Sandia National Laboratories

SAND2014-17049PE

Restoration & Recovery Following the Release of a CBW Agent – Overview of Capabilities at Sandia National Laboratories

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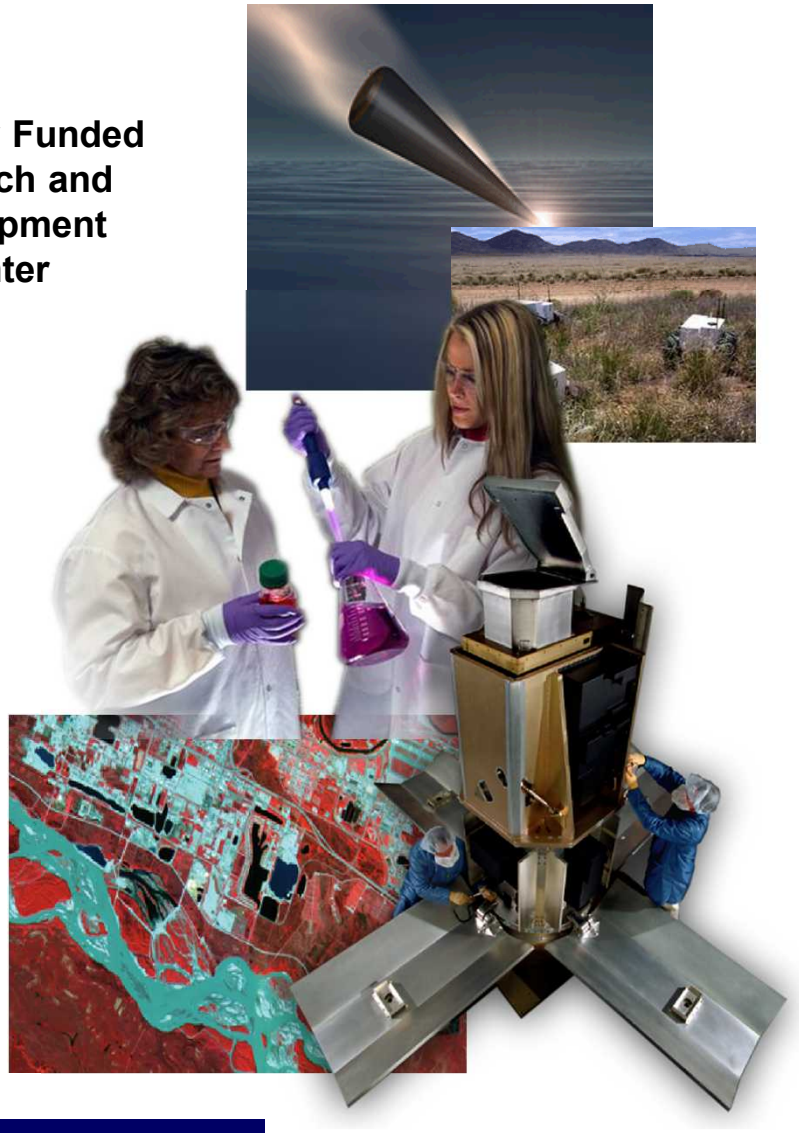
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

Overview of Sandia National Laboratories

Federally Funded Research and Development Center



We develop technologies for <u>national security applications</u> to:

- Sustain, modernize and protect our nuclear arsenal
- Prevent the spread of weapons of mass destruction
- Provide new capabilities to our armed forces
- Protect our national infrastructures
- Ensure the stability of our nation's energy and water supplies.
- Defend our nation against terrorist threats

