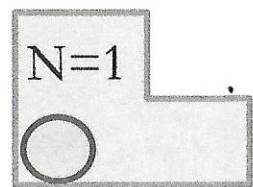


# Microaerosol Fundamentals

## ► Microaerosol

- Behaves like a gas (particles size in the range of 0.2 – 5  $\mu\text{m}$ )
- Evenly fills confined environment
- Reaches all areas/surfaces including otherwise inaccessible
- High surface area to volume ratio
- Has enormous adsorption/penetration ability
- Extremely efficient in contacting complex surfaces
- Gradually desiccates
- Leaves virtually no wastes

Liquid: 1 ml

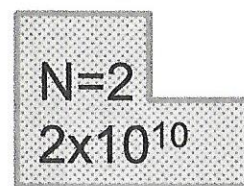


$$S_1 = \sim 4.9 \text{ cm}^2$$

$\text{cm}^2$

$$\frac{\sum S_2}{S_1} = 3 \times 10^3$$

Microaerosol from 1 ml of liquid



$$S_2 = \sim 0.75 \times 10^{-6} \text{ cm}^2$$

$$\sum S_2 = \sim 1.5 \times 10^4$$

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# PAEROSOL Fundamentals

- ▶ **PAEROSOL** – semi-dry microaerosol atomized from EAS ANOLYTE
  - Eventually fills entire environment
  - Particles size in the range of 0.2 – 5  $\mu\text{m}$
  - Each droplet of PAEROSOL possesses intrinsic properties of metastable EAS anolyte
    - acts as a micro-reactor continually producing highly reactive mixed ROS
  - ROS are effectively offgassing from the surface of aerosol droplets through interfacial mass transfer
    - Droplets eventually desiccate
  - ROS reach/contact microorganisms residing on inanimate surfaces and airborne
    - favorable surface-to-volume ratio promotes efficient ROS offgassing
    - destroy microorganisms by disintegrating their outer membranes,
    - penetrate inside microorganisms to cause oxidative damage leading to microorganism death
  - Remains germicidal until all droplets desiccate
    - bulk gas phase ROS concentration falls below a critical level.

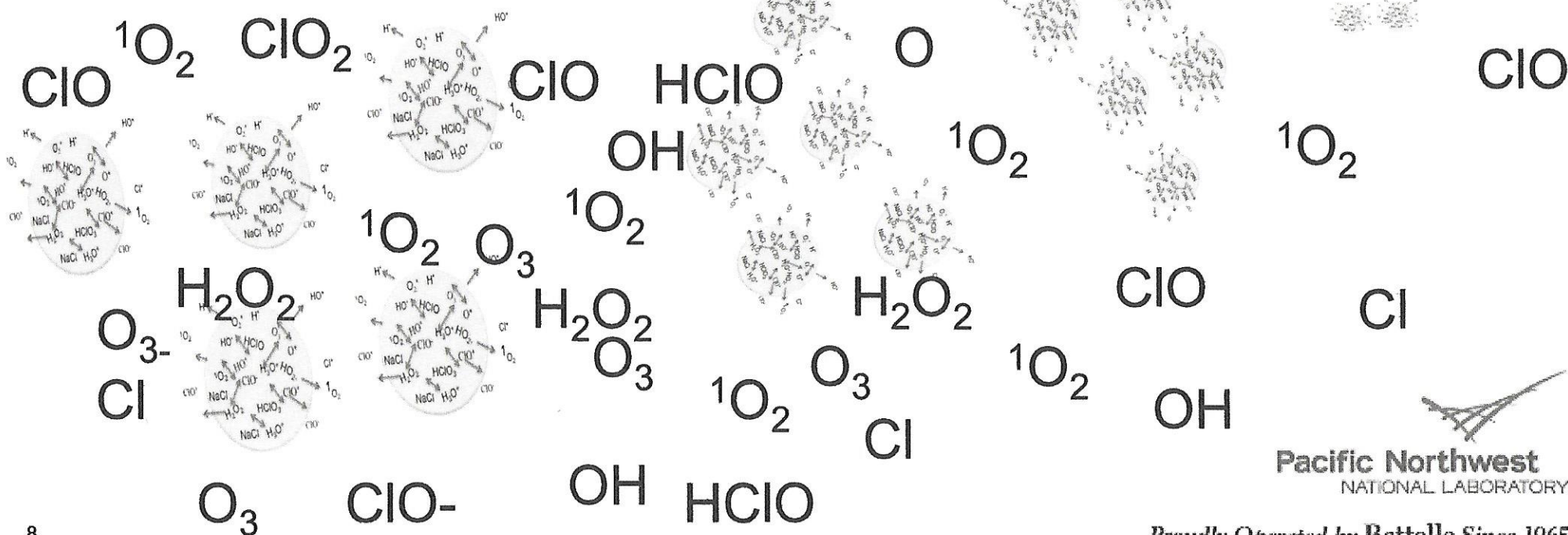
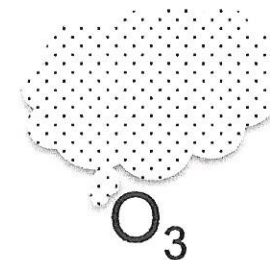
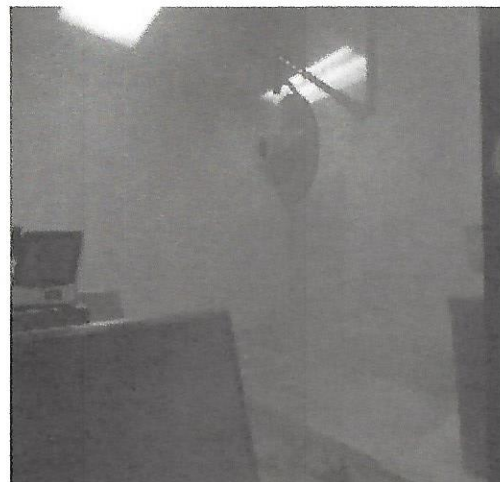


