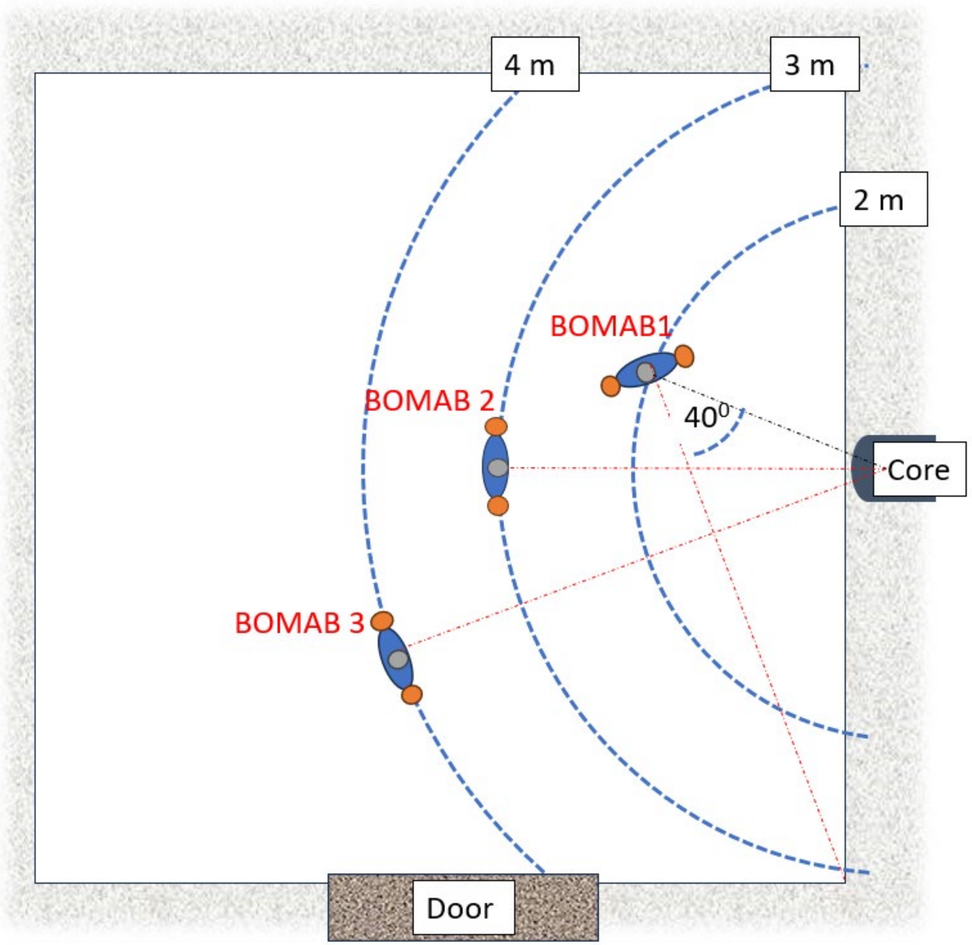
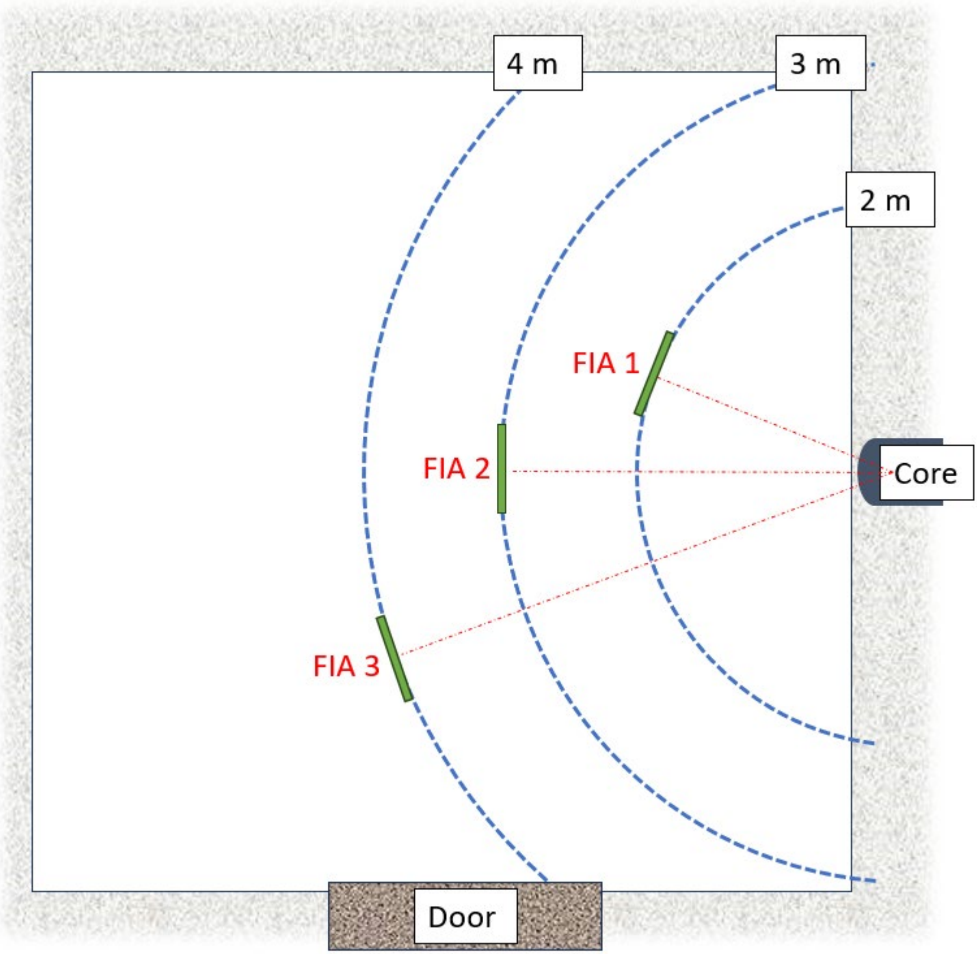
Characterization Positions (from IER 484)



