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PANTEX PLANT | Y-12 NATIONAL SECURITY COMPLEX

The Y-12 Legacy Criticality Accident Alarm System

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Outline

Purpose of testing – qualifying CAAS detectors

- Configuration of Y-12 Legacy CAAS
- Historic Qualification
  - Previous Reactor Testing Results
- Reactor Testing with Godiva
- New Missions
- Conclusions

Legacy CAAS Configuration

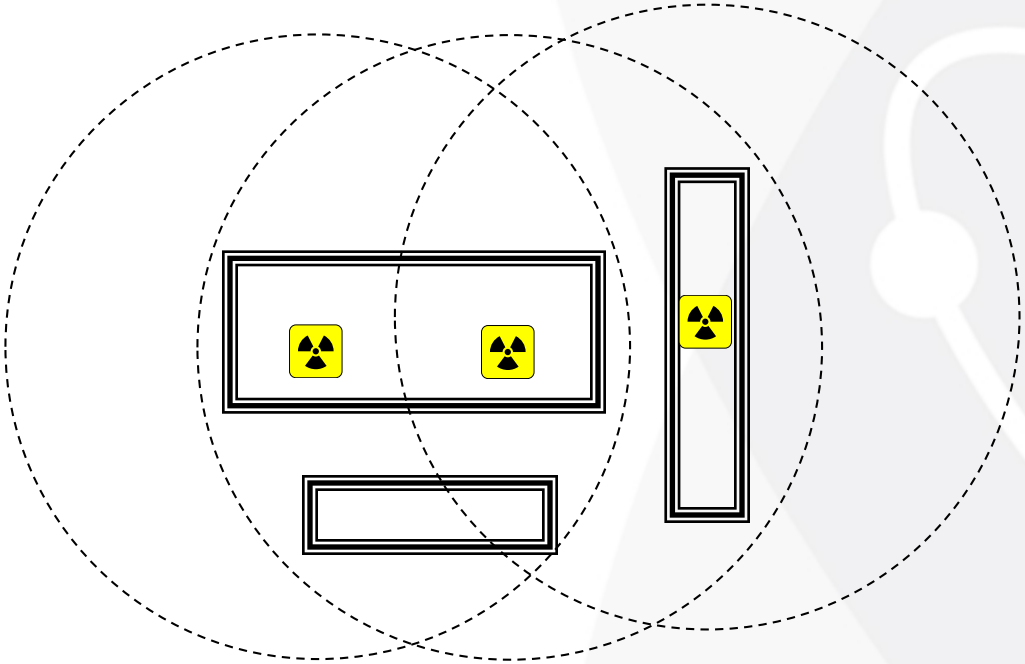
- Gamma sensitive NMC GA-6 detectors
  - Plastic scintillators
  - PMTs
  - 30 +2/-5 mR/hr setpoint
  - Light source creates ~1 mR/hr artificial background
- Detector states
  - Normal
  - “Fail” (< ~0.1 mR/hr)
  - “Hi Rad” (above setpoint)
- CAAS Station
  - 2 detectors
  - Control relay circuit
  - Alarms on 2 “Hi Rad” signals
- Accident Coverage
  - Generic 400-ft range of coverage
  - “Overlapping” coverage required

