Decision Aids for CBRN Investment Planning & Analysis

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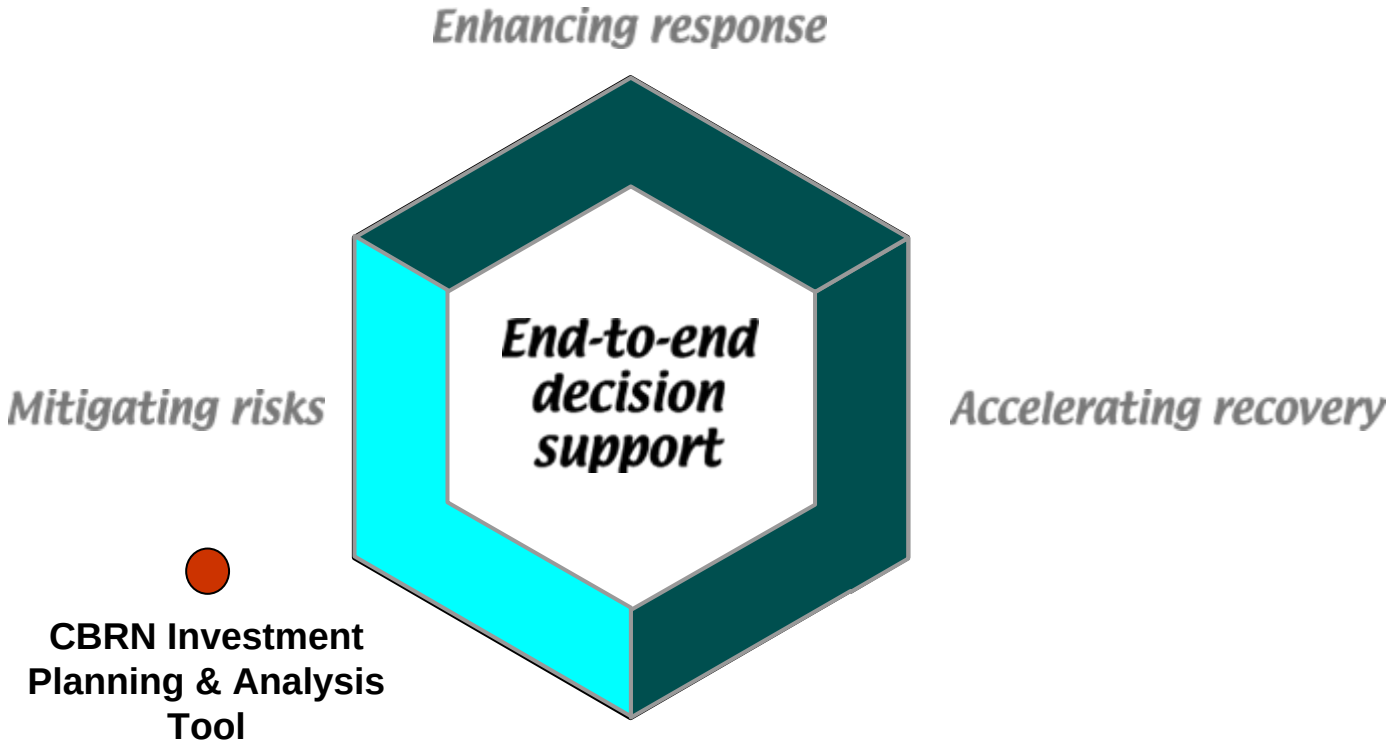
Agenda

- End-to-end decision support context
- Investment planning & analysis for CBRN Defense Architectures
  - Problem motivation
  - Analysis questions
  - Challenges
- CBRN Investment Planning & Analysis Tool project
  - Overview
  - Program manager support
  - Foundational capabilities
- Leveraged capabilities
  - BioDAC
  - Knowledge elicitation and domain expertise
  - DAKOTA
  - MIDST
- Summary

Pre-event planning is a critical component of end-to-end decision support for CB events.



Procurement and deployment of CBRN defense architectures requires understanding and evaluation of complex option space.