Day 1: Unblinded Irradiations



Positions 1, 5, 9



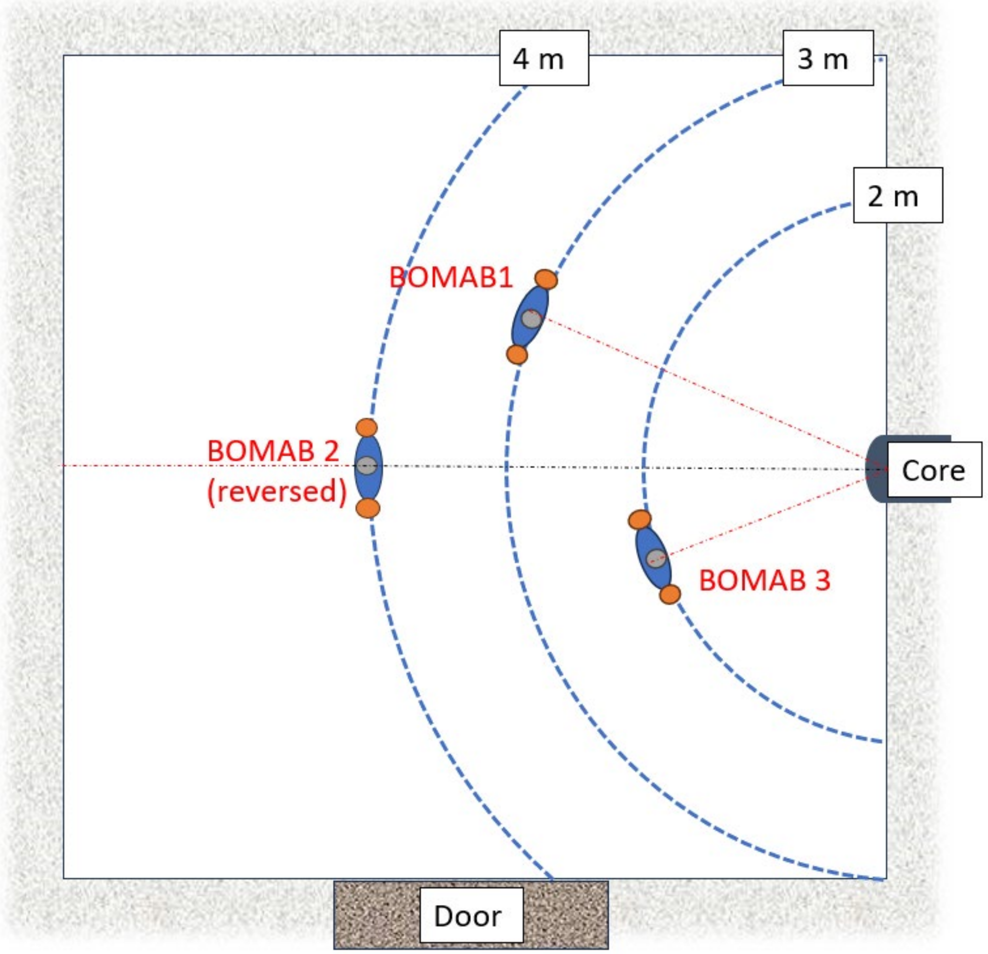
Positions 1, 5, 9

Day 1 Results

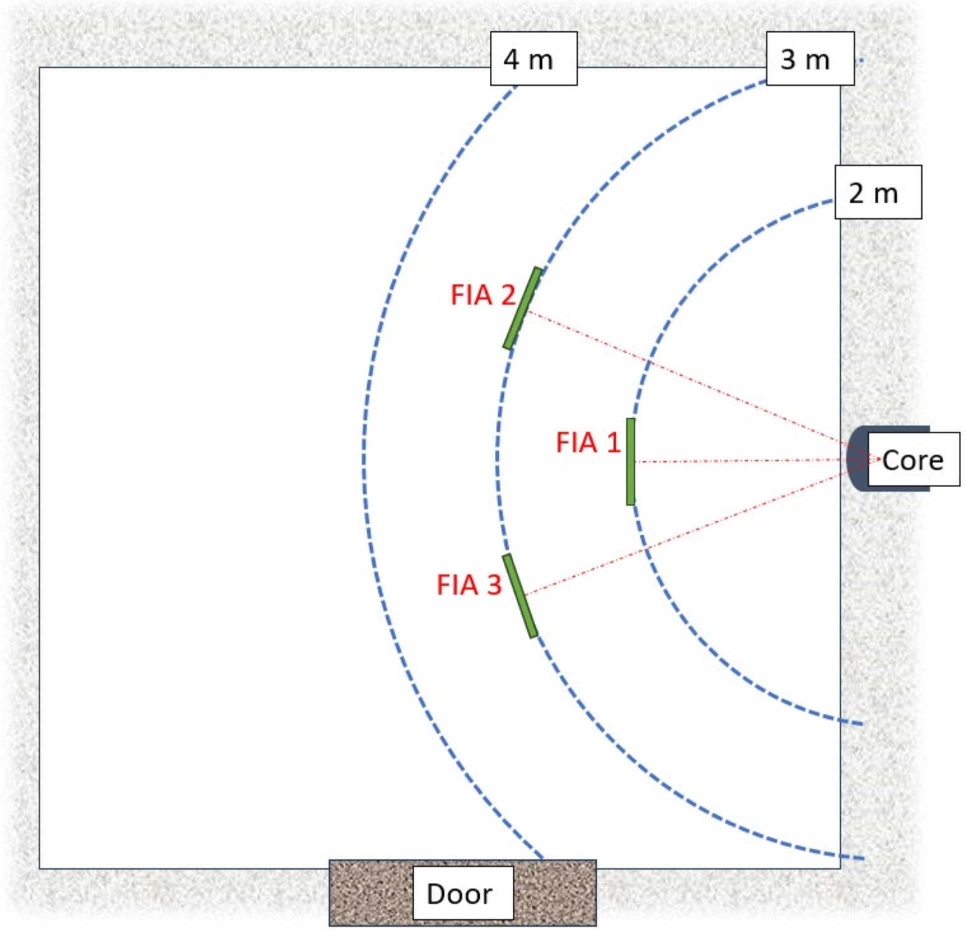
	Neutron [Gy]			Gamma [Gy]		
Lab Number	BOMAB 1	BOMAB 2	BOMAB 3	BOMAB 1	BOMAB 2	BOMAB 3
1	3.50	2.14	1.50	5.60	3.40	2.40
2	2.37	1.62	1.25	3.79	2.58	2.00
3		2.39				
4	4.41	2.25	1.75			
5	3.41	2.10	1.91	3.81	2.03	1.53
6	2.30	1.05	0.68	4.50	2.31	1.53
7	1.84	1.09	0.74			
8	2.27	1.23	0.68	4.21	2.54	1.88
9	2.43	1.56	0.95			
10	6.30	3.32	1.71			
Average	3.20	1.87	1.24	4.38	2.57	1.87
Standard Deviation	1.41	0.71	0.49	0.74	0.51	0.36
Target	3.68	1.93	1.21	5.53	3.15	2.17
Uncertainty	0.36	0.20	0.18	0.42	0.24	0.20
Upper Test Criteria	4.67	2.45	1.56	6.98	3.97	2.74
Lower Test Criteria	2.69	1.40	0.86	4.09	2.32	1.59
% Meeting Criteria	33%	60%	33%	60%	60%	60%