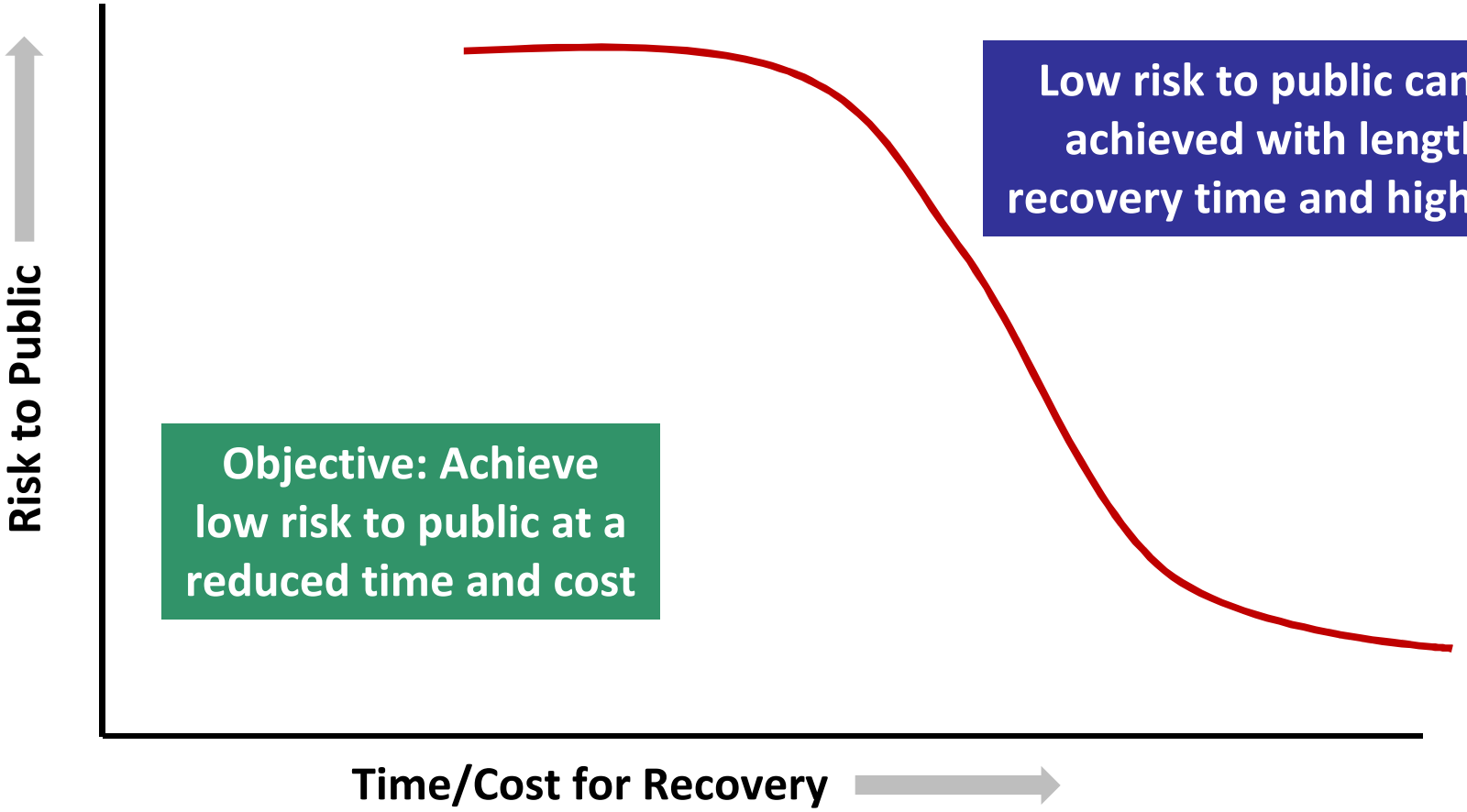
Includes CBRNE Threats

National response to the 2001 anthrax incidents was costly and time consuming

- Postal facilities, Senate buildings, and news organizations were contaminated
- Very little experience decontaminating large indoor facilities
- CDC reports that over 125,000 samples were tested at LRN laboratories costing $25-30M
- Many facilities were closed for years and restored at great cost
  - Capitol Hill (4 mo, $42M)
  - Brentwood (26 mo, $130M)
  - US Postal Facilities (3+ yr, $800M)

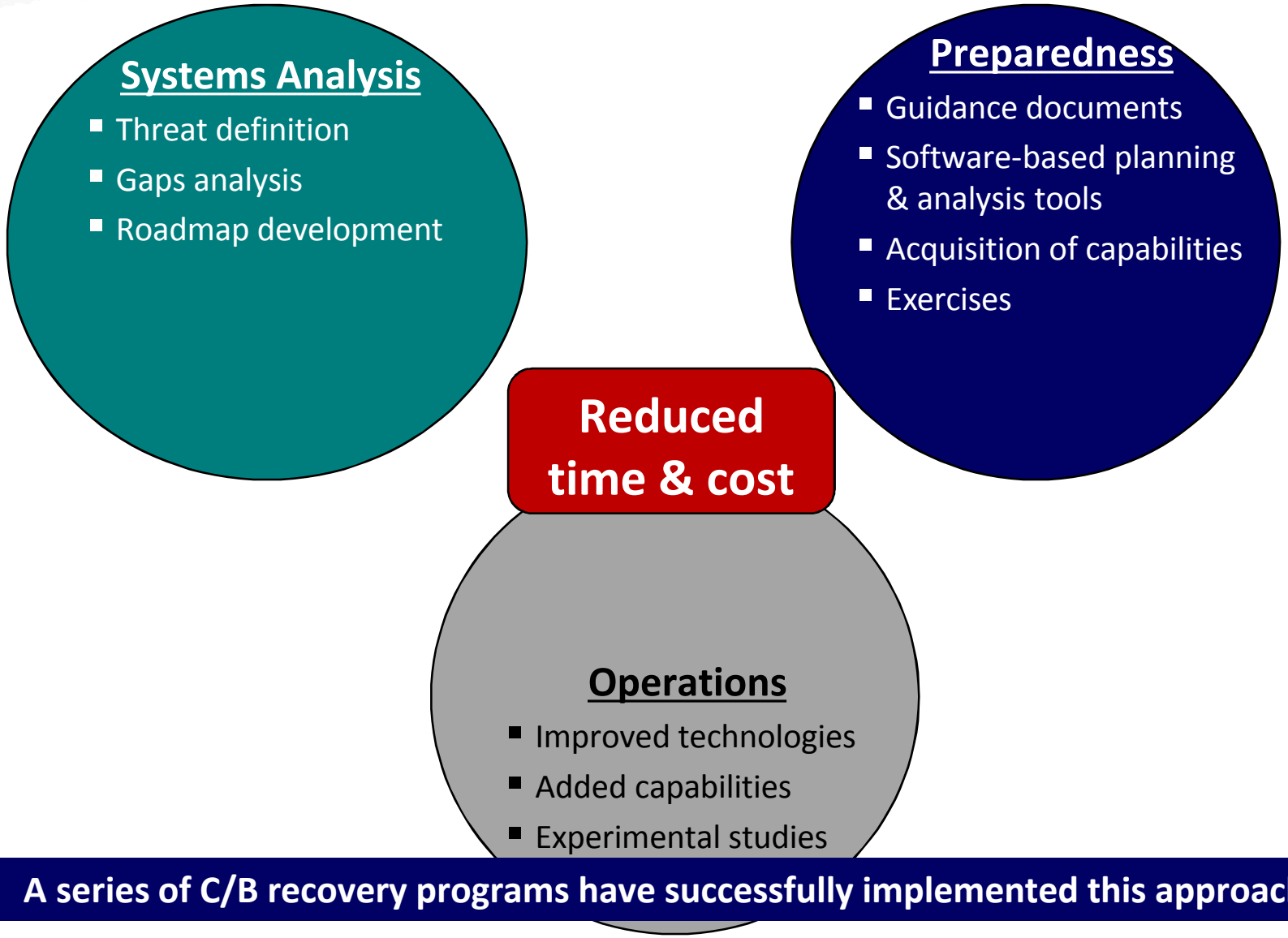
The need to improve the end-to-end remediation process was evident

The overall objective for recovery is to minimize the risk to the public



This concept can be applied to military operations as well.