DoD program managers and installation planners must:

- Procure, deploy, and refresh chemical, biological, radiological, and nuclear (CBRN) detection, response, mitigation, and restoration capabilities to protect the warfighter and DoD installations/critical assets
- Effectively analyze and quantify the system effectiveness of these defensive architectures against a CBRN threat spectrum
- Determine requirements for future capabilities to meet evolving mission needs

All within limited budgets!

Example: Guardian Installation Protection Program

Investment analysis questions extend beyond technology effectiveness tradeoffs and can be asked for both procurement and R&D.

Procurement analysis questions:

- Given a fixed budget for procurement and annual O&M, what investments would be recommended in detection and response technologies for a given suite of threat scenarios?
- What technologies are required to meet specified minimum damage and casualty or mission capability thresholds?
- How can the critical assets/mission capabilities on an installation be best protected, taking into account resources available across the entire base?
- If a civilian detection and response capability exists proximate to a military installation, what detection, protection, and/or response technologies should be purchased and how should it be deployed to protect the venue? What impact will the CONOPS and information sharing across civilian/military communities have on the effectiveness of this architecture?

R&D analysis questions:

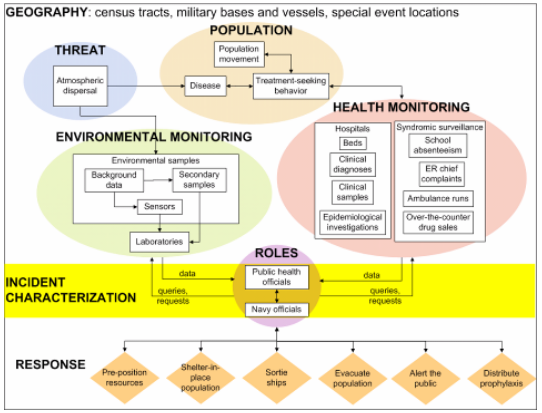
- What sensor system research investment strategy is most cost effective (over the lifetime of the sensors) in detecting a given suite of chemical, biological, or radiological/nuclear attacks?
- Given a spectrum of detection and response technology investment options and associated research risks, which combination of investments is most likely to meet specified detection and/or response thresholds for a given suite of WMD attacks?

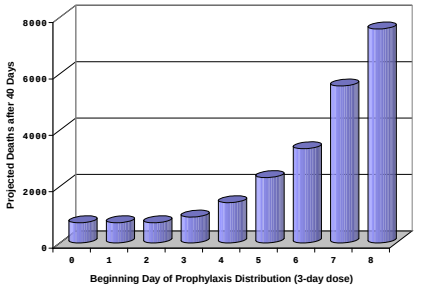
Challenges in addressing and answering investment questions must encompass technical and human factors and address uncertainty.

- Complexity of trade-off space
  - Threat types, threat scenarios, environments, technologies, CONOPS, etc.
- Developing meaningful, vetted performance assessments
  - Technology (e.g., sensors, protective gear, comms, etc.)
  - Operations
  - Integrated defensive architecture
- Defining measures of system effectiveness
  - Ability to complete mission
  - Morbidity and mortality
  - Loss of critical assets
- Characterizing and quantifying effects of uncertainty
  - Aleatory – irreducible uncertainty due to inherent (stochastic) properties
  - Epistemic – subjective uncertainty due to lack of knowledge

The CBRN Investment Planning & Analysis Tool (IPAT) project will develop methods and software to support investment decisions.

- FY07 new-start project funded through DTRA JSTO (M/S Battlespace, Decision Support)
- Develop knowledge elicitation, quantification, and representation techniques to capture and represent attack scenarios, defensive technologies and CONOPS, and site characteristics
- Meld scenario-based WMD attack models with computer codes supporting “what-if” trade-offs and sensitivity analysis capabilities to understand uncertainties

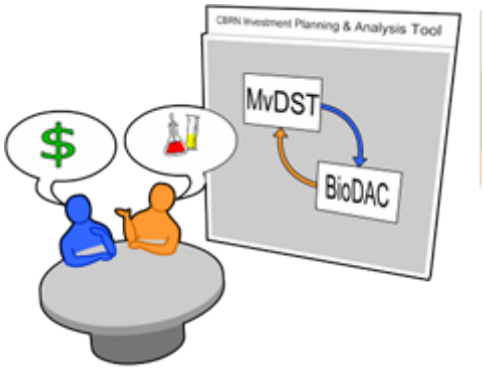




Mitigating risks

The CBRN IPAT project is targeting the Guardian Installation Protection Program decision makers.

