The Probabilistic Risk Assessment of the Abandoned Chemical Weapons in China

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Performed for the ACW Cabinet Office of Japan 2003 - 2007

Background of ACW in China

- 1945: Abandoned
- 1949-55: Buried in Northern China
- 1995-7: CWC Ratification
- 1999: the Abandoned Chemical Weapons (ACW) Office Formed

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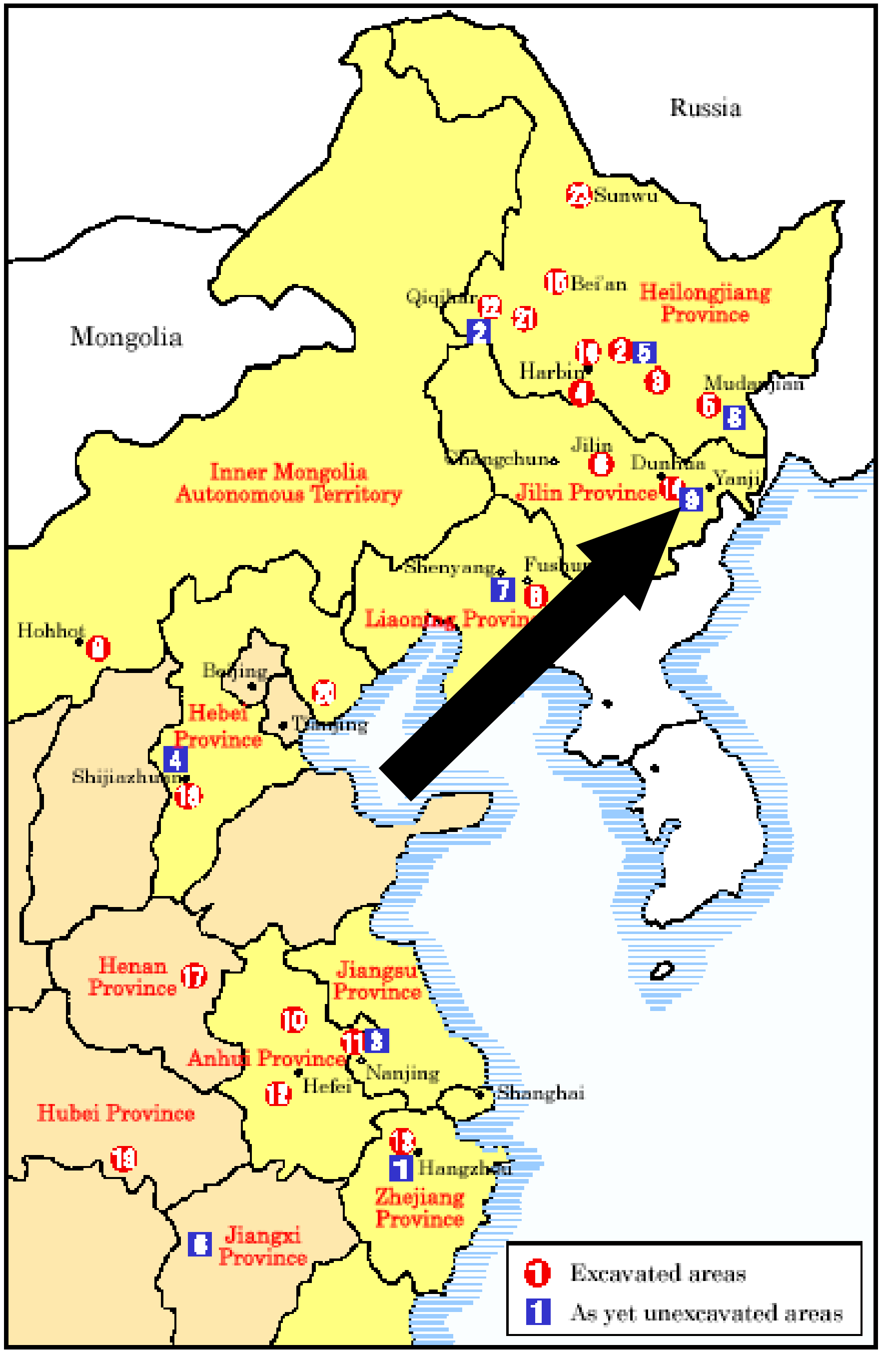
According to the treaty, the weapons were to be Excavated and Disposed of by 2007; now, perhaps, by 2015.



Haerbaling District, Dunhua City, Jilin Province

- The number of CWs is believed to be about 500,000.
- Mainly concerned with two types of Chemical agents:
  - Yellow agent
  - Red agent (DC/DA)

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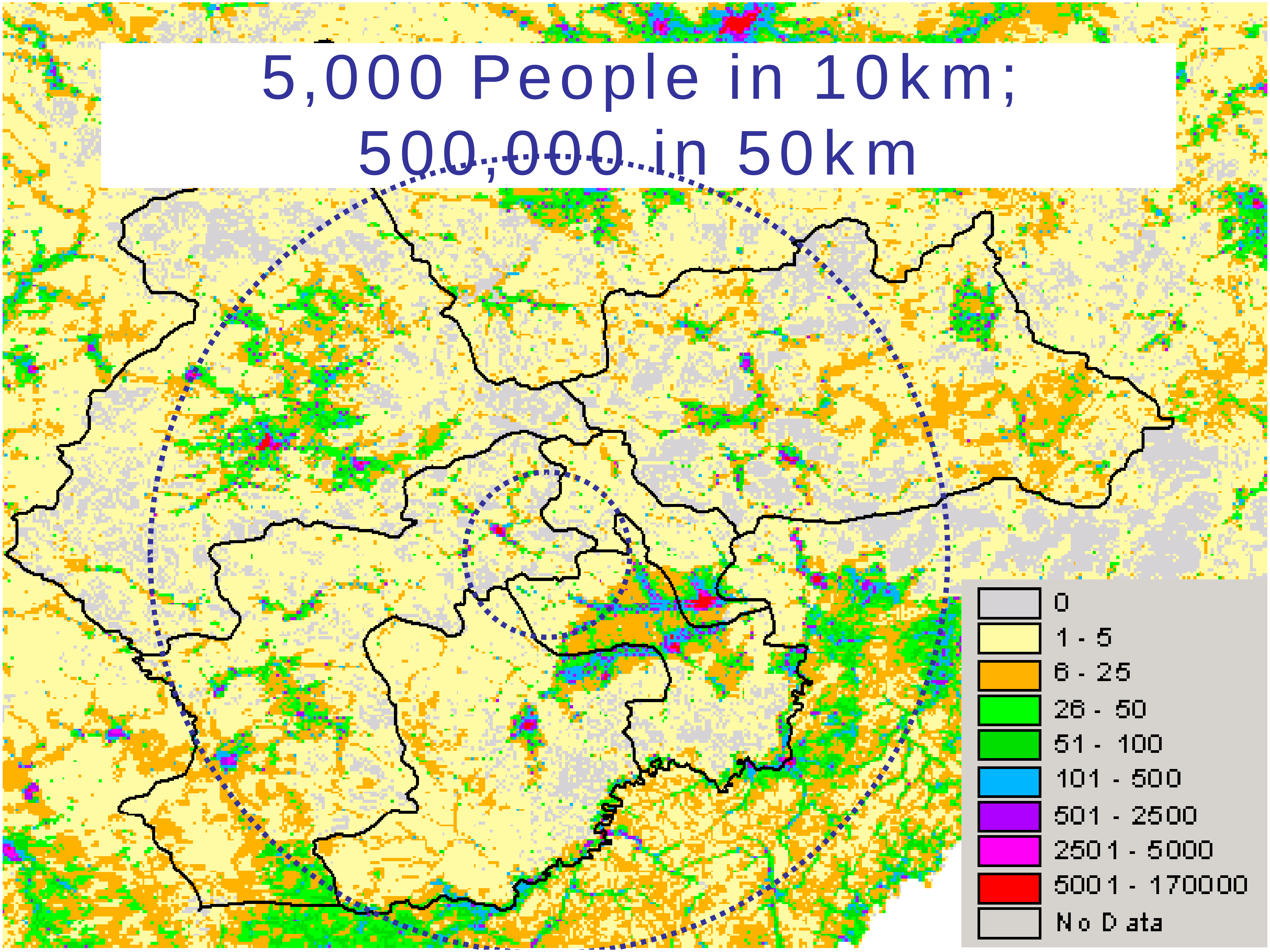
5,000 People in 10km; 500,000 in 50km



The Three Questions of Probabilistic Risk Assessment

(1) What can go wrong?
(2) What is the likelihood?
(3) What is the damage?

Scenario	Likelihood	Damage
s_1	ℓ_1	x_1
s_2	ℓ_2	x_2
s_3	ℓ_3	x_3
•	•	•
•	•	•
•	•	•
•	•	•
•	•	•
s_N	ℓ_N	x_N

$$R \equiv \text{Risk} = \{< s_i, \ell_i, x_i >\}$$

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What the Japanese Government Wanted to Know

1. What Can Go Wrong?
   - Weapon explosions
   - Release of toxic materials
2. What are the Potential Damages?
   - Worker Injuries
   - Population injuries
   - Facility damages
   - Environmental pollutions (soil, air, water)
3. What is our Financial Exposure?
   - Third party liability
   - Workers compensation
   - Repair/Recovery Cost

What We Needed to Know

1. What can happen during the processes?
2. Under what conditions does a weapon explode?
3. How much of agent is released to air?
4. What are the weather conditions?
5. Blast effect to buildings and equipment?
6. What are the effects to human health? How many people may be injured?
7. Is environment contaminated? Cleanup necessary?
8. Effectiveness of emergency response?

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Three Big Questions We Had

1. The ACW in China have been buried underground for decades
   - How can we estimate the conditions, types, and number of buried weapons?
2. There is a Large amount of weapons
   - If a weapon detonates, could it start a domino effect?
3. Weapons contain toxic materials
   – How do we estimate the long term health effects of toxic materials (or even short term)?