Enhanced recovery can only be achieved through a systems approach

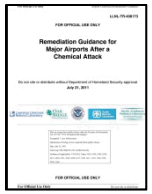


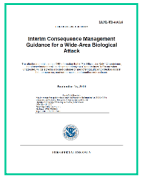
A series of C/B recovery programs have successfully implemented this approach

A series of chemical and biological restoration projects have had the objective of enhancing the recovery process

Bio DDAP (2003-2005)

Chemical OTD (2004-2009)



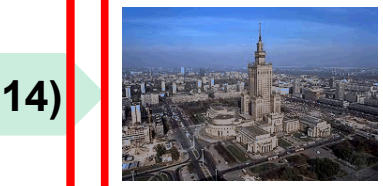


IBRD (2007-2010)

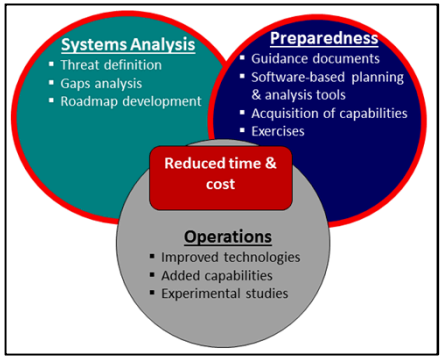
WARRP (2010-2012)

IDDD (2011-2013)

TaCBRD (2011-2014)

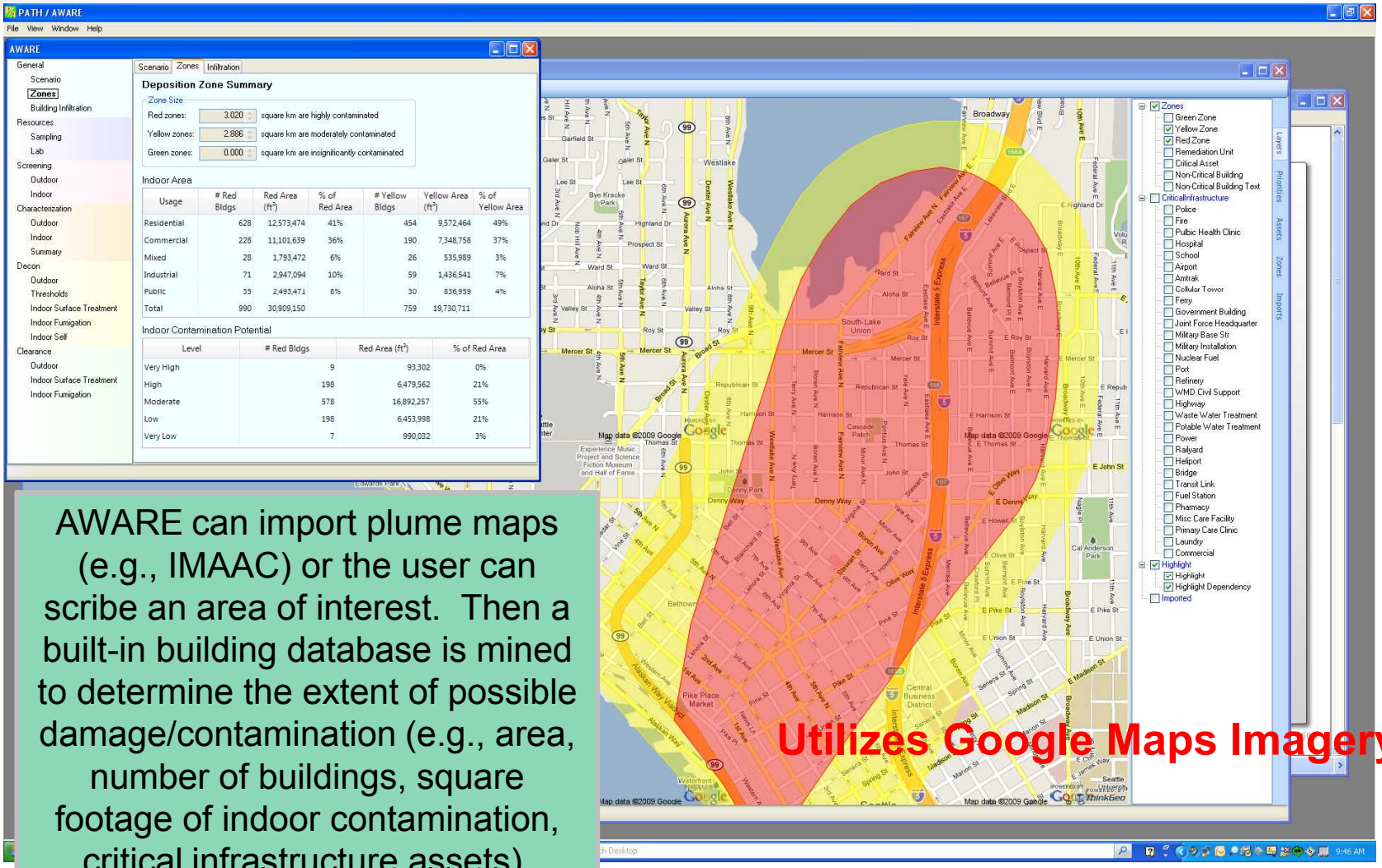


UTR (2013-2017)



2003 2007 2011 2013 2017

PATH and AWARE enable detailed planning and analysis of the complex wide area recovery process



AWARE can import plume maps (e.g., IMAAC) or the user can scribe an area of interest. Then a built-in building database is mined to determine the extent of possible damage/contamination (e.g., area, number of buildings, square footage of indoor contamination, critical infrastructure assets).

Utilizes Google Maps Imagery

PATH/AWARE output enables better decision-making

PATH / AWARE - [PATH (Beta-Release -- Not for public distribution)]

