

# The Probabilistic Risk Assessment of the Abandoned Chemical Weapons in China





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



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

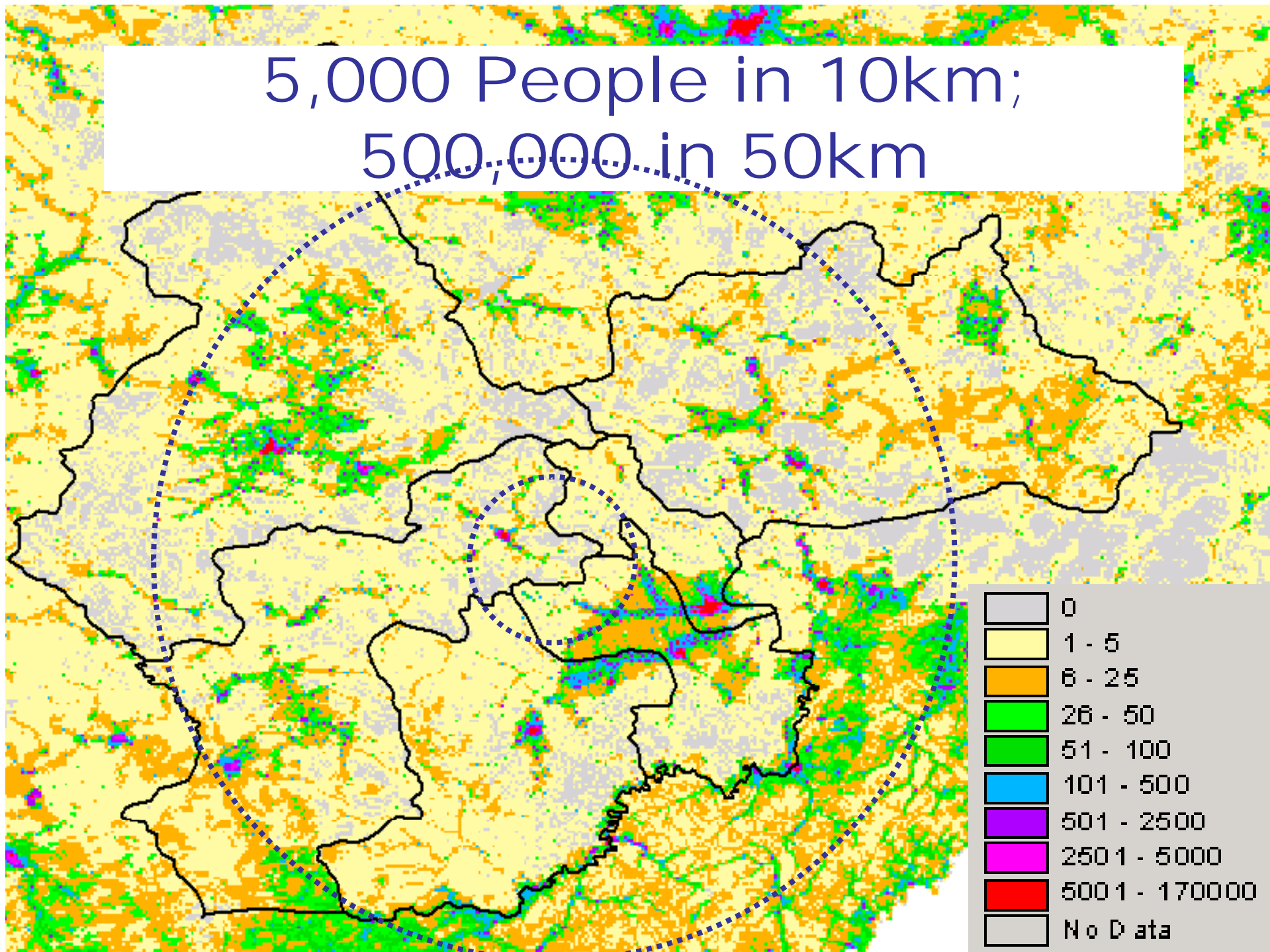


## Haerbaling District, Dunhua City, Jilin Province

- 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)



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 <sub>1</sub>	$l_1$	X <sub>1</sub>
S <sub>2</sub>	$l_2$	X <sub>2</sub>
S <sub>3</sub>	$l_3$	X <sub>3</sub>
•	•	•
•	•	•
•	•	•
•	•	•
•	•	•
S <sub>N</sub>	$l_N$	X <sub>N</sub>

$$\mathbf{R} \equiv \text{Risk} = \{ \langle s_i, l_i, x_i \rangle \}$$

# 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



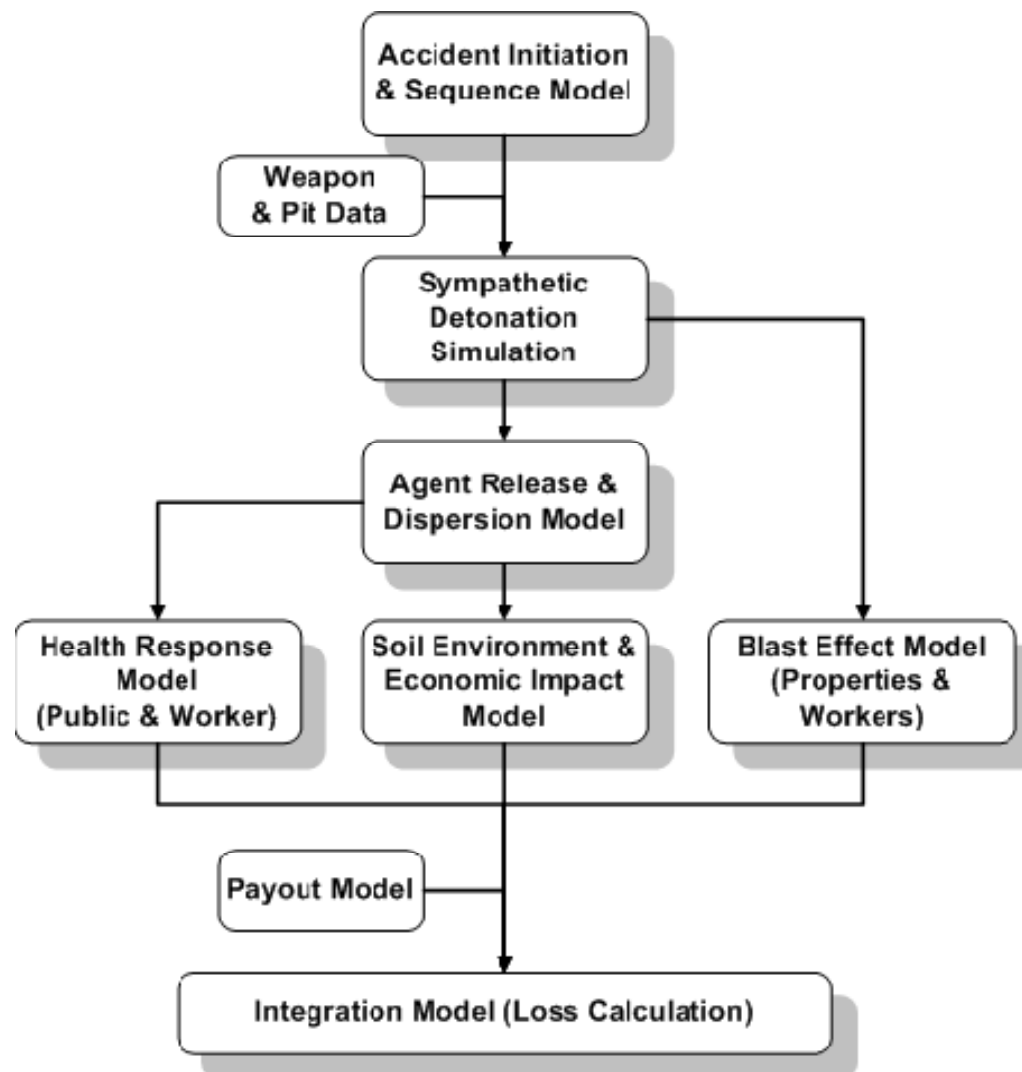
# What We Needed to Know

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?