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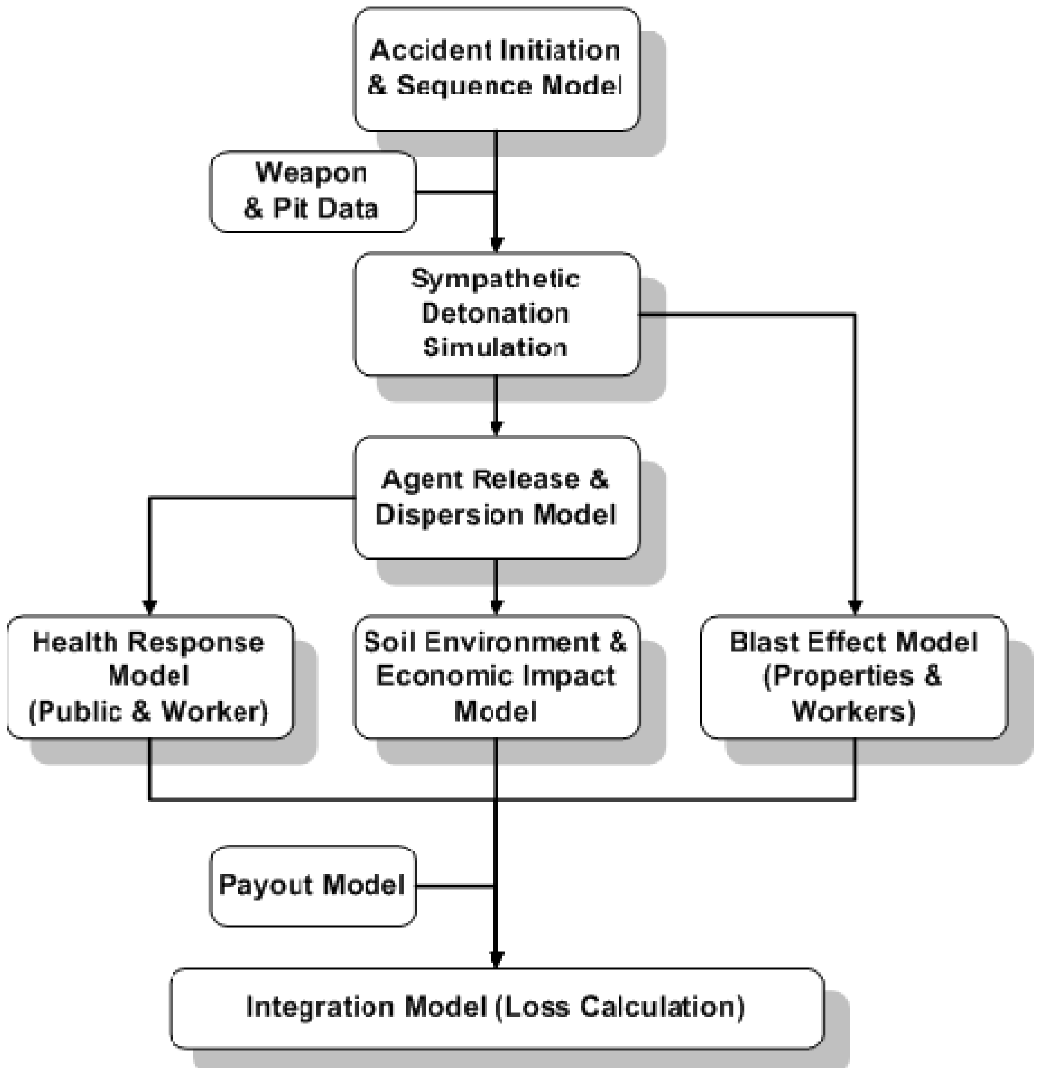
Roadmap



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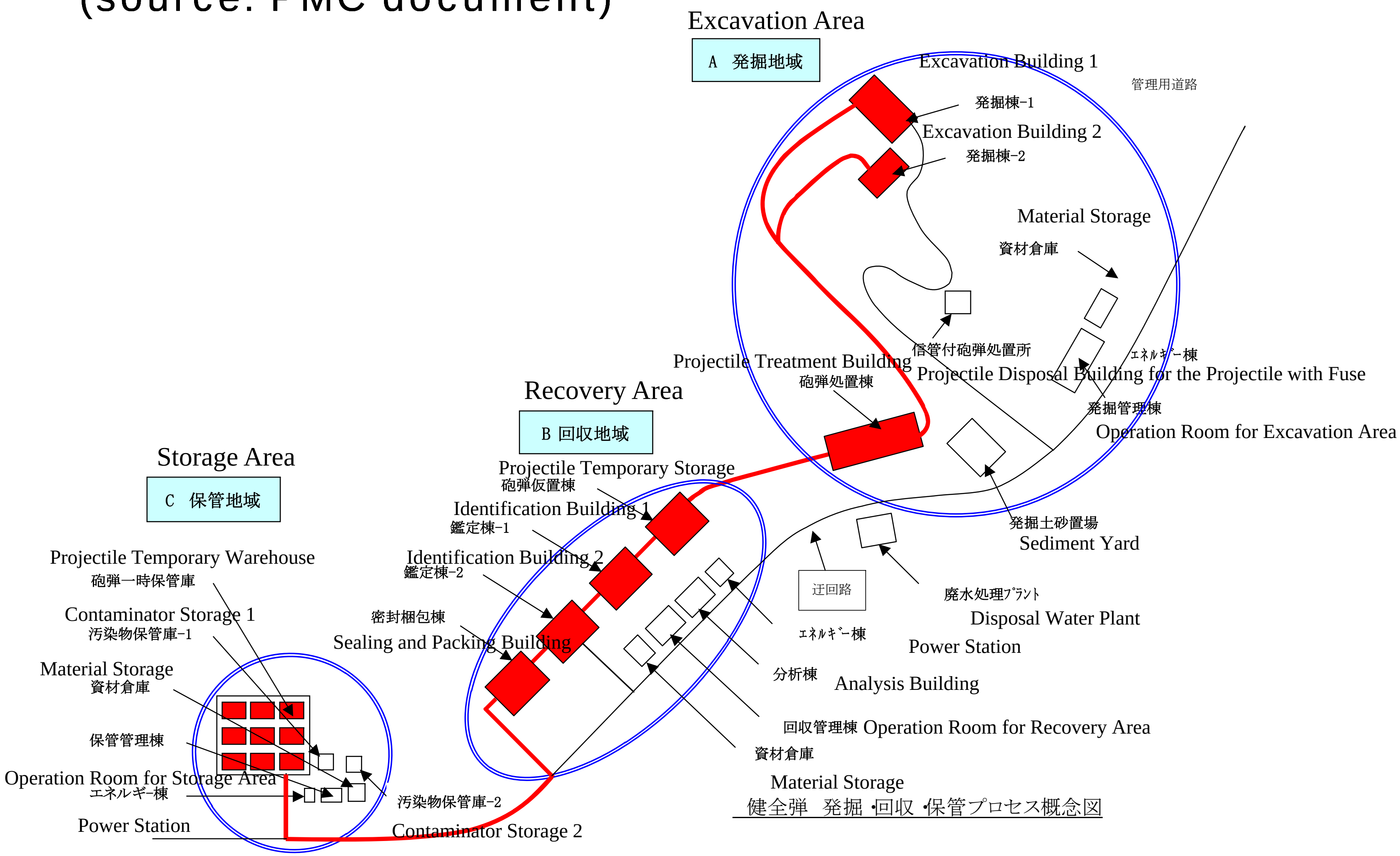
Overview of the ACW Hearbaling Site

(source: PMC document)



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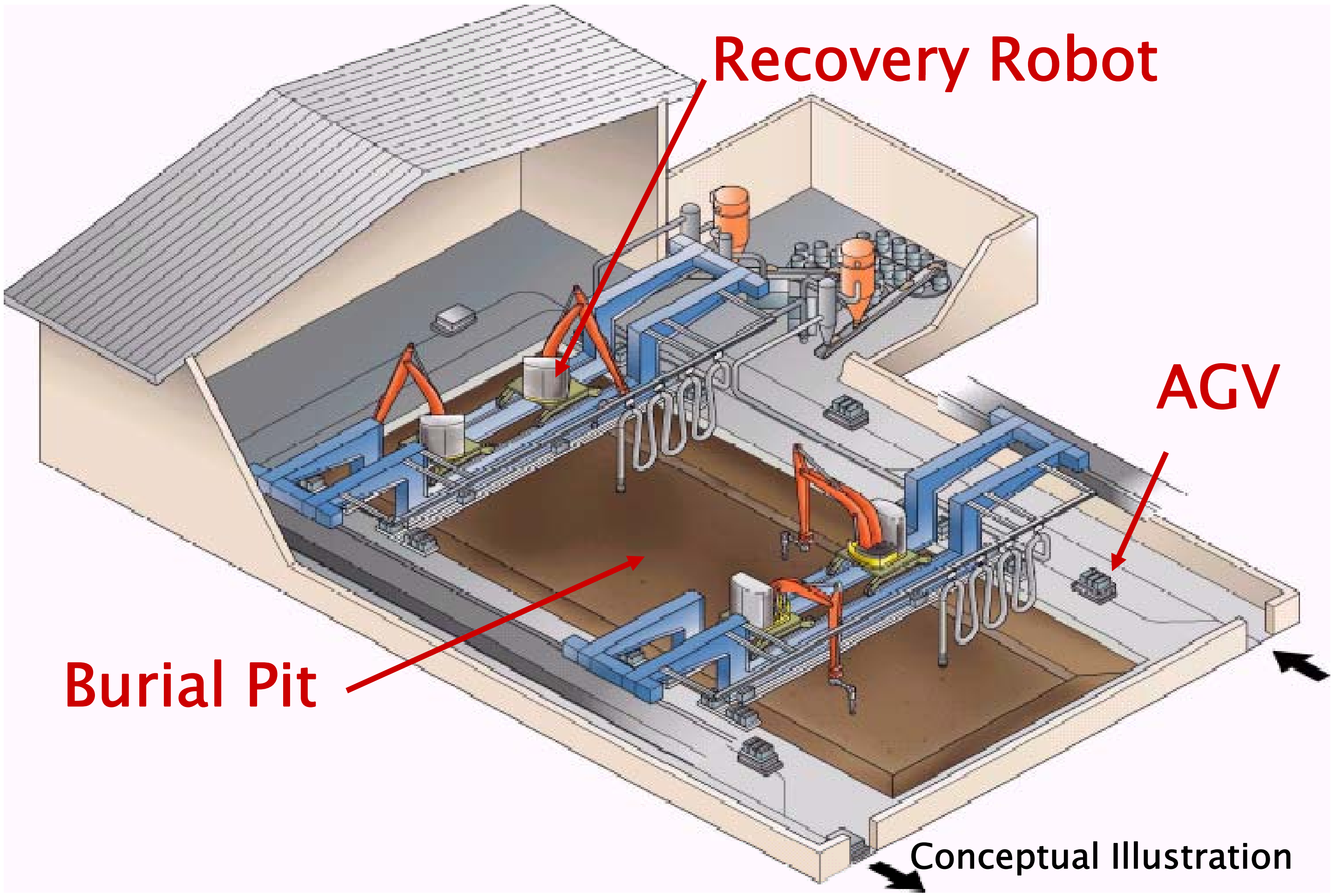
Excavation