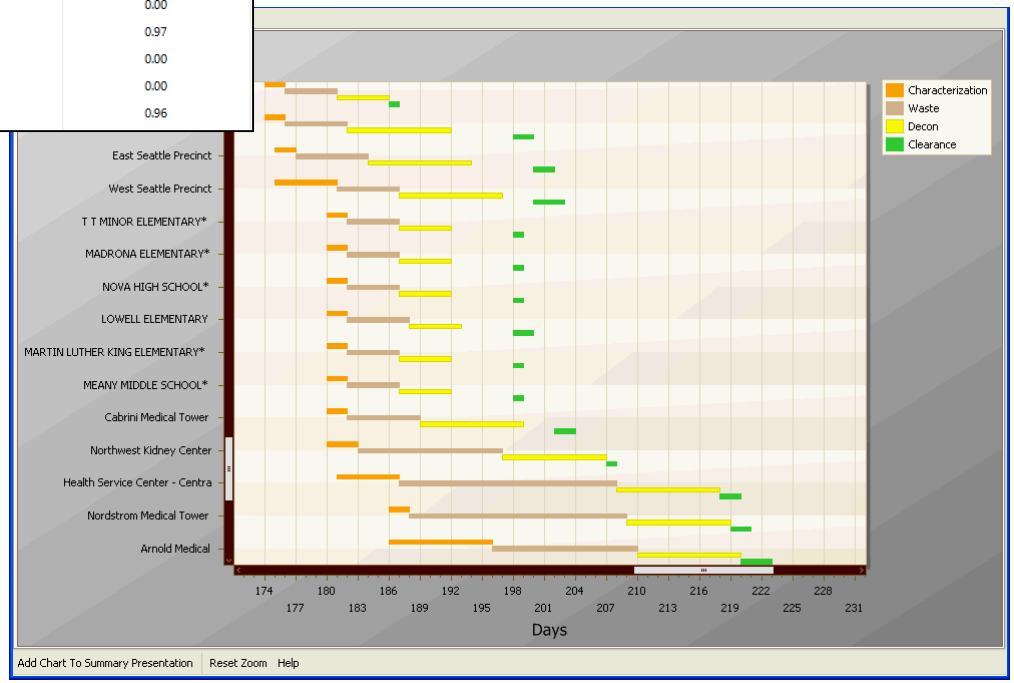
File View Window Help

Prioritization Objectives | Critical Infrastructure Asset List | Prioritization Objective Asset Contribution | Asset Prioritization | Asset Dependency Viewer

Drag a column

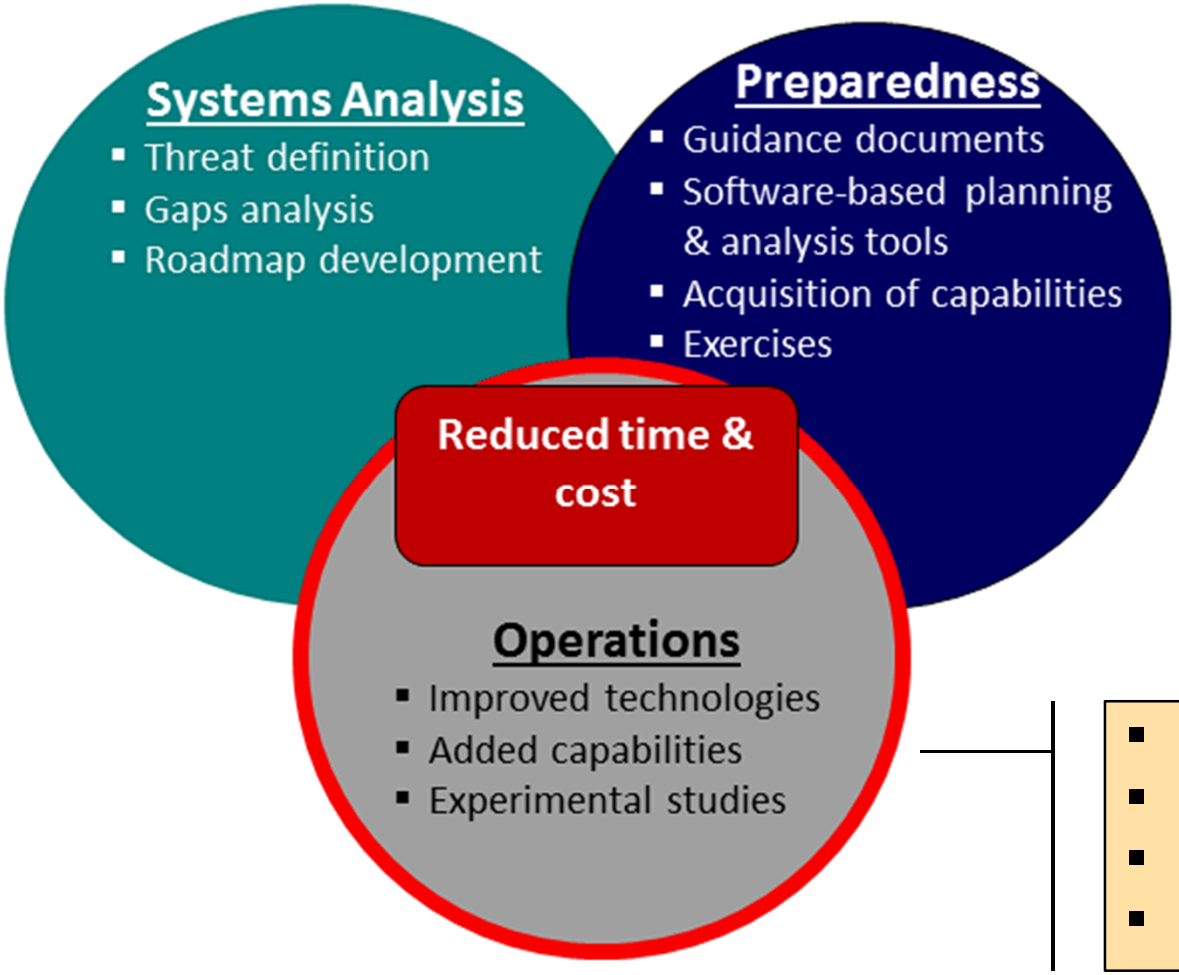
Pri	Name	Category	SpecialI...	Overall...	Maintain Economy	Mini...	Maintain Public Safety	Maintain Public Health
1	Interstate B	Highways	EA	0.13	0.97	0.00	0.00	0.00
2	Blood Bank A	Hospital	EA	0.13	0.86	0.00	0.00	0.00
3	Hospital D	Hospital		0.13	0.00	0.00	0.00	0.99
4	Military asset	CellularTowers		0.14	0.96	0.00	0.97	0.00
5	Hospital B	Hospital		0.08	0.92	0.00	0.00	0.98
6	Fire Station 12 (EOC)	Fire		0.07	0.00	0.00	0.99	0.00
7	Police HQ	Police	EA	0.07	0.00	0.00	0.93	0.00
8	Police Station A	Police		0.07	0.00	0.00	0.98	0.00
9	Hospital C	Hospital		0.06	0.84	0.00	0.00	0.97
10	Port Railyards	Railyards	EA	0.04	0.00	0.00	0.00	0.00
11	Port Terminal A	Ports		0.04	0.99	0.00	0.00	0.00
12	Army Medical Center	Hospital		0.04	0.91	0.00	0.00	0.96