# Three Big Questions We Had

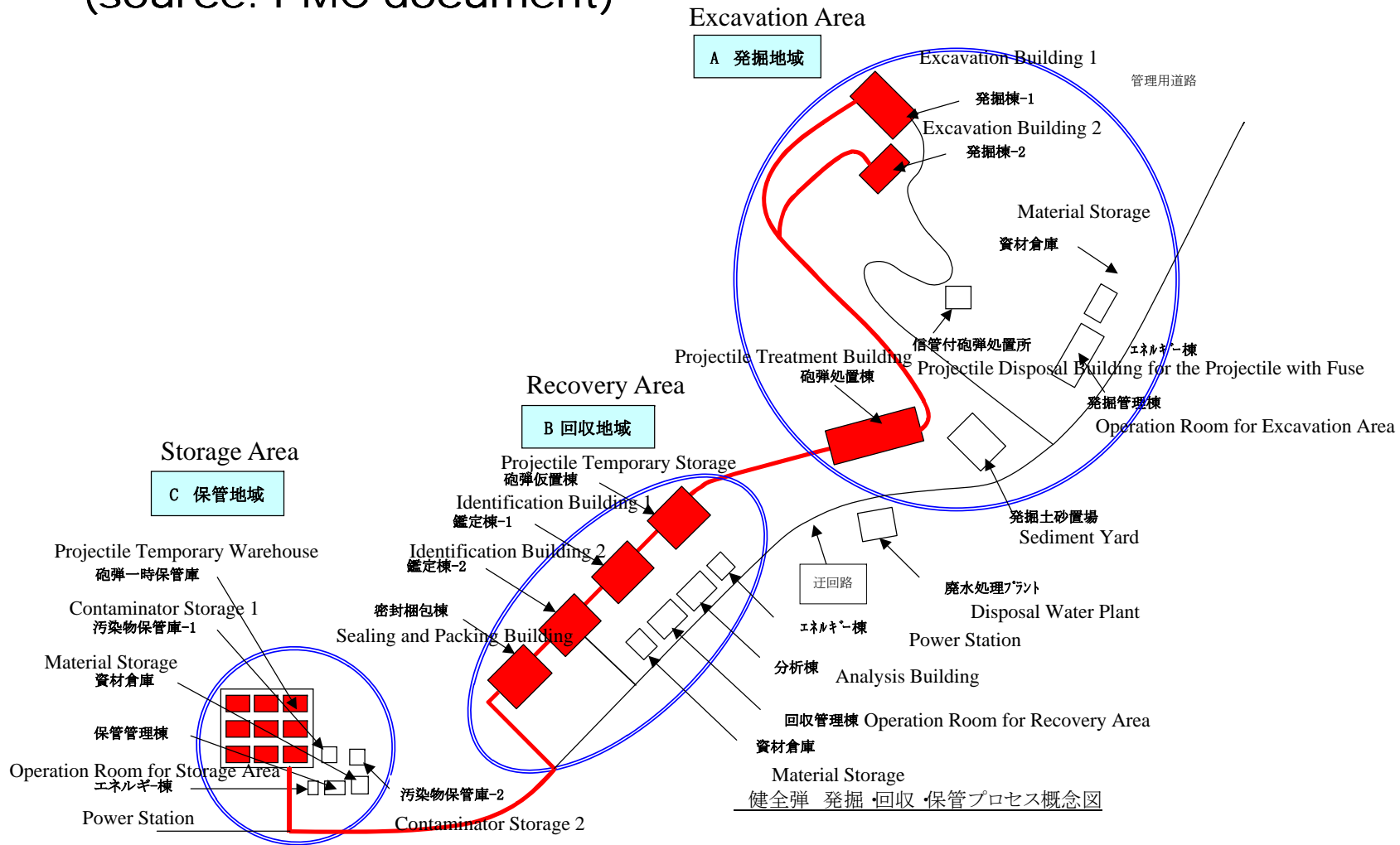
1. The ACW in China have been buried underground for **decades**
  - How can we estimate the conditions, types, and number of buried weapons?
2. There is a **Large amount** of weapons
  - If a weapon detonates, could it start a domino effect?
3. Weapons contain **toxic materials**
  - How do we estimate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

# Roadmap

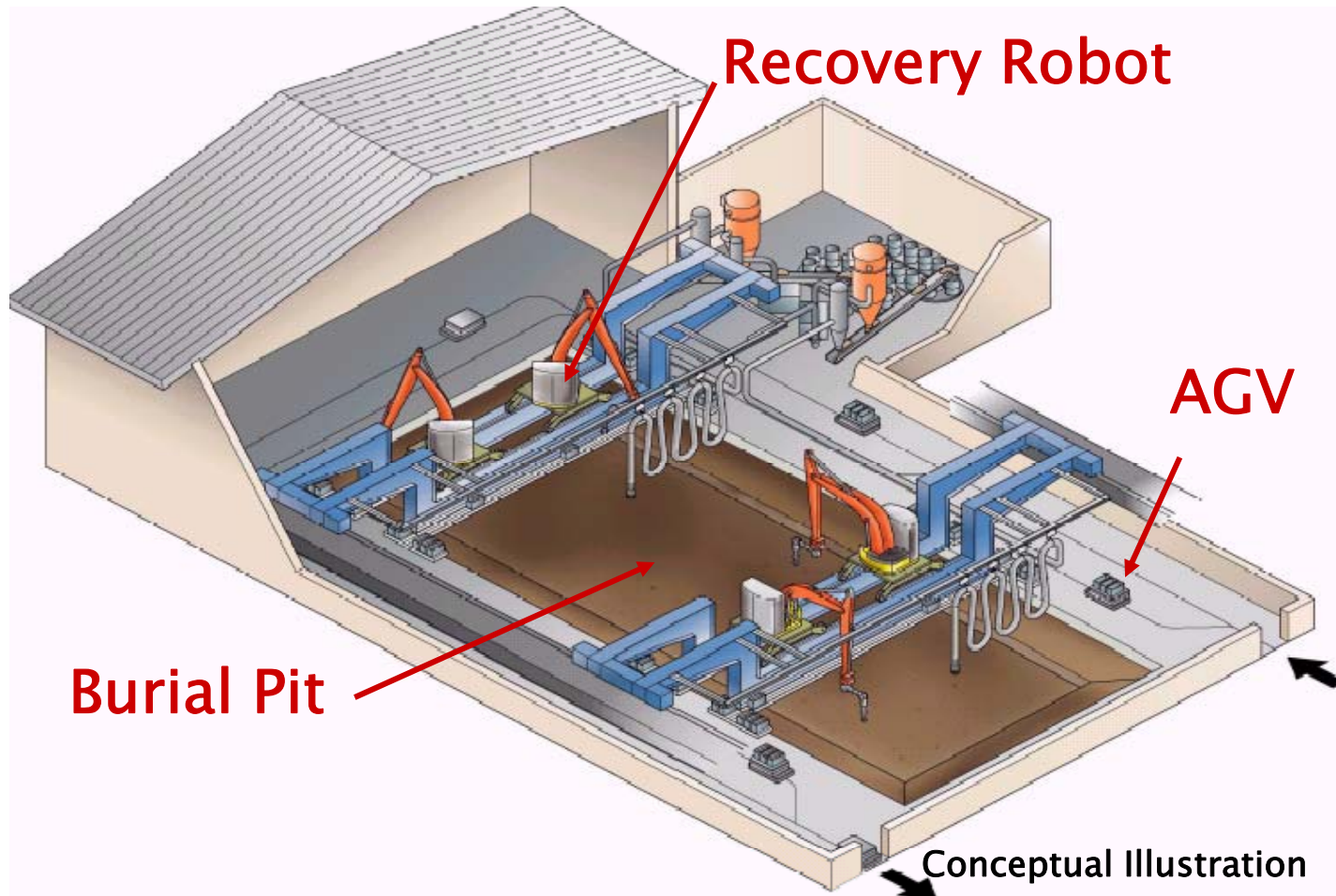


# Overview of the ACW Hearbaling Site

(source: PMC document)

