



# **Spray Knockdown System for Rapid Containment and Neutralization of Airborne CBW Agents**

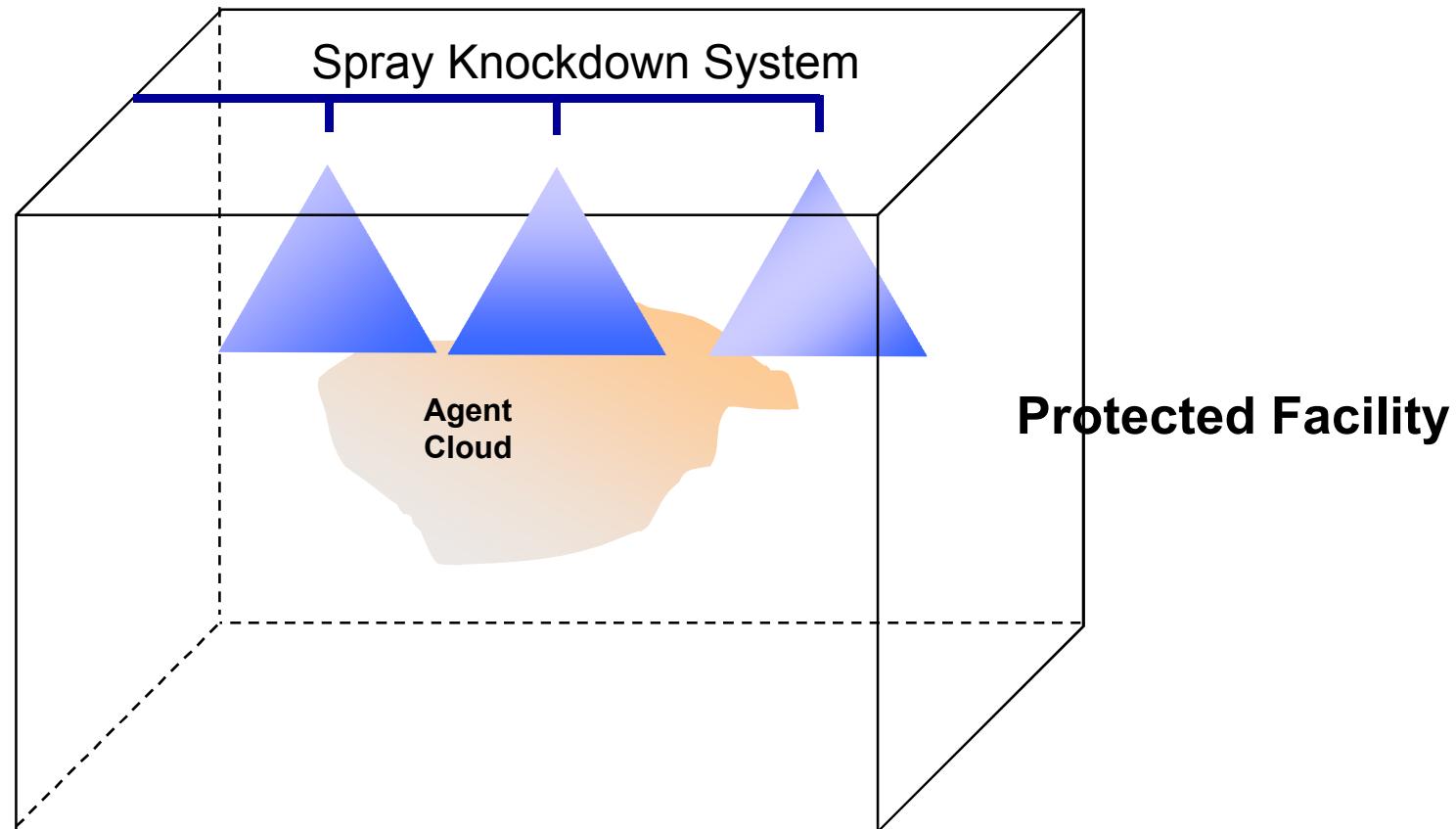
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**Sandia National Laboratories**

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# Spray Knockdown & Neutralization Concept

## Interior Protection



Our objective is to investigate the use of small, charged liquid droplets to knockdown and neutralize clouds of CBW agents

# Through a series of four projects, Sandia has developed and demonstrated a fundamental spray knockdown process

2001-2002

DARPA Immune Building Project



2004-2005

Laboratory Directed Research and Development (LDRD)