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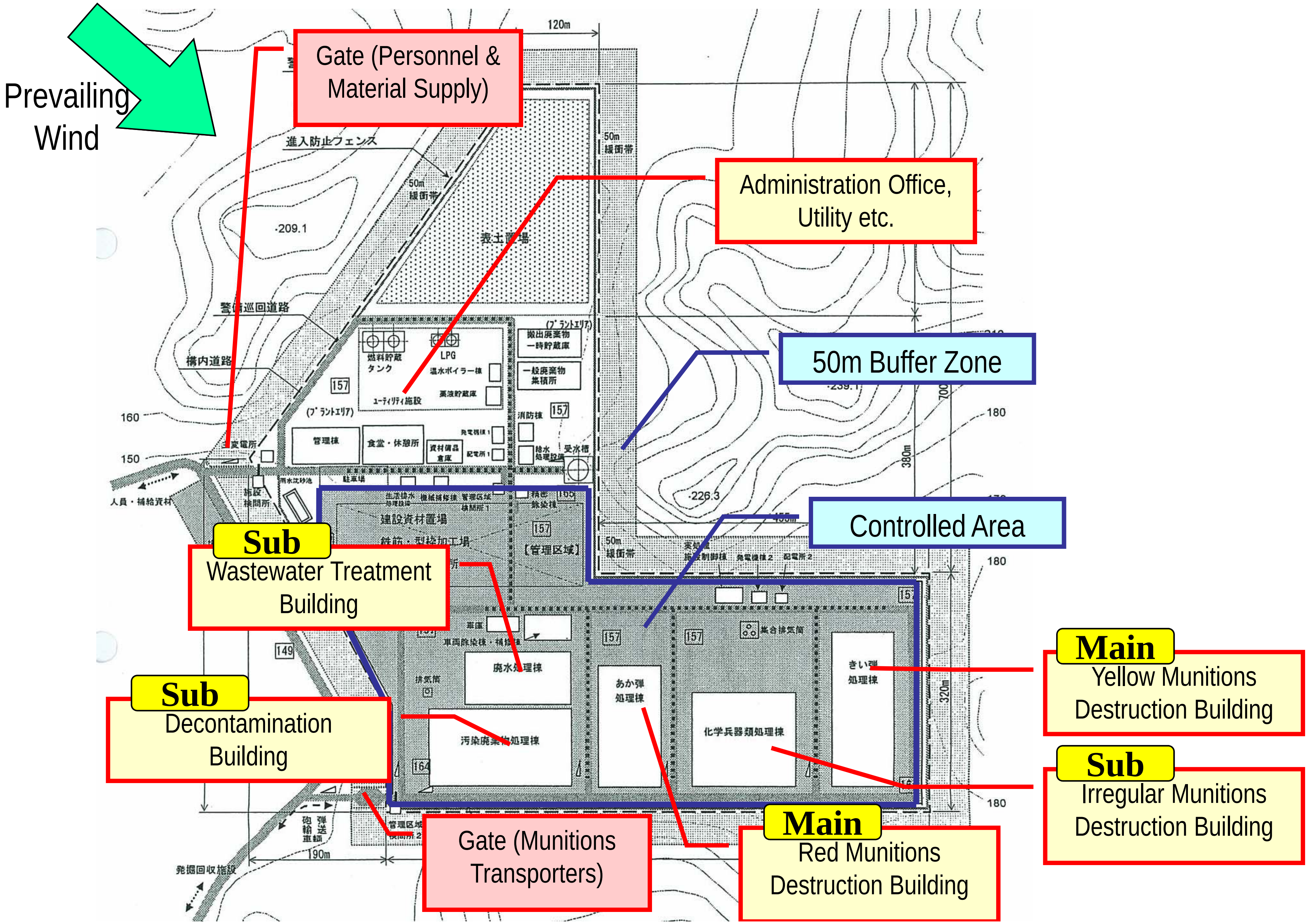
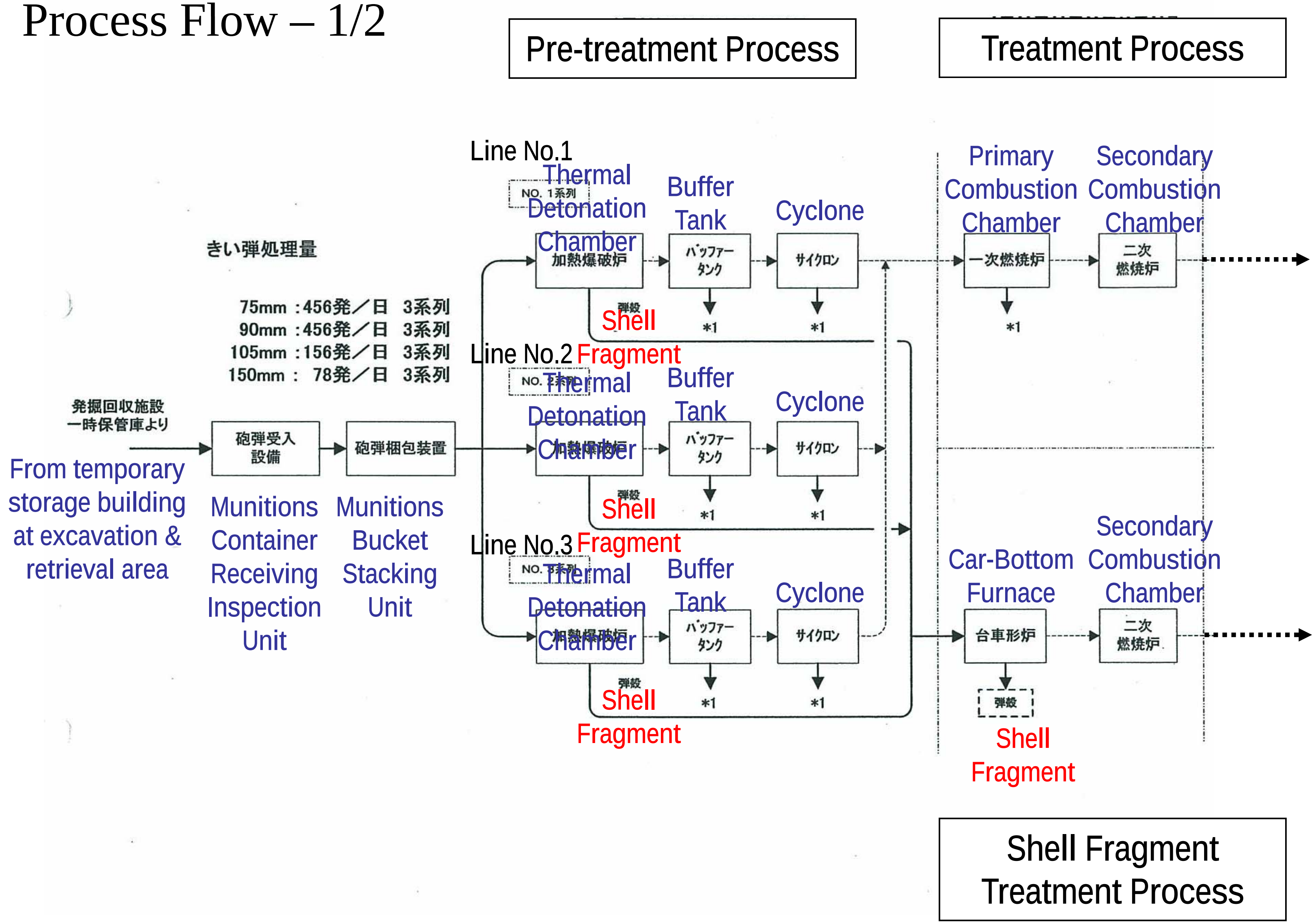
Layout Plan


Prevailing Wind
Gate (Personnel & Material Supply)
Administration Office, Utility etc.
50m Buffer Zone
Controlled Area
Sub
Wastewater Treatment Building
Sub
Decontamination Building
Main
Yellow Munitions Destruction Building
Sub
Irregular Munitions Destruction Building
Main
Red Munitions Destruction Building
Gate (Munitions Transporters)

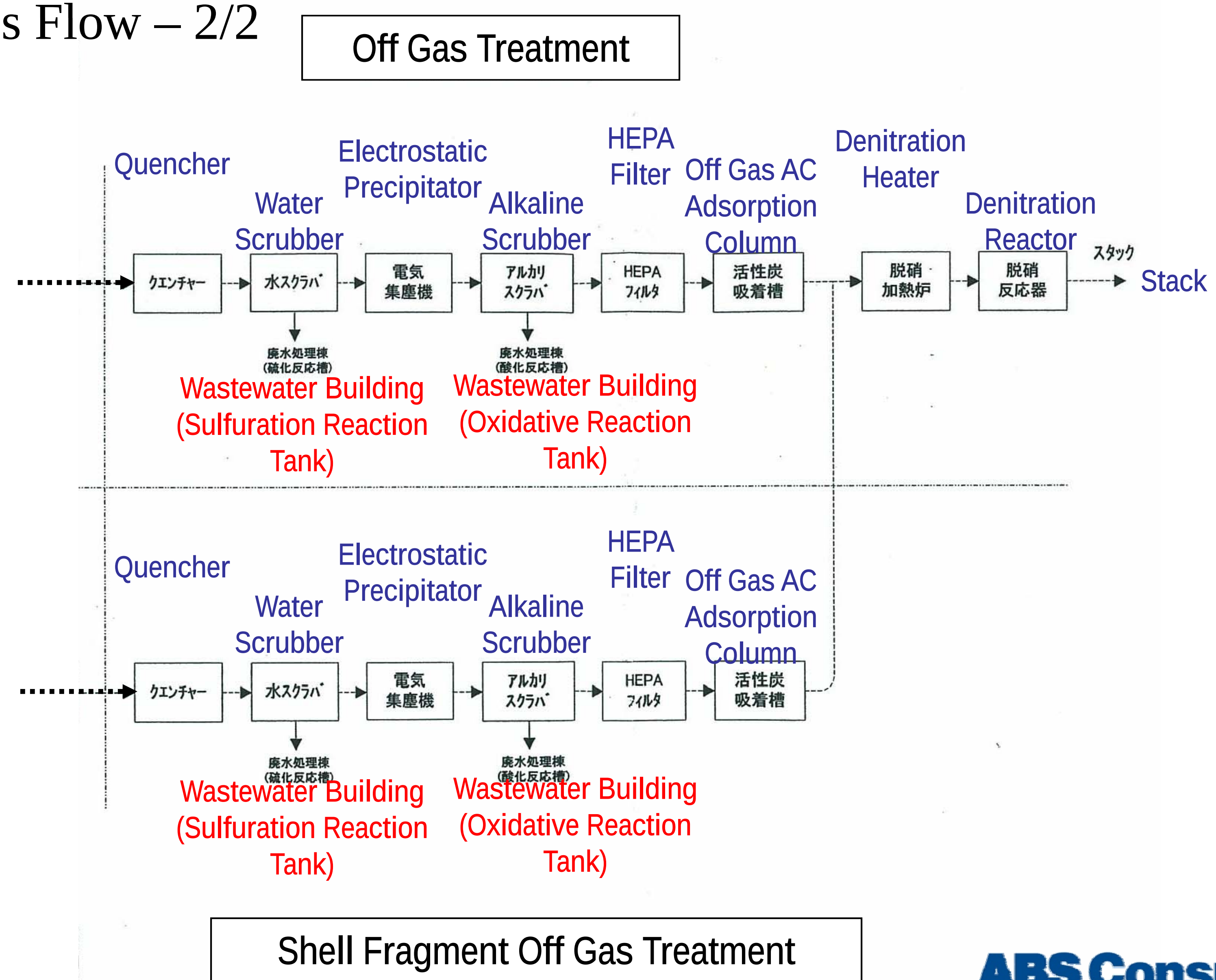
Main Plant (Yellow Munitions)

Process Flow – 1/2



Main Plant (Yellow Munitions) (Cont.)