A logical, transparent, priority list provides a starting point for prioritization negotiation and decision making



Remediation timelines, cost, and resource estimates provides improved planning capabilities

Improving technologies and capabilities for restoration/recovery operations is a key for success



- **Sampling/Analysis**
- **Decontamination**
- **Mitigation/Elimination**
- **Decision Support Tools**

Our work started with the development of the Sandia Decontamination Foam in the mid 1990's

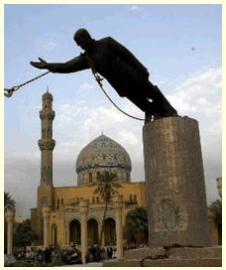
Initial (1996-1999) and Enhanced (2000-2002) Development (DOE CBNP)

DF-100

DF-200

Successful Deployments (2001- present)

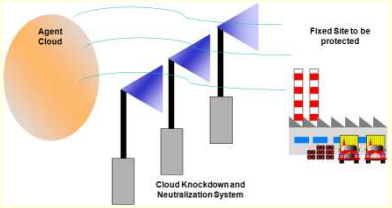
2001 Anthrax Incidents



Operation Iraqi Freedom

Civilian First Responders

Expansion of Use and Commercial Success (2004 – present)



Spray Knockdown

Aerosolized Delivery

Commercial Products

Sandia Decon Formulation (DF-200)

How Does it Work?

Components

- **Foam Component (Surfactants, mild solvents, buffers)**
- **Peroxide (7.9% Solution)**
- **Novel Activator**

Mix

Formulation

Synergistic formulation (multiple reactive species)

Spray, Foam, Mist, or Gel

Multiple Uses

- **Kill of BW Agents**
- **Kill of Bio Pathogens**
- **Neutralization of CW Agents**
- **Neutralization of TICs**

Final peroxide concentration is ~3.6%

Sandia Decon Formulation (DF-200)

Surface Decontamination

Small-scale Foam System

Large-scale Foam System

Indoor Foam Application

Medium-scale Foam System

Fog/Mist Application

Liquid Spray Application

Decontamination of complex interior spaces is difficult

HOMELAND SECURITY

Complex Interior Spaces

Decontaminant Selection

Liquids
Oxidants, enzymes, solvents

Advantage: Agent-specific, can be non-corrosive

Disadvantage: difficult to reach all surfaces

Gases
ClO_2, Ozone, EtO

Advantage: Can reach all surfaces

Disadvantage: all known gases are toxic and/or corrosive

Vapors
VHP, mVHP

Advantage: Can reach all surfaces under certain conditions

Disadvantage: too corrosive for many interior spaces

Aerosols
Oxidants,enzymes, solvents

Advantage: Agent-specific, can be non-corrosive; enhanced reactivity

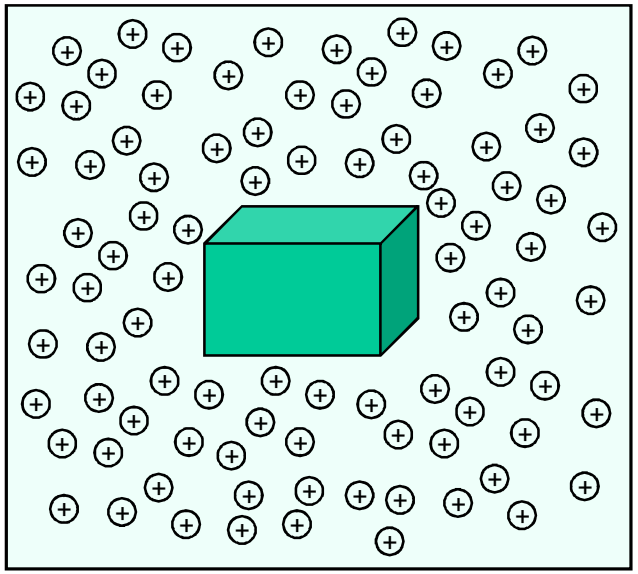
Disadvantage: need controlled conditions to reach all surfaces

Objective

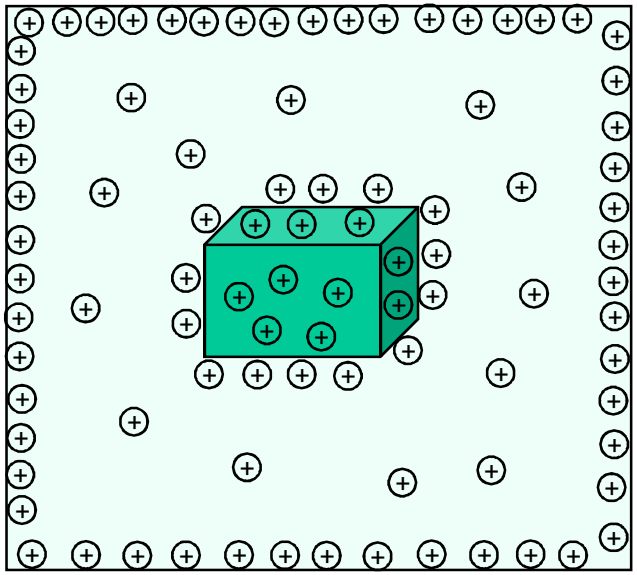
Develop approach for aerosol delivery of decontaminants

Use of the space charge effect can significantly enhance aerosol transport and surface coverage

Airborne charged droplets in a space



Charged droplets forced to surfaces by space charges



For uniform deposition on exposed and hidden surfaces we need:

- **Droplet size small enough to remain airborne during convection to hidden surfaces**
- **High enough droplet charge (charge to mass ratio) to make electrostatic forces dominant**
- **High enough droplet concentration to provide sufficient space charge to drive deposition**

