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Systems Analysis for Countering Weapons of Mass Destruction

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Objectives

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- Present systems analysis approaches to Countering Weapons of Mass Destruction (CWMD)
  - Bio-restoration example project
- Describe how systems analysis results inform federal government policy, and technology investment

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- Department of Energy (DOE) lab, Federally-Funded R&D Center (FFRDC) focused on complex national security problems
- Wide-ranging engineering and research in energy, nuclear weapons, resilience, counter-terrorism, sustainability, etc.
- Main site in Albuquerque, NM (~11,000 people); Local site in Livermore, CA (~1,000 people)

Sandia CA: Systems Research and Analysis Group

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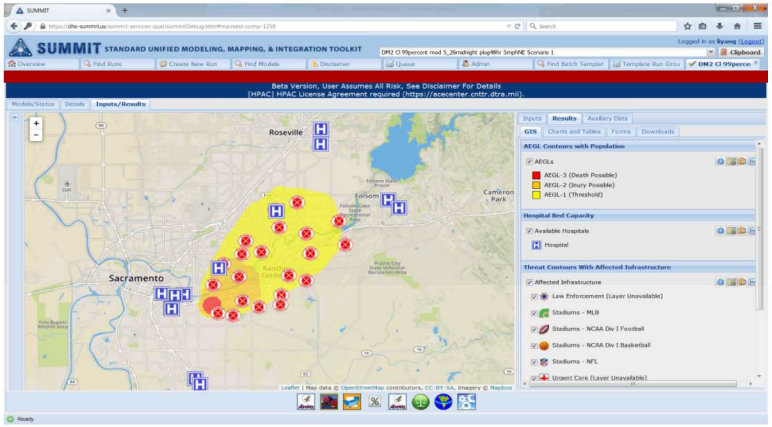
- Composed of engineers, scientists, technology and policy experts, political scientists
- Problems we work on have these characteristics:
  - Identification and prioritization of capability gaps; then, determination of how to fill gaps through technology, policy, science, capacity-building
    - E.g., “DHS should invest in X, Y in order to improve…”
    - E.g., “To support adoption of a technology, X, Y policy changes are needed”
  - Open-ended problems that need scoping to be tractable
  - Data may be sparse and uncertainties can be vast
  - Customer and stakeholders rarely have technical background
  - End-user engagement is critical

Systems Analysis Approaches/Tools

- Decision frameworks
- Influence diagrams
- Multi-Attribute Risk Assessment
- Scenarios analysis (baseline vs. desired end-states)
- Modeling and Simulation
- Sensitivity analyses
- Techno-Economic Analysis (TEA)

- Selection of approaches is based on:
  - Needed level of rigor and accuracy (e.g., exercise vs. planning vs. response)
  - Data availability (empirical vs. modeled vs. SME data)



Common themes:
Looking for critical system parameters that are key drivers of outcomes– solutions should act on these parameters

Measuring impact of solutions (technology, policy, etc.) using metrics that reflect desired outcomes

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Example: Critical Infrastructure resilience to Bio-Attack

Interagency Biological Restoration Demonstration
(Wide-area restoration)

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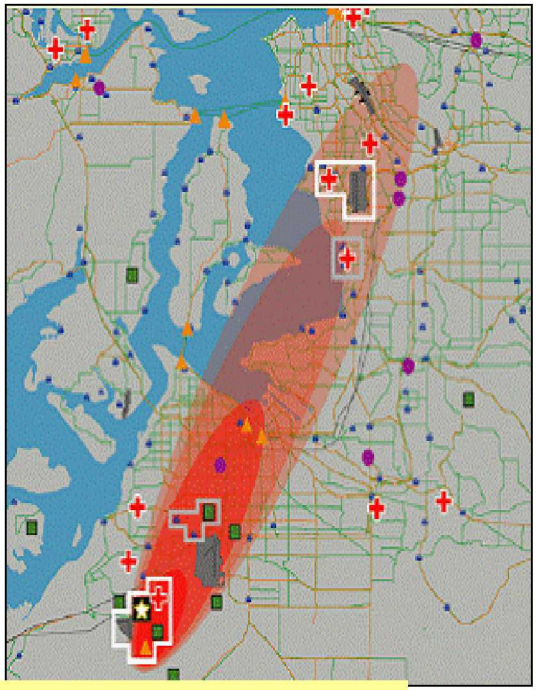
Goal: Working with interagency including state & local, reduce time and resources required to recover and restore wide urban areas, military installations, and other critical infrastructures following a biological incident