Process Flow – 2/2



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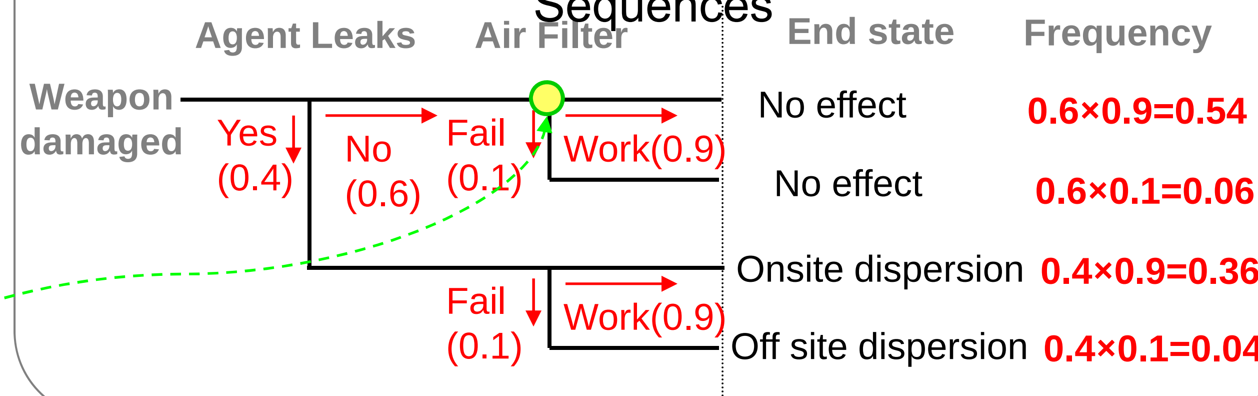
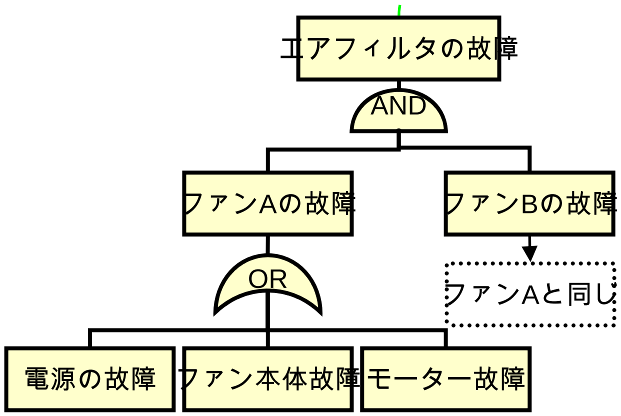
ACW PRA

1.What can go wrong?
2.How likely is it?
3.What are the consequences ?

Level 1 PRA : Quantification of Frequencies of Sequences





Level 2 PRA : Development of Source Terms

No.1 : Leaking of Agent: Inside of the facilities
⇒10kg DC

No.2 : Leaking of Agent: Outside of the facilities
⇒ 30kg DC

Level 3 PRA : Consequence Analysis

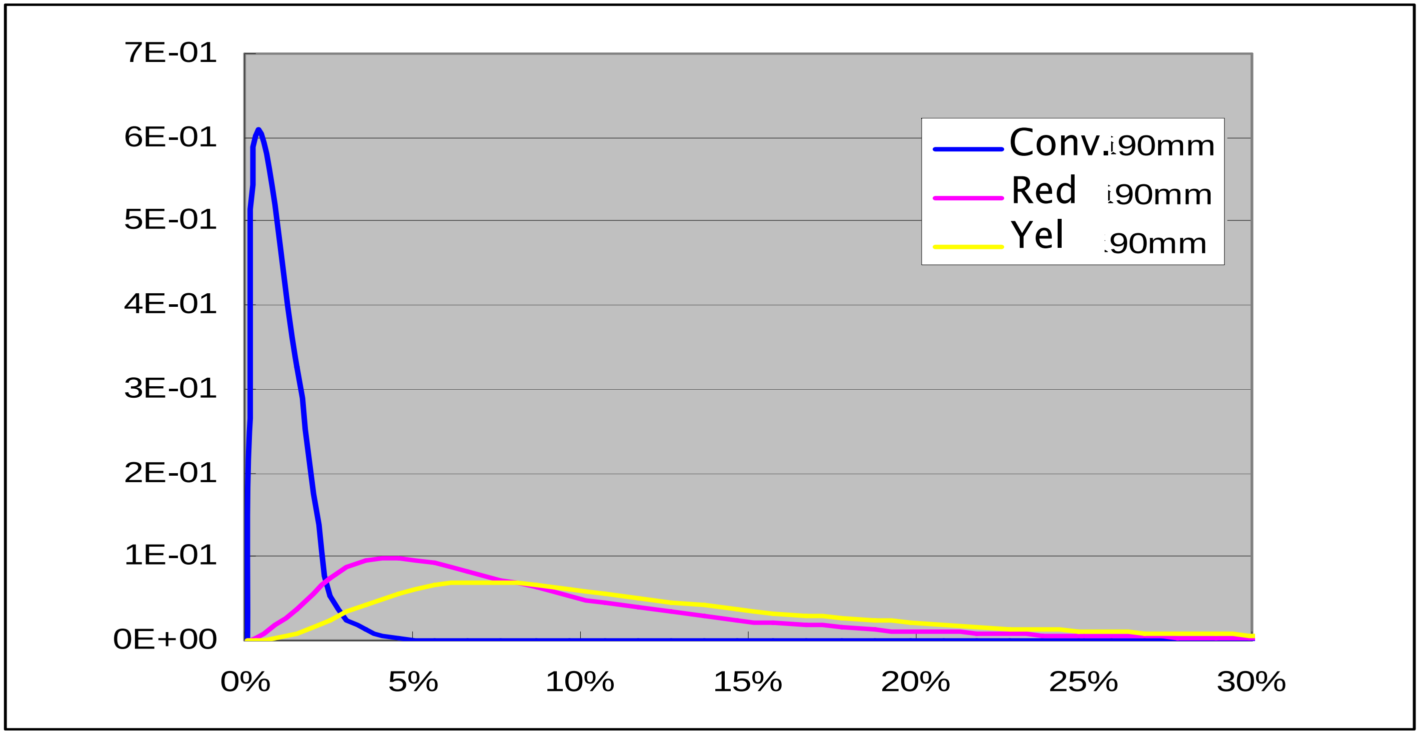
No.1
3 workers get minor injury (Frequency = 0.36)
No.2
250 people (general population) get major injury (Frequency= 0.04)

Data Gathering

- Using Data from Other Weapon Sites

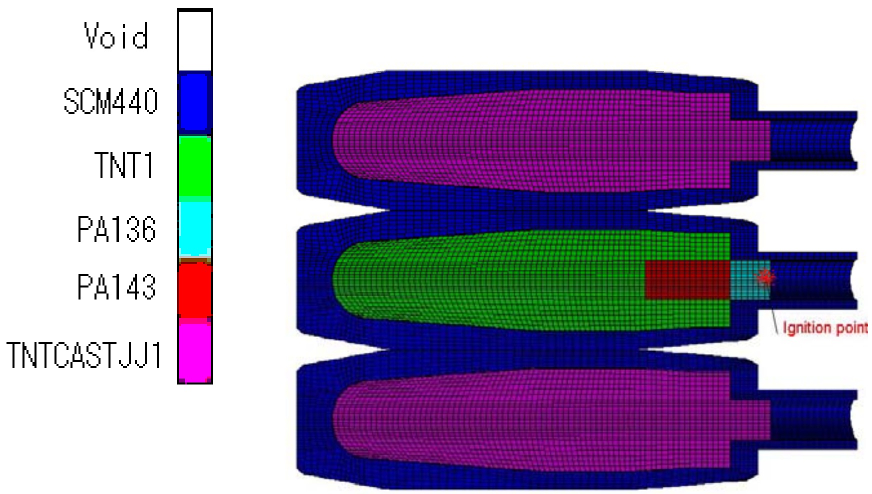
  Bayesian 2nd stage update technique was used to create uncertainty distributions for each weapon type, based on:

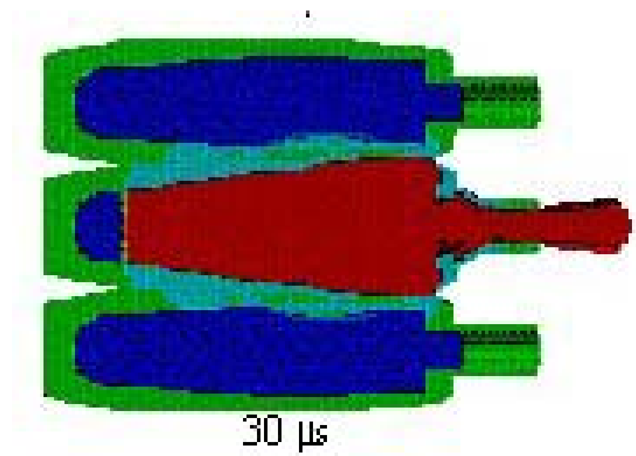
  - Weapon data of other sites,
  - Expert opinions, and
  - Exploratory excavation at the Haerbaling site.



Sympathetic Detonation

AUTODYN 3 D
(76mm)





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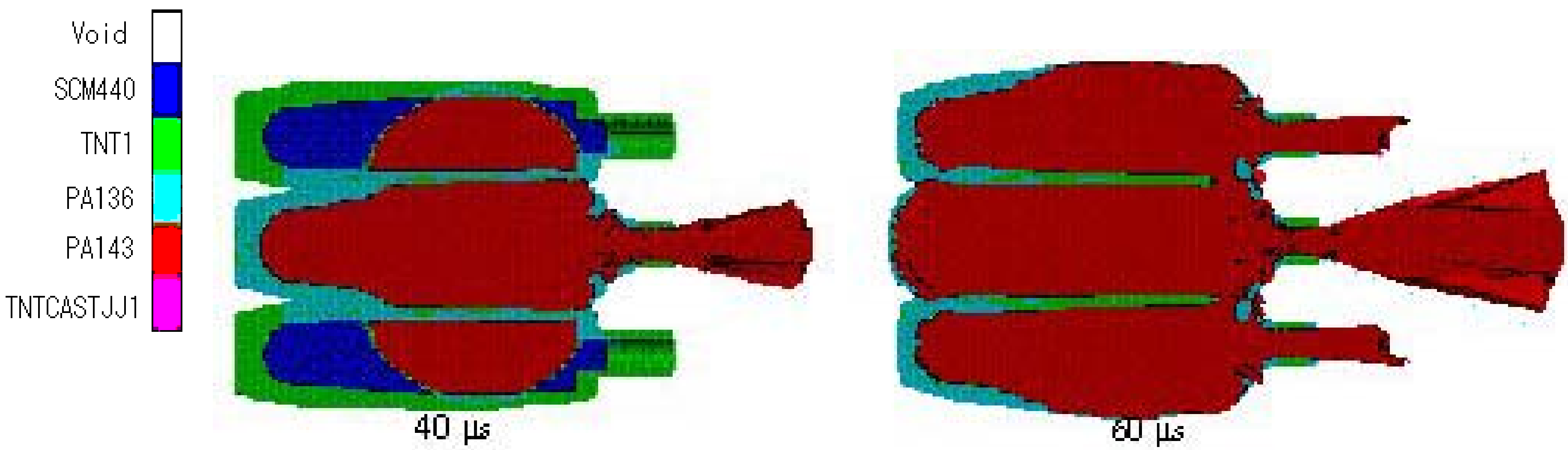
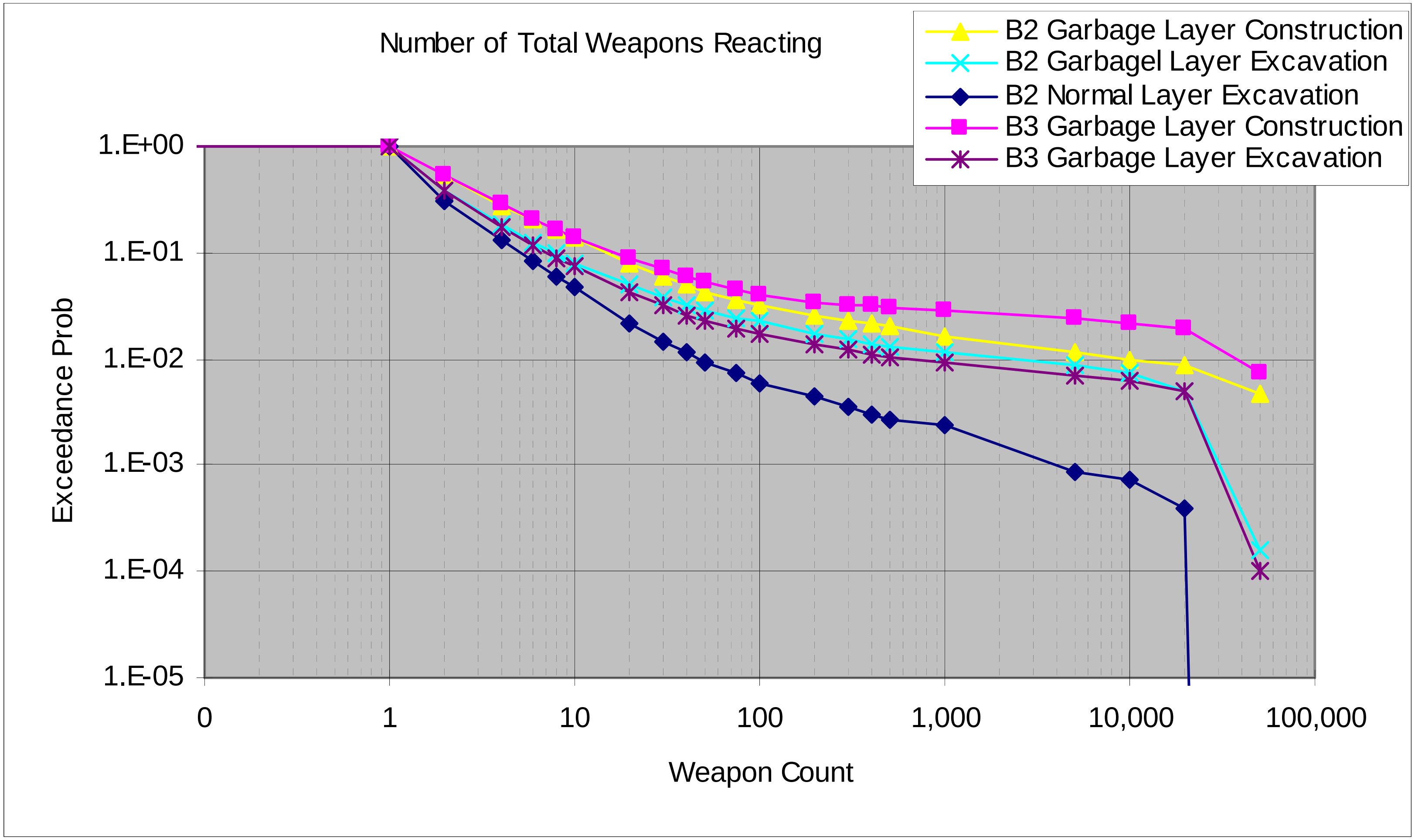
Sympathetic Detonation (Continued)

