Uncertainties in Bioterrorism Planning

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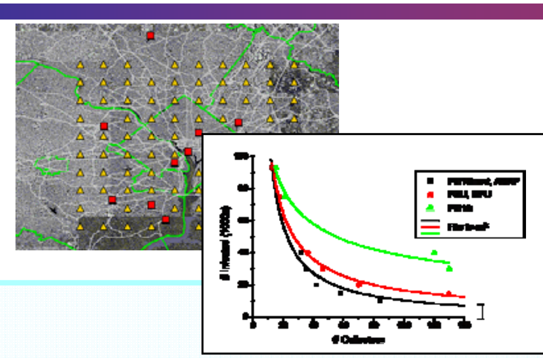
Biodefense studies and planning tools objectives

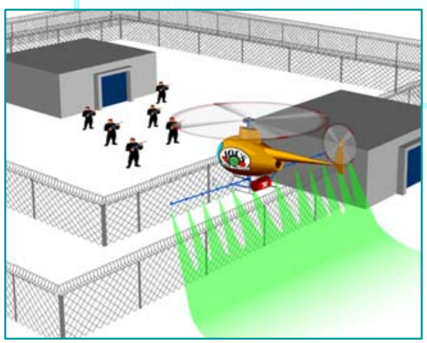
- Provide DHS and the nation with a broad end-to-end understanding of this nation's capabilities for preparing for a set of attack scenarios and a strategy for improving that capability with time
- Develop architectural configurations, concepts of operation, performance metrics, and assessments
- Provide needed tools to support these evaluations and assessments
- Define capability gaps and requirements for key technologies, and provide focused analytical studies

Systems analysis approaches are varied

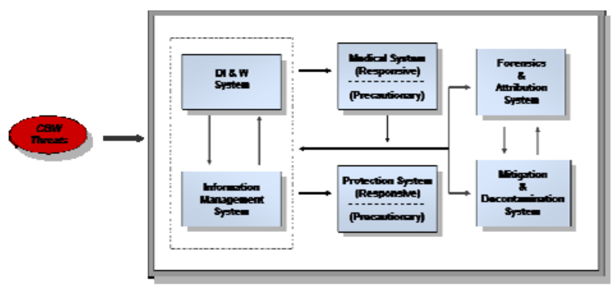
Historic case studies



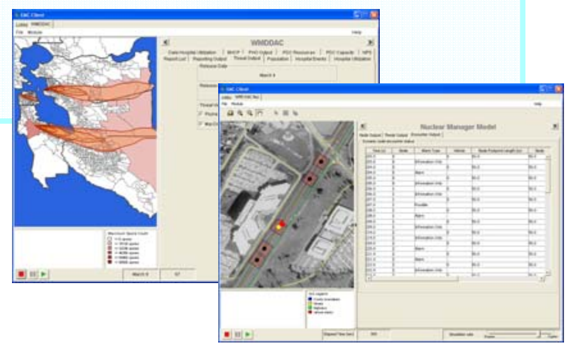
Trade-offs



Scenarios



Architecture



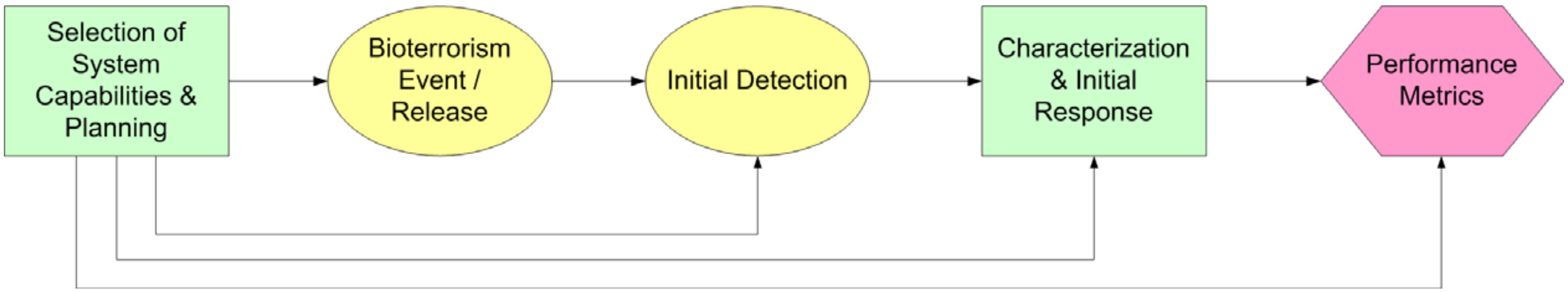
Simulations

We focus on understanding context and informing decisions

Outline: Two examples of dealing with uncertainty

- **Detection and initial response**
  - How can detection systems and responsive measures mitigate the consequences of an attack?
- **Restoration and recovery**
  - What strategies should we use to clean and clear potentially hundreds of contaminated facilities?