DOD (DTRA) & DHS (S&T) co-sponsored program

Objectives:

- Study social, economic & operational interdependencies
- Establish civilian and military coordination
- Develop guidance and decision frameworks
- Identify & demonstrate technologies that support operations
- Exercise activities & available technology solutions



Coordination & partnership with the Seattle, WA region

Analysis is historical/exemplary; results shown are not representative of current capabilities.

Sandia led a Front-end Systems Analysis

- Objective: identify and prioritize gaps in wide-area bio-restoration
- Process:

Many unknowns and uncertainties: methodology must be flexible!

Step 1: Create a representative **Baseline Scenario**

Step 2: Develop and test a **Decision Framework**

Step 3: Parameterize baseline scenario in spreadsheet to identify **Critical Parameters**

Step 4: Conduct qualitative and quantitative analyses to prioritize **Gaps, Chokepoints**

- Tools: Decision framework, Scenario analysis, Monte Carlo simulation, Critical path assessments, Influence diagrams

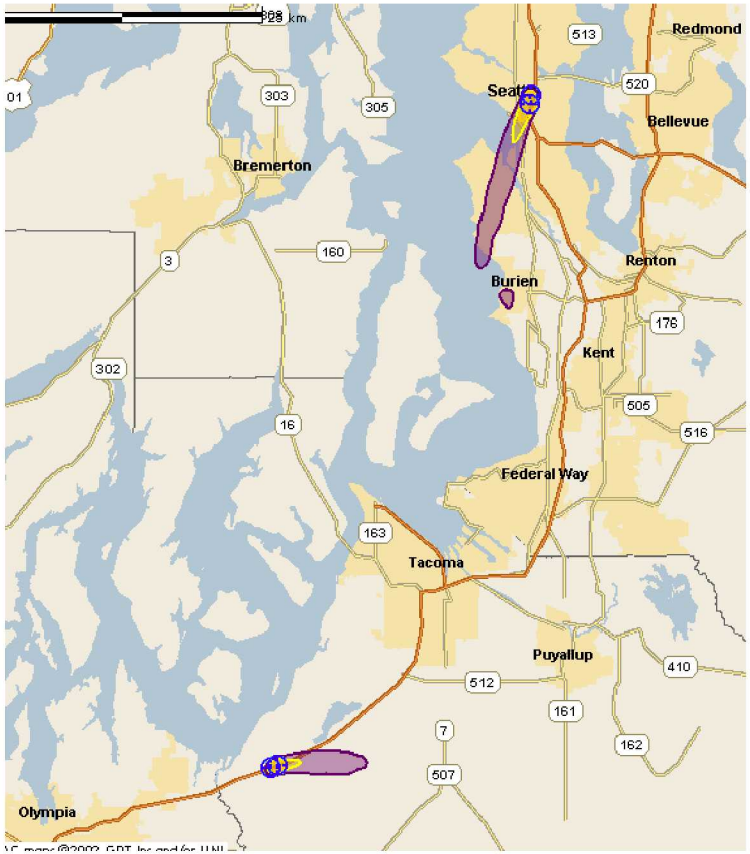
Created a Baseline Scenario, using a National Planning Scenario

Problem:

- Two surreptitious releases of *Bacillus anthracis* spores in downtown Seattle and at Fort Lewis

Initial conditions:

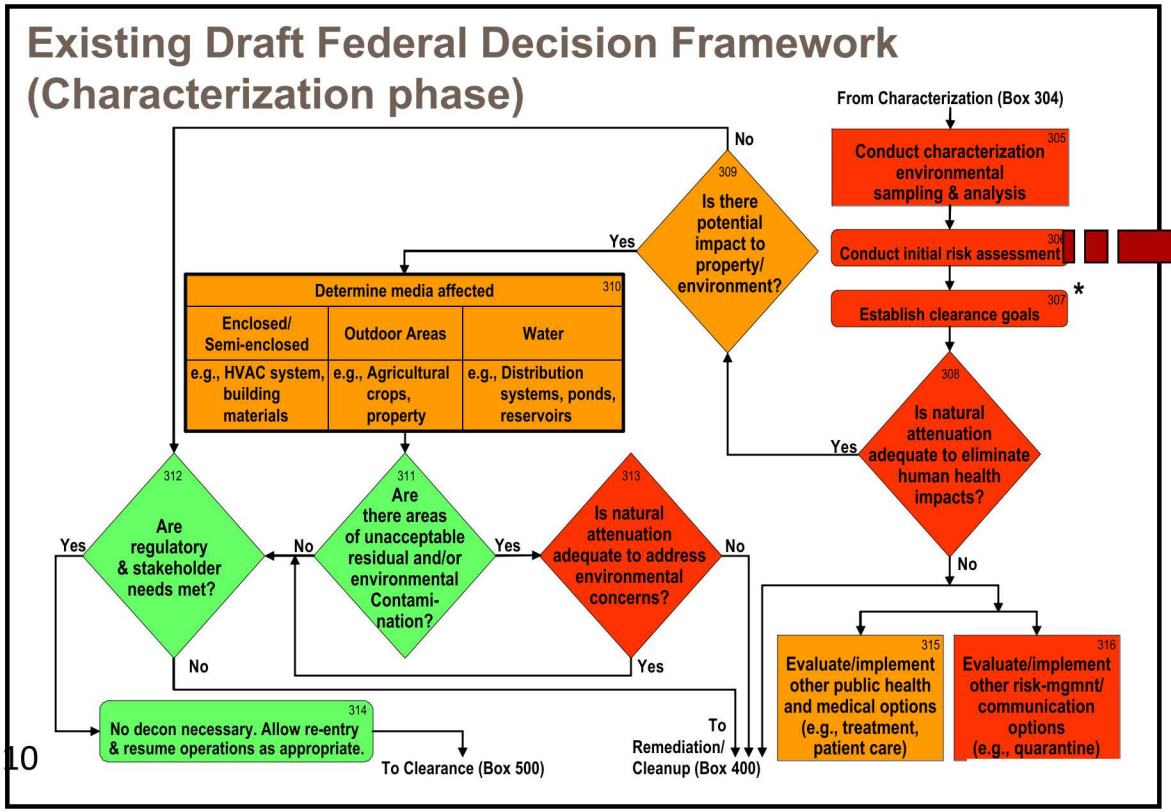
- BioWatch positives for *Bacillus anthracis*
- Confirmatory tests have been made
- Emergency response has been activated and is underway
- Mass prophylaxis distribution has begun
- Hospitals are in surge mode and overwhelmed with sick and worried well
- People who were contaminated live in other communities as well
- Some contaminant has been tracked into surrounding areas



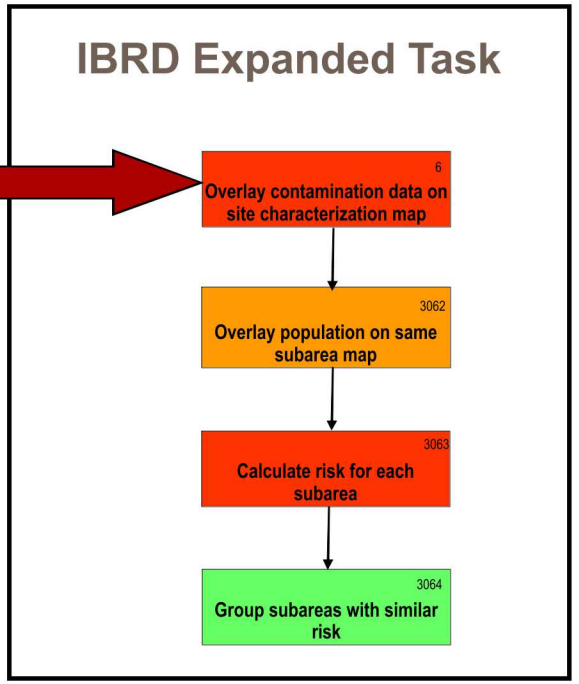
Area for restoration is on the order of tens of square miles, including hundreds of contaminated facilities.

Developed a Decision Framework for wide-area restoration

STRATEGIC: What are the tasks?