- Knockdown and neutralization of CBW agents in an interior facility
- Small (~30-50 $\mu$ m), uncharged droplets of modified DF-200
- Prototype system developed for Anniston, AL test facility

2008-2009

Chemical Materials Agency (Chem Demil)



2014-2017

Underground Transport Restoration Project



- Knockdown and neutralization of CBW agents in an outdoor setting
- Small (~30-50 $\mu$ m), charged droplets of modified DF-200
- Feasibility study

- Knockdown and neutralization of CBW agents in an interior or temporary demil facility
- Small (~30-50 $\mu$ m), charged droplets of modified DF-200
- Prototype system installed

- Knockdown and neutralization of CBW agents in a subway system
- Small (~30-50 $\mu$ m), charged droplets of modified DF-200
- Demonstration in mock subway tunnel

# Fundamental Requirements for Spray Knockdown & Neutralization System

Define the Threat

- Agents of Concern
- Airborne Concentrations and Exposures
- Knockdown & Neutralization Efficacy Required

Detect the Agent Cloud

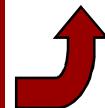
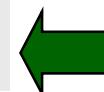
- Stand-off Detection
- Direct Detection
- Particle Detectors

Knockdown efficacy requirements have been developed for each project

Knockdown and Neutralize the Agent Cloud

- Chemical Properties for Neutralization
  - Efficacy
  - Solubility
  - Safety and Environment
- Physical Properties for Efficient Collection
  - Droplet Size
  - Charge
- Deployment
  - Disperse Knockdown Spray into Agent Cloud

Our work has primarily focused on this part of the problem



# Example calculations for knockdown efficacy requirements

Toxic Material	Initial Airborne Concentration (mg/m <sup>3</sup> )	Exposure at Initial Airborne Concentration (mg-min/m <sup>3</sup> ) <sup>1</sup>	LCt <sub>50</sub> (mg-min/m <sup>3</sup> ) <sup>3</sup>	Log reduction required to reach LCt <sub>50</sub>	No significant effects dosage (mg-min/m <sup>3</sup> ) <sup>5</sup>	Log reduction required to reach no significant effects
VX	560	300	15	1.3	0.09	3.5
GB	560 <sup>6</sup>	300	35	0.9	0.5	2.8
HD	5600 <sup>7</sup>	3000	900	0.5	2.0	3.2
Anthrax Spores	0.009 <sup>3</sup>	0.0054	0.00015 <sup>4</sup>	1.6	0.0000094	3.0
Chlorine gas	681,000 <sup>2</sup>	408,600	52,740	0.9	150	3.4

1: Estimated from scenarios in open literature

2: From estimated maximum concentration following Graniteville, SC release

3: Data from "Immune Building Systems Technology", Kowalski, WJ, 2003

4: Assumes 10<sup>11</sup> spores/g

5: Data for VX, GB, and HD from "Compilation of Existing Chemical Agent Guidelines Table as of September 1997", ORNL/TM-13649

6: Sarin attack by truck with sprayer from Davis et al. (2003, ISBN 0-8300-3473-1) 100 kg Sarin sprayed into 6 mph wind, 1 km down wind

7: Used same conditions as Davis but with 100 kg for VX and 1000 kg for HD

# Fundamental Requirements for Spray Knockdown & Neutralization System

Define the Threat

Detect the Agent Cloud

Knockdown and Neutralize the Agent Cloud

- Agents of Concern
- Airborne Concentration and Exposure
- Knockdown & Neutralization Efficacy Required

Modified Sandia DF-200 chemistry is being utilized for the knockdown and neutralization spray formulation

- Chemical Properties for Neutralization
  - Efficacy
  - Solubility
  - Safety and Environment
- Physical Properties for Efficient Collection
  - Droplet Size
  - Charge
- Deployment
  - Disperse Knockdown Spray into Agent Cloud

# 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%**



# Efficacy of Sandia DF-200 Formulation against CW Agents (US DoD Testing)

Decontaminant	GD		VX		HD	
	10 Min.	60 Min.	10 Min.	60 Min.	10 Min.	60 Min.
DS2	>99.9	>99.9	>99.9	>99.9	>99.9	>99.9
DF-200	>99.9	>99.9	97.8	>99.9	84.8	99.9

Percent decontamination from kinetic tests against CW agents (US DoD stirred reactor tests using EasyDECON™-200 Lot 3829 at 25°C).