A simple view of bioterrorism planning – detection and initial response



- **Breadth of scenarios must be considered**
  - Agent
  - Size
  - Location
  - Dissemination
  - Exposure
- **Given all of the uncertainties, how can we best inform decision makers?**

D.K. Manley and D.M. Bravata, *Am. J. Disaster Med.*, Jan/Feb 2009

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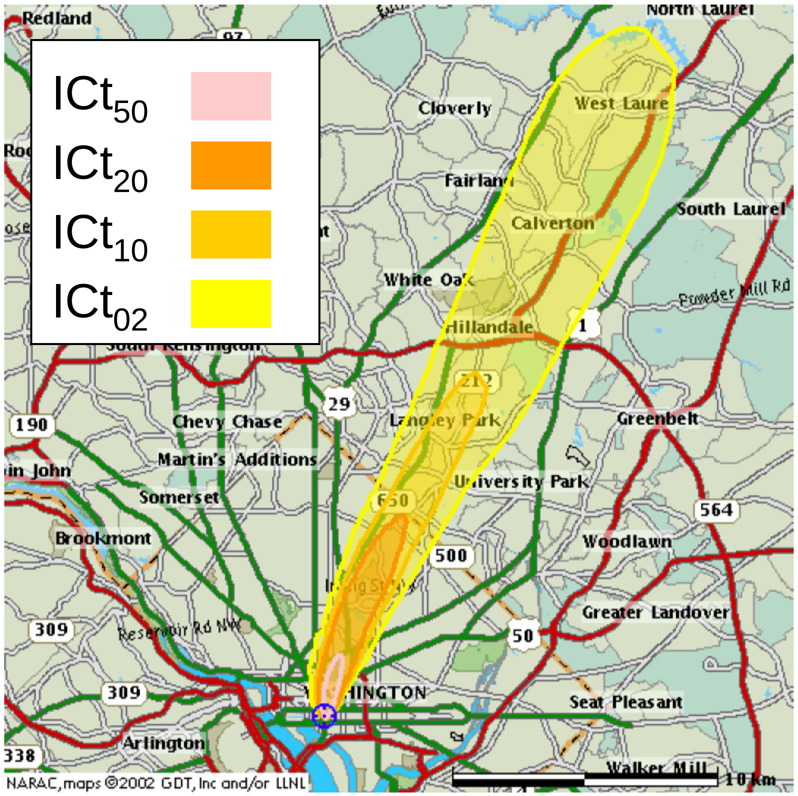
How can we best defend cities against a bioterrorism event?

- Which attacks?
- How do we measure the impact of attacks? What are the metrics?
- How do we estimate the impact of alternative defensive architectures?
- What is the role of detection? Health surveillance vs. sensors?
- How can we leverage existing infrastructure?

Goal: Inform decisions that can significantly improve protection over a range of scenarios

Example: Consider outdoor release of *Bacillus anthracis* in an urban area



- **Realistic consideration of:**
  - Agent acquisition and production
  - Release amount
  - Dissemination
  - Health effects
  - Detection and response
- **Systematic consideration of scenario variability and uncertainty**

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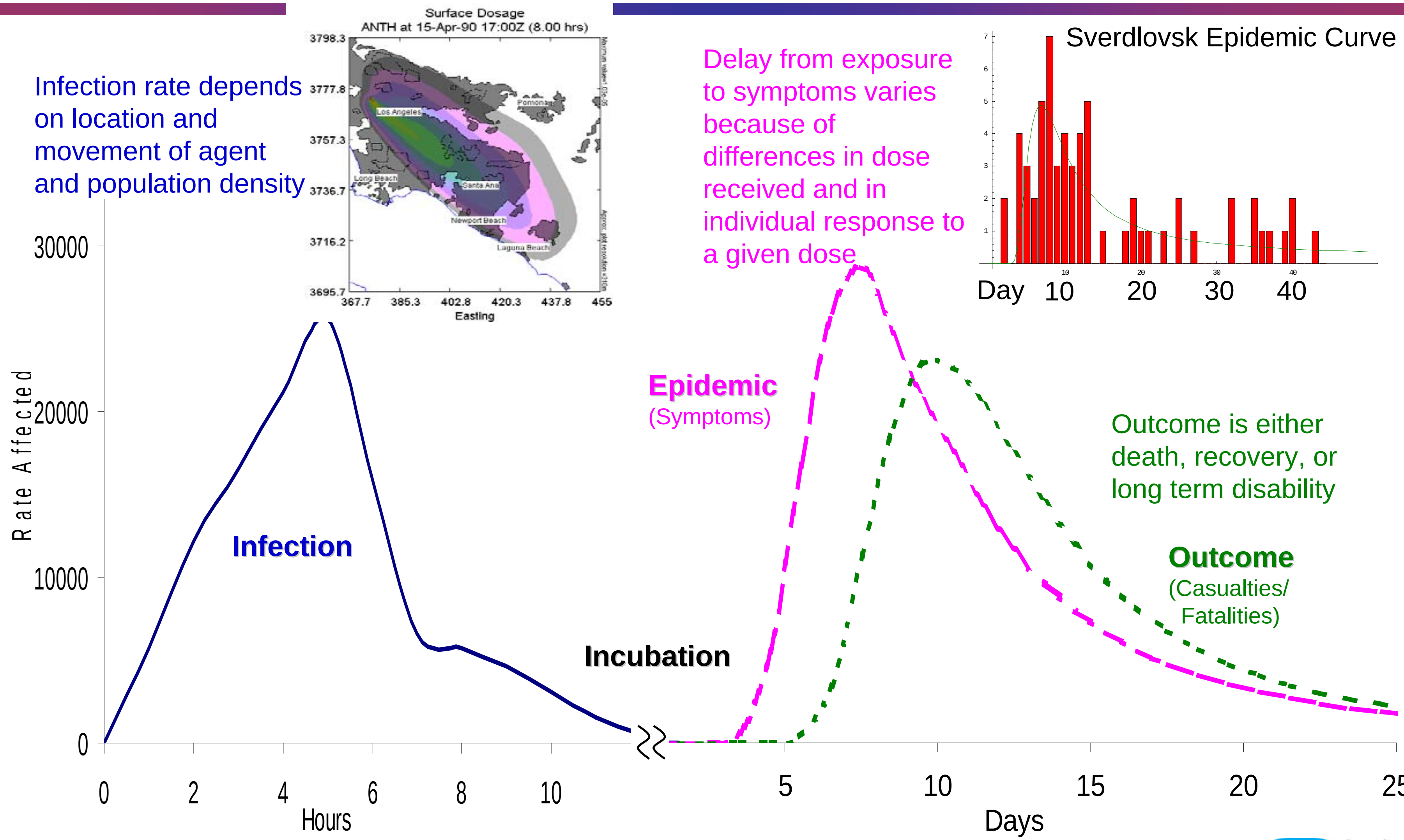
Example anthrax scenario