	Neutron [Gy]			Gamma [Gy]		
Lab Number	FIA 1	FIA 2	FIA 3	FIA 1	FIA 2	FIA 3
1						
2						
3						
4						
5	3.29	2.02	1.26	3.29	2.02	1.26
6	2.56	1.27	0.91	4.50	2.34	1.66
7	2.95	1.36	0.91			
8	3.01	1.36	0.84			
9	2.60	1.41	0.91			
10	7.98	8.12	3.71			
Average	3.73	2.59	1.42	3.90	2.18	1.46
Standard Deviation	2.10	2.72	1.13	0.86	0.23	0.28
Target	3.37	1.60	1.31	5.37	2.88	2.07
Uncertainty	0.26	0.05	0.13	0.25	0.04	0.06
Upper Test Criteria	4.26	2.00	1.66	6.74	3.60	2.59
Lower Test Criteria	2.49	1.20	0.96	4.00	2.16	1.55
% Meeting Criteria	83%	67%	17%	50%	50%	50%

Day 2: Blinded Irradiations



Positions 4, 8, 3



Positions 2, 4, 6

Day 2 Results

	Neutron [Gy]			Gamma [Gy]		
Lab Number	BOMAB 1	BOMAB 2	BOMAB 3	BOMAB 1	BOMAB 2	BOMAB 3
1	1.20	1.00	2.24	1.96	1.79	3.36
2	1.28	0.74	2.65	2.13	1.24	4.42
3	1.01	0.44	2.28			
4	1.10	0.78	2.19			
5	1.38	0.87	2.42	1.94	1.54	3.08
6	1.52	0.99	2.64	1.97	1.34	3.67
7	0.33	0.43	1.18			
8	0.93	0.67	1.90	1.40	1.13	2.83
9	1.09	0.83	2.01			
10	2.44	0.32	2.98			
Average	1.23	0.71	2.25	1.88	1.41	3.47
Standard Deviation	0.53	0.24	0.49	0.28	0.26	0.62
Target	1.29	0.67	2.70	2.10	1.36	3.71
Uncertainty	0.20	0.20	0.77	0.18	0.16	0.49
Upper Test Criteria	1.68	0.93	3.72	2.65	1.73	4.76
Lower Test Criteria	0.91	0.41	1.68	1.54	0.98	2.66
% Meeting Criteria	80%	70%	90%	80%	80%	100%

	Neutron [Gy]			Gamma [Gy]		
Lab Number	FIA 1	FIA 2	FIA 3	FIA 1	FIA 2	FIA 3
1	1.95	1.37	1.37			
2						
3						
4						
5	2.22	1.18	1.17	2.22	1.18	1.17
6	2.48	1.10	1.28	3.44	1.89	1.89
7						
8	1.72	0.93	0.92	2.43	1.43	1.49
9	2.11	1.12	1.15			
10	2.61	1.53	1.20			
Average	2.18	1.21	1.18	2.70	1.50	1.52
Standard Deviation	0.33	0.21	0.15	0.65	0.36	0.36
Target	2.16	1.02	0.89	3.48	1.75	1.85
Uncertainty	0.25	0.09	0.18	0.27	0.17	0.06
Upper Test Criteria	2.75	1.29	1.18	4.40	2.22	2.32
Lower Test Criteria	1.56	0.75	0.60	2.57	1.28	1.38
% Meeting Criteria	100%	67%	50%	33%	67%	67%

Day 3 (optional)

- Designed to test shielding and activation of personal items

5.3 Procedures

- Methods to evaluate shielding of individuals and dosimeters.