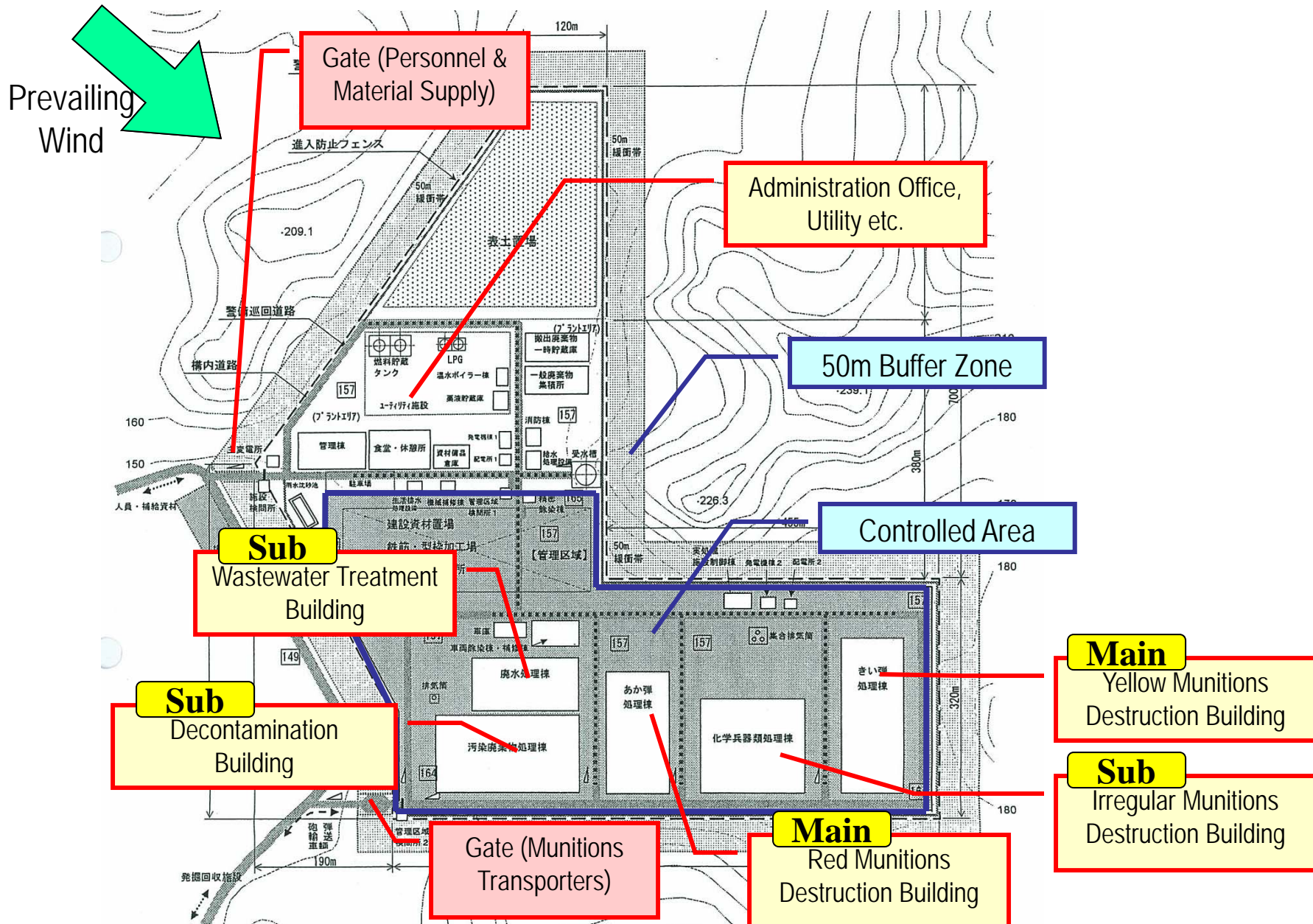


# Excavation



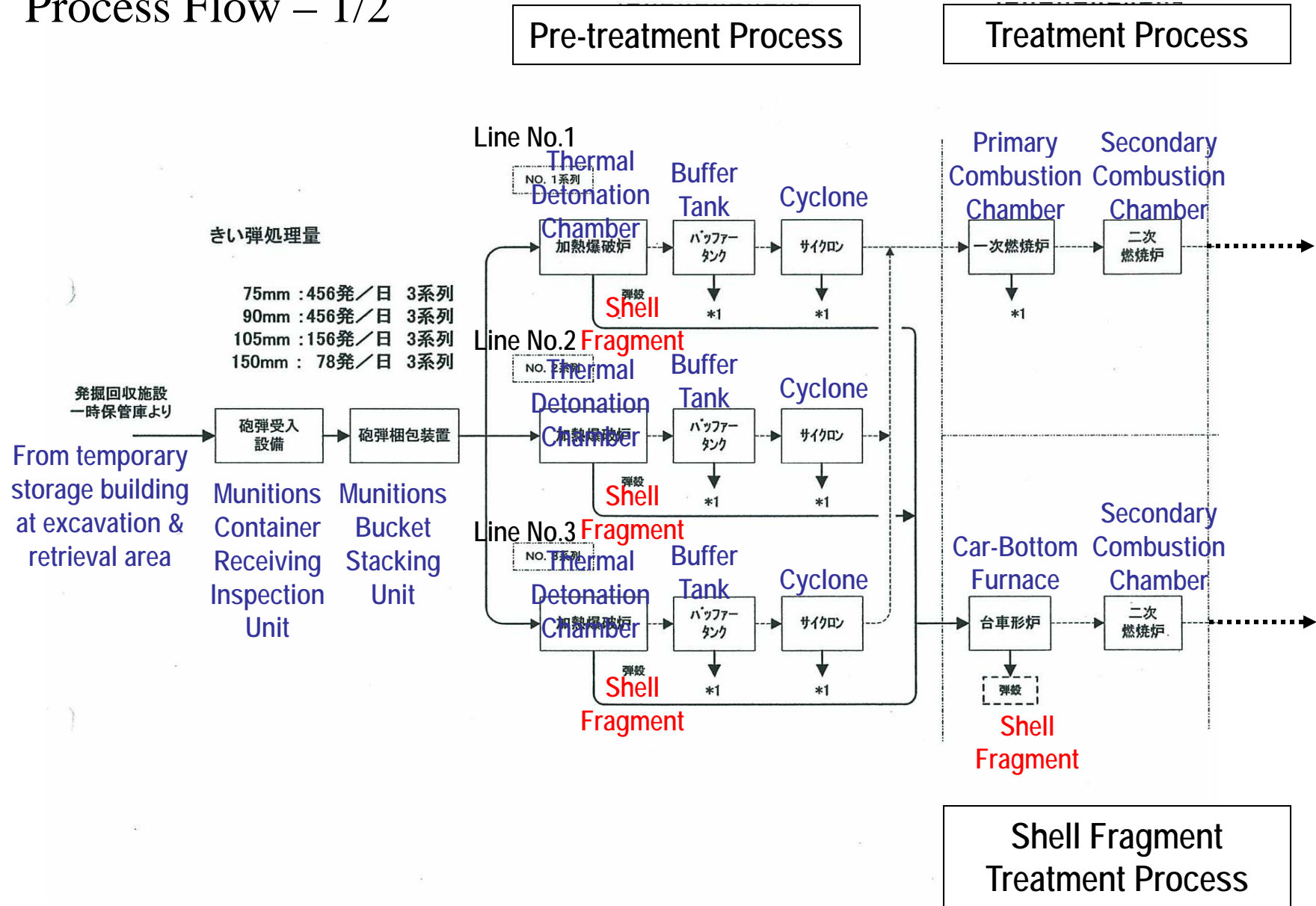


# Layout Plan



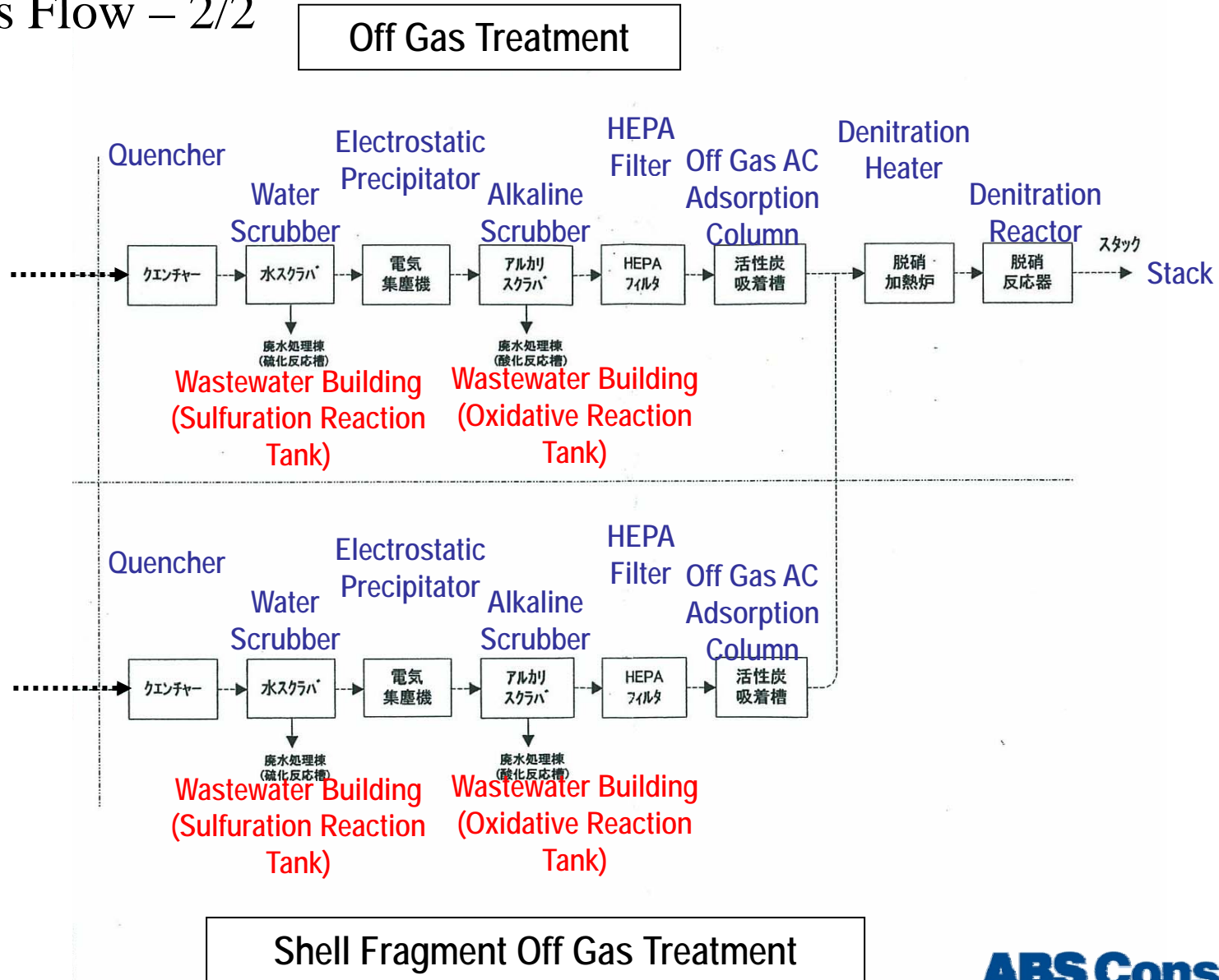
# Main Plant (Yellow Munitions)

## Process Flow – 1/2



# Main Plant (Yellow Munitions) (Cont.)

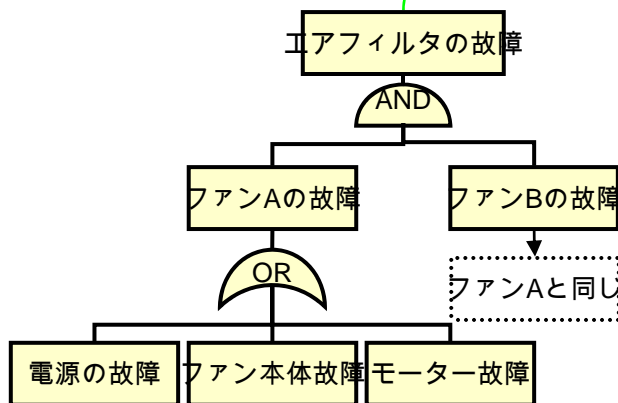
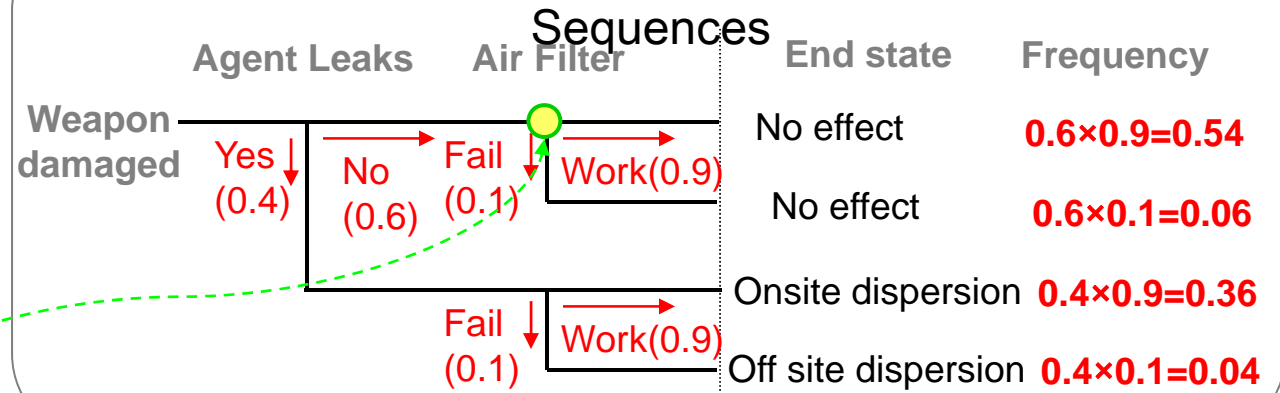
Process Flow – 2/2