- **Large-scale (10,000s potential casualties) attack employing *Bacillus anthracis***
- **End-to-end scenario with a realistic consideration of**
  - B. anthracis production and delivery
  - Anthrax dose-response and disease progression
  - Impact of current detection and response systems
  - Potential for re-aerosolization
- **Examine impact of inherent variability and uncertainty in scenario inputs**
- **Scenario purpose:**
  - Identify data gaps and response capability shortfalls
  - Illuminate data operational decision makers require
  - Test/examine existing and proposed systems
  - Generate alternative strategies for urban defense
  - Guide improvements in technologies and capabilities

Master timeline curves illustrate timing of critical events and outcomes



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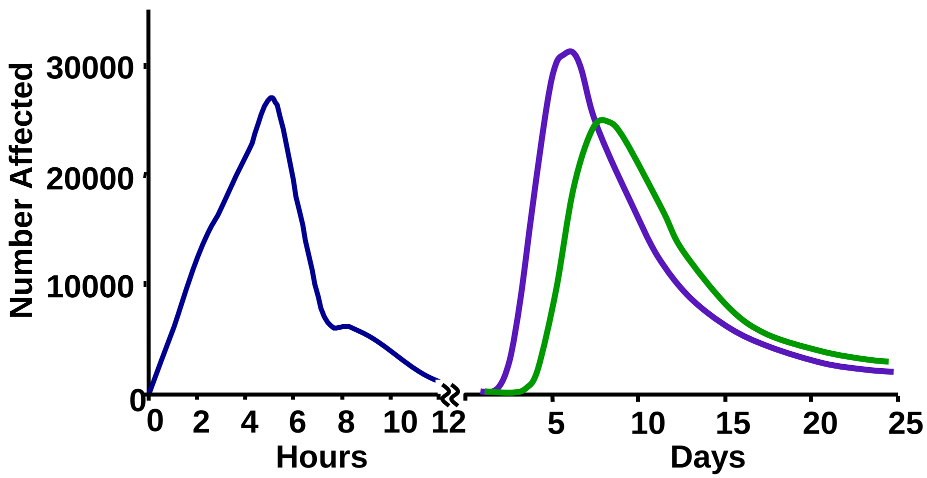
Metrics enable evaluation

Scenario: Anthrax



217,000 fatalities
without intervention

Metrics for Sample Architectures

Case 1: Medical surveillance cues **Prophylaxis**

→ **86,000 fatalities**

Case 2: Environmental Monitoring cues **Prophylaxis**

→ **22,000 fatalities**

Case 3: **Protection** (improved filtration) and *Environmental Monitoring* cues **Prophylaxis**

→ **16,000 fatalities**

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We conducted Monte Carlo analyses to determine likelihood of catastrophic outcomes

- **Determine which scenarios are likely (or unlikely) to lead to catastrophic outcomes**
  - Has important implications for detector requirements

- **Verify which uncertainties have biggest impact on numbers of infections**
  - Identify key knowledge gaps

Agent form[1]
Release amount
Agent concentration
Particle Size
Respirable Fraction
Daytime aerosol decay rate
Environmental decay rate
Dissemination efficiency
Fraction disseminated
Release time
Release location
Atmospheric transport
Meteorological conditions
Population density[2]
Fraction of population inside buildings[3]
Protection factor from buildings[4]
Breathing rate[5]
ID_{50}[6]
Probit slope[7]