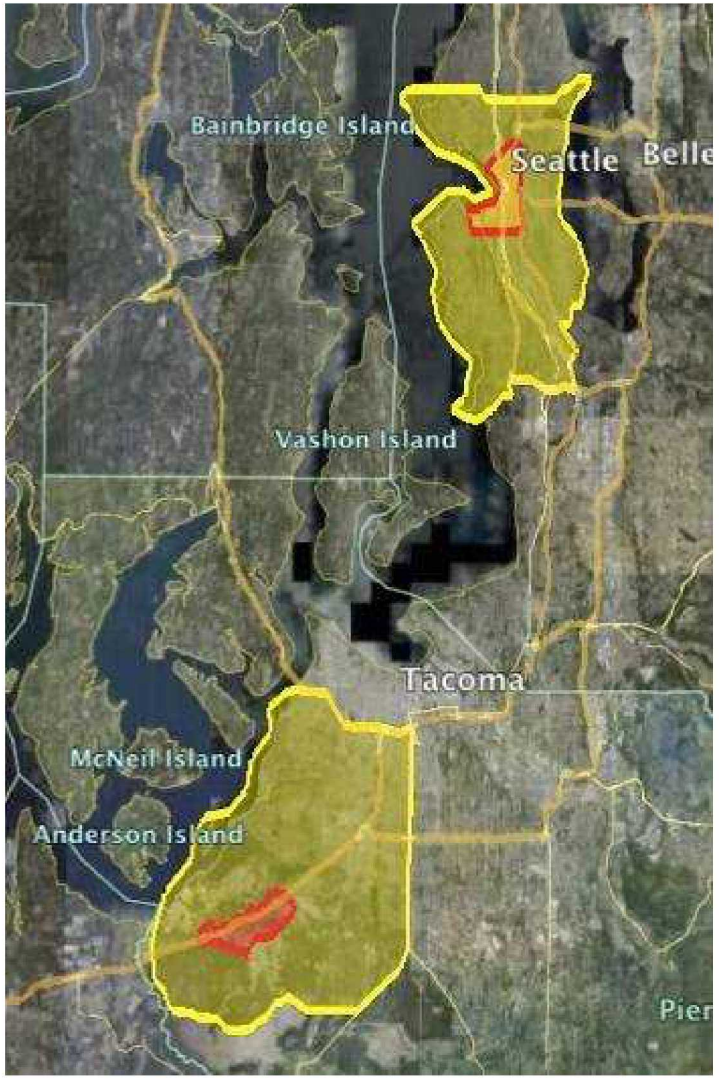


OPERATIONAL: How to conduct the tasks?



Baseline scenario: E.g., First restoration step is characterization to establish contamination zones

- Strategy to establish Hot Zone and contaminated buildings
  - Low-density sampling
    - Grid surface sampling outdoors
    - Targeted indoor sampling: HVAC inlets and building entrances
  - High-density sampling
    - Directed surface sampling outdoors
    - Surface sampling in buildings identified by low-density sampling
    - Air samplers measure level of re-suspension
- Strategy to establish Warm Zone
  - IMAAC plume, possible epidemiological data (human and animal)
  - Air sampling outdoors and in critical infrastructure finds hot spots



A spreadsheet tool, Analyzer for Wide Area Restoration Effectiveness (AWARE), was developed to conduct quantitative analyses

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Outdoor Characterization	
Area of suspected contamination	blocks
Phase 1 outdoor sampling density	samples/block
Percent Red Zone	%
Percent Yellow Zone	%
Phase 2 outdoor sampling density	samples/block
Contaminated street area	sq meters