# 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

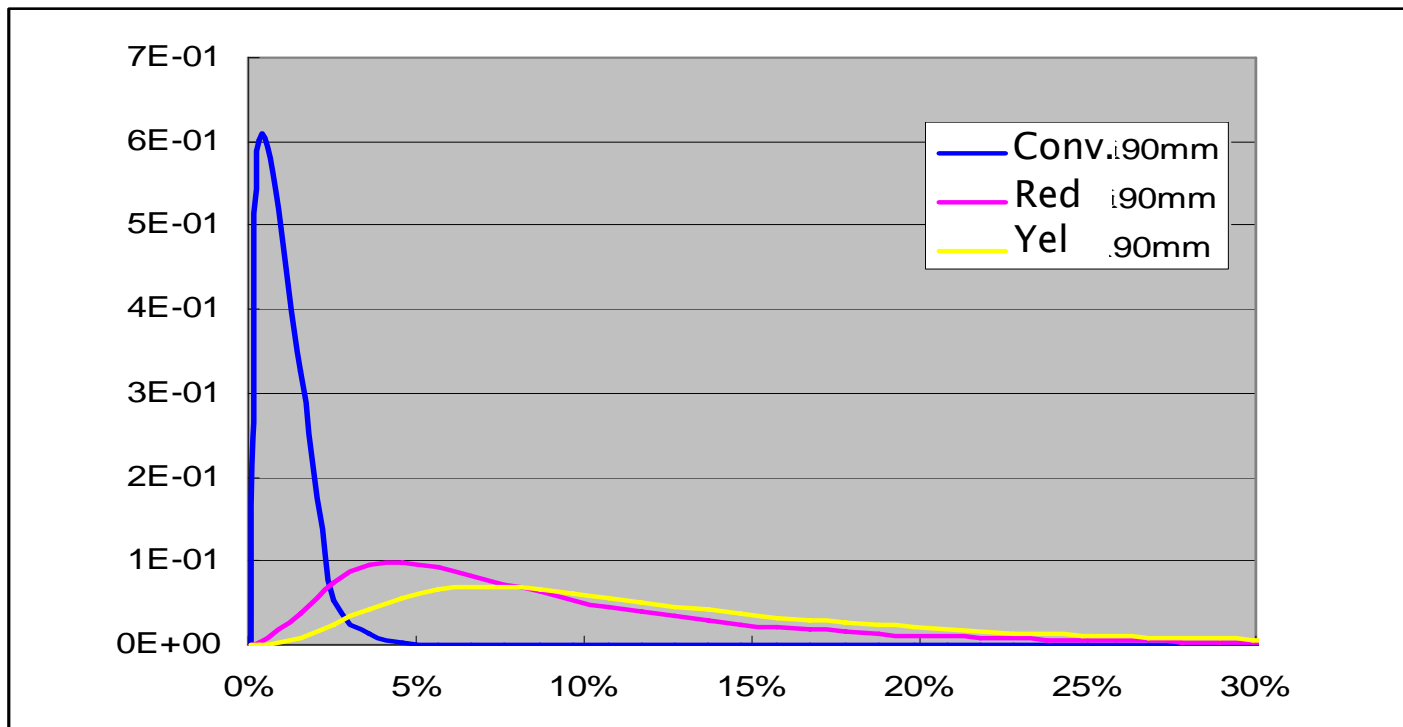
- No.1  
3 workers get minor injury  
(Frequency = 0.36)
- No.2  
250 people (general population) get major injury (Frequency= 0.04)

# Data Gathering

## ■ Using Data from Other Weapon Sites

Bayesian 2<sup>nd</sup> 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.

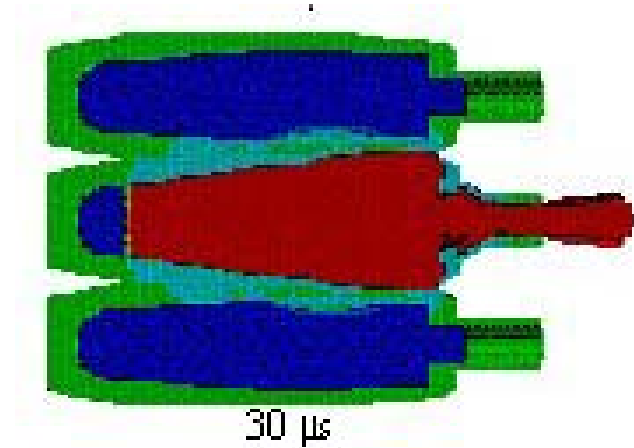
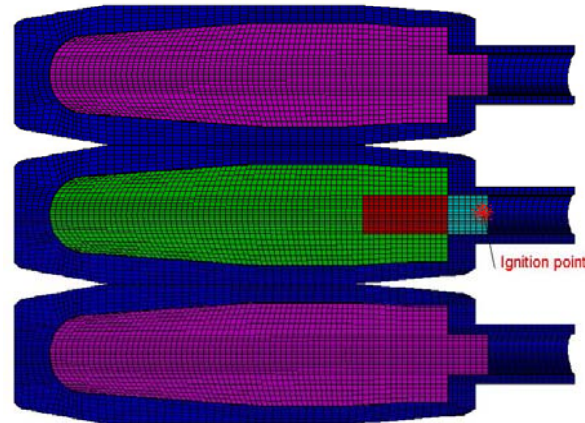




# Sympathetic Detonation

AUTODYN 3 D  
(76mm)

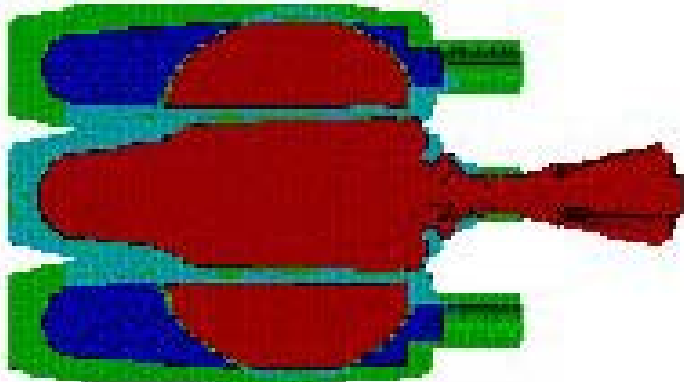
Void  
SCM440  
TNT1  
PA136  
PA143  
TNTCASTJJ1



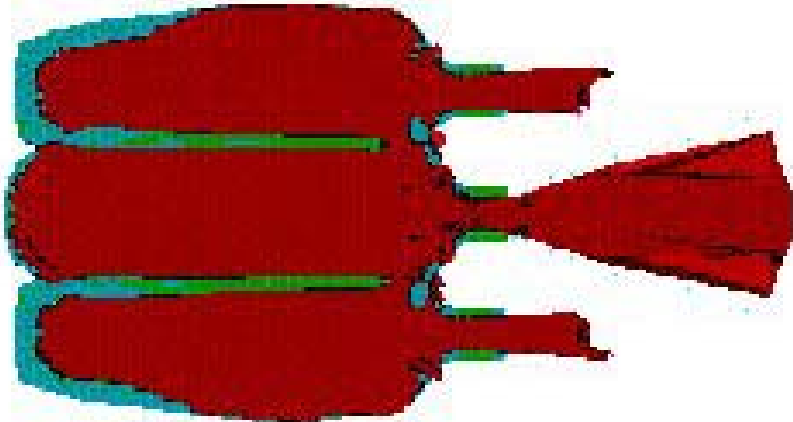
# Sympathetic Detonation (Continued)