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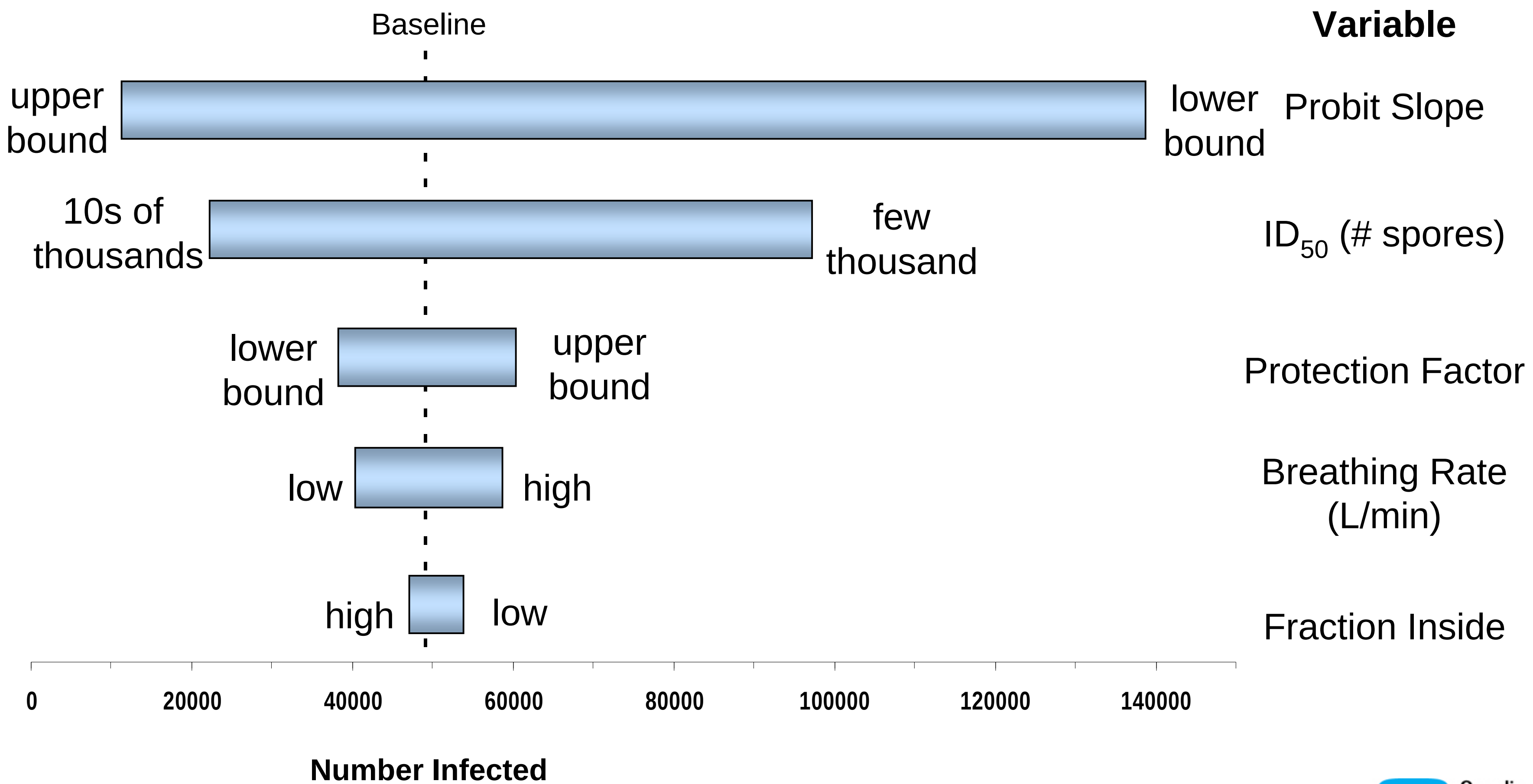
Anthrax uncertainty analysis: dose-response uncertainties have the largest impact for the baseline release



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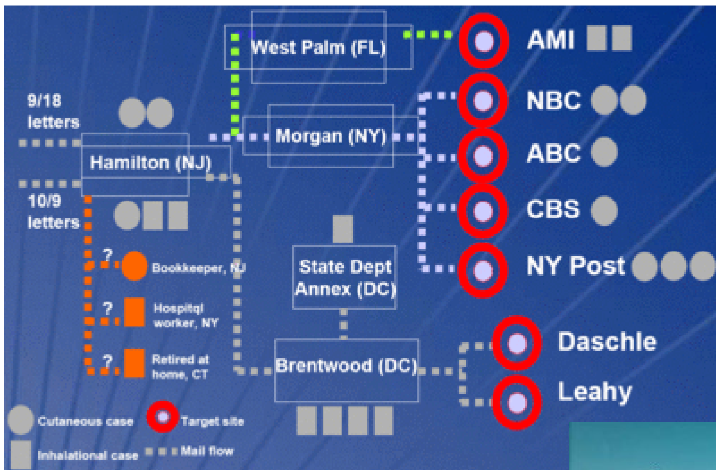
Example 2: Restoration after an event

In 2001, seven letters with anthrax…

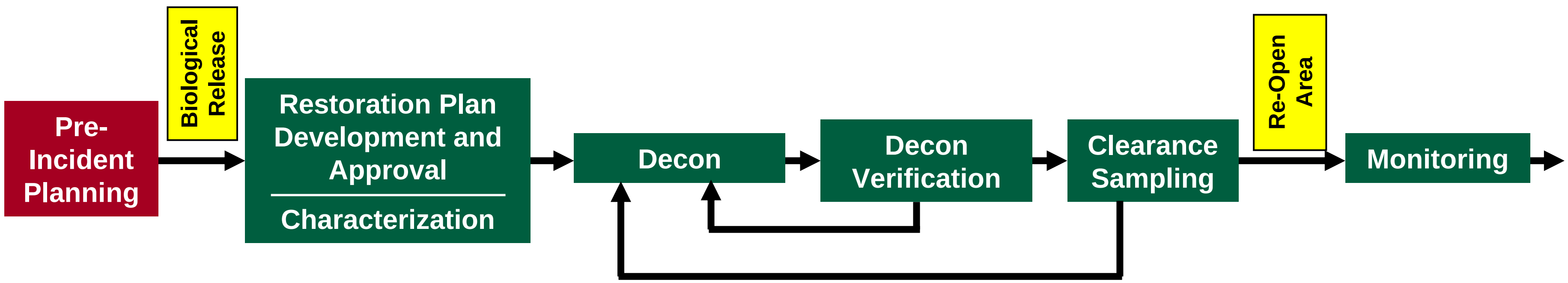


- Brentwood postal facility closed 26 months, \$130 M
- Hamilton, NJ postal facility closed > 3 years, \$65M
- Capitol Hill Buildings closed 3 months, \$27M
- DOJ mail facility in Landover, MD, closed 4.5 months, \$0.5 M

…contaminated at least 17 facilities.