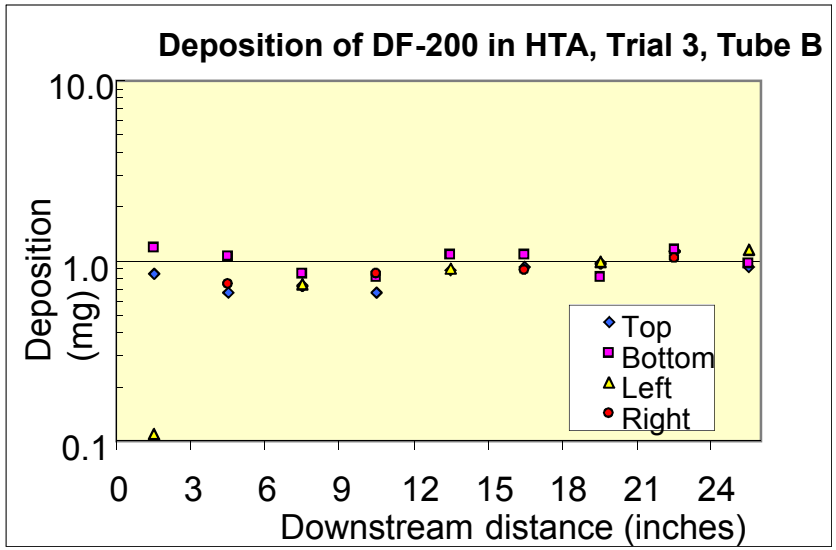
A rotary atomizer was found to be the best device for dispersal of liquid decontaminants

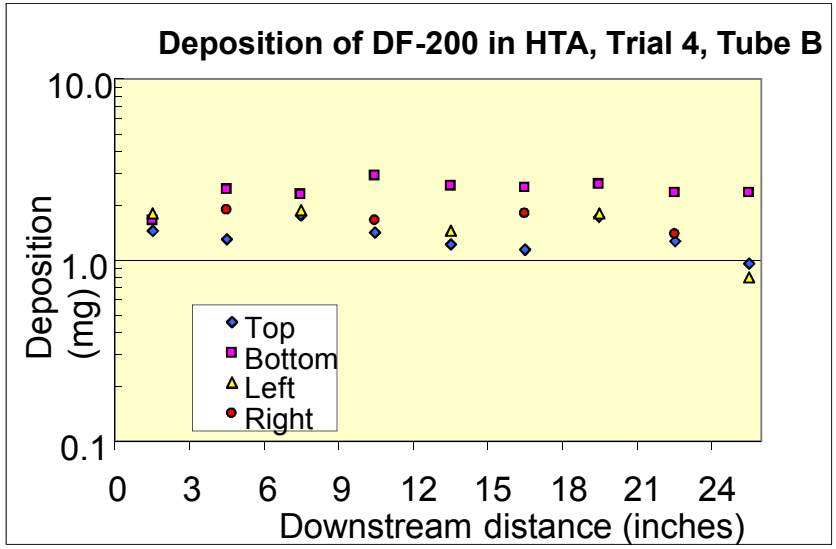
Rotary atomizer for aerosol delivery of decontaminants

Test chamber

Advantages of this technology include: 1) Droplet size (~3-5 μm), 2) Ability to charge droplets, and 3) Uses a mechanical process to create droplets so it does not require large volume of air.

Example of experimental results using the rotary atomizer aerosol generation device





Aerosol generation conditions (i.e., charge and concentration) were varied until nearly uniform deposition was achieved on all surface orientations and down the length of the hamster tubes

Following the selection of an aerosol generation device, we investigated decontamination methods using the device

- Application of a modified DF-200 formulation (for both CW and BW agent surrogates)
- Application of a two-step decontamination process for bacterial spores
  - Aerosol dispersal of a germination solution
  - Aerosol dispersal of a mild “kill” solution

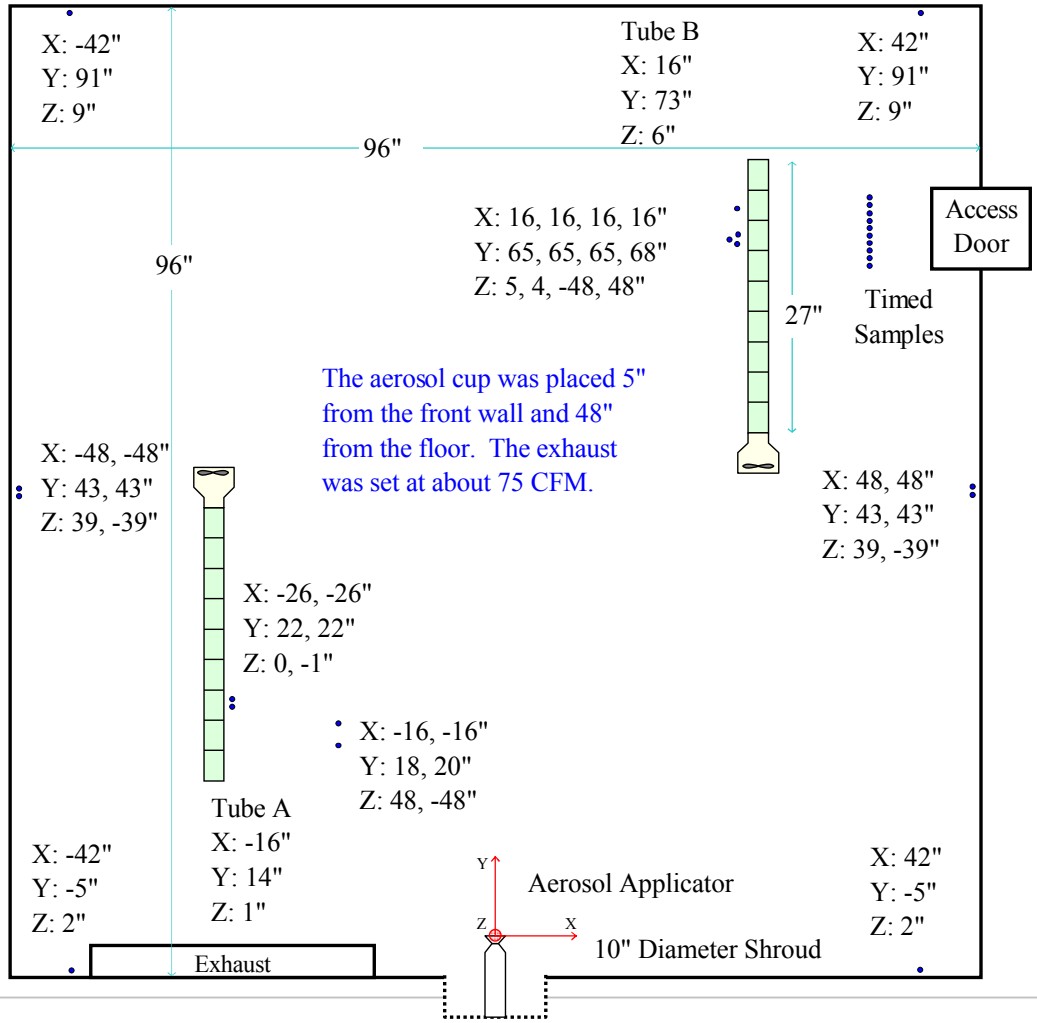
Tests were conducted in the 512 cu. ft. test chamber