AUTODYN 3 D  
76mm

- Void
- SCM440
- TNT1
- PA136
- PA143
- TNTCASTJJ1

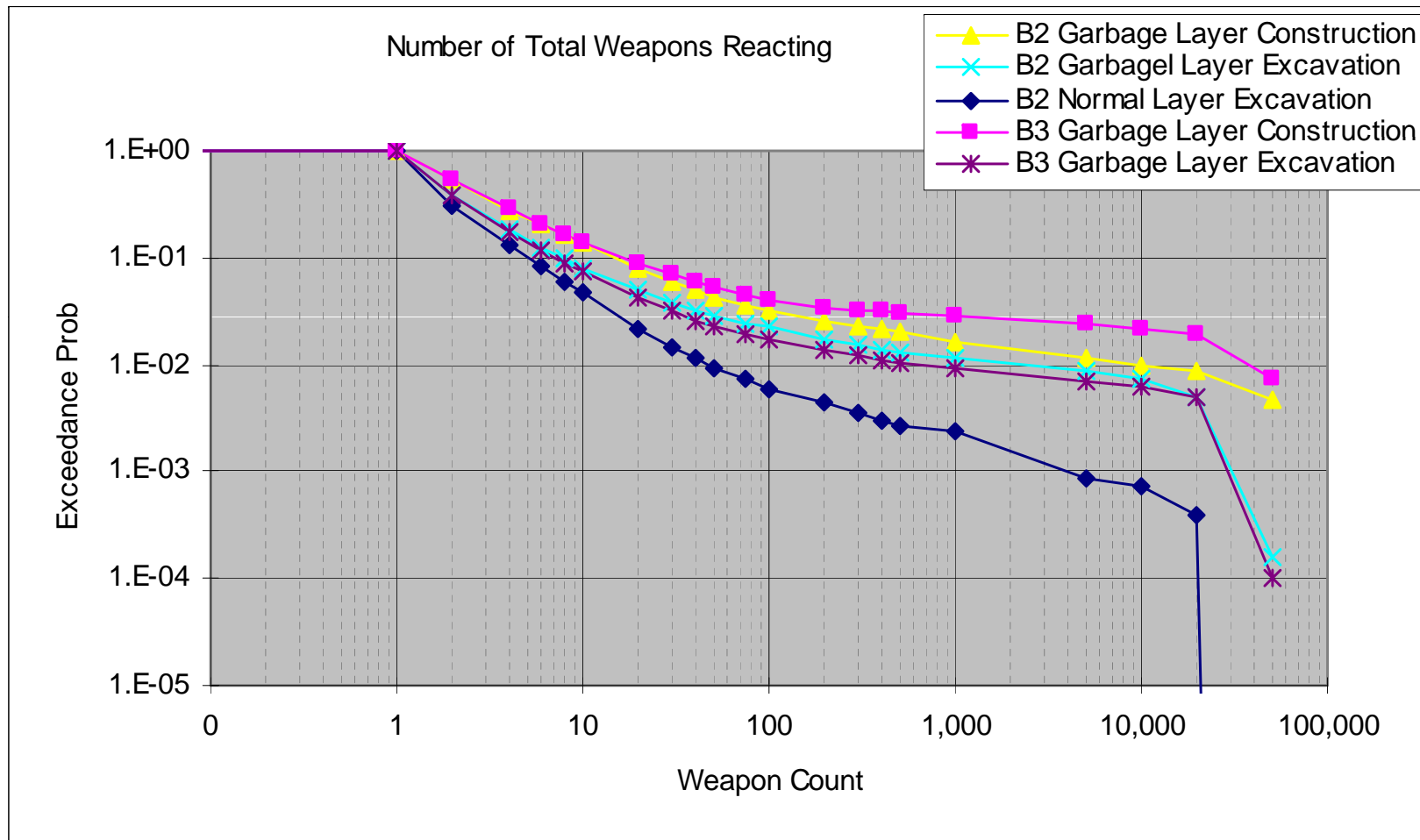


40  $\mu$ s



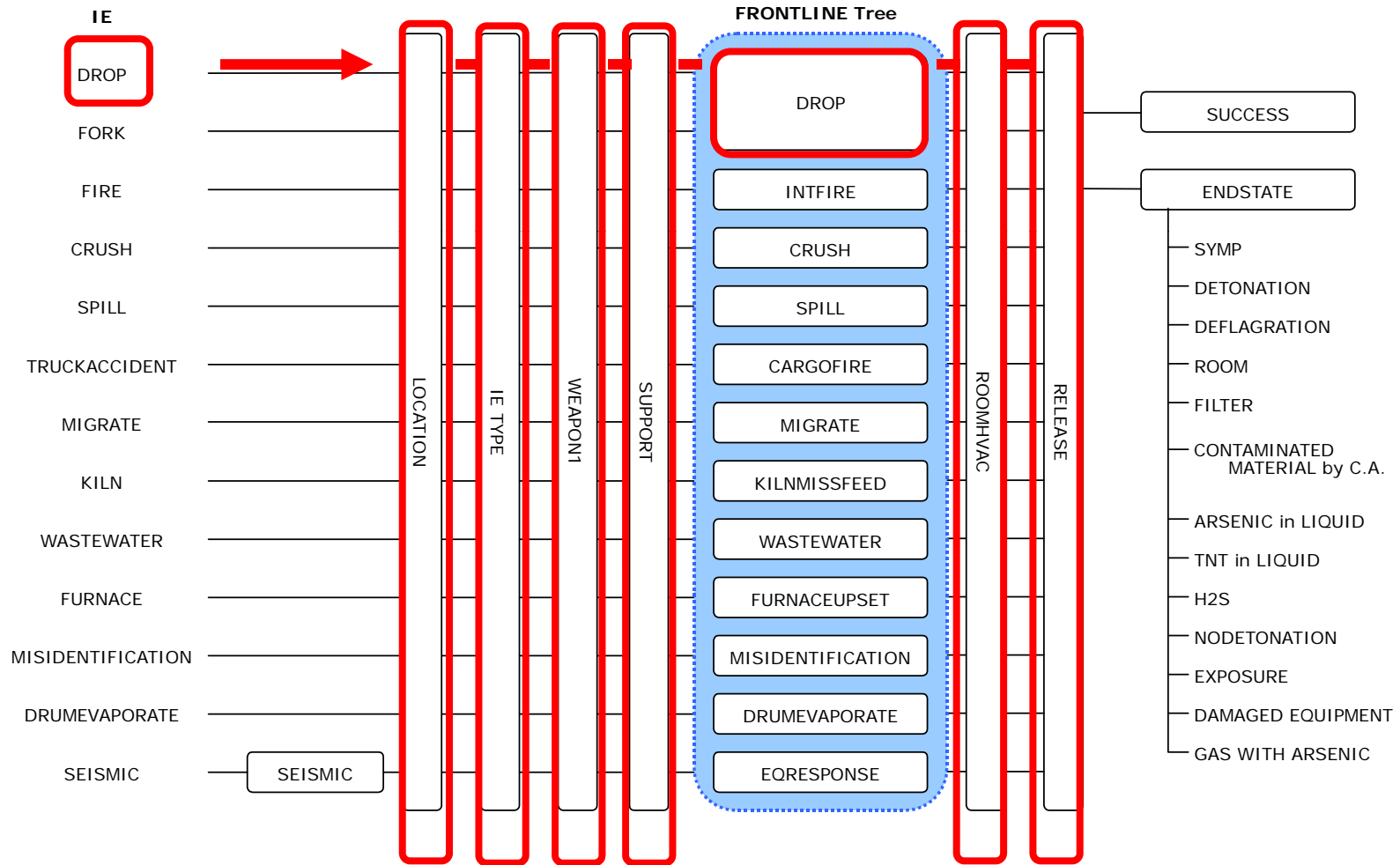
60  $\mu$ s

# Results of SympFD



# Event Sequence Model for Disposal

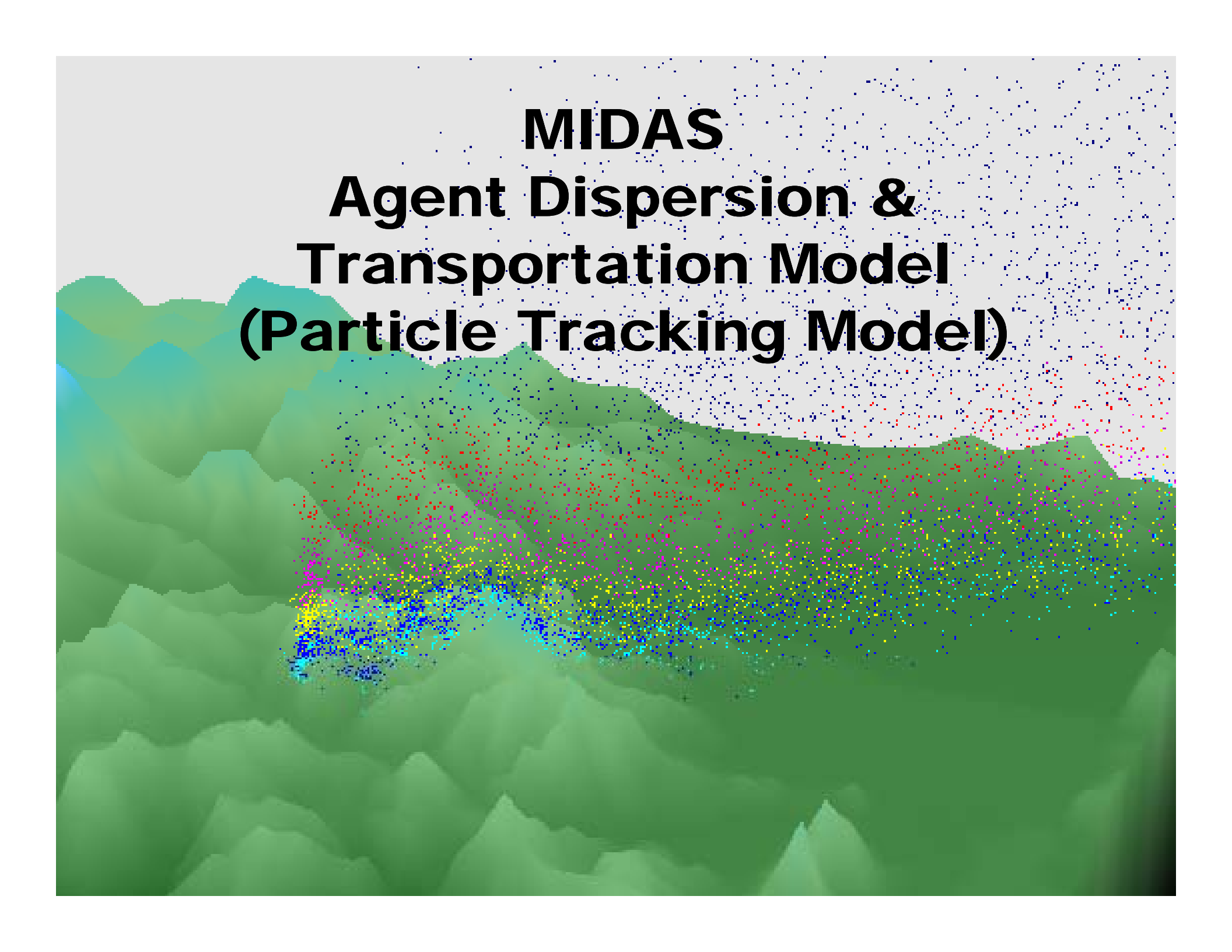
E.g. Weapon Drop



# Transportation Fire Simulation

0.260485883	Uniform Random Number for Event																				
			<b>Tank Capacity Full</b>																		
<b>Event</b>	Simulation Probability Used	Spill Area	Correlated Fuel	First Truck Simulation	Middle Truck Simulation	Last Truck Simulation															
Car-Truck	0	8	230	0.2177	0	0.1012															
Single Truck	0.343	6	150	0.4675	0.343	0.4009															
Truck-Truck	0.657	10	300	0.3148	0.657	0.4978															
Probability of Single Truck Colliding with Object			0.105																		
Probability of Single Truck Rollover/Fire Only Event			0.895																		
Event Scenario:	<b>Single Truck</b>	Type:	<b>Rollover</b>	0.2941699	Uniform Random Number for Event Type																
Combustion Rate:	0.16	inches/min																			
Burn Time=	150 liters	x	1000 cm <sup>3</sup> /liter																		
	6 ft <sup>2</sup>	x	929 cm <sup>2</sup> /ft <sup>2</sup>	x	0.16	inches/min	x	2.54	cm/inch												
Unmitigated Burn Time:	<b>66.22 min</b>																				
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																				
<b>Final Adjusted Burn Time</b>	<b>6.321716688</b>			0	1	0	0														