Overlapping CAAS Coverage

400-foot range of coverage for each station

All fissile material areas within the range of at least 2 stations

Each CAAS station has 2 detectors



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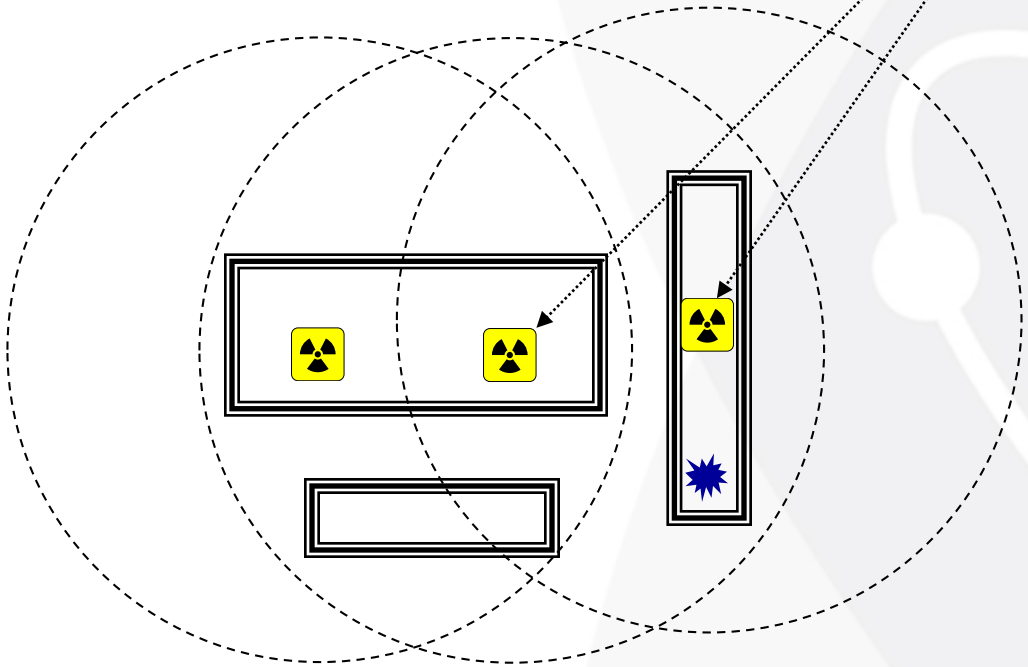
Postulated criticality accident



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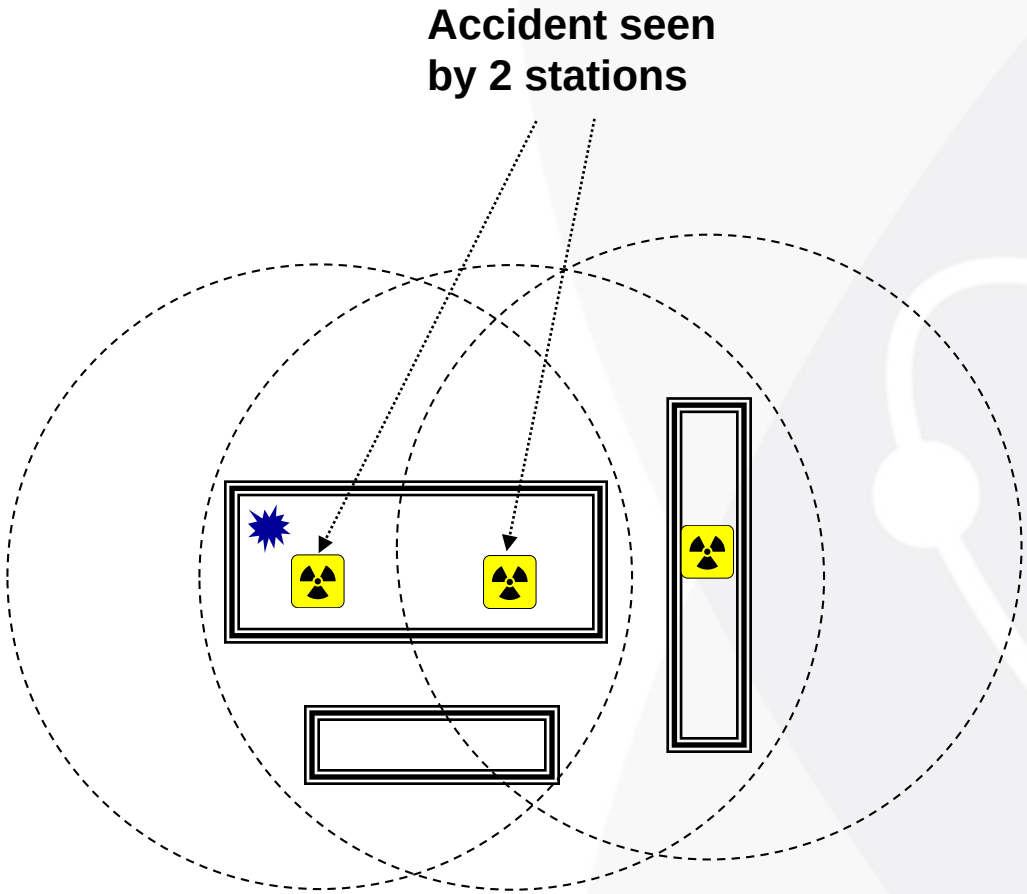