Coupon Placement for Bio-Efficacy Tests

Coupon Placement

- 8 coupons on the walls.
- 2 coupons on the ceiling and 2 coupons on the floor.
- 2 coupons on top of the platforms supporting the hamster tubes.
- 2 additional coupons at various positions in the chamber.
- 8 timed samples not in the line-of-sight of the aerosol (bio-tests).
- 10 coupons in each hamster tube (bio-tests).
- 10 coupon controls (bio-tests)

Test Chamber (Plan View)



Bio-Efficacy Test Results with DF-200

Sample	Description	Bio-Efficacy Trial		
		38	39	40
Process Data				
	Charge (KV)	Level 1	Level 2	Level 3
	Aerosol Concentration mg/m^3	207.8	76.8	39.6
Log CFU Results				
47-56	Controls (Avg. of 10)	6.32	6.28	6.23
1-12	Wall Samples	0	0	0
13	Top Sample, Stand A	3.42	4.07	0
14	Bottom Sample, Stand A	0	2.64	0
15	Top Sample, Stand B	3.39	3.01	0
16	Bottom Sample, Stand B	5.14	3.31	0
17	Timed Sample (30 min)	4.20	5.70	5.69
18	Timed Sample (60 min)	0	4.15	4.27
19	Timed Sample (90 min)	0	0	4.00
20	Timed Sample (120 min)	0	0	3.44
21	Timed Sample (150 min)	0	0	0
27-46	Hamster Tube Samples	0	0**	0

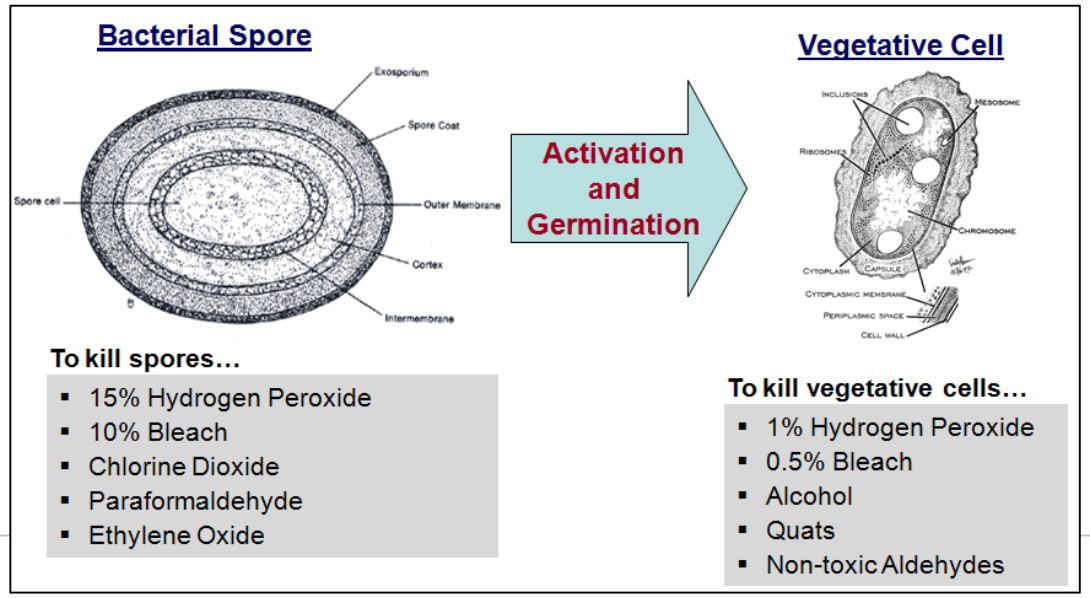
***Colony Forming Units**
****One out of 20 Hamster tube samples showed very mild growth.**

Conclusions

- Nearly uniform coverage can be achieved with certain droplet parameters (size, charge, concentration)
  - Spatially (droplet penetration)
  - On all surface orientations
- Excellent kill rates can be achieved even in confined spaces using DF-200
  - Required surface coverage is ~100 times less than foam applications
- Changes in parameters significantly effects results
  - Size, charge, concentration
  - Only a few conditions have been examined
  - Many additional conditions are possible and should be examined
- This method can potentially work with other types of liquid decontaminants

We have investigated a non-toxic, low-corrosivity decontamination method to kill highly resistant bacterial spores in complex interior spaces