AUTODYN 3 D
76mm



Results of SympFD



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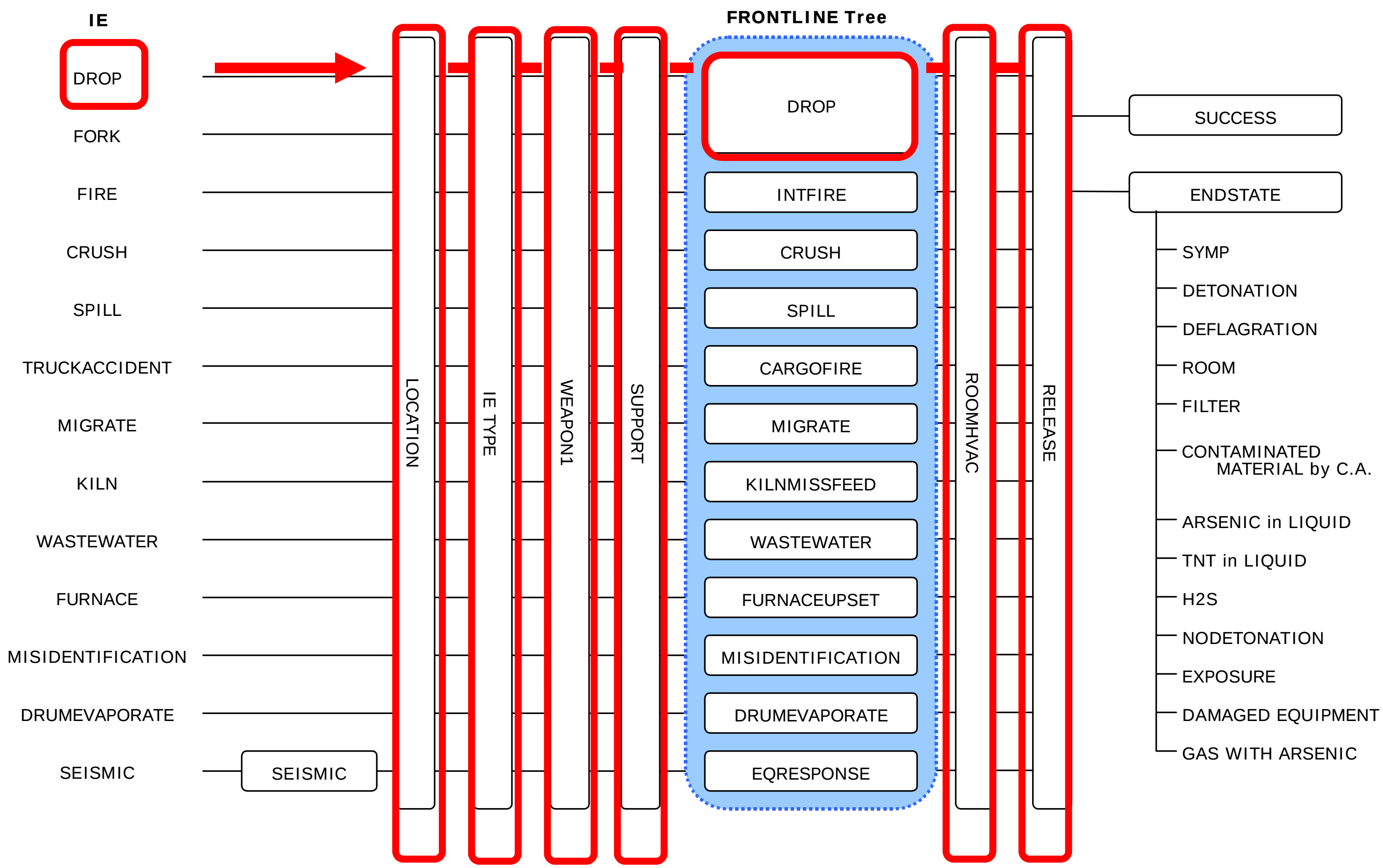
Event Sequence Model for Disposal

E.g. Weapon Drop



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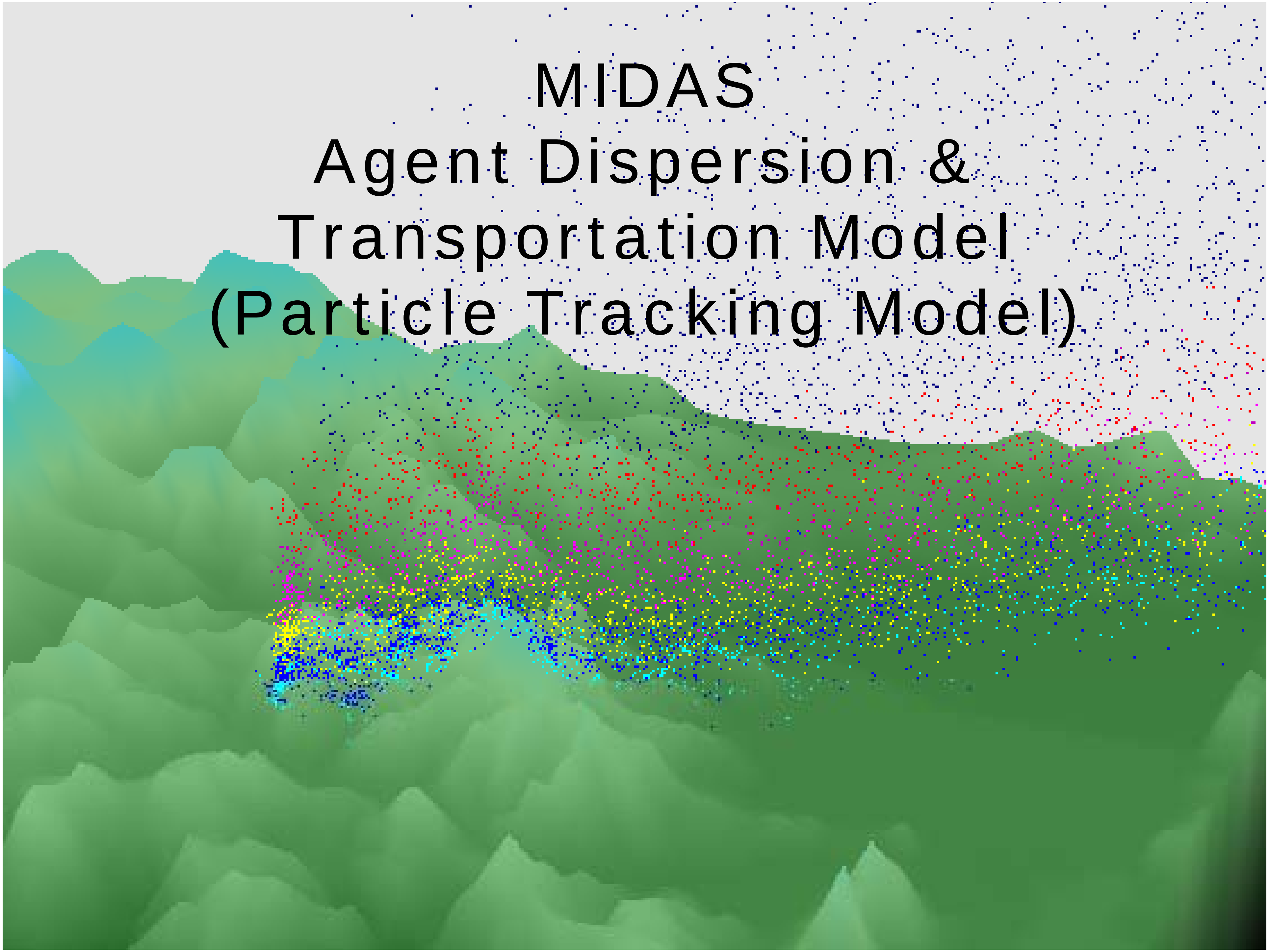
Transportation Fire Simulation