# Efficacy of Sandia DF-200 Formulation against BW Agents (US DoD Testing)

	<i>B. atrophaeus</i>		<i>B. anthracis</i> Ames		<i>B. anthracis</i> Vollum		<i>B. anthracis</i> Vollum 1B	
	MREF	Dahlgren	MREF	Dahlgren	MREF	Dahlgren	MREF	Dahlgren
	CFU	CFU	CFU	CFU	CFU	CFU	CFU	CFU
HTH (2%)	0	0	0	0	0	0	0	0
STB	0	5158 (SD=7837)	33 (SD=58)	28 (SD=48)	0	0	0	0
MDF-200	0	4	0	0	0	0	6 (SD=10)	0
EasyDECON	0	0	0	0	0	0	0	0

Residual spores following decontamination of CARC coupons (Initial surface loading:  $1 \times 10^7$  spores; Contact time: 30 minutes; coupons rinsed in sterile de-ionized water following testing)

# Fundamental Requirements for Spray Knockdown & Neutralization System

Define the Threat

- Agents of Concern
- Airborne Concentrations and Exposures
- Knockdown & Neutralization Efficacy Requirements

Detect the Agent Cloud

- Stand-off Detection
- Direct Detection
- Particle Detectors

We have utilized fundamental physics and experimental work to determine the required physical properties

Knockdown and Neutralize the Agent Cloud

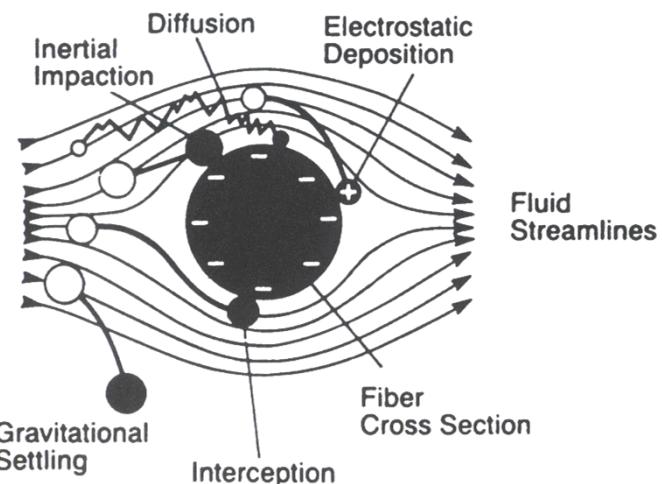
- Chemical Properties for Neutralization
  - Efficacy
  - Solubility
  - Safety and Environment
- Physical Properties for Efficient Collection
  - Droplet Size
  - Charge
- Deployment
  - Disperse Knockdown Spray into Agent Cloud

# Physical properties of the knockdown spray droplets are important for optimal collection of agent vapors, liquid aerosols, and particles

- Particles may be collected by falling droplets with various mechanisms

- Diffusion
- Interception
- Impaction
- Thermal effects
- Electrostatic effects

- Collection efficiency may be enhanced by certain physical properties of the droplets
  - Droplet size
  - Charge on the droplet
  - Concentration of the droplets
  - Surface tension (wettability)



From Spurney, "Advances in Aerosol Filtration"

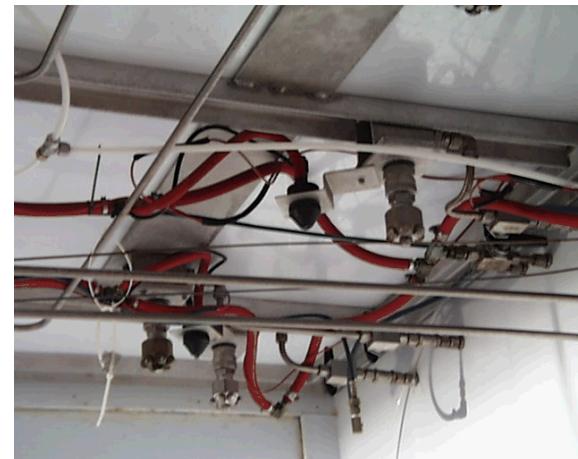
**The optimal properties of the knockdown spray droplet properties have been determined through modeling and experimental work**