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# PAEROSOL Desiccation



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# Compatibility: interior materials, electronic, and fixtures

<b>Equipment and materials exposed to PAEROSOL</b>	<b>Visual effect after consecutive PAEROSOL applications in a room of 3,000ft<sup>3</sup> (each application of 2-6L)</b>									
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>
Oscillating Fan (4)	-	-	-	-	-	-	-	-	-	-
Telephone (2)	-	-	-	-	-	-	-	-	-	-
Mobile phone (2)	-	-	-	-	-	-	-	-	-	-
Computer (1)	-	-	-	-	-	-	-	-	-	-
Laptop (1)	-	-	-	-	-	-	-	-	-	-
Calculator (2)	-	-	-	-	-	-	-	-	-	-
Display (2)	-	-	-	-	-	-	-	-	-	-
DVD (2)	-	-	-	-	-	-	-	-	-	-
Lighting equipment (4)	-	-	-	-	-	-	-	-	-	-
Heaters (2)	-	-	-	-	-	-	-	-	-	-
RH/ T° sensor (4)	-	-	-	-	-	-	-	-	-	-
Colored PE & PP	-	-	-	-	-	-	-	-	-	-
Patterned PVC	-	-	-	-	-	-	-	-	-	-
Patterned wallpaper	-	-	-	-	-	-	-	-	-	-
Patterned cotton fabric	-	-	-	-	<i>Slight fading</i>	<i>Slight fading</i>	<i>Slight fading</i>	<i>Slight fading</i>	<i>Slight fading</i>	<i>Slight fading</i>
Patterned synthetic fabric	-	-	-	-	-	-	-	-	-	-
Lacquered wood	-	-	-	-	-	-	-	-	-	-
Bare wood	-	-	-	-	-	-	-	-	-	-
Stainless steel	-	-	-	-	-	-	-	-	-	-
Nickel-plated steel	-	-	-	-	-	-	-	-	-	-
Painted tile	-	-	-	-	-	-	-	-	-	-



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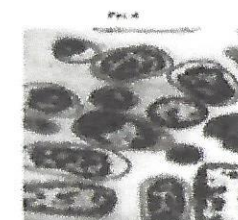
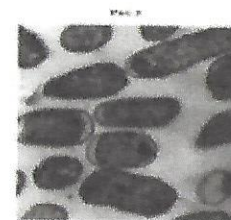
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# Efficacy: Vegetative cells

