



Hazard Mitigation - From Science to Systems

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Introduction



For a given asset (e.g., radio, weapon, vehicle) that has been contaminated with chemical warfare agent and *decontaminated*, would health effects result from using the asset?

Goal: provide the simplest approach to quantify potential exposure risks with *acceptable* accuracy using the least resources necessary

Achievement: methods developed and implemented using efficient Retained Agent (RA) analysis, implementation of a shim panel, scale-up calculations, and maximum potential dose construct

Changes are revolutionary rather than evolutionary

New Test Item: Shim Panels

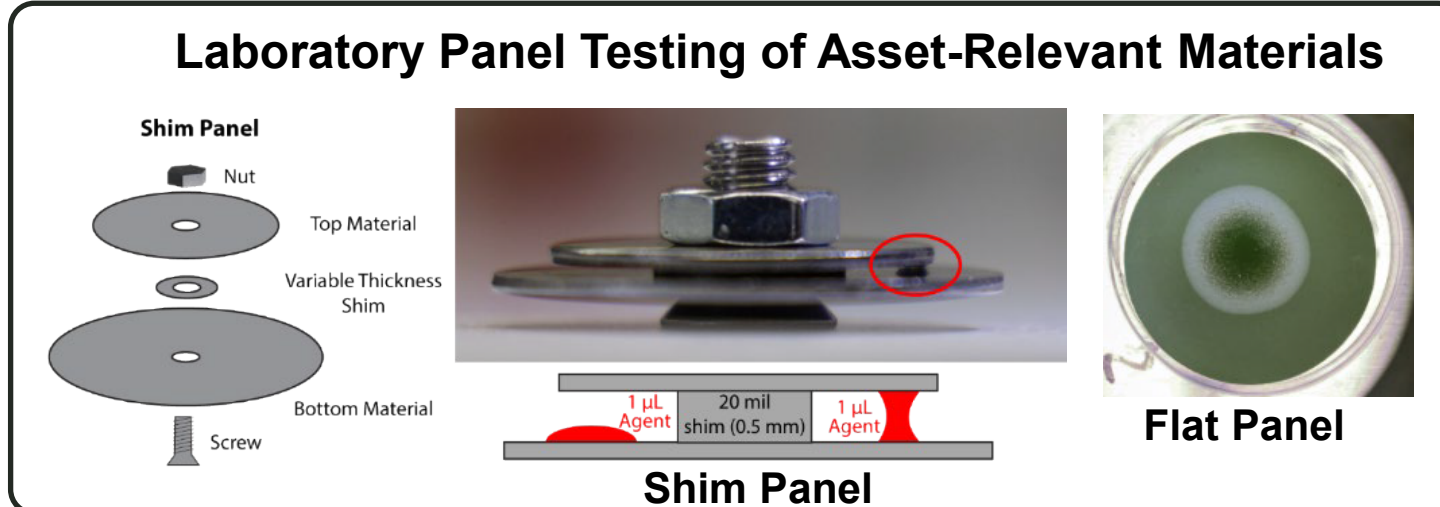
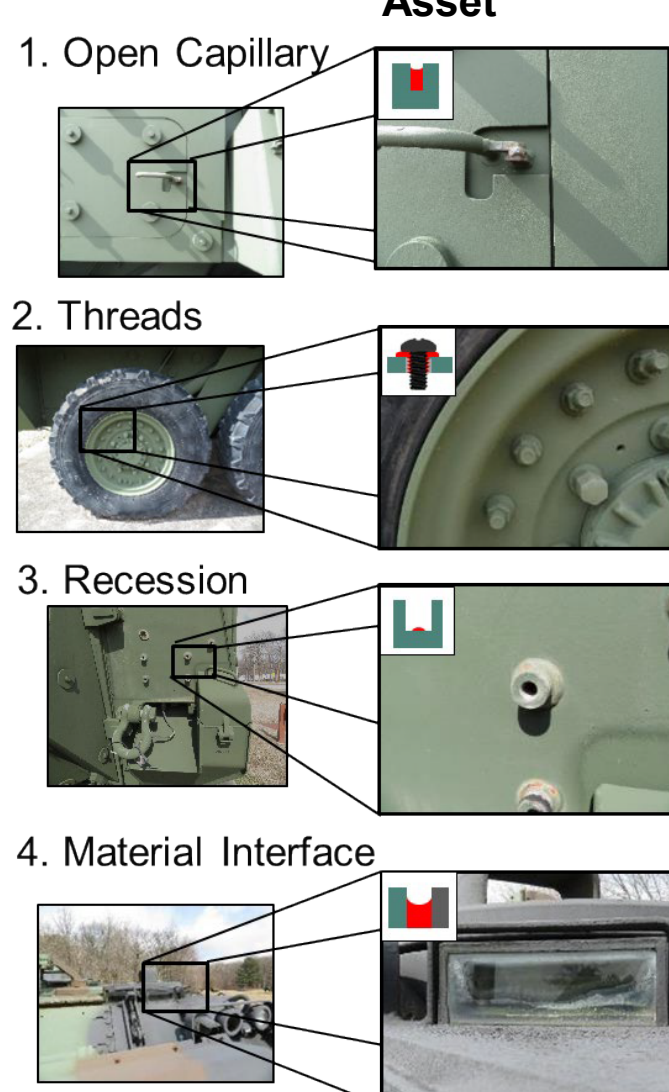
- Any factor that influences agent distribution affects decon efficacy
- Horizontal flat panels represent surfaces, shim panels represent agent entrainment in confined geometries

– *Feature size is critical, not specific geometry*

– Assumption: shim panels represent agent retained in: screw threads, holes, seams, weather stripping, gaps, etc.