The CBRN Investment Planning & Analysis Tool (CBRN IPAT) will enable automated, transparent, standardized cost/benefit analyses of CBRN defense architectures.

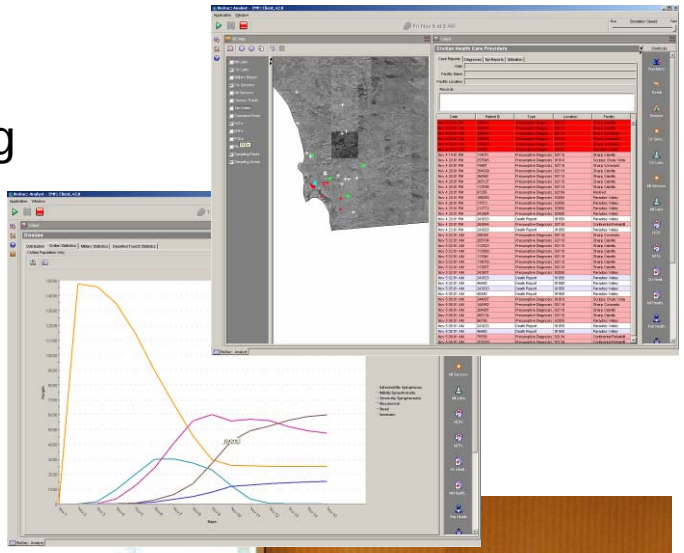


The CBRN IPAT will support installation protection investment decisions through:

- Methods and tools for assessing measures of effectiveness
  - Formulating performance and effectiveness measures and metrics
  - Comparing the potential impact of different procurement options on CBRN architecture effectiveness across a multitude of attack scenarios
  - Identifying gaps and impact of new capabilities
- Methods and tools for capturing and quantifying uncertainties
  - Approaches for handling aleatory and epistemic uncertainty
  - Assessing the sensitivity of the analysis results to variations in threat scenarios, technology performance, and other architecture factors

CBRN IPAT development will leverage CBRN domain expertise, knowledge elicitation and representation, and M&S capabilities developed through DHS, DoD, and DOE.

- Existing methods, tools, and applicable CBRN domain expertise will be leveraged to support the IPAT analysis methodology and supporting software. These capabilities include:
  - Conceptual models for CBRN events and response timelines
  - CBRN defense analysis tools (e.g., BioDAC)
  - Optimization, uncertainty quantification and sensitivity analysis libraries (DAKOTA)
  - Systems and numerical analysis experience



- In addition, Sandia will partner with the DTRA University Partnership Gold Team to:
  - Share research in multivariate decision support algorithms
  - Provide bi-directional data feeds between IPAT and the Multivariate Investment Decision Support Tool (MIDST)

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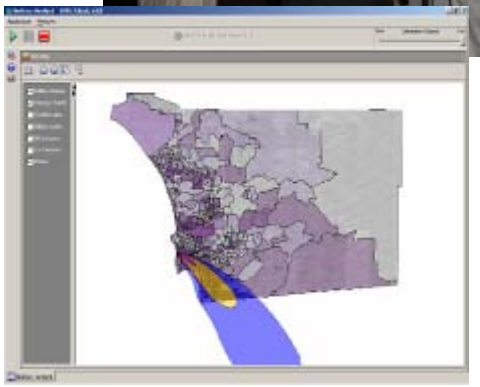
Mitigating risks

BioDAC allows systems analysis of defensive architectures in bio-attack scenarios to evaluate system effectiveness

The BioNet program (2005-2006) integrated and enhanced civilian and military capabilities to detect and characterize a bioattack in an urban area.

Developed through the BioNet program, the Biological Decision Analysis Center (BioDAC) simulation tool:

- Models system-level performance of bio-defense architectures in a major urban area
- Calculates simulation results for bio-attack scenarios – timing of events, resource utilization, CONOPS, people affected, etc.
- Displays metrics that reflect technology and human-in-the-loop performance
- Allows alternative scenarios and architectures to be examined
- Can be used in analyst or role player modes



These capabilities allowed stakeholders to explore ConOps and evaluate and optimize the integrated defense systems for urban areas.