A.4 Advance Preparation

accident. In addition, information which can be used in supplemental techniques (such as the analysis of jewelry, coins, or blood sodium) should be readily available.

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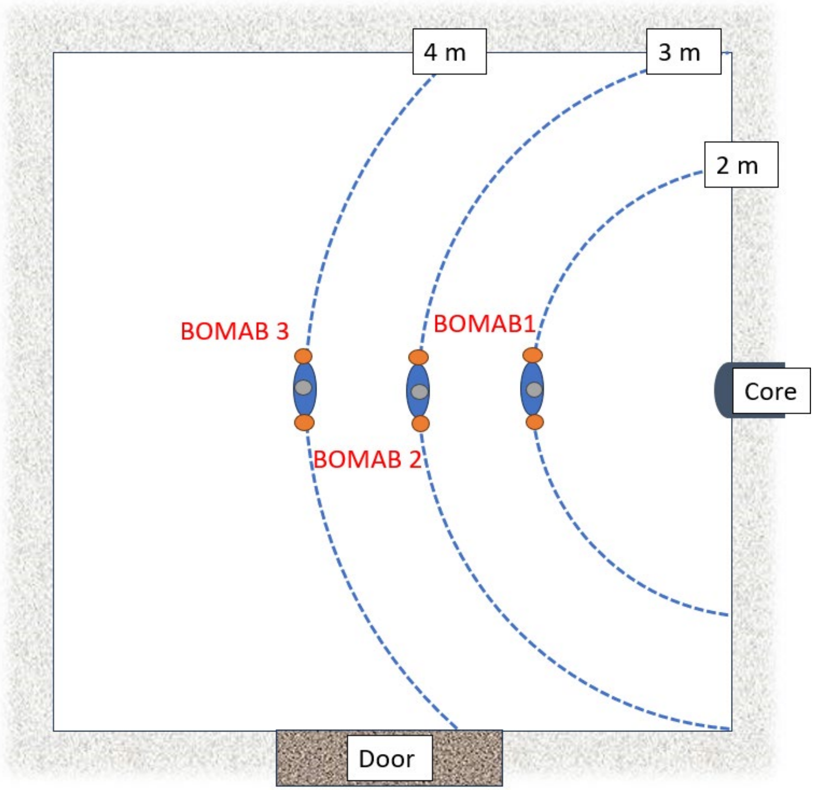
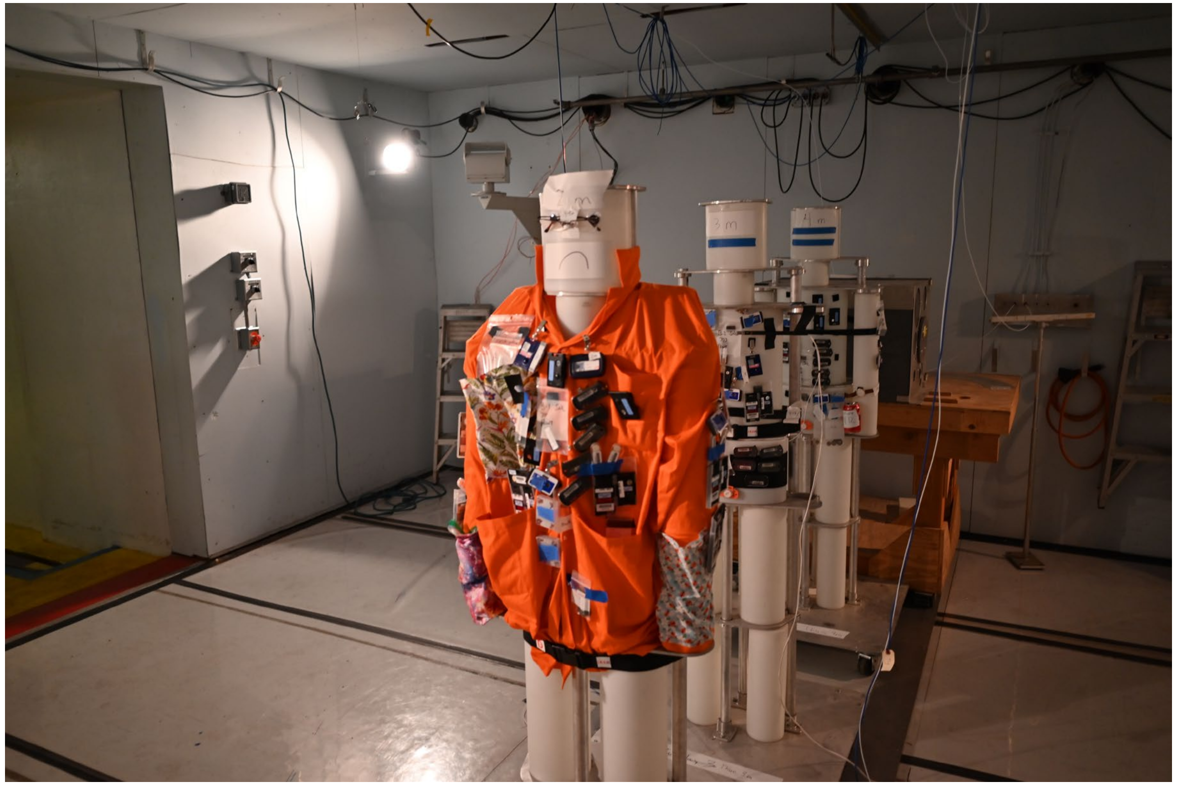