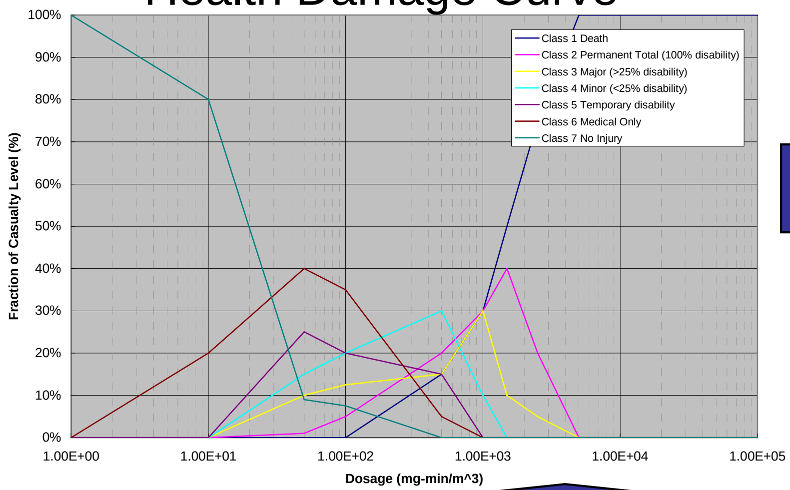
0.260485883	Uniform Random Number for Event												
				Tank Capacity Full									
Event		Simulation Probability Used	Spill Area	Correlated Fuel	First Truck Simulation	Middle Truck Simulation	Last Truck Simulation		**Tank Capacity Full**				**Tank Filled**
Car-Truck		0	8	230	0.2177	0	0.1012			capacity			
Single Truck		0.343	6	150	0.4675	0.343	0.4009		Car Tank	80	liters		Car Tank
Truck-Truck		0.657	10	300	0.3148	0.657	0.4978		Truck Tank	150	liters		Truck Tank
Probability of Single Truck Colliding with Object				0.105									**Tank Filled**
Probability of Single Truck Rollover/Fire Only Event				0.895									
													Car Tank
Event Scenario:		**Single Truck**	Type:	**Rollover**	0.2941699	Uniform Random Number for Event Type							Truck Tank
Combustion Rate:		0.16	inches/min										
Burn Time=		150	liters	x	1000	cm^3/liter							
		6	ft^2	x	929	cm^2/ft^2	x	0.16	inches/min	x	2.54	cm/inch	
Unmitigated Burn Time:		**66.22**	**min**										
Upper Limit of Fuel for Escort Fire Fighting		225	liters										
Pr Escort Takes Actions		0.75	0	Uniform Random Number for Escort Taking Action									
Escort Would Fight Fire		Yes		1									
Time for FD to Arrive		3	Minutes										
Pr FD Takes Action		0.8	0	Uniform Random Number for FD Taking Action									
FD Would Fight Fire		Yes											
Escort Adjusted Burn Time		31.60858344											
Final Adjusted Burn Time		6.321716688		0	1	0	0						

MIDAS
Agent Dispersion & Transportation Model (Particle Tracking Model)



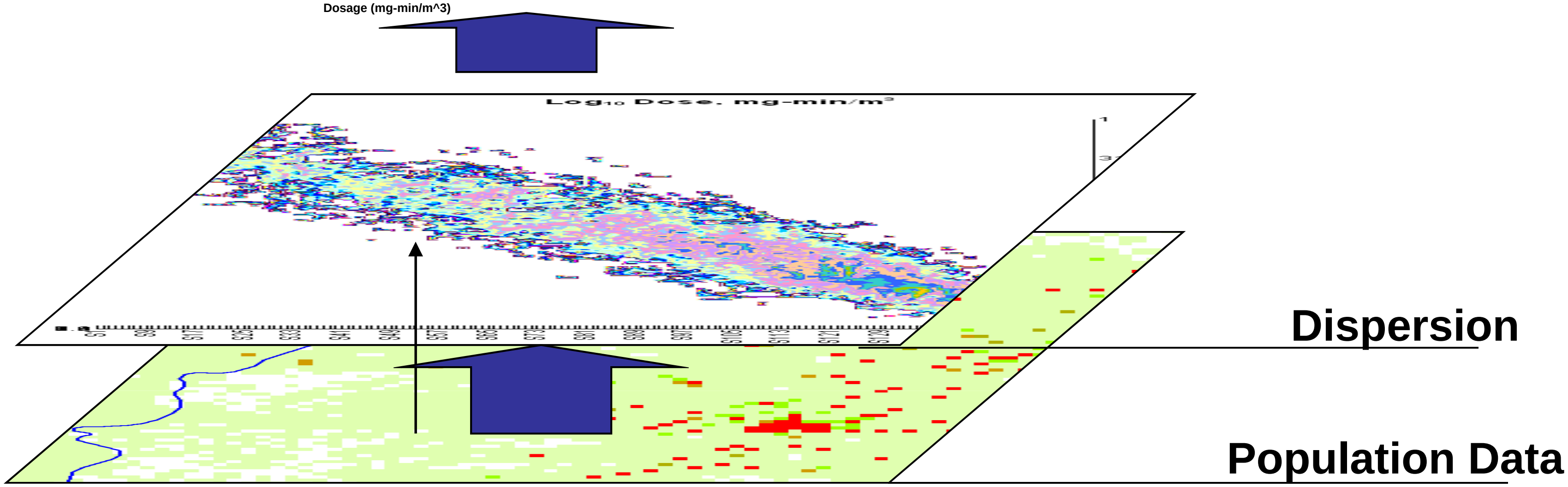
Health Effect Analysis

Health Damage Curve

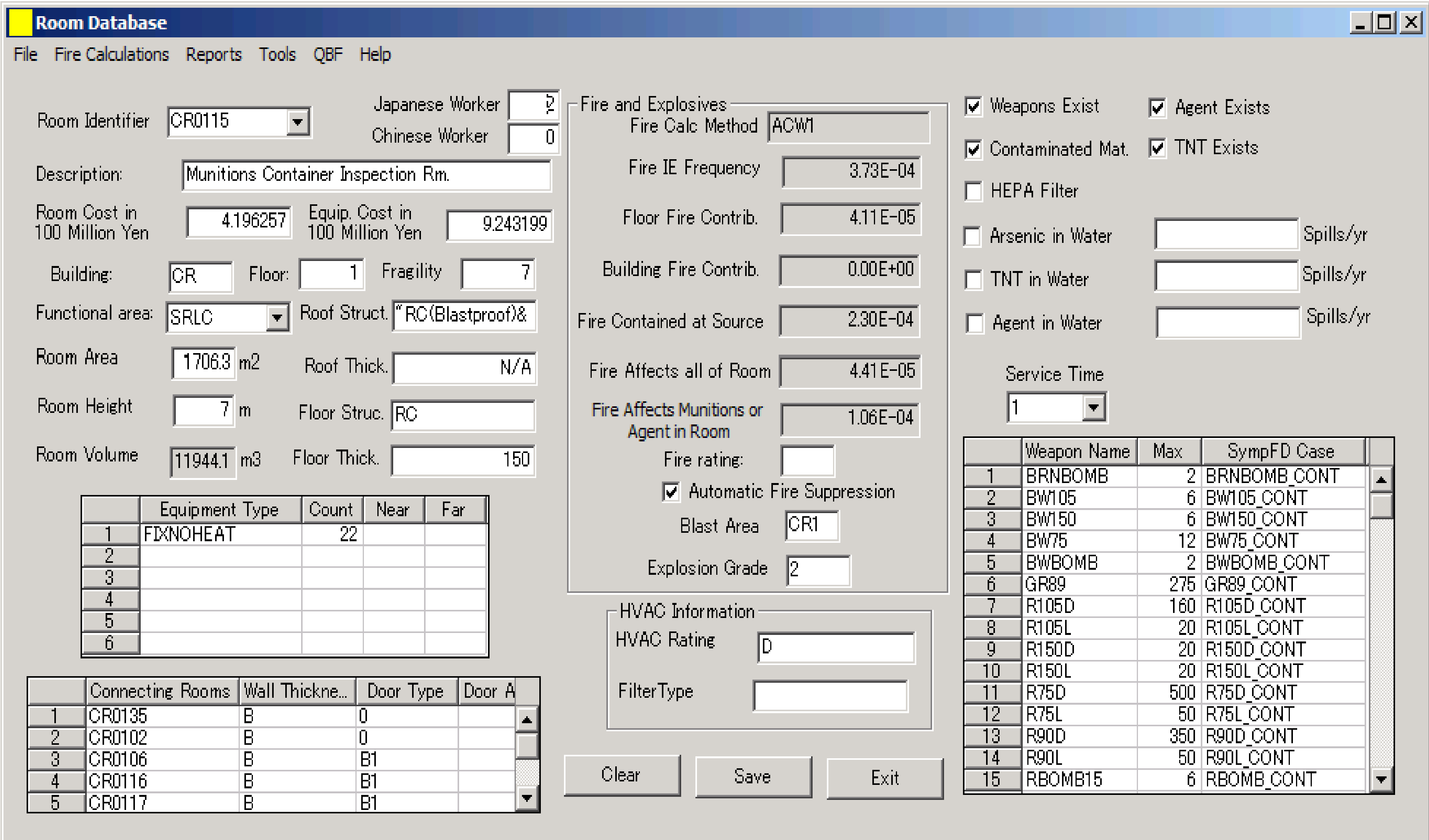


# of injured people

Explosive (kg)	General Public		
	Fatal	Major	Minor
5	0	0	2
100	0	315	5,711
500	5	7,601	33,453
1,000	174	19,786	53,689
5,000	14,095	67,879	51,834
50,000	54,819	67,589	21,690