Knowledge elicitation, quantification and vetting was conducted throughout the BioDAC modeling and analysis process

Knowledge elicitation interviews

↓ Conceptual model development

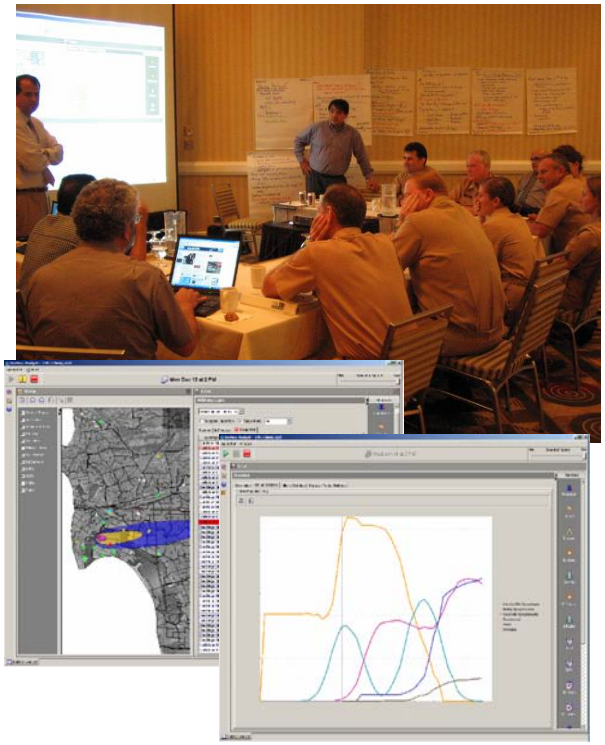
Meetings to validate conceptual models

↓ Conceptual model refinement
Simulation software development

Meetings and exercises to vet simulation

↓ Simulation refinement

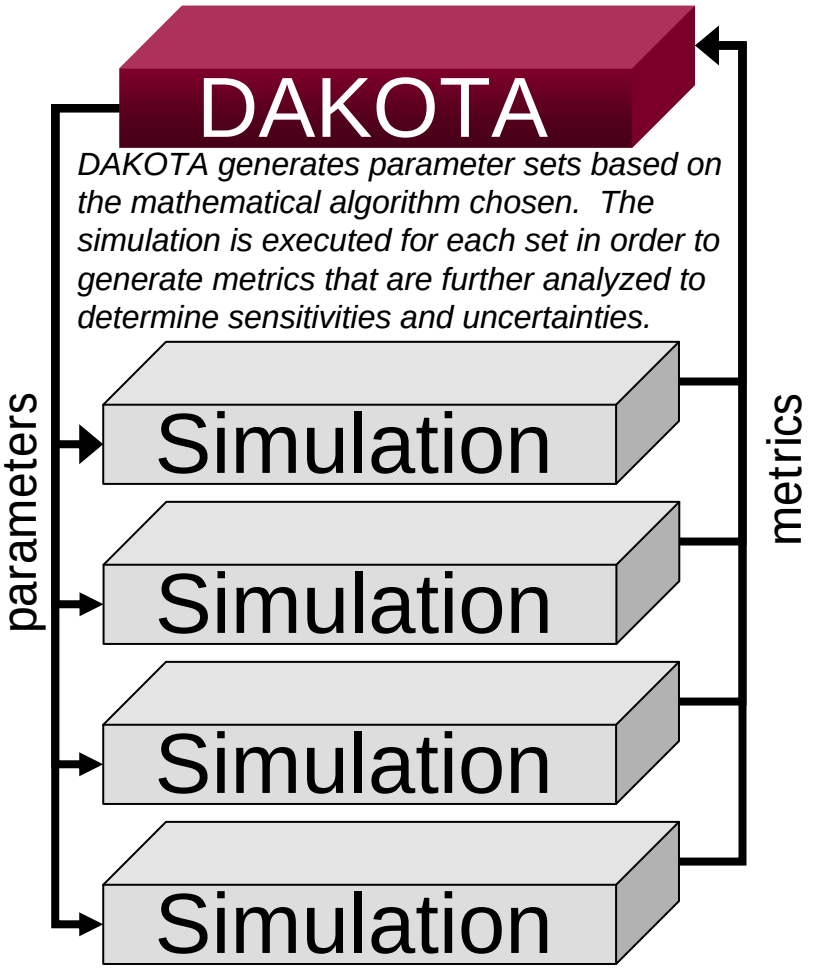
Use of simulation for exercises and analyses



These interactions and analyses provided insights and conclusions on operations and preparedness.