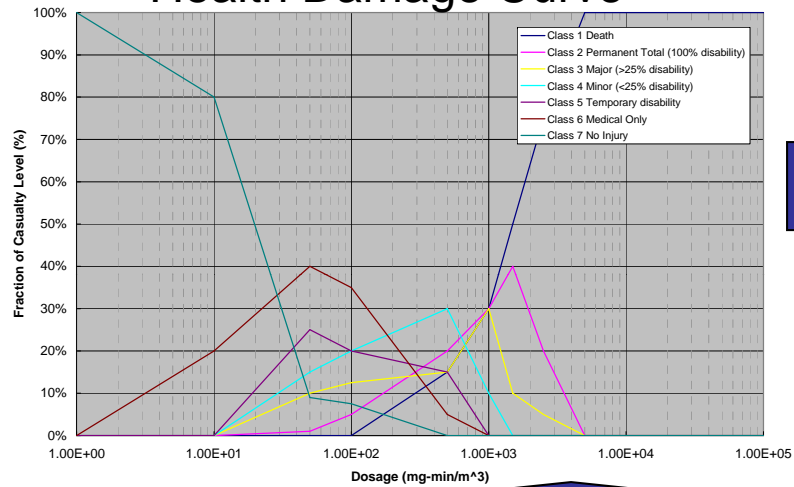




MIDAS  
Agent Dispersion &  
Transportation Model  
(Particle Tracking Model)

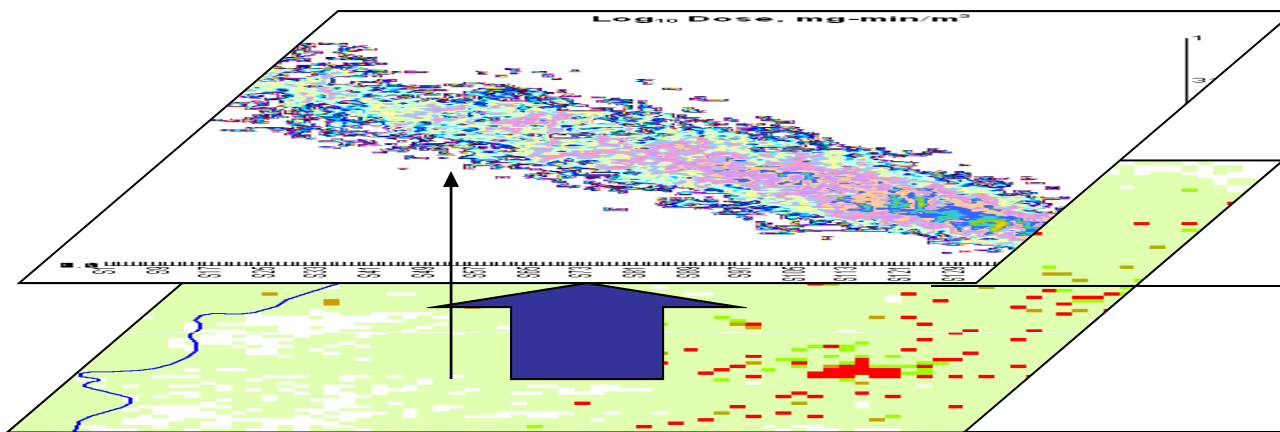
# Health Effect Analysis

Health Damage Curve



# of injured people

Expbsive (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



Dispersion

Population Data

# Spatial Database of Rooms

**Room Database**

File Fire Calculations Reports Tools QBF Help

Room Identifier: CR0115 Japanese Worker: 2 Chinese Worker: 0

Description: Munitions Container Inspection Rm.

Room Cost in 100 Million Yen: 4.196257 Equip. Cost in 100 Million Yen: 9.243199

Building: CR Floor: 1 Fragility: 7

Functional area: SRLC Roof Struct.: RC(Blastproof)&

Room Area: 1706.3 m<sup>2</sup> Roof Thick.: N/A

Room Height: 7 m Floor Struct.: RC

Room Volume: 11944.1 m<sup>3</sup> Floor Thick.: 150

	Equipment Type	Count	Near	Far
1	FIXNOHEAT	22		
2				
3				
4				
5				
6				

	Connecting Rooms	Wall Thickne...	Door Type	Door A
1	CR0135	B	0	
2	CR0102	B	0	
3	CR0106	B	B1	
4	CR0116	B	B1	
5	CR0117	B	B1	

**Fire and Explosives**

Fire Calc Method: ACW1

Fire IE Frequency: 3.73E-04

Floor Fire Contrib.: 4.11E-05

Building Fire Contrib.: 0.00E+00

Fire Contained at Source: 2.30E-04

Fire Affects all of Room: 4.41E-05

Fire Affects Munitions or Agent in Room: 1.06E-04

Fire rating:

Automatic Fire Suppression

Blast Area: CR1

Explosion Grade: 2

**HVAC Information**

HVAC Rating: D

FilterType:

Weapons Exist  Agent Exists

Contaminated Mat.  TNT Exists

HEPA Filter

Arsenic in Water  Spills/yr

TNT in Water  Spills/yr

Agent in Water  Spills/yr

Service Time: 1

	Weapon Name	Max	SympFD Case
1	BRNBOMB	2	BRNBOMB_CONT
2	BW105	6	BW105_CONT
3	BW150	6	BW150_CONT
4	BW75	12	BW75_CONT
5	BWBOMB	2	BWBOMB_CONT
6	GR89	275	GR89_CONT
7	R105D	160	R105D_CONT
8	R105L	20	R105L_CONT
9	R150D	20	R150D_CONT
10	R150L	20	R150L_CONT
11	R75D	500	R75D_CONT
12	R75L	50	R75L_CONT
13	R90D	350	R90D_CONT
14	R90L	50	R90L_CONT
15	RBOMB15	6	RBOMB_CONT

Clear Save Exit

Room Attributes

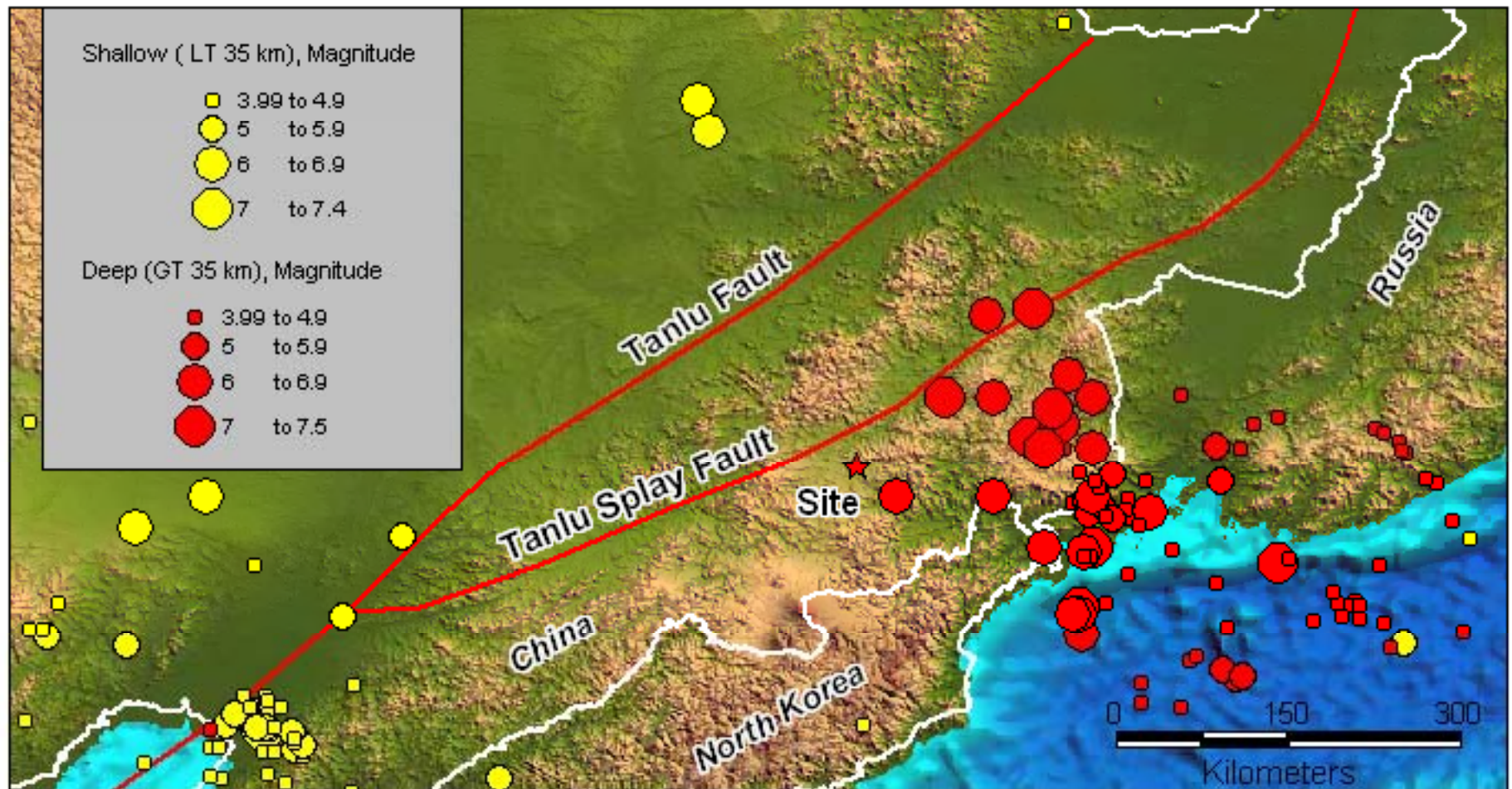
Fire Frequency

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



# 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

**Model Integration Runs**

Save Save As Delete Exit

Integration Run Name: OCIP2\_CONST

Description: OCIP2 During Construction of Disposal

End States File Name: C:\rm10\OCIP2\INTEGRATION\OCIP2\_DCNST.txt

Met File Name: C:\rm10\OCIP2\INTEGRATION\MET.txt

LOSS\_WR File Name: C:\rm10\OCIP2\INTEGRATION\LOSS\_WR.txt

Iterations: 6250 Iteration Start: Iteration Finish: 6249

Seed 1: 36637 Seed 2: 13425  Ignore Blast Effects Emergency Plan:

Phase	Description	PML
1	CNST Construction	<input checked="" type="checkbox"/> Add to Total
2		<input type="checkbox"/> Add to Total
3		<input type="checkbox"/> Add to Total
4		<input type="checkbox"/> Add to Total

Start Time: 18:16:06 22 FEB 2006  
 Iteration : 6250  
 Building Final Curves  
 00:31:03 23 FEB 2006  
 Finish Time: 00:31:03 23 FEB 2006

**CW Variables**

	SoK Name	Distribution
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

**Health Variables**

	SoK Name	Distribution
1	H1	HRHL62
2	H2	HRHL72
3	H3	HRHL23
4	H4	HRHL33
5	H5	HRHL43
6	H6	HRHL53
7	H7	HRHL63
8	H8	HRHL73
9	H9	HRHL24
10	H10	HRHL34

**Economic Variables**

	SoK Name	Distribution
1	E1	ECON01
2		
3		
4		
5		
6		
7		
8		
9		
10		

Run Save Exit

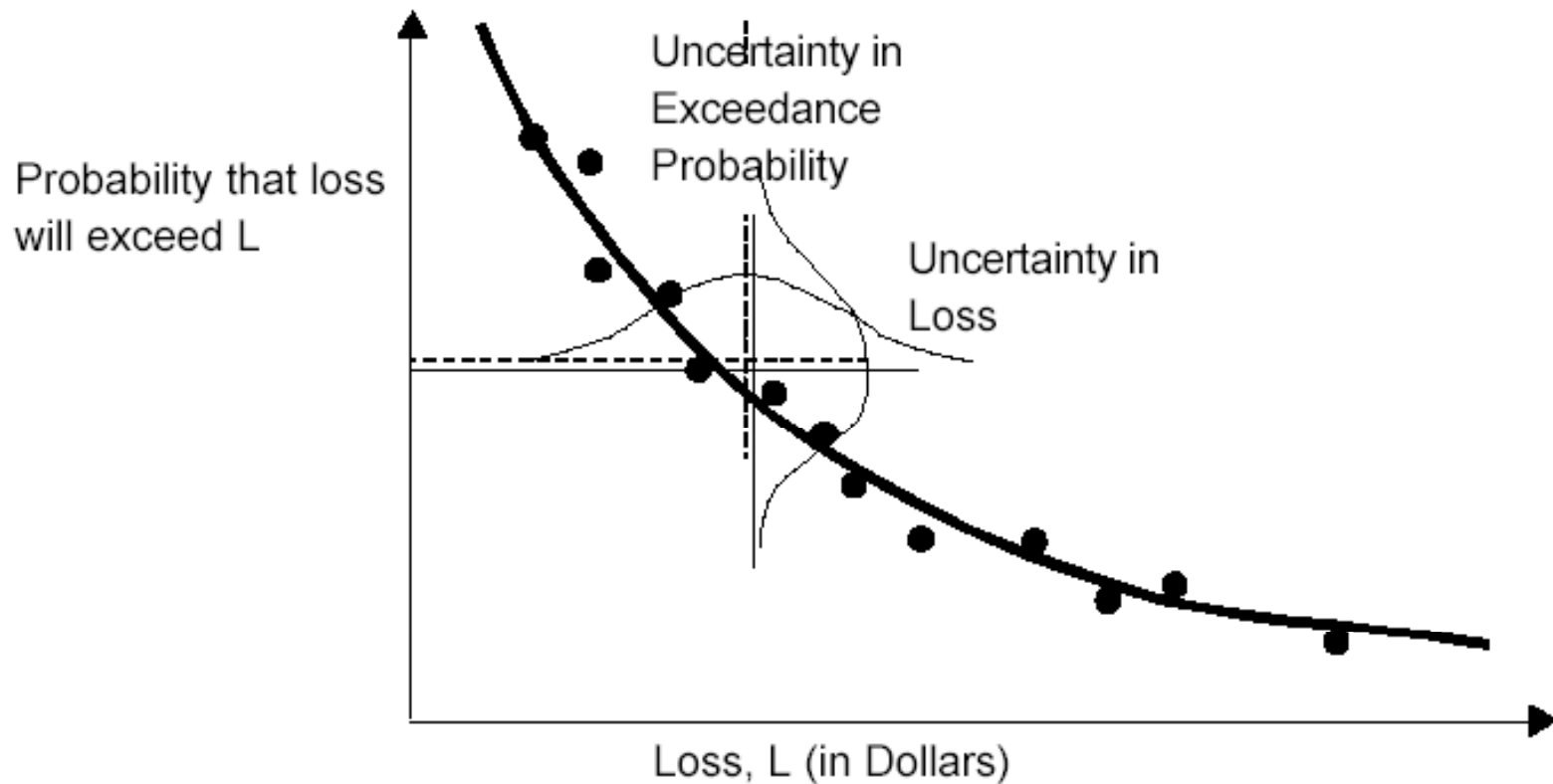


# Sample Risk Curve Uncertainties

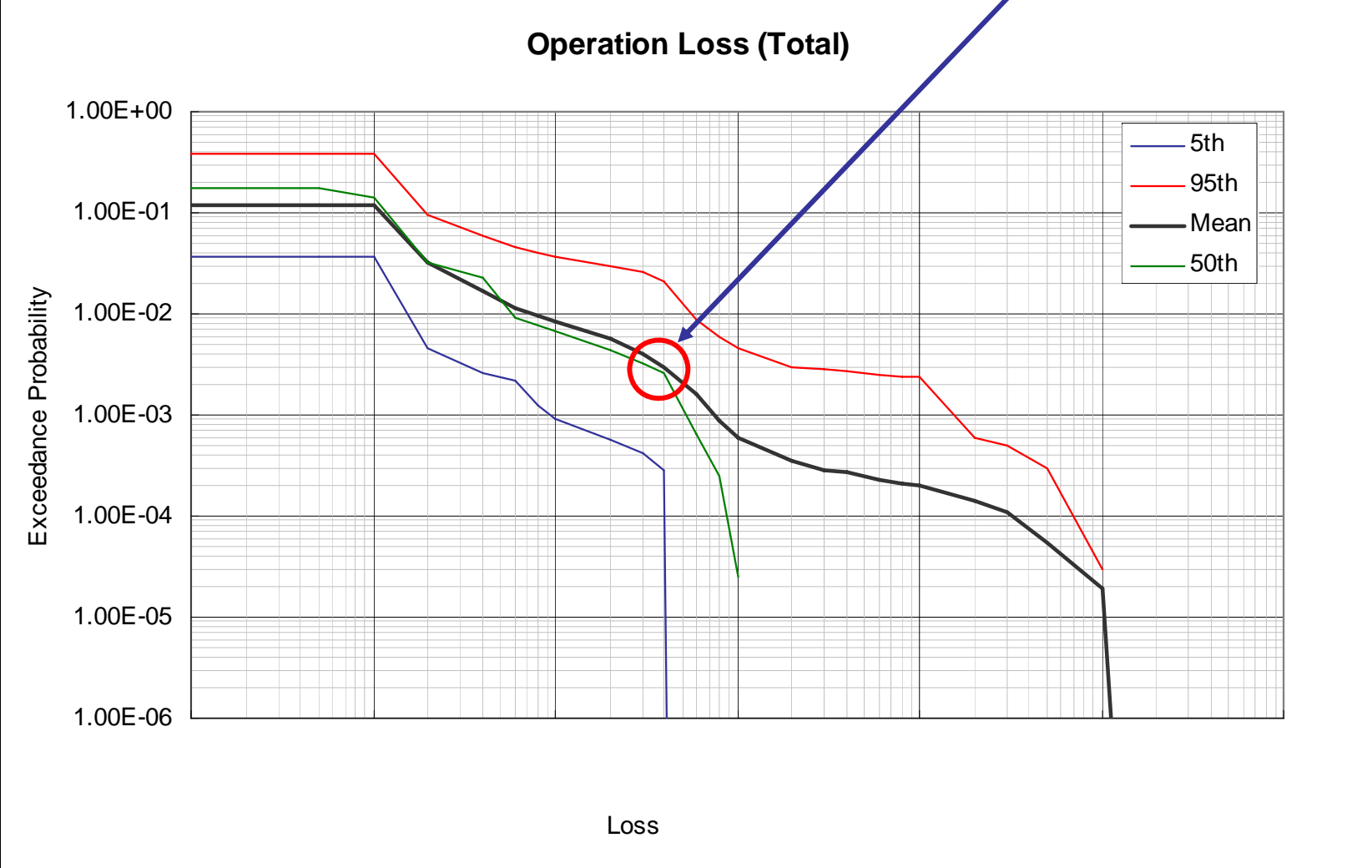