## Aerosol chamber of ~100ft<sup>3</sup>

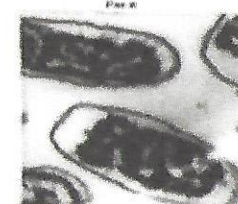
Test microbe	Colonized or Airborne	Organism, CFU/cm <sup>2</sup> , CFU/M <sup>3</sup>	Exposure to PAEROSOL, hours	Organism survived CFU/cm <sup>2</sup> /m <sup>3</sup>	Reduction versus natural die off, %
<i>S. aureus</i>	Glass, Tile, Fibrous cotton	3x10 <sup>6</sup>	0.5	<3	99,9999
MRSA	Glass, SS, hospital curtains	1.5x10 <sup>6</sup>	0.5	<3	99,9999
<i>S. enteritidis</i>	Green leafs, egg shell, polyethylene	0.5x10 <sup>6</sup>	0.5	<1	99,9999
<i>A. baumannii</i>	Hospital curtains, glass, SS, fibrous cotton	2.4x10 <sup>6</sup>	1.0	<1	99,9999
<i>E. coli</i>	Plastic, glass, brick, latex wood	3x10 <sup>6</sup>	0.5	<1	99,9999
<i>M. tuberculosis</i>	Tile, oilcloth both sides, cotton	2x10 <sup>4</sup>	4.0	<3	99,99
<i>M. tuberculosis</i> MDR		1.5x10 <sup>4</sup>	4.0	<3	99,99
<i>S. aureus</i>	AIRBORNE	10 <sup>6</sup>	0.2	<1	99,9999
MRSA	AIRBORNE	10 <sup>6</sup>	0.3	<1	99,9999
<i>S. enteritidis</i>	AIRBORNE	10 <sup>6</sup>	0.2	<1	99,9999
<i>A. baumannii</i>	AIRBORNE	10 <sup>6</sup>	0.5	<1	99,9999
<i>E. coli</i>	AIRBORNE	10 <sup>6</sup>	0.2	<1	99,9999

A



*E. coli* :  
A - native  
B - after  
PAEROSOL

B



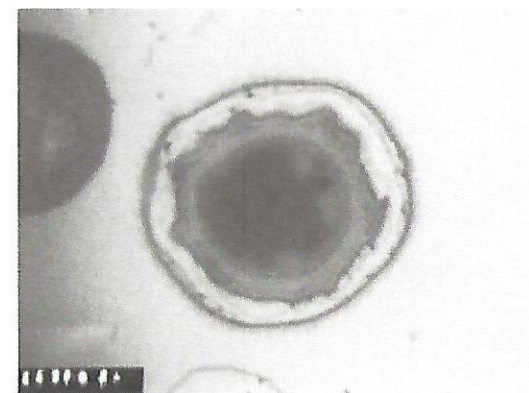


# Efficacy: Microbial spores and mold

## Aerosol chamber of ~100ft<sup>3</sup>

Test culture	Colonized or Airborne	Organism, CFU/cm <sup>2</sup> , CFU/M <sup>3</sup>	Exposure to PAEROSOL, hours	Organism survived CFU/cm <sup>2</sup> /m <sup>3</sup>	Reduction versus natural die off, %
<i>B. cereus</i> Spores	Fibrous cotton, tile, glass	10 <sup>6</sup>	2	<1	99,9999
<i>B.thuringiensis</i> Spores		10 <sup>6</sup>	2	<1	99,9999
<i>B. cereus</i> Spores	AIRBORNE	10 <sup>6</sup>	0.3	<1	99,9999
<i>B.thuringiensis</i> Spores	AIRBORNE	10 <sup>6</sup>	0.3	<1	99,9999
<i>Aspergillus niger</i>  <i>Penicillium ochrochloron</i>	Bare wood, sheetrock (mold)	~ 1x10 <sup>7</sup>	12	<10 <sup>2</sup>	99.99
	Glass (dried)	~ 1x10 <sup>7</sup>	5	<10	99,9999

*B. cereus* spores



*B. cereus* spores exposed to PAEROSOL



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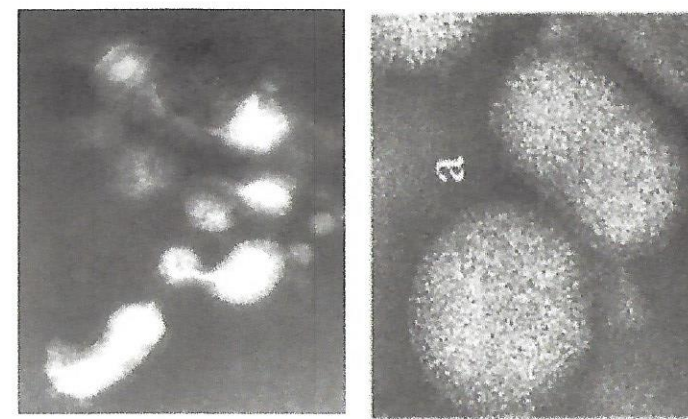
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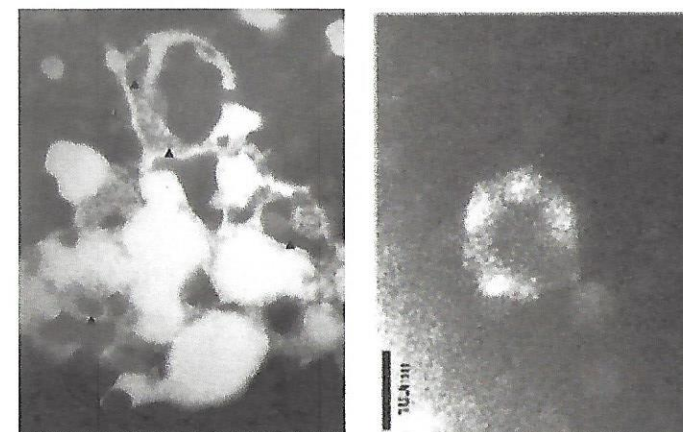
Aerosol chamber of  $\sim 100\text{ft}^3$