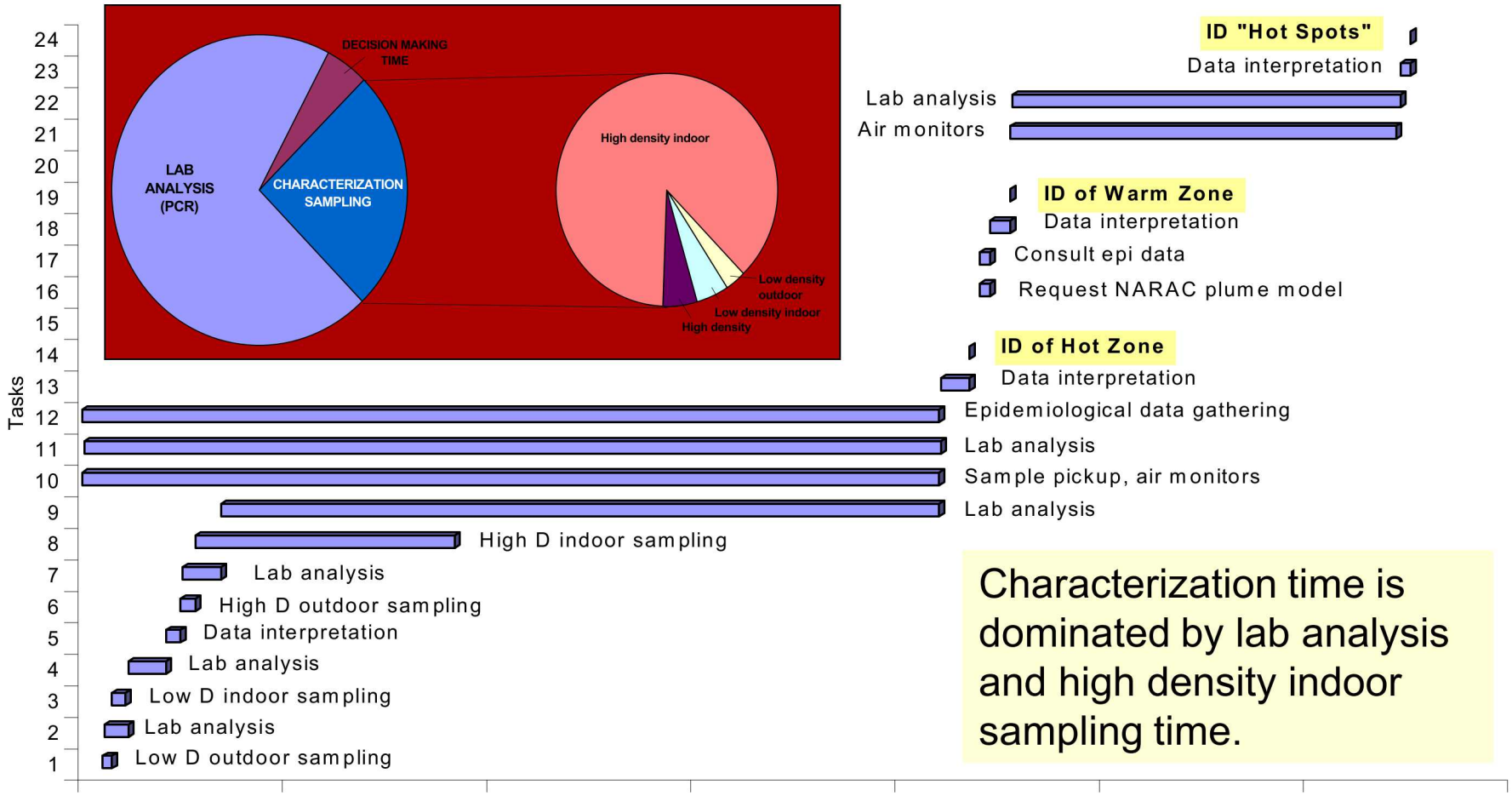
Indoor Characterization	
Average no. buildings per block	buildings
Average no. floors per building	floors
Avg block coverage by buildings	%
Phase 1 Indoor sampling density	samples/building
Percent of buildings contaminated	%
Phase 2 Indoor sampling density	samples/sq meter
No of contaminated buildings	buildings

Sampling/Analysis	
No. outdoor sampling teams	teams
No. individuals per outdoor team	indiv/team
Outdoor sampling rate	samples/hour
No. indoor sampling teams	teams
No. individuals per indoor team	indiv/team
Indoor sampling rate	samples/hour
Lab analysis rate--culture	samples/day
Lab analysis rate--PCR	samples/day
Lab analysis rate--HTP PCR	samples/day