# Loss Exceedance Curve (LEC)

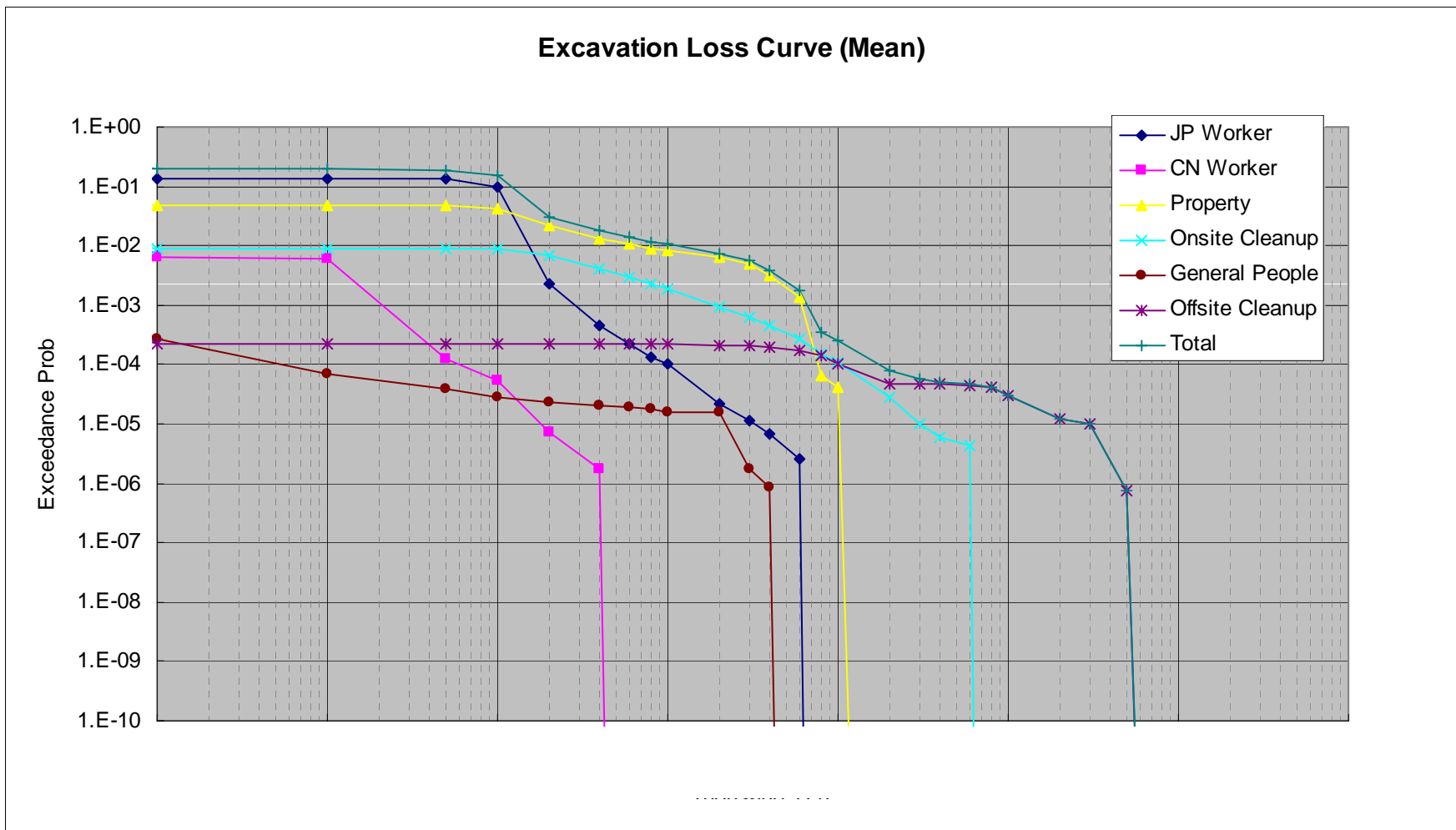
- Represents the probability that a certain level of monetary loss will be exceeded during 2.5-year project.
- LEC incorporates uncertainty in event occurrence probability and




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.

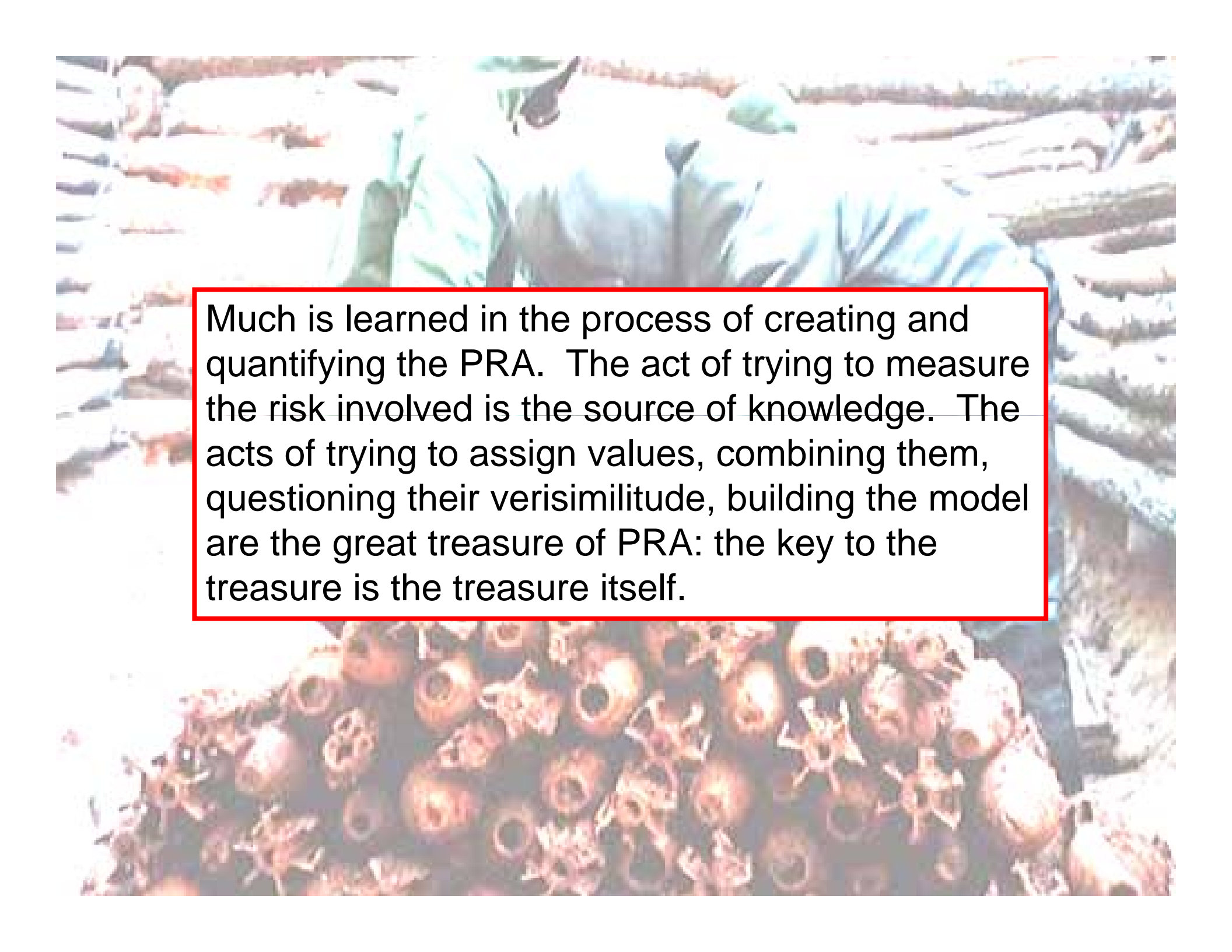


# Components of Loss Exceedence Curve

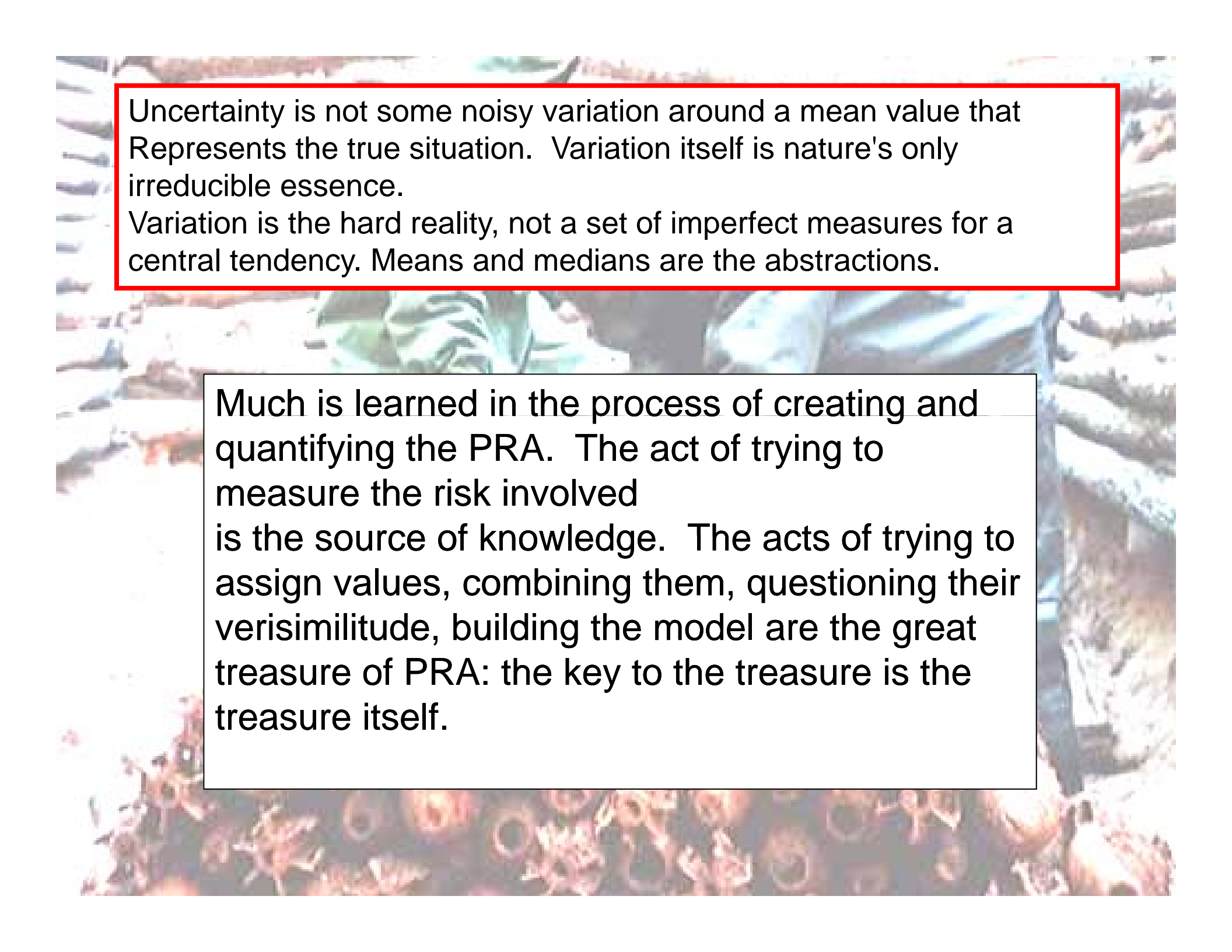


A photograph showing two individuals wearing green protective suits and hoods, leaning over a large pile of logs. The logs are stacked in neat rows, and the ground is covered with a layer of wood chips or sawdust. The scene appears to be outdoors in a wooded area, possibly a logging site or a forest management area. The workers are focused on their task, and the overall atmosphere is one of careful inspection or sampling.

**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