Spatial Database of Rooms



Room Attributes

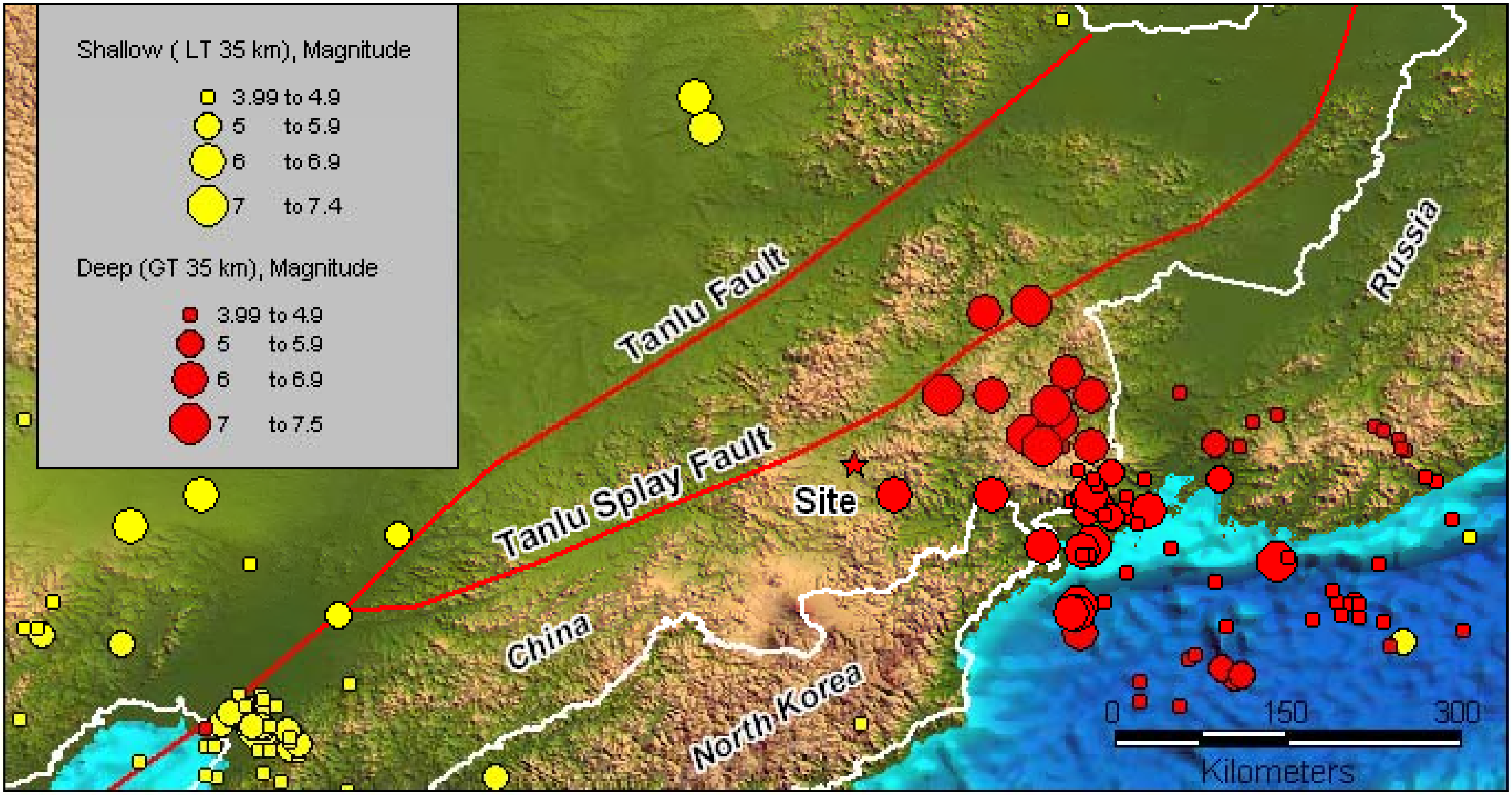
Fire Frequency

Weapon Inventory

Fire Propagation Simulation

- Monte Carlo Simulation
- Modeled all Rooms
  - With and Without Weapons
  - Localized or Propagation throughout the room, to floor, or Entire Building
- Time Step Simulation
- Propagation of Fire Due to Detonation/ Deflagration

Past Seismic Events



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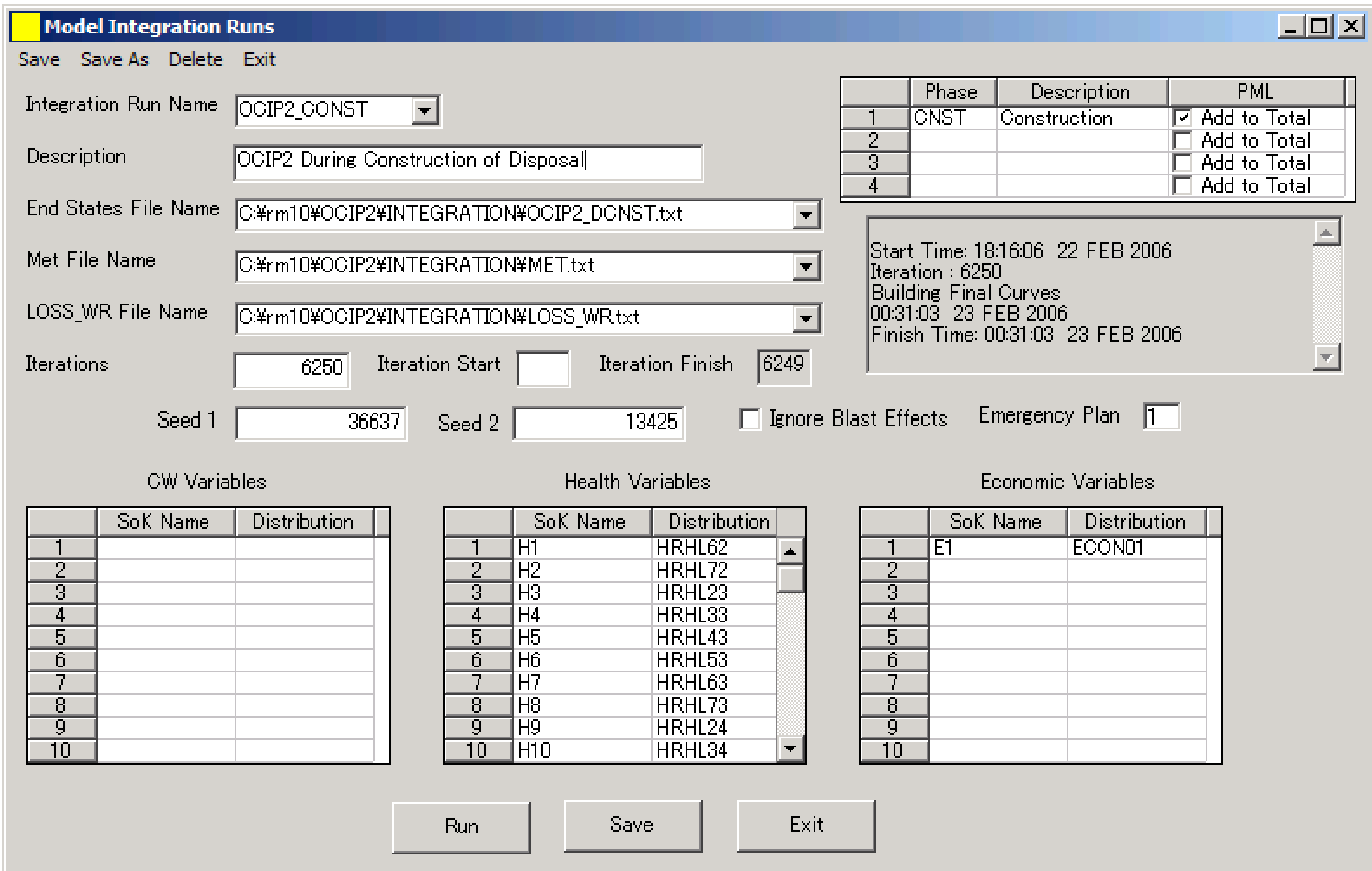
Simulation of Seismic Consequences

- Monte Carlo Simulation
- Considered all Buildings and Rooms Simultaneously
- Structure Fragility Design Specific
- Time Step Simulation
- Propagation of Damage Due to Detonation/ Deflagration

Integrating the Models
Batches of End States Grouped by Project Phase



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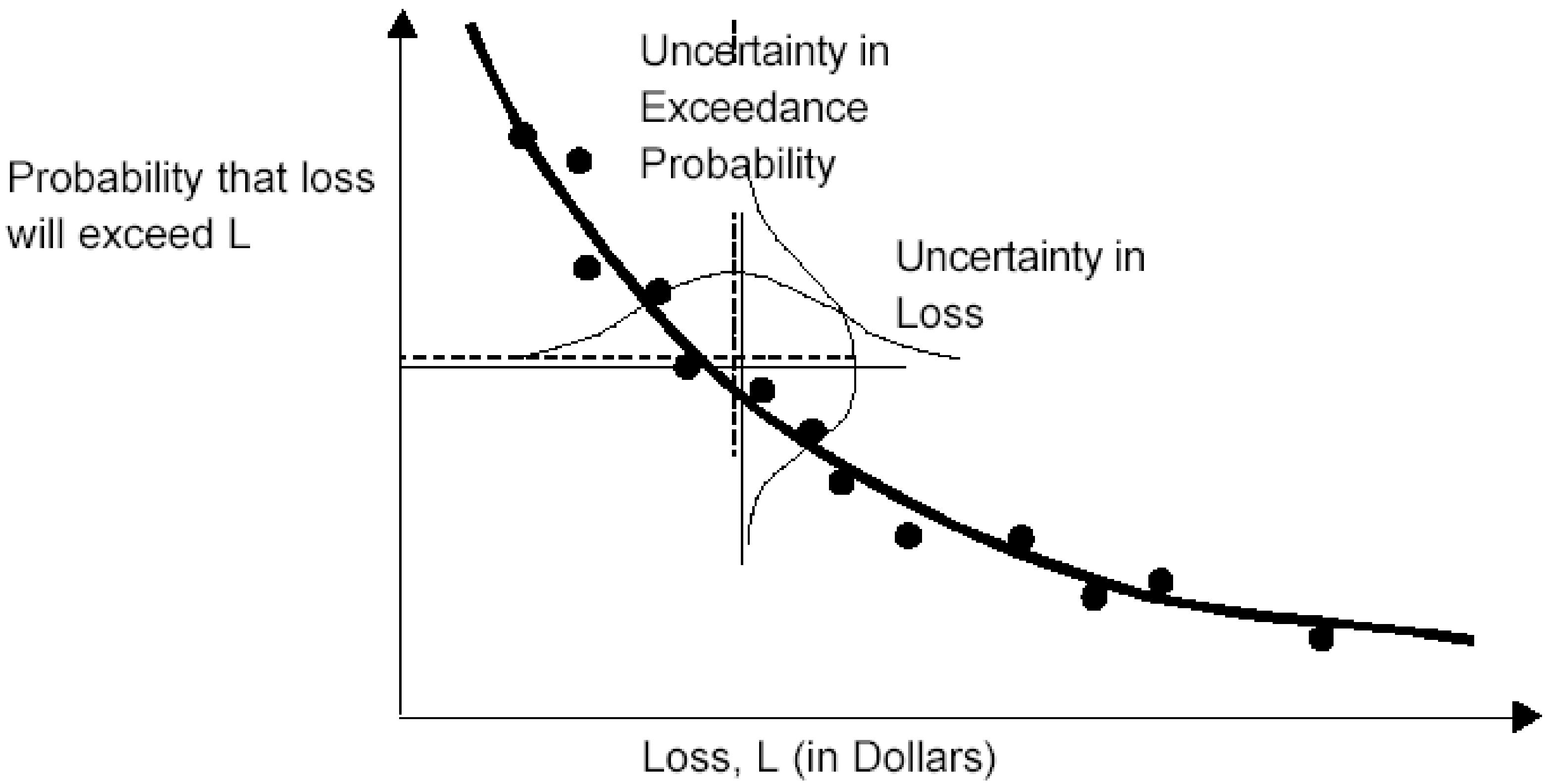
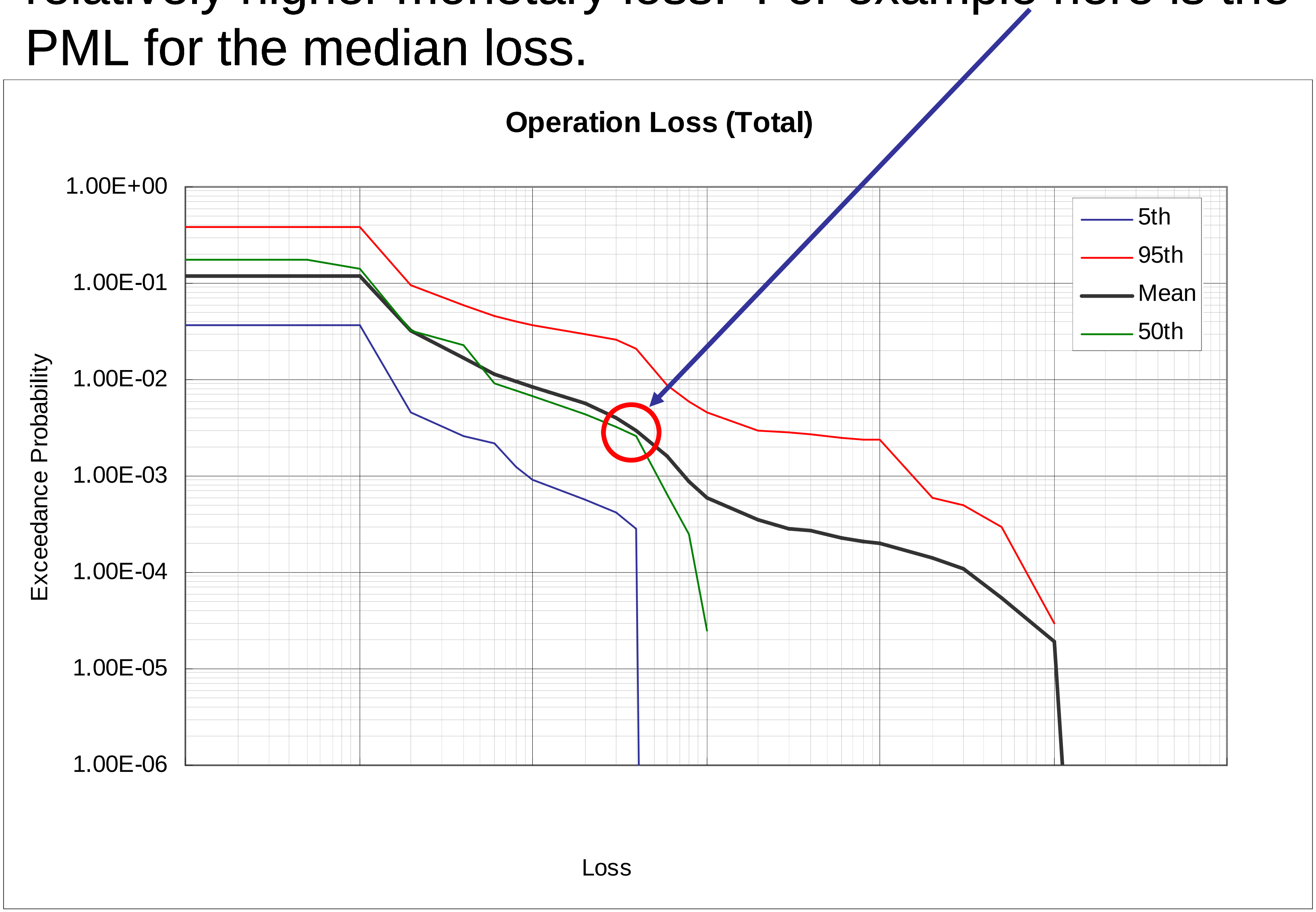
Sample Risk Curve Uncertainties