Decontamination	
Small facility decon time	days
Small facility decon cost	$/sq ft
Medium facility decon time	days
Medium facility decon cost	$/sq ft
Large facility decon time	days
Large facility decon cost	$/sq ft
Biological Indicators	per 100 sq ft
Cost of BI analysis	$/anal
Cost per environmental sample	$/anal
Sm facil fumigation systems	generators
Med facil fumigation systems	generators
Lg facil fumigation systems	generators
Sensitve equip--sm facility	cu ft/facil
Sensitve equip--med facility	cu ft/facil
Sensitive equip--lg facility	cu ft/facil
Waste per sm facility	tons
Waste per med facility	tons
Waste per lg facility	tons
Waste per city block--Red zone	tons/blk
Waste per city block--Yellow zone	tons/blk
Sensitive equip per city block -- Red zone	cu ft
Sensitive equip per city block -- Yellow zone	cu ft

Clearance	
Outdoor clearance sample density	samples/sq meter
Indoor clearance sample density	samples/sq meter

Timeline Analysis identified critical path and chokepoints



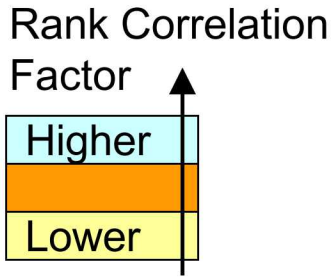
Characterization time is dominated by lab analysis and high density indoor sampling time.

Sensitivity Analysis identified critical parameters across a range of assumptions

- Monte Carlo identifies parameters with greatest impact on outcomes
- Takes into account uncertainty by varying all parameters across defined ranges and distributions.

Characterize Hot and Warm zones	Outdoor and MEI remediation	Critical facilities remediation	Non-Critical facility remediation	Total area restoration
Area of suspected contamination	Area of suspected contamination	Area of suspected contamination	Area of suspected contramination	Area of suspected contamination
High density indoor characterization sampling density	Time required to decon 1 outdoor city block	% of buildings that are contaminated	% of buildings that are contaminated	% contaminated buildings that require fumigation
% of buildings that undergo high density sampling	Outdoor clearance sample density	% suspected contaminated area classified as "Hot"	% contaminated buildings that require fumigation	Time required to decon 1 outdoor city block
# characterization samples per building	% suspected contaminated area classified as "Hot"		% suspected contaminated area classified as "Hot"	High density indoor characterization sampling density
% suspected contaminated area classified as "Hot"				Outdoor clearance sample density

Area of suspected contamination has downstream effects on all phases of restoration.



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Results from all analysis approaches were combined to generate the gap priority list

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TOP: These scope the restoration effort and have downstream effects

- Lack of risk-based approach for determination of inhalation hazard (indoor and outdoor)
- Lack of validated methods for outdoor characterization
- Lack of validated outdoor decontamination strategy, methods, materials and technologies

SECOND: These reflect high multiplier or uncertainty effects

- Current indoor clearance standard may be impractical for wide area. Lack of validated methods and standards for outdoor clearance
- Lack of approach for evaluating agent fate and transport in the environment

THIRD: Some experience, but need to apply to wide area

- Limited resources for indoor decontamination
- Lack of validated method to identify building decontamination requirements