– Agent entrainment can alter decon efficacy by >2,000 ×

Feature Geometries



Lab Produced
Source Terms (Data Elements)
 K

$$M_{Asset} = \sum_{k=1} RA_k(V_k)$$

Mass of agent retained by a material per agent drop after treatment

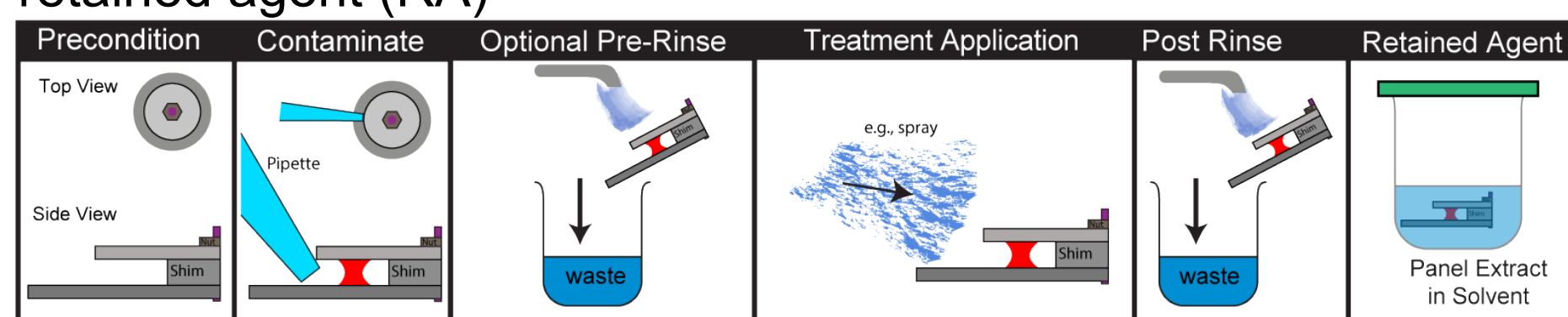
New per drop normalization technique, rather than fixed contamination density



- Validate scale-up using small, real asset
- Core Assumption** – the *magnitude and variability* of laboratory data represents what would be observed on the asset in operational context

Retained Agent Treatment

- Contaminate and decontaminate panels
- Extract in solvent to quantify total mass of retained agent (RA)



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Retained Agent Source Terms

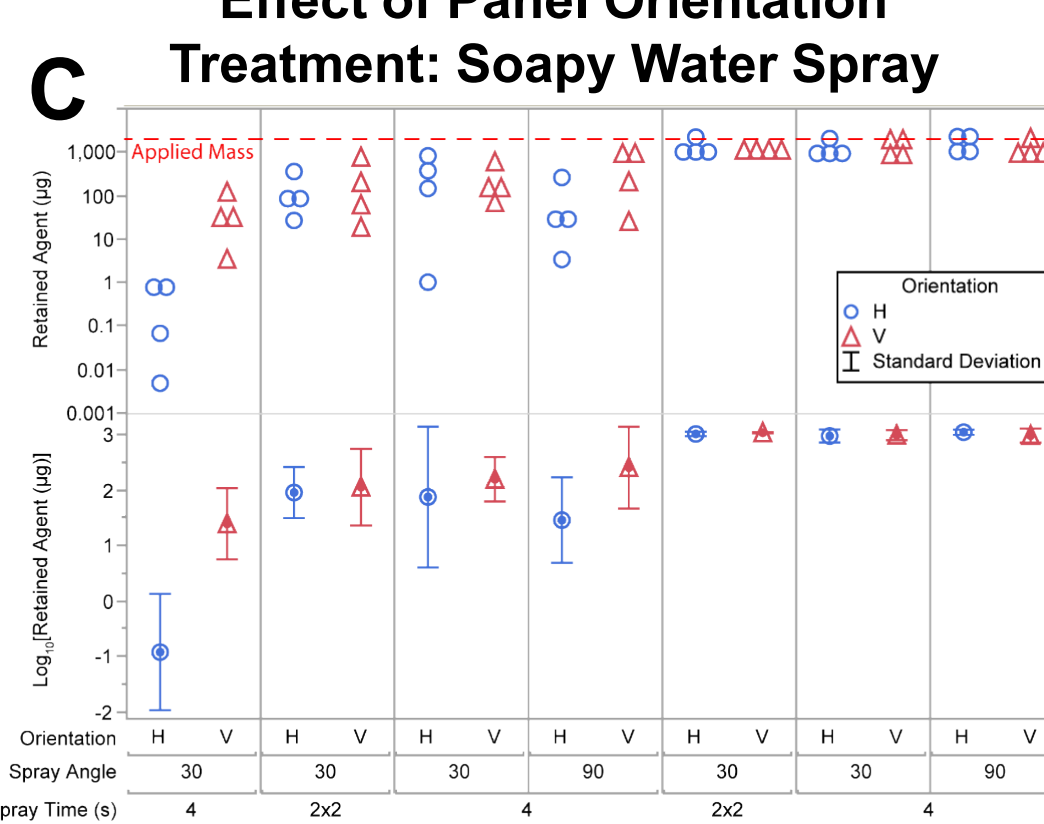