Test culture	Colonized or Airborne	Organism, CFU/cm <sup>2</sup> CFU/M <sup>3</sup>	Exposure to PAEROSOL, hours	Organism survived CFU/cm <sup>2</sup> /m <sup>3</sup>	Reduction versus natural die off, %
H1N1 A/Puerto Rico/8/34	Glass, fibrous cotton, tile	$10^4 \text{EID}_{50}/\text{cm}^2$	0.5	<1	99,99
H5N1a/Duck/Kurgan/5/05		$10^4 \text{EID}_{50}/\text{cm}^2$	0.5	<1	99,99
H1N1A/ Puerto Rico/8/34	AIRBORNE	$10^6 \text{EID}_{50}/\text{m}^3$	0.1	<1	99,9999
H5N1a/Duck/Kurgan/5/05	AIRBORNE	$10^6 \text{EID}_{50}/\text{m}^3$	0.1	<1	99,9999

Native virus



Exposed to PAEROSOL



# Efficacy: : Microbial spores and Mold

Room of ~3,000ft<sup>3</sup>

Test culture	Colonized	Organism, CFU/cm <sup>2</sup> CFU/M <sup>3</sup>	Exposure to PAEROSOL, hours	Organism survived CFU/cm <sup>2</sup> /m <sup>3</sup>	Reduction versus natural die off, %
<i>E. coli</i>	Plastic, glass, brick, latex wood	3x10 <sup>6</sup>	4.0	<1	99,9999
<i>B. cereus</i> Spores	Fibrous cotton, tile, glass	10 <sup>6</sup>	4.0	<1	99,9999
<i>B.thuringiensis</i> Spores		10 <sup>6</sup>	4.0	<1	99,9999
<i>Aspergillus sp</i> <i>Mucor sp</i>	Natural contamination in poultry farm	3x10 <sup>3</sup>	6	<5	99.9



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# Validation at Madigan Army Medical Center (MAMC)

## Results

- 99,999% reduction on formica, tile, and curtains
- 99% - 99,99% reduction on carpet
- No negative impact to interior and electronics
- Posed no risk to those running the trial or building occupants



## Protocol

- 3-5x10<sup>5</sup>/inch<sup>2</sup> of each organism were inoculated on each material
- Electronic devices, furniture, and fixtures remained uncovered
- ▶ ■ Post-mortem room in the midst of crowded hospital environment
- ▶ ■ No precautions except closing the door and shutting off air-handling system
- ▶ ■ PAEROSOL unattended diffusion - 15 min x 2 times
  - ▶ ■ 1.7L of EAS ANOLYTE per 2000ft<sup>3</sup>
- ▶ ■ Door closed for 3.5 hours to complete disinfection
- ▶ ■ One operator – 15 min involved

### MAMC Pathogens tested

- *Klebsiella pneumoniae*
- *Staphylococcus aureus*
- *Pseudomonas aeruginosa*
- *B. cereus*

### MAMC materials tested

- Formica
- Floor tile
- Privacy curtain fabric
- Carpet





# Toxicity Study

## Study set-up

- ▶ Outbred white mice: males – different age and weight
  - Multi experimental and control groups - high external validity test
    - Directly exposed to PAEROSOL for 30-60 min
- ▶ Swiss Webster pathogen-free (SPF) female mice
  - Multi experimental and control groups - high internal validity test
    - Directly exposed to PAEROSOL for 30-60 min
- ▶ All groups were observed during 14 consecutive days
  - Daily: behavior, motor activity, convulsions, irritant reactions, state of hair and skin, appetite, and changes in body weight
- ▶ On day 14, blood samples were obtained under anesthesia and animals were euthanized
  - Organs pathology, hematology, immunology, histology, and statistical analysis