# Aerosol Test Chamber for Spray Knockdown Tests

- 8-ft wide by 16-ft long by 8-ft high chamber divided into two 8-foot cubes separated by an intervening wall (512 cu. ft.)
- The chamber was fitted with an array of nine electrostatic spray (ESS) nozzles (Maxcharge™ Spray Nozzle - Agricultural Manufacturing Company, Inc.) located at the top of the test chamber
- Spray droplet sizes from the nozzles are 30-40 microns in diameter
- Required air pressure for each nozzle is 20-90 psi
- Air consumption is 2.9–10 CFM
- The liquid flow rate is 50–200 ml/min for each nozzle



Aerosol Test Chamber at Sandia National Laboratories



ESS nozzles in the chamber

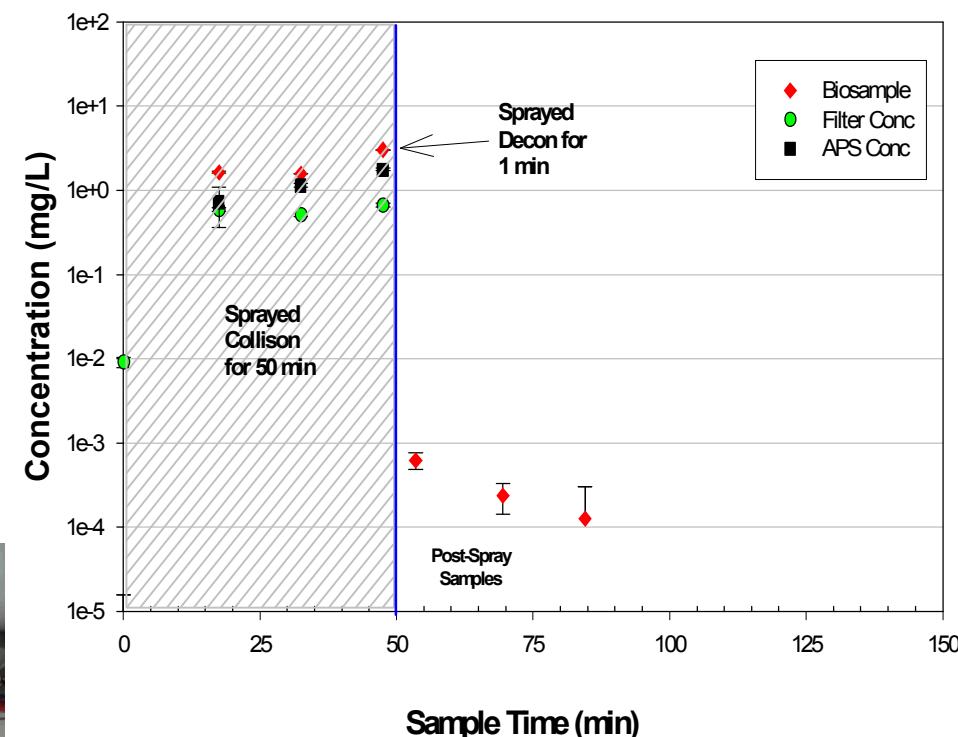
# DF-200 Knockdown & Neutralization Spray

## CW Agent Simulant Data

- Charged spray system
- 3.2 g/m<sup>3</sup> G-agent simulant
- 138 g/m<sup>3</sup> DF-200 Spray density
- Immediate decrease of nearly 4 orders of magnitude
- Knockdown/neutralization proof of concept
- Various simulant and spray densities have been evaluated



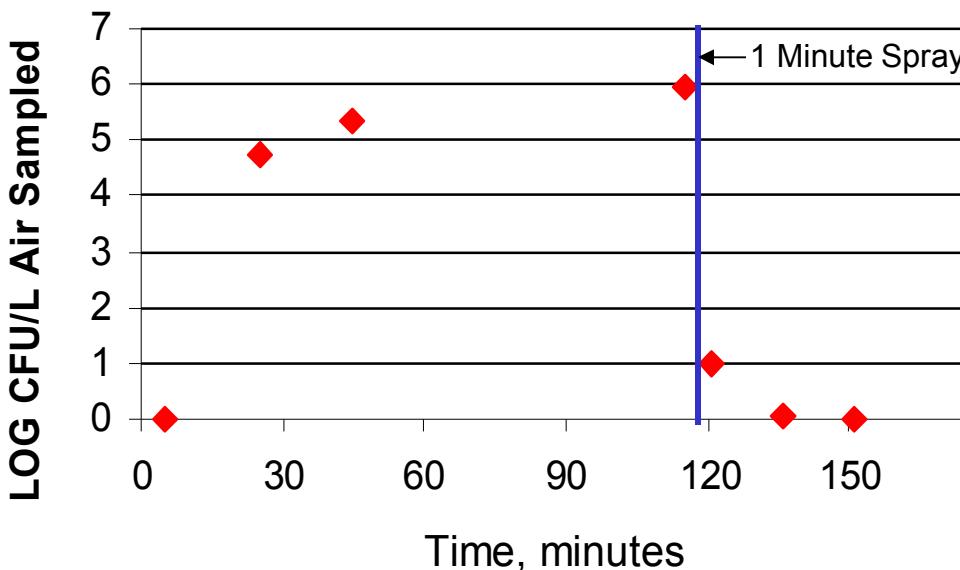
G-Simulant Characterization Tests  
1 Minute Decon Spray  
December 3, 2004