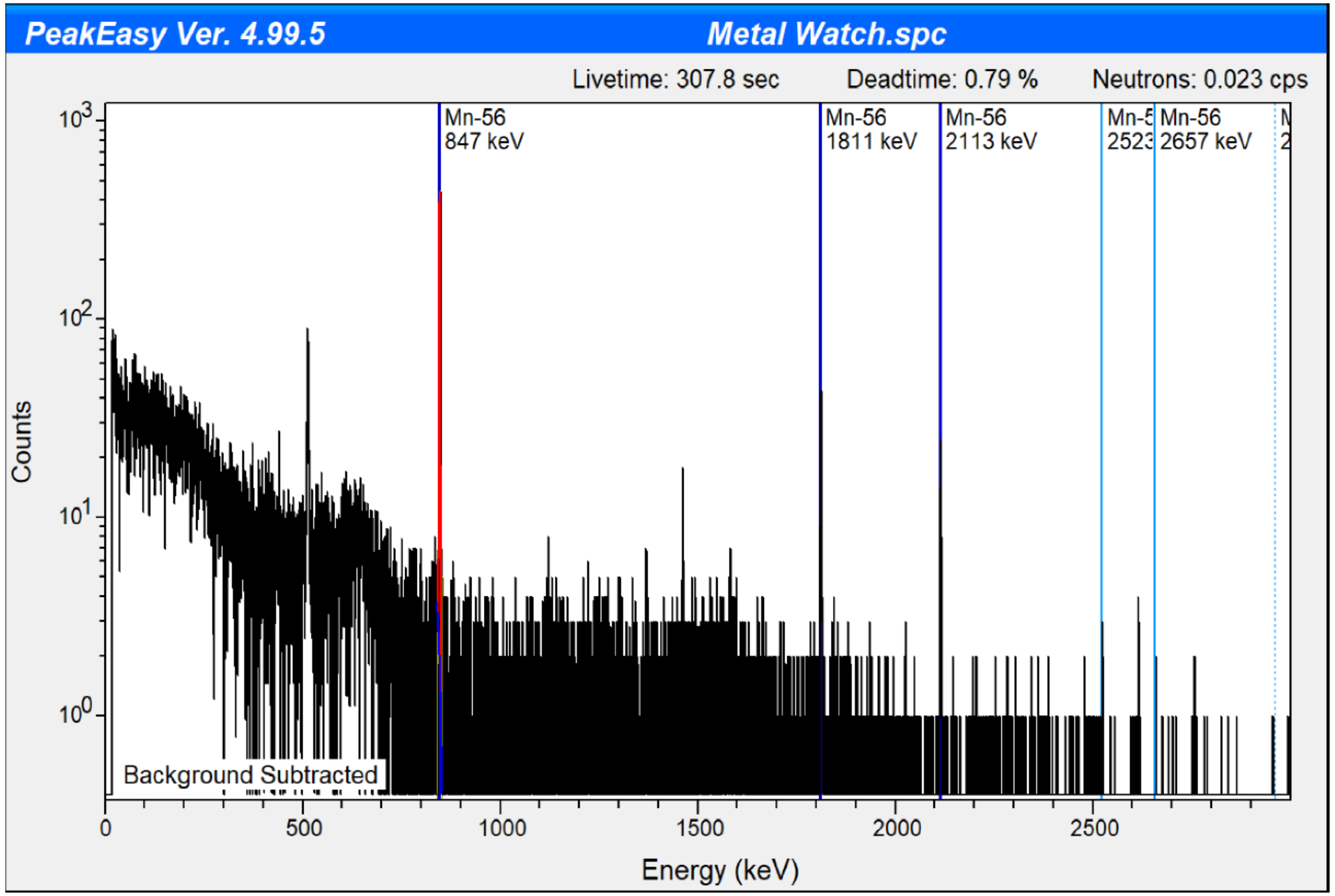
Day 3 (optional): Shielding Effects

- Expected Neutron Doses
  - 2 m: 100 %
  - 3 m: 41%
  - 4 m: 25%

- Reported
  - 2 m: 100%
  - 3 m: 31%
  - 4 m: 24%

Day 3 (optional)

- Watch
- Batteries
- Coins
- Glasses
- Belt
- ID Holder (AWE)
- Cigarette (IRSN)
- Bracelet
- Rivets
- Empty Soda Can