Loss Exceedance Curve (LEC)

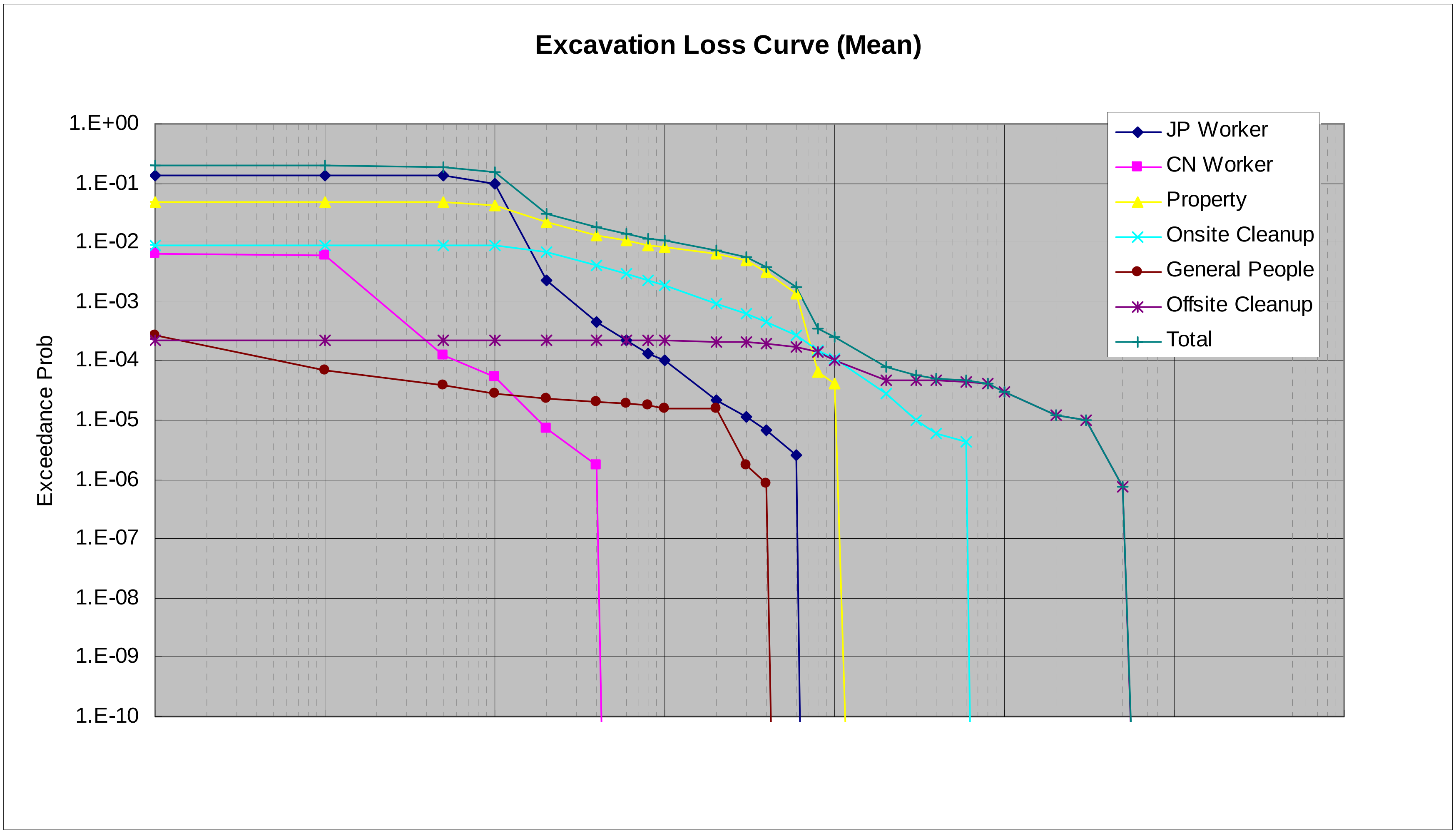
- Represents the probability that a certain level of monetary loss will be exceeded during 2.5-year project.
- LEC incorporates uncertainty in event occurrence probability and



The PML is that place on the exceedence curve where a lower probability of loss will NOT translate into a relatively higher monetary loss. For example here is the PML for the median loss.



Components of Loss Exceedence Curve



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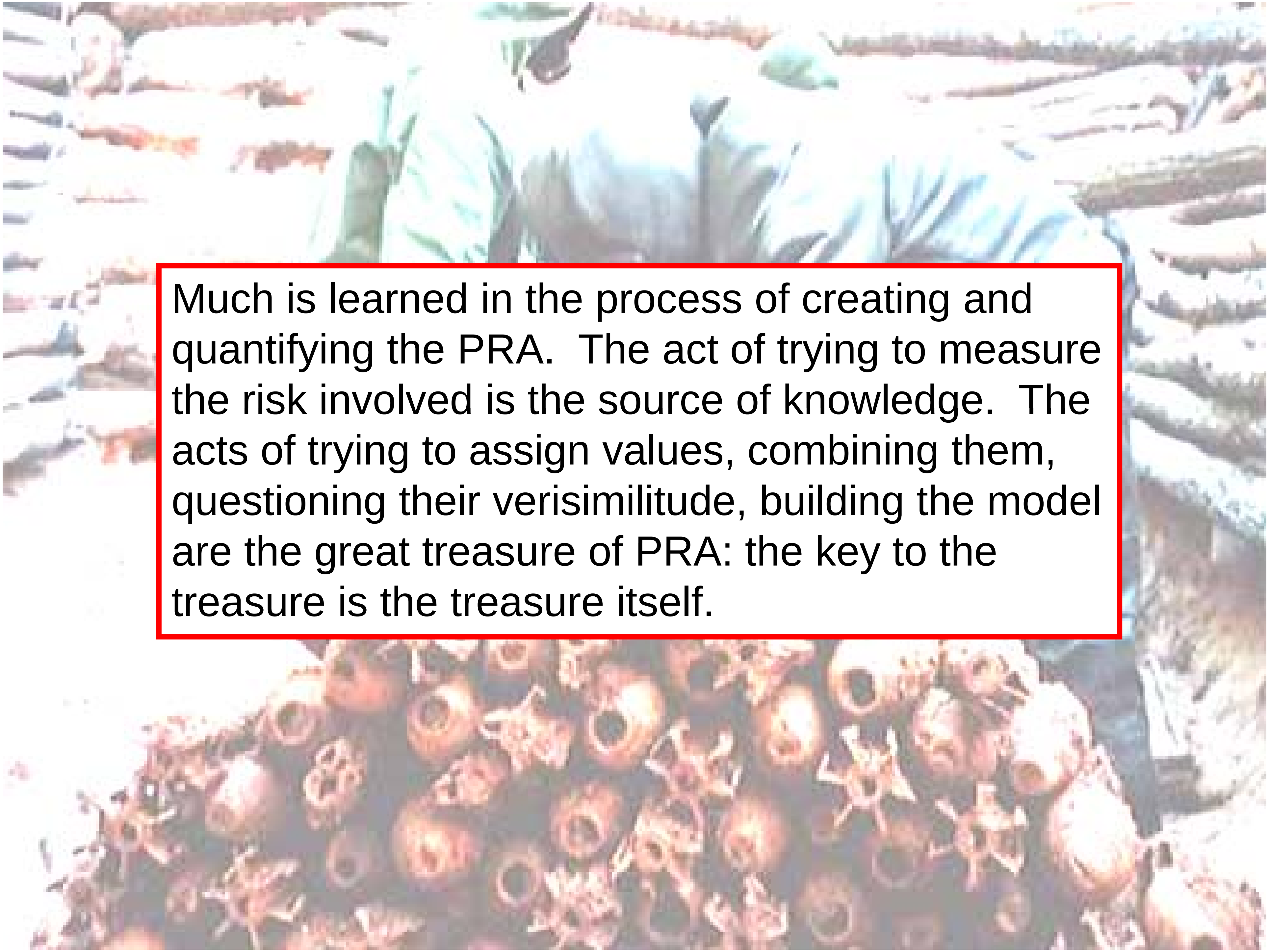
But Caveat Consulters!
Some important things
to remember about
PRA



Much is learned in the process of creating and quantifying the PRA. The act of trying to measure the risk involved is the source of knowledge. The acts of trying to assign values, combining them, questioning their verisimilitude, building the model are the great treasure of PRA: the key to the treasure is the treasure itself.

Uncertainty is not some noisy variation around a mean value that Represents the true situation. Variation itself is nature's only irreducible essence.
Variation is the hard reality, not a set of imperfect measures for a central tendency. Means and medians are the abstractions.

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Too often risk is defined as **risk = likelihood * consequence** and **safety = 1-risk**.

This can misinform: acceptable risk is a consideration of likelihood **AND** consequence, not a simple multiplication with safety as the additive inverse of risk.

Acceptable risk and safety are normative notions, changing with situations and expectations, and must be assessed accordingly.

Contact Information

- David Johnson
  djohnson@absconsulting.com
- Steve Epstein
  sepstein@absconsulting.com