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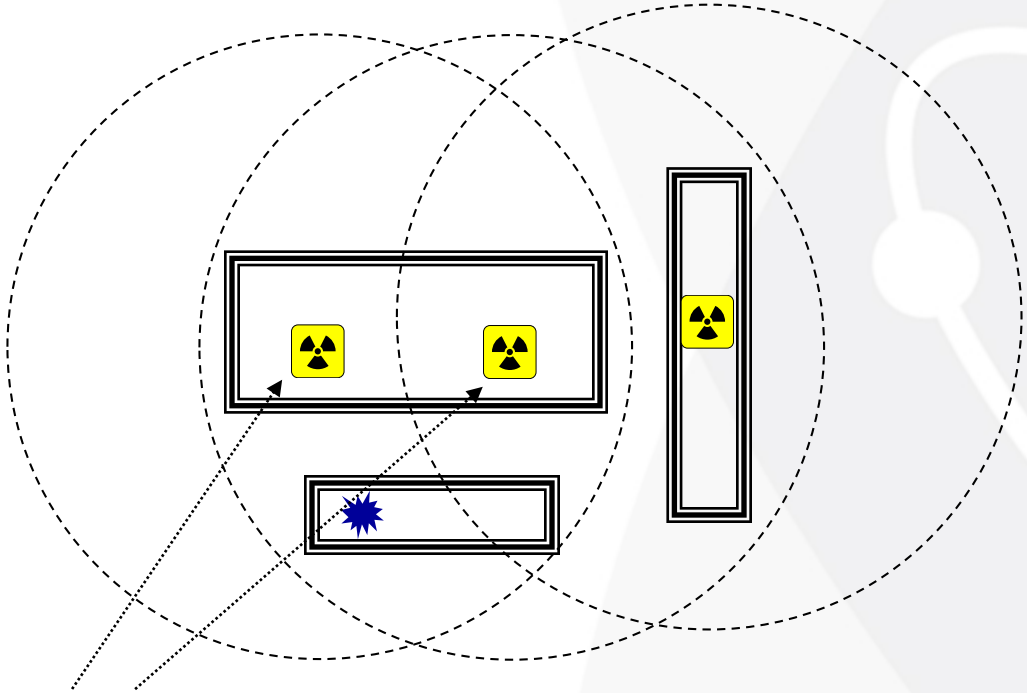

Accident seen by 2 stations

Historic CAAS Detector Qualification and Maintenance

- History of pulse reactor testing dating back to 1950s
  - Range of accident coverage
  - Detector qualification
- Detector checks
  - “Fail” indicator monitoring
  - Periodic visual checks
  - Periodic source checks
- Detectors require periodic calibration due to setpoint drift
  - Y-12 maintains an onsite calibration facility
  - Detectors periodically removed from service and replaced with ones recently calibrated
  - Removed detectors are recalibrated and queued reuse

Previous Reactor Testing

- Detector Qualification (ANSI/ANS-8.3)
  - Minimum accident of concern (20 rad/m @ 2 m or alternate)
  - Response to minimum duration transient (1 ms)
  - Tolerance to maximum radiation (10 rad/s)
- Detector qualification criteria from 1980s
  - 10^{15} fissions 800 feet from detector (distant pulse test)
  - 10^{17} fissions 14 feet from detector (intense pulse test)
  - Required for every detector

Previous Reactor Testing

- Basis for generic range of coverage
  - Testing at ORNL, SNL, and LANL
  - Rudimentary shielding calculations
  - Expert judgment

SHEBA 1994 (most recent)

Dose[1] @ 2 m (rad)	Peak Dose[1] Rate @ 2 m (rad/min)	Distance (ft)	Shielding	Alarms[2]
38	38	800	None	3/3
4.3	12	400	2 clay tiles	3/3
7.2	43	400	3 clay tiles	3/3
11	37	400	2 concrete blocks	1/1

1: Combined gamma and neutron doses
2: Units that alarmed / units available to alarm

Previous Reactor Testing

Qualification Testing from 1980s-1990s

Godiva IV Test Results (April 1989)

Distance (ft)	Pulse Width (FWHM) (μs)	Fissions	Dose[1] @ distance (rad)	Dose[1] Rate @ distance (rad/s)
32 of 32 detectors alarmed				
12	40	3.23×10^{16}	133	3.31×10^{6}
1600	3,500	3.54×10^{14}	8.18×10^{-5}	0.0234
1600	2,000	1.57×10^{15}	3.64×10^{-4}	0.182
1: Combined gamma and neutron doses				

SPR-III Test Results (March 1992)