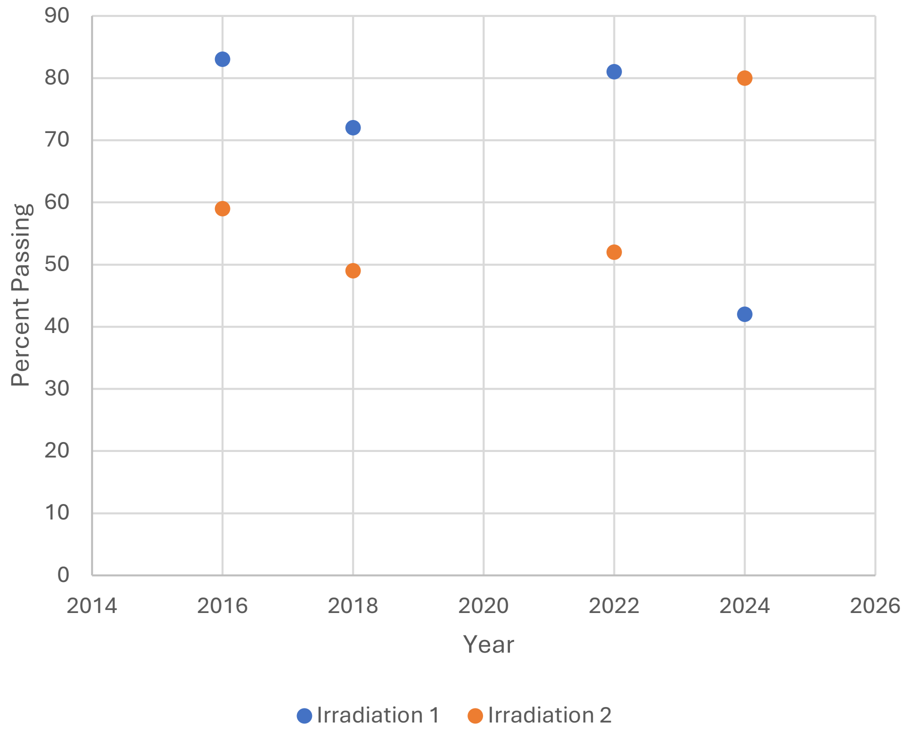


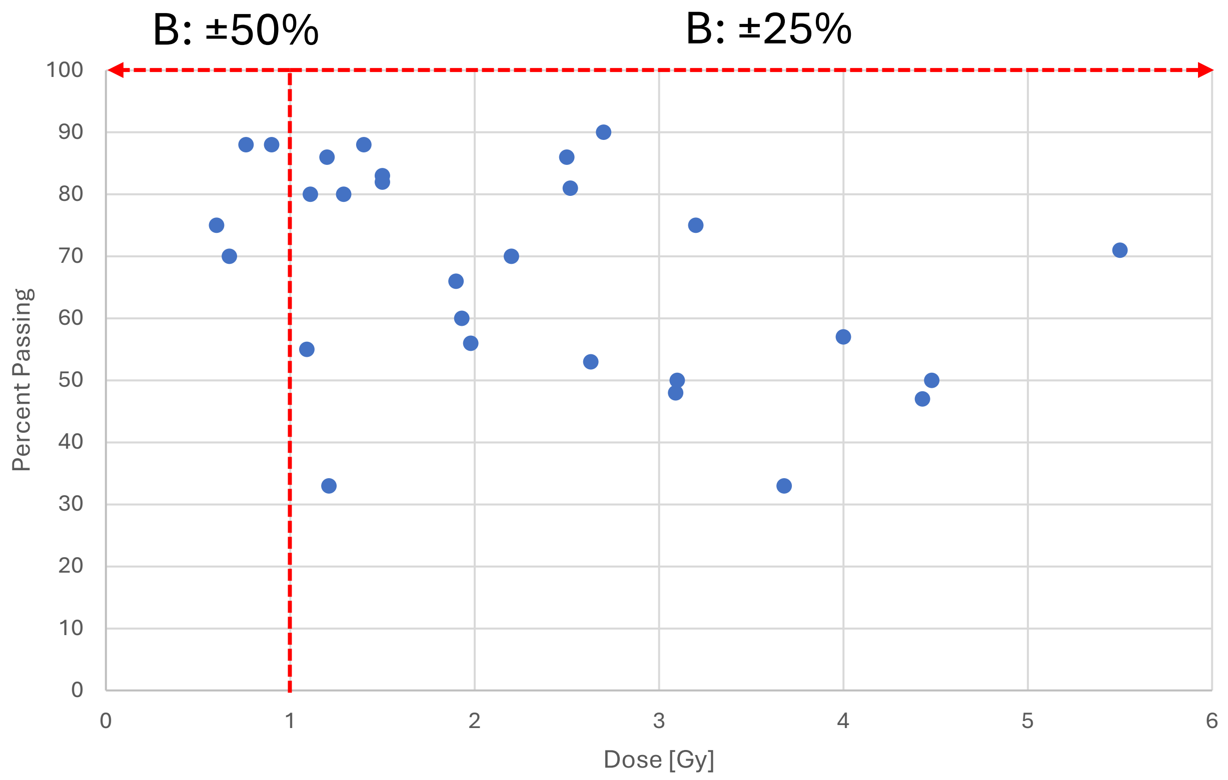
Y-12: Metal Watch

Historic Results

- IER 148 at Godiva (2016)
  - Irradiation 1: 83% pass, Irradiation 2: 59% pass, Irradiation 3: 80% pass
- IER 253 at Flattop (2018)
  - Irradiation 1: 72% pass; Irradiation 2: 49% pass
- IER 538 at Godiva-IV (2022)
  - Irradiation 1: 81% pass; Irradiation 2: 52% pass

Historic Results





Conclusion

- Testing and verification of nuclear accident capabilities is required by regulatory flow downs
- Nuclear accident intercomparisons are valuable to share best practices and foster community
  - Benefit of training new staff as others retire
- Diverse sources continue to present additional value for testing
  - Cohort average matched target value, but individual performance varied

Thank you. Any questions?