# DF-200 Knockdown & Neutralization Spray

## BW Agent Simulant Data

- Tests were conducted against 'weaponized-like' *Bacillus atrophaeus* spores
- Spores were introduced into the chamber at a concentration of  $10^6$  log CFU/l. After 120 minutes of mixing, DF-200 spray was deployed for one minute through the ESS nozzles.
- Total spray volume deployed was 2 L and the concentration of DF-200 was approximately 138 g/m<sup>3</sup> in the chamber.
- The simulant was collected by aerosol sampling and concentration in the chamber was determined by culturing at <1, 15, and 30 minutes after the end of the spray period.
- The results demonstrated a **5 log knockdown and kill** of the simulant immediately after the spray was stopped. A 5 log knockdown and kill was also observed using a 92 g/m<sup>3</sup> spray density and a 4 log knockdown and kill was observed using a 46 g/m<sup>3</sup> spray density.



Results of cloud knockdown tests using a mist of DF-200 against *Bacillus atrophaeus* spores (an anthrax simulant).

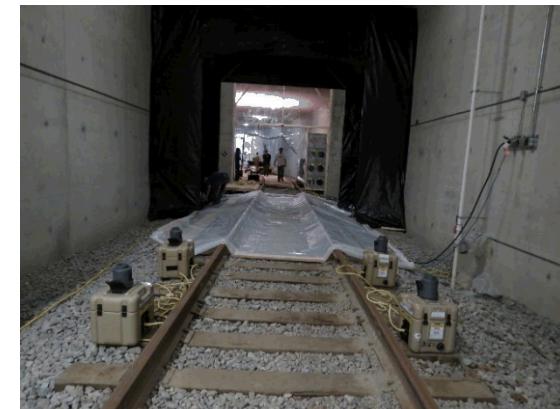
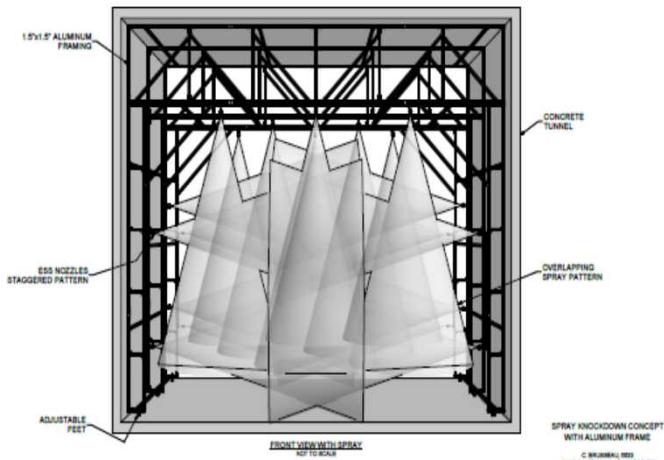
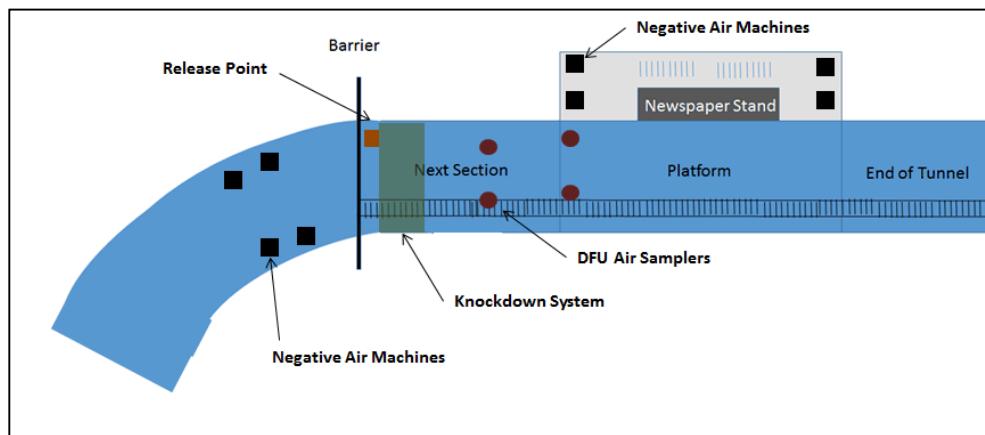
# Potential Spray Knockdown Applications