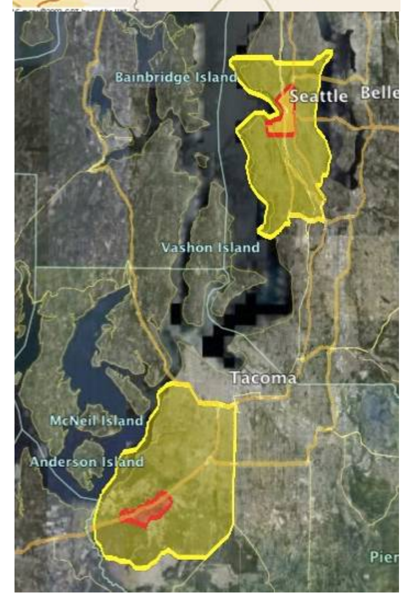
What if an attack were to contaminate hundreds of facilities?

Phases of restoration



Interagency Biological Restoration Demonstration

- **Objective: Develop comprehensive understanding, methodologies and tools for efficient remediation of a large-scale urban/military bio-contamination event**
- **Approach: Use the Seattle urban area, including major nearby military facilities as an information gathering and demonstration venue. Focus on a wide-area *Bacillus anthracis* contamination event.**
- **Sponsors:**
  - US Department of Homeland Security Science and Technology Branch
  - Defense Threat Reduction Agency CB/Physical Science and Technology Division
- **Participants: Sandia, LLNL, PNNL, LANL, Cubic Inc., Tauri Group**



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Analyzer for Wide-Area Restoration Effectiveness

- **Evaluate overall impact of technical resources, technology insertions or changes, available manpower, etc. on total restoration time and cost**
- **Incorporates all major aspects of the remediation process:**
  - Site characterization planning
  - Sampling & analysis
  - Indoor and outdoor decontamination & waste handling
  - Post-decon outdoor area and building clearance
- **Developed by subject matter experts**
- **Incorporates Monte Carlo analyses to characterize input variable and output result uncertainties**
- **Enables identification of the most influential variables in the restoration process**

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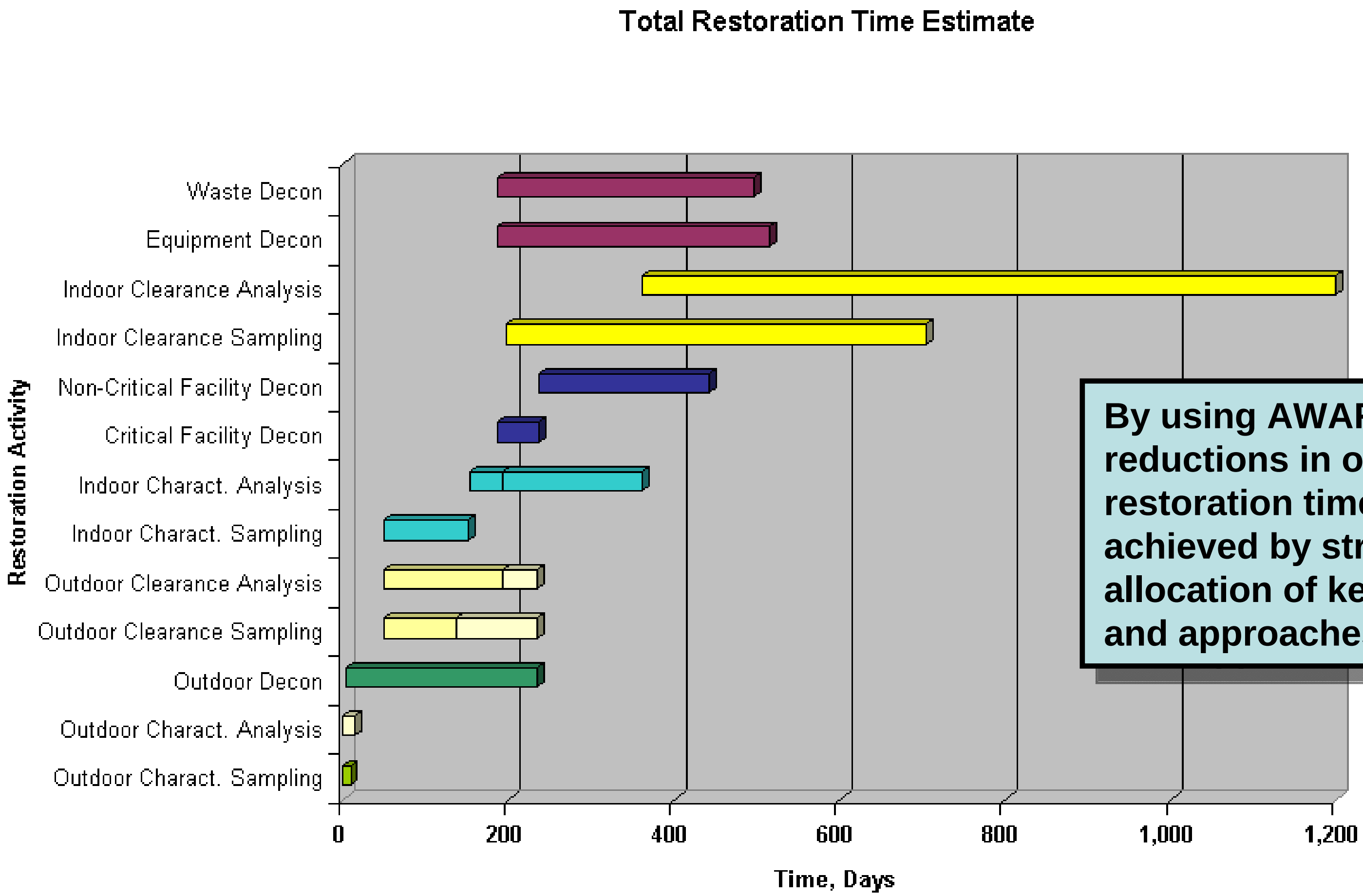
Example input variable uncertainties