Pulse Width (FWHM) (ms)	ΔT (°C)	Fissions[1]	Dose[2] @ 3 m (rad)	Dose[2] Rate @ 3 m (rad/s)
Detectors located 12’ 8” from reactor; 63 of 63 detectors alarmed				
2.59	41	2.73×10^{16}	101	3.88×10^{4}
2.79	42	2.80×10^{16}	103	3.70×10^{4}
1.54	50	3.33×10^{16}	123	7.94×10^{4}
Detectors located 722’ from reactor; 54 of 63 detectors alarmed				
0.382	95	6.33×10^{16}	349	9.14×10^{5}
0.442	98	6.53×10^{16}	338	7.65×10^{5}
0.348	99	6.60×10^{16}	356	1.02×10^{6}
1: Based on 150°C corresponding to 1×10^{17} fissions 2: Combined gamma and neutron doses				

Y-12 CAAS Post 1990s

- DOE no longer has an operational fast pulse reactor (until circa ~2010)
- New detectors purchased in 2005
- New PMTs purchased in 2016
- Detector qualification only involves passing calibration process
  - Setpoint equivalent to radiation level at 400 feet from a 20 rad/min @ 2m source (shielding from 3 hollow clay tile walls or 12 inches of concrete)
  - Lacking qualification for maximum radiation and minimum pulse width
- Recent assessment discovered some detectors in service that were tested in 1992 and had inconclusive results reported

Godiva IV Testing

- Subject “sample” of detectors to an intense pulse at close range
  - Maximum expected radiation
  - Minimum pulse width
- 6 detectors tested
  - 2 new detectors
  - 4 existing detectors with replacement PMTs
- Data Logging
  - Data logger in control room
  - Output voltage from each detector connected to data logger
  - Contact closure signal from each detector connected to data logger
  - Signal from reactor acquired to record time of burst

Godiva IV Testing

- Configuration
  - Detectors positioned within an arc around the reactor
  - AC power supplied to each detector
  - 180 cm above the floor
  - 2 meters from the reactor core centerline
  - NADs and CaF_2(Mn) dosimeters placed in similar locations
- Schedule
  - Equipment set-up on day 1
  - 95¢ pulse on day 2 to confirm detector operability and data connections
  - Prompt pulses of increasing magnitude on days 2, 3, and 4
- Data measurements
  - Temperature rise from RTDs
  - Reactivity and fission yield determined from relationship with ΔT
  - Pulse width (FWHM) from PD output trace
  - Dose from relationship with ΔT (IER-147)
  - Dose rate from total dose integrated over pulse shape (PD output trace)

Godiva IV Testing

Results

Burst #	Reactivity (¢ above prompt)	Burst Temp. (ΔT °C)	Fission Yield (x10^{16} fissions)	Pulse Width FWHM[§] (µsec)	Total Absorbed Air Dose* and Dose Rate at 2 m from Godiva IV		CAAS Alarm Response[¥]
					Dose (Rad)	Dose Rate[§] (MRad/s)	
2025	0.8	47.5	0.63	970	28 (14 n + 14 γ)	.017	Immediate
2026	3.0	71.8	0.95	310	42 (20 n + 22 γ)	0.10	Immediate
2027	8.0	149.0	2.0	180	86 (42 n + 44 γ)	0.35	Immediate

New Missions

- Annunciation Areas
  - 200 feet based on 1959 memo (dose from subsequent pulses)
  - Dose received assumed stationary worker
  - New estimates of dose during evacuation
    - Dose avoidance due to evacuation
  - Allows for 50-ft annunciation area boundary as TSR requirement
    - Assemble at stations ~200 feet away
  - Based on general employee training and emergency response, personnel expected to relocate further than 50 feet
- High-fidelity calculations for re-purposed warehouse
  - Specific configurations analyzed
  - Legacy CAAS system supporting enduring facility
  - Lessons learned:
    - Detector height important
    - Storage reconfiguration may require changes to detector placement
    - Controls needed to protect CAAS detectability

Conclusion

- Re-established DOE capability to test detectors with intense, short-duration mixed neutron and gamma field
- Established confidence that new detectors and existing detectors with new PMTs:
  - Will detect a minimum duration criticality accident
  - Are tolerant to maximum radiation
- Fielded dosimetry agreed with IER-147 within 25%
- Future work
  - Re-test detectors purchased in 2005
  - Simulate distant pulse?

Acknowledgments

- DOE NCSP for overall support and funding
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Disclaimer