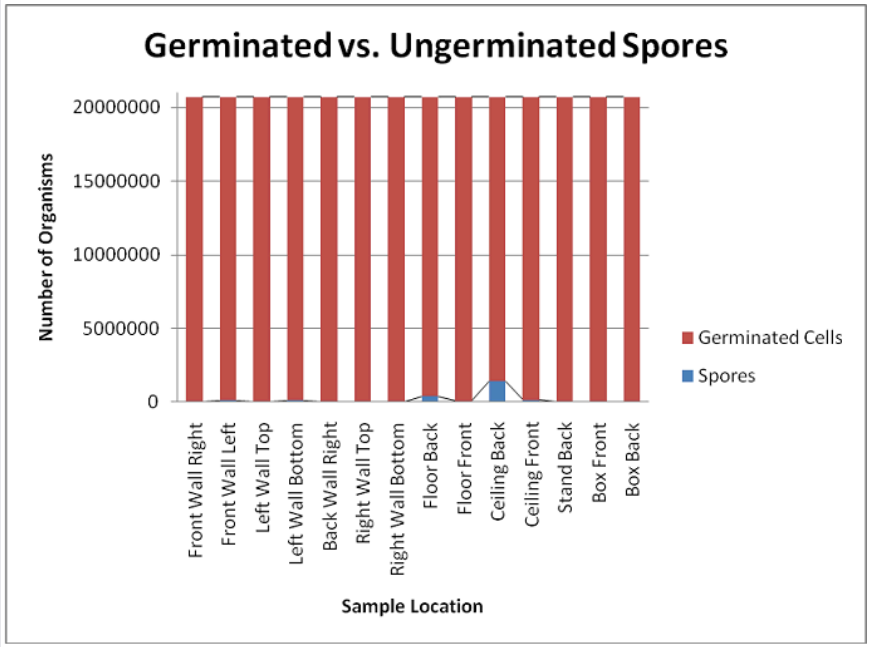
1. A chemical solution is applied that triggers the germination process in bacterial spores and causes those spores to rapidly and completely change to much less-resistant vegetative cells that can be easily killed.
2. Vegetative cells are then exposed to mild chemicals (e.g., low concentrations of hydrogen peroxide, quaternary ammonium compounds, alcohols, aldehydes, etc.) or natural elements (e.g., heat, humidity, ultraviolet light, etc.) for complete and rapid kill.

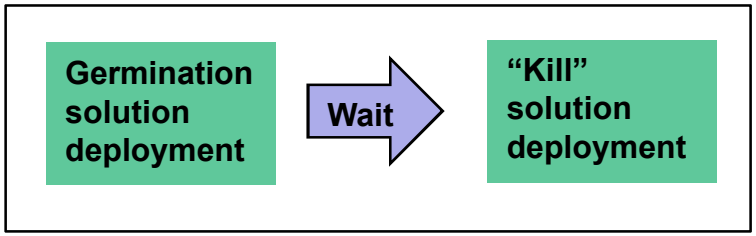


Aggressive fumigation formulations are currently needed because bacterial spores are extremely resistant.

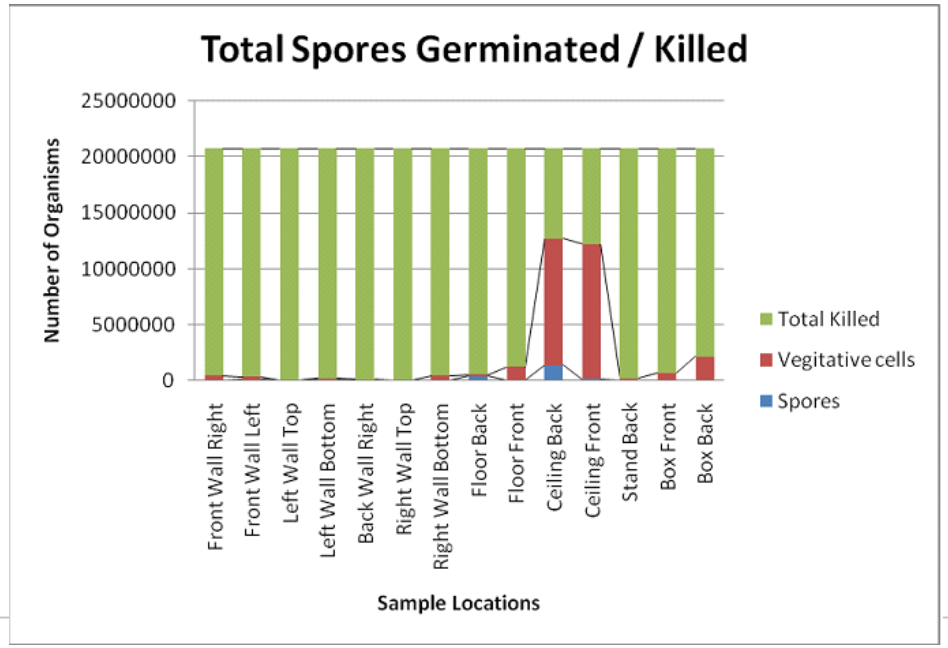
Summary of rapid germination results

Red = germinated spores
Blue = un-germinated spores





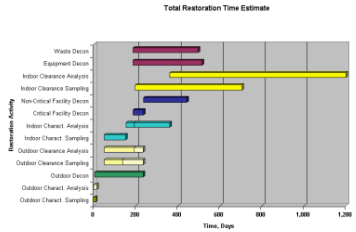
Green = spores that germinated and were killed
Red = spores that germinated and were not killed
Blue = un-germinated spores



"Kill" solution was 3% hydrogen peroxide

Sandia has broad expertise in applying a systems approach to post-event consequence management

Formal Response & Recovery Guidance and Decision Tree Development



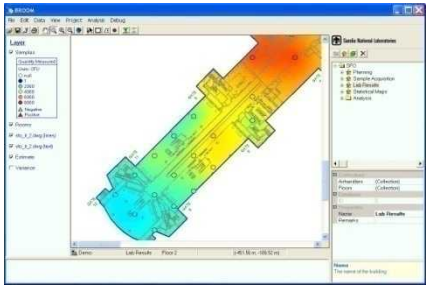
Remediation Planning and Decision Tools

Blast experiments

Strippable gel for rad decon

Aerosol experimental chambers

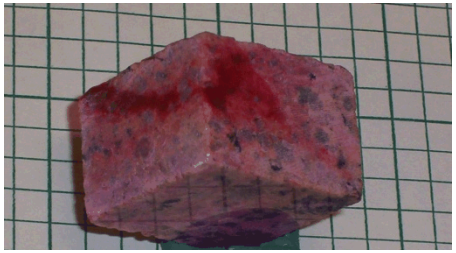
Decontamination technologies



Real-time contamination mapping and sampling decision tools

Systems studies of CB and dirty bomb threats

NISAC tools for infrastructure analysis



Surface sorption experiments

Sandia's broad experience assures a comprehensive, systems-level solution