Scenario	Characterization Sampling & Analysis	Decontamination	Clearance Sampling & Analysis
• Area of suspected contamination • Estimate of outdoor area contaminated • Estimated number of hot buildings in contam. zone • Floor space/volume of "hot" buildings • Number of critical facilities	• Primary and secondary sample density (outdoor and indoor) • Number of outdoor/indoor sampling teams • Indoor/outdoor sampling rate • Sample type (swab, wipe, vacuum) • Type of analysis (HTP-PCR, culture) • Lab throughput rates	• Allocation of surface decon vs. fumigation • Number of indoor/outdoor decon units • Outdoor/indoor decon rate • Outdoor/indoor decon material cost • Mass of waste & sensitive equipment per facility • Waste & equipment decon rate	• Judgmental vs. statistical sampling approaches • Outdoor clearance sample density • Indoor clearance sample density • Sample collection rates • Lab throughput rates
12 inputs	**22 inputs**	**100+ inputs**	**24 inputs**

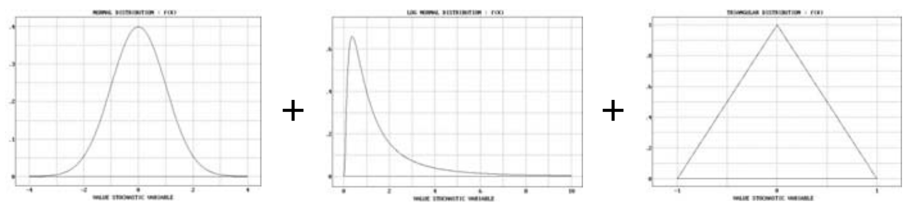
Critical path timeline analysis



By using AWARE, significant reductions in overall restoration time/cost can be achieved by strategic allocation of key resources and approaches

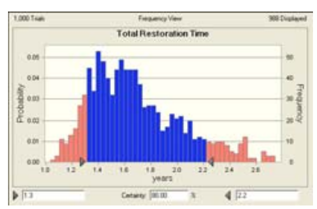
Utilizing Monte Carlo and Sensitivity Analysis Techniques to Prioritize Needs

Sample Input Parameter Distributions To Propagate Uncertainty



Perform Multiple Realizations of Scenario While Varying Input Parameters

Analyze Results and Perform Sensitivity Analyses



The Monte Carlo technique quantifies output uncertainties, while the Sensitivity Analysis techniques deduce the relative importance of the parameters from the uncertainty results.

The AWARE tool is coupled with Crystal Ball® in Excel to carry out uncertainty/sensitivity analyses