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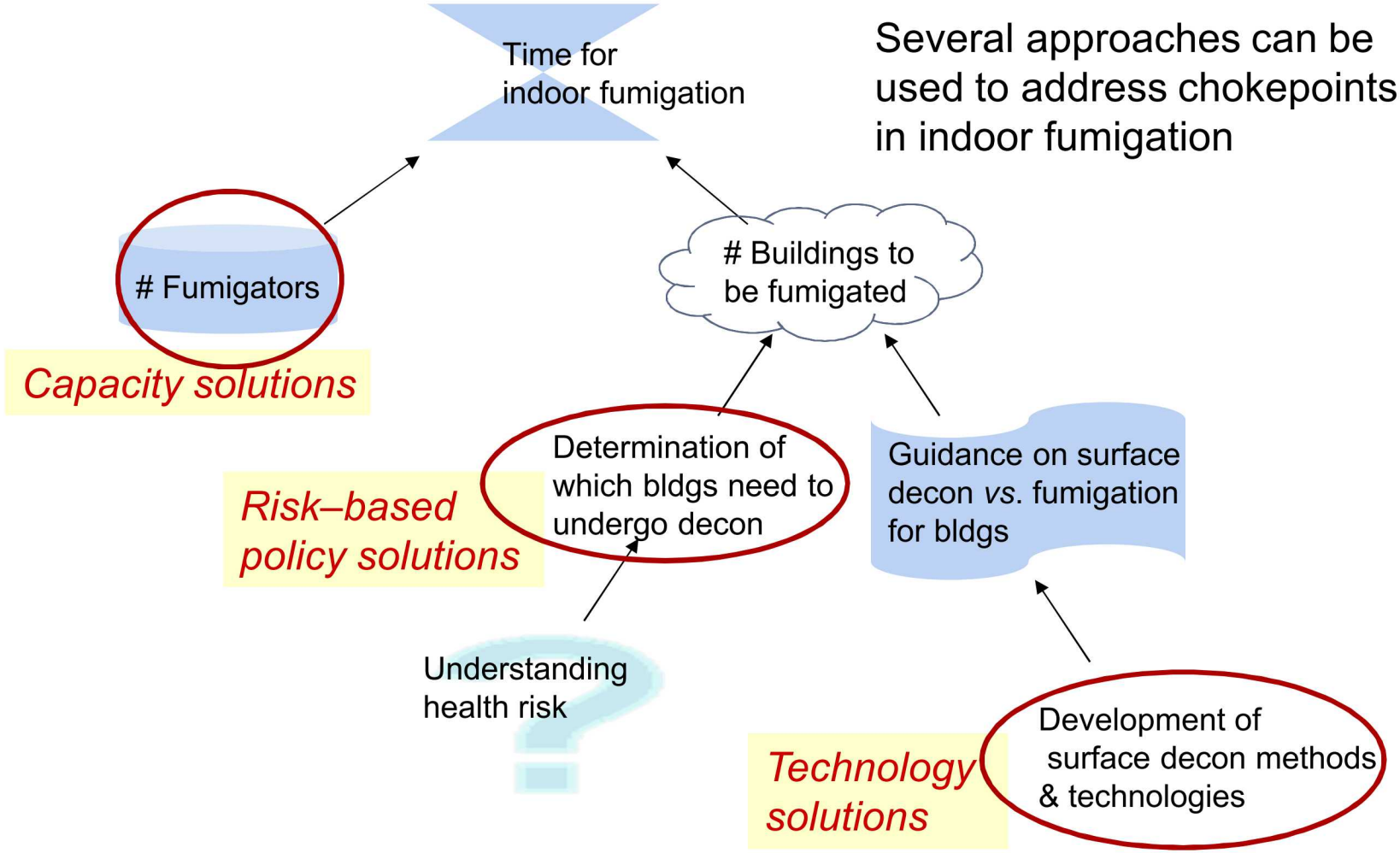
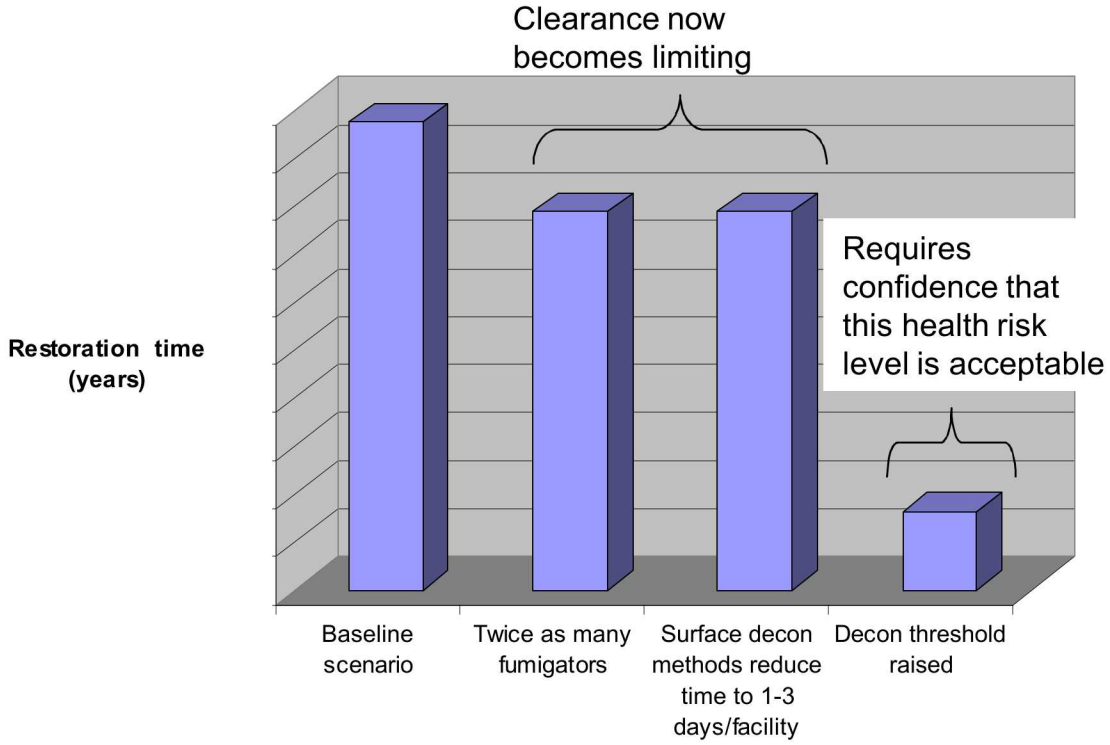
Utilized influence diagrams to identify solutions that fill gaps