DAKOTA provides a common interface to an extensive set of algorithms for automated model exploration and analysis

- Getting the best coverage: sampling, design of computer experiments
  - Monte Carlo, Quasi-Monte Carlo, central composite, Box-Behnken, centroidal Voronoi tesselation
- Determining the most important parameters: sensitivity analysis
  - main effects, correlations, variance-based decomposition
- Analyzing the uncertainties: (epistemic) uncertainty quantification
  - second-order probability, Bayesian inference, Dempster-Shafer evidence theory
- Identifying the best/worst: optimization
  - mixed integer, multi-objective, multi-level, with or without uncertainty

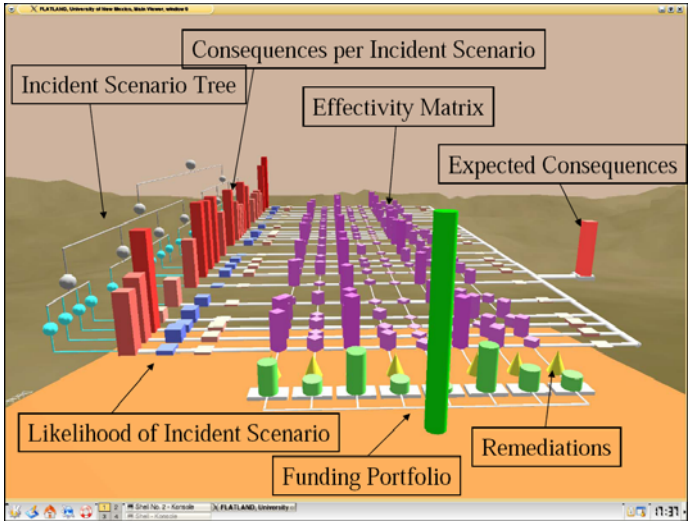


The Multivariate Investment Decision Support Tool provides an environment for studying technology investment strategies and optimization

MIDST: evaluates and optimizes R&D investment strategies to support program managers

- Collaboration
  - Collected scenario, investment options, technology performance, and consequence data
  - Integrate with to provide derived effectiveness metrics for new technologies based on IPAT analyses.

- Related presentations:
  - Data & Decision Support Tools
    - Roshan Rammohan, Wed, 4pm
    - Frank Gilfeather, Thurs, 8:45am
    - William Ogden, Thurs, 9:15am
    - Shan Xia, Thurs, 9:45am
  - Operational Effects
    - Nadipuram Prasad, Thurs, 3:30pm
    - Stephen Helmreich, Thurs, 4:30pm



The Multivariate Investment Decision Support Tool, which allows users to study tradeoffs between technology investment strategies, is being developed by the DTRA University Partnership Gold Team.

The CBRN IPAT development strategy is multi-phase with initial emphasis on requirements elicitation.

- Phase 0: complete funding transfer
- Phase 1: User requirements analysis, knowledge elicitation, conceptual model formulation, bio attack scenario development, initial uncertainty characterization
- Phase 2: Simulation development and integration for bio attack scenarios. Initial uncertainty quantification and analyses.
- Phase 3: Investment tradeoff studies, vetting with decision makers and users.
- Phase 4: Extension to CRN scenarios, more sophisticated models, UQ, and analyses.

Summary

- The IPAT will support CBRN planning by allowing decision makers to evaluate investment options.
  - Informed investment decisions are critical to ensure robust risk mitigation, an accelerated response, and efficient recovery in case of a CBRN attack.
- This project will combine systems analysis, advanced modeling, computing and mathematical techniques, and state-of-the-art visualization technologies to create transparent, vetted methods and tools.
- The IPAT methods and tools will leverage existing capabilities and expertise developed through DTRA-, DHS- and DOE-sponsored programs.

Questions?