Example restoration uncertainty analysis results

Include uncertainty in the input restoration variables

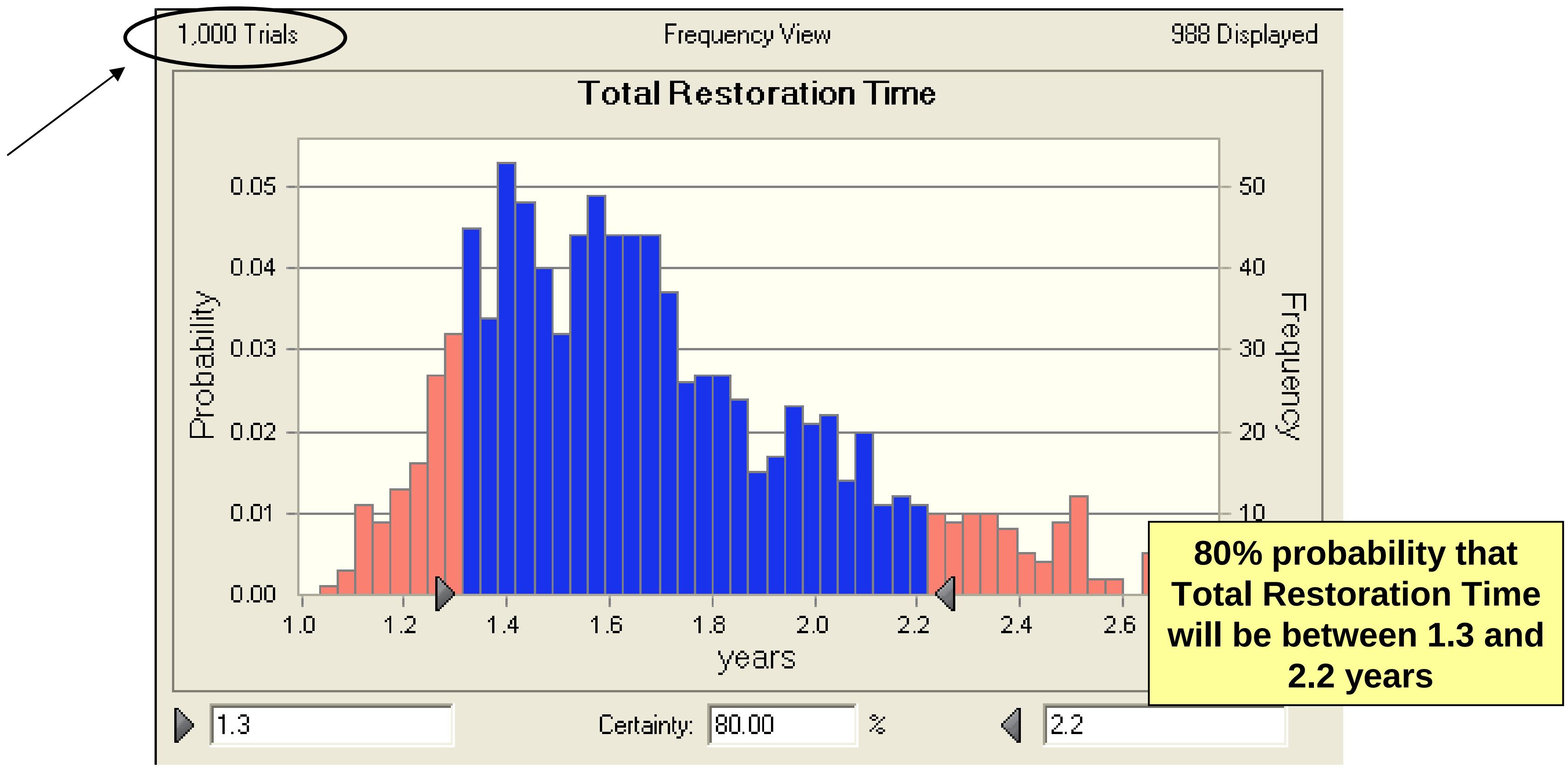


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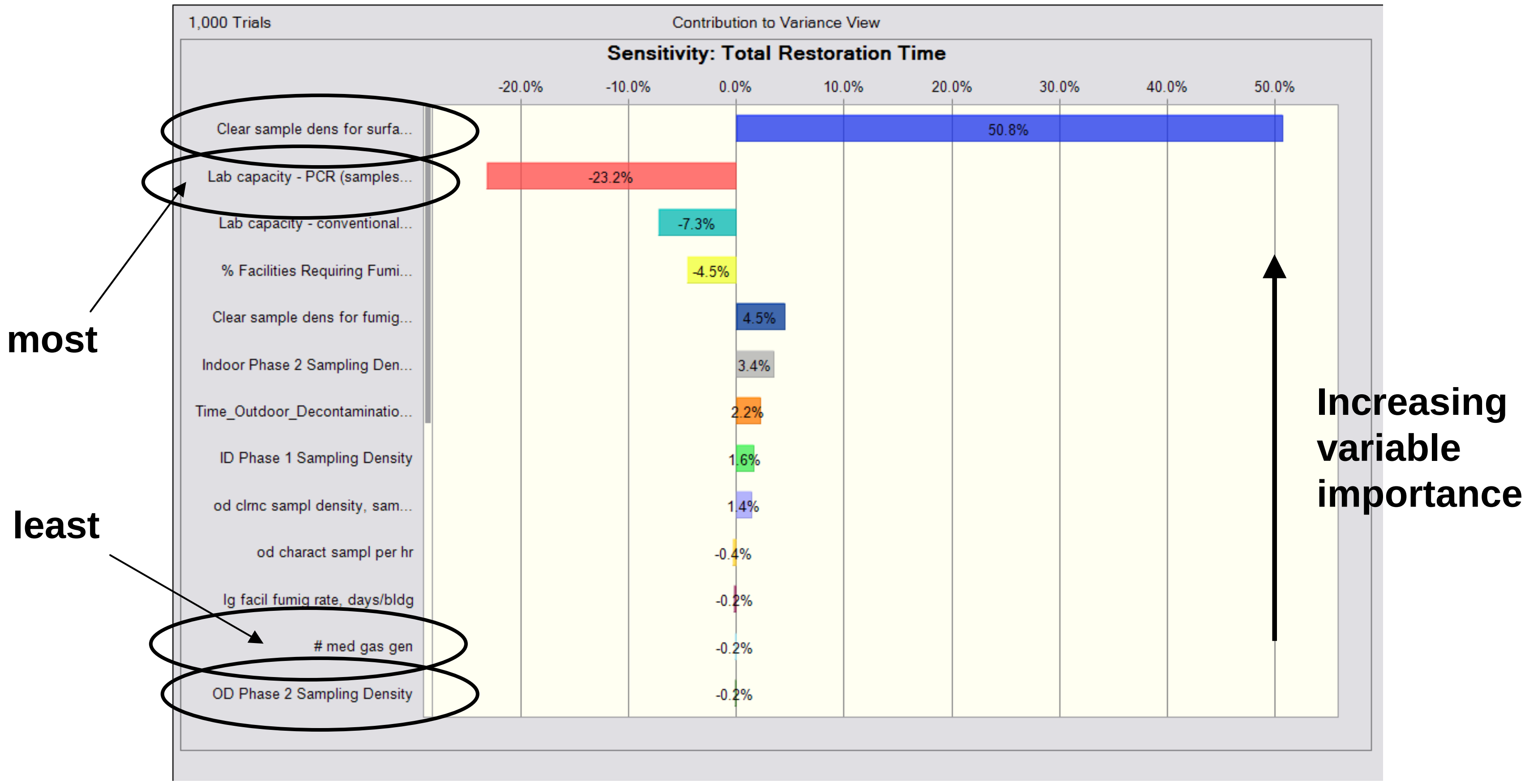
Illustration of parameter sensitivity analysis