Several approaches can be used to address chokepoints in indoor fumigation

Prioritized solutions to fill gaps



Different solutions have varying impacts on the restoration metrics

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- Improving decontamination throughput means clearance sampling and analysis is now rate limiting
  - Need to address both decon and clearance to see overall timeline benefit
- Relaxing the decon threshold reduces the number of buildings to be decontaminated, thus decreasing both the fumigation and clearance burdens, giving it a potentially greater impact on timelines

Developed 5-yr Wide-area Bio-restoration Federal Government R&D Roadmap

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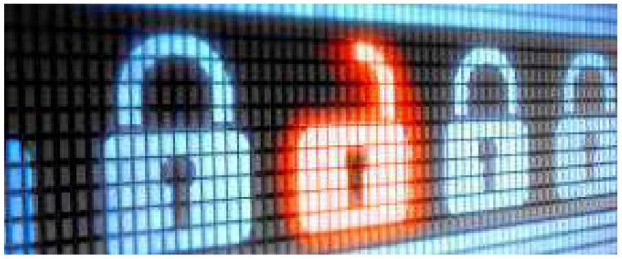
5-Year END-STATE CAPABILITY	R&D STRATEGY (MILESTONES) TO ACHIEVE CAPABILITY		
	NEAR-TERM MILESTONES (1-2 years)	MID-TERM MILESTONES (2-4 years)	LONG-TERM MILESTONES (5+ years)
CLEARANCE – Criteria			
25. Risk-based, site- and scenario-specific clearance methodology and policy	**25A.** Conduct studies to identify risk-based, site- and scenario-specific considerations, to inform clearance methodology and policy	**25B.** Develop scientific basis for assessment of health risk	**25C.** Develop and implement risk-based, site- and scenario-specific clearance methodology and policy

25. Risk-based, site- and scenario-specific methodology and policy
This capability provides a clearance methodology that takes into account health risk that is specific to the scenario and site (see Section 4.1). This capability is strongly informed by understanding of agent fate, transport, reaerosolization, and health risk (Capabilities #1 and #3), and underlies nearly all other capabilities in the roadmap, including sampling strategies and methodologies for characterization, decontamination and clearance; decontamination methods effectiveness; decision support and analysis tools; prioritization methodologies; self-remediation protocols; and risk communication.

Used in EPA, DHS, DoD to inform R&D investments

Systems Problems are Everywhere

- Systems analysis approaches can be applied to many domains. At Sandia, we've applied these in:
  - CI resilience
  - Cybersecurity
  - Disaster management
  - Counter-terrorism
  - Energy and Water Sustainability
  - etc.



Lessons learned for Systems Problems

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- Scoping is a big part of the process: what problem are you trying to solve?
- Identify desired end-state
- Define baseline state
- Use systems analysis approaches to identify and prioritize solutions to get from baseline to desired end-state
  - What are the critical gaps: Lack of understanding, policy, tools, authority, data?
    - These imply types of solutions: technology, science, behaviors, capacity-building…
    - Technology is not always the answer

Other Tips:

- Know when and how to consult SMEs.
- If empirical data doesn't exist, substitute with SME data to start.
- The "right" solution is not always the realistic solution. We provide another voice at the table.

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