## Results

- ▶ **NON-TOXIC**



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# PAEROSOL Distinctive Features

- ▶ Does not use or generate toxic chemicals
- ▶ Minimal decontaminant volume
  - 2L of EAS ANOLYTE per 2,500 ft<sup>3</sup>
- ▶ Self-disappearing decontaminant
  - Does not result in pathogens resistance to disinfectants & antibiotics
- ▶ No facility prerequisites to perform disinfection
  - Highly effective in the presence of organic load (on soiled surfaces)
    - Does not require thorough pre-cleaning of inanimate surfaces
- ▶ No requirements for strict isolation of disinfecting facility
  - Can be routinely applied in vacated rooms in the midst of crowded buildings, like hospitals
- ▶ Time-practical - from minutes to hours
- ▶ Easily deployable for consequence management, including in distant settings



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# Capability

- ▶ Prevent cross contamination of occupants in confined environments by routine short - term (10-15 minutes) regular application
  - eradicate airborne pathogens associated with droplet nuclei or dust particles containing infectious agents that may remain suspended in the air for long periods of time
    - Minimize number of live pathogens eventually settled on inanimate surfaces
    - Reduce risk of infection transmission beyond contaminated environment
- ▶ Eradicate infective organisms on inanimate surfaces and airborne by thorough disinfection requiring 3-4 hours.
  - Reduce manpower and improve a quality of laborious final cleaning protocol
    - Minimize risk of cross contamination and infection transmission beyond contaminated environment
- ▶ Prevent and Combat epidemics by combination of short-term and thorough applications
- ▶ Combat bio-threat agents and return facility to operation



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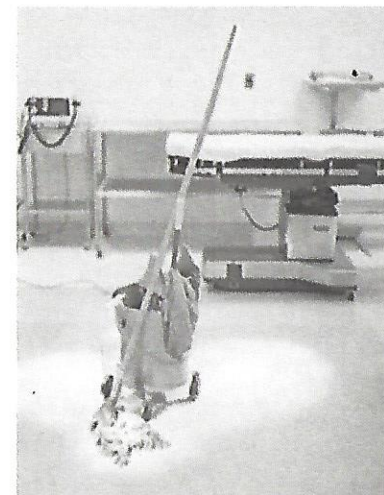
# Application

- ▶ Health Care
  - Hospitals
  - Nursing homes
  - Ambulance
- ▶ Pharmacy and medical supply production
- ▶ Food processing and food packaging
- ▶ Transportation
- ▶ Correction facilities
- ▶ Public Buildings
  - Schools
  - Gyms
  - Community & Conventional Centers
  - Airports
- ▶ Bio-threat reduction and facilities restoration



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# Unattended PAEROSOL vs. Conventional Cleaning



**HAZARDS INFORMATION**  
**Virkon**  
 Potential Health Effects  
 Danger: Powder is corrosive.  
 Causes skin burns &  
 irreversible eye damage.  
 Harmful if swallowed, absorbed  
 through skin or inhaled.  
 Do not get into eyes, on  
 skin, or on clothing.



**HAZARDS INFORMATION**  
**Chlorine dioxide**  
**DANGER:** Corrosive to steel, stainless steel,  
 and many other materials  
**TARGET ORGANS:** Eyes, skin, respiratory  
 tract and mucous membrane  
 Harmful if swallowed.

**HAZARDS INFORMATION**  
**Hydrogen Peroxide 30%**  
 Health rating: 3 - Severe (life)  
 Reactivity rating: 3 - Severe (Oxidizer)  
 Contact rating: 4 - Extreme (Corrosive)



**HAZARDS INFORMATION**  
**Clorox**  
**DANGER: CORROSIVE.** May  
 cause severe irritation  
 or damage to eyes and skin.  
 Vapor or mist may irritate.  
 Harmful if swallowed.  
 Keep out of reach of children.  
 Ingredient Concentration Exposure  
 Limit Sodium hypochlorite 6.15%



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# Acknowledgements and Technical POC

- ▶ Funding for development of PAEROSOL provided by DOE-GIPP and Internal Research and Development Funds
- ▶ Funding for demonstration of PAEROSOL at Madigan Army Medical Center provided by DTRA S&T Innovation
- ▶ Pacific Northwest National Laboratory is operated by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830 for the U.S Department of Energy.



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