Sensitivity analysis identifies and rank orders the key variables in the restoration process



Implication: To speed restoration, reduce the clearance sample burden

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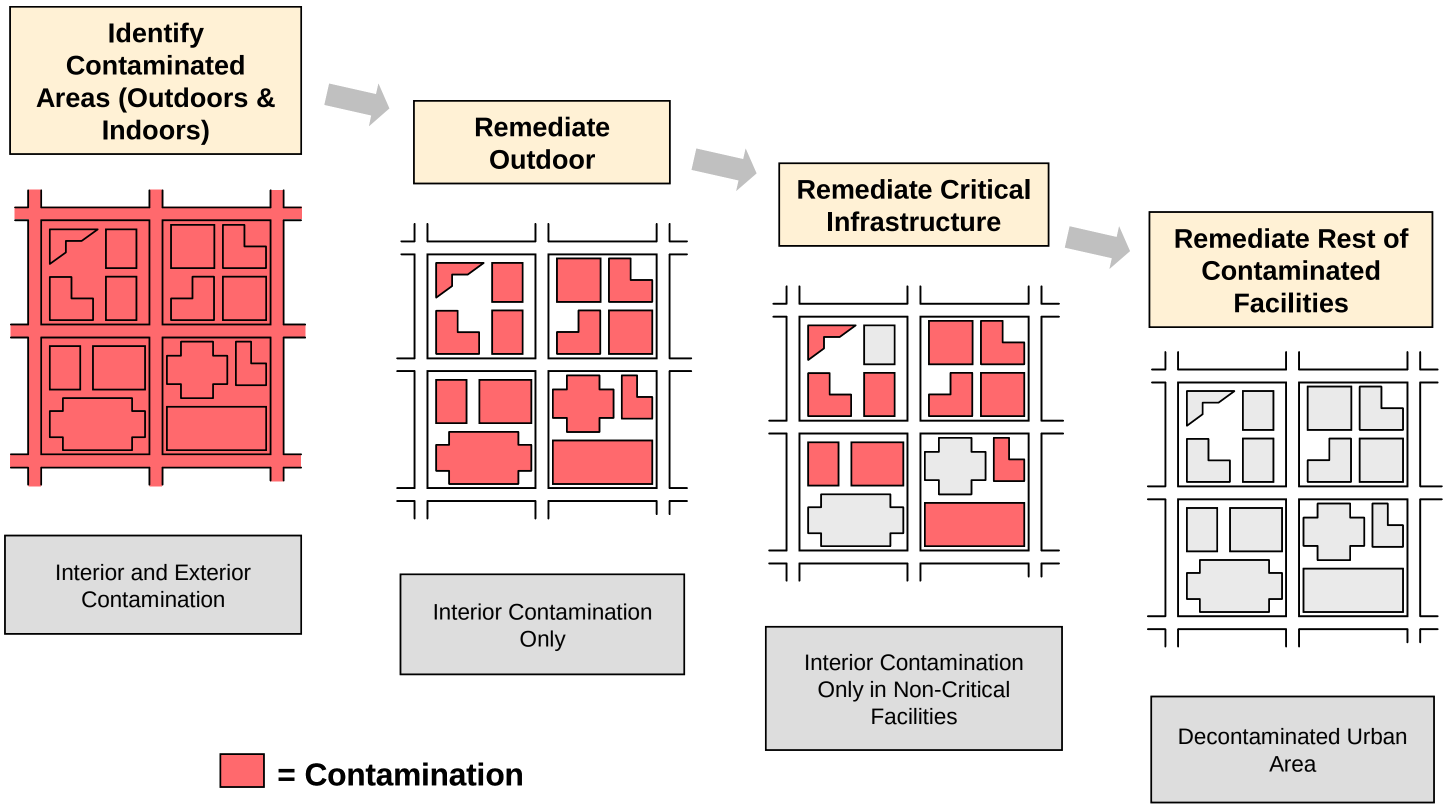
Inform strategies for wide area decontamination and restoration



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Uncertainty in bioterrorism planning could benefit from greater engagement with risk and UQ communities

- **Incorporates Monte Carlo analyses to characterize input variable and output result uncertainties**
  - Identify most influential variables in preparedness and restoration processes
- **Sparse historical data**
  - Rely upon subject matter experts
- **Consequence-based**
  - Opportunity to consider risk-based analyses