- Many applications for fundamental capability
- Potential applications for military use
  - Force protection (battlefield)
  - Force protection (fixed sites)
  - Chemical demilitarization
  - Immune building
- Potential applications for civilian use
  - Chemical plants
  - Subways
  - Nuclear plants
  - High-profile buildings



# Spray Knockdown System for Containment and Neutralization of CBW Agents in Subways

## Spray Knockdown Test at the OTD



# Spray Knockdown System for Containment and Neutralization of CBW Agents in Subways



# Spray Knockdown System for Containment and Neutralization of CBW Agents in Subways

## Test Parameters:

- Airflow was approximately 40 ft/min
- Spray was turned on for 1 minute, 30 seconds
- B.g. spores were released (25 mg)
- Spray continued for 18 minutes, 30 seconds
- Approximately 12 gallons of modified DF-200 liquid was deployed
- 6 Liquid (pool) and 4 DFU samples were collected 15 minutes after the end of the spray
- Control (release with no spray) and background (pre-test) samples were collected

## Results:

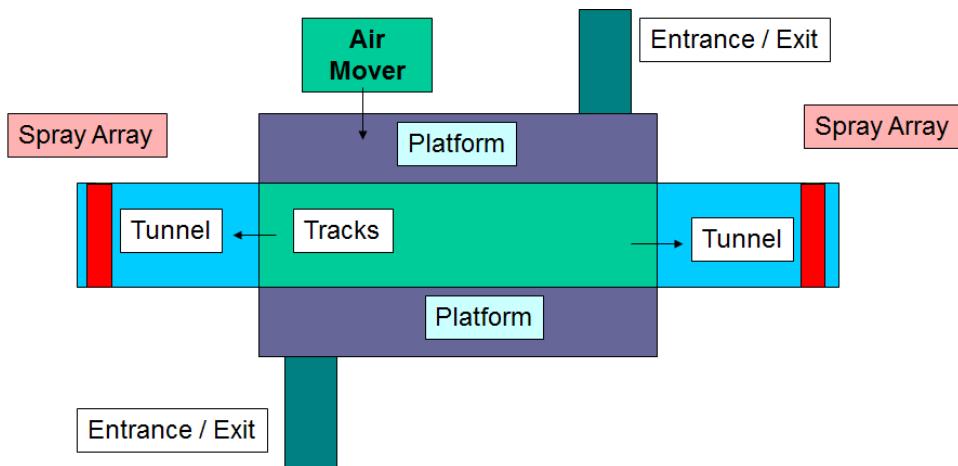
- Control (i.e., no spray) resulted in ~ 4 log CFU on DFUs
- Spray Test resulted in non-detects on all DFUs
- Spray Test resulted in non-detects in all liquid (pool) samples



Average Spore Count  
(Preliminary Data)

DFU	Background	Control	Spray
1	ND	18000	ND
2	ND	24100	ND
3	ND	28900	ND
4	ND	27000	ND
5	13.3	13800	ND

# CBW Spray Knockdown & Neutralization Subway System Concept



## Advantages:

- Large order of magnitude knockdown
- Low regret action

## Disadvantages:

- Depends on detection
- Must be pre-installed

# Summary of Sandia Chemical and Biological Spray Knockdown Effort

- The Sandia Decon Formulation (DF-200) can neutralize CW agents, BW agents, and many toxic industrial chemicals
- DF-200 is considered to be the “best available technology” by the US Military and was staged in Iraq
- DF-200 is commercially available in several all-liquid packaging options
- Sandia has successfully demonstrated knockdown and neutralization of agent simulant clouds
- Various deployment scenarios have also been developed
- A demonstration system was successfully tested in a mock subway system as part of the Underground Transport Restoration project



Charged spray of modified DF-200 in the Sandia Aerosol Test Chamber during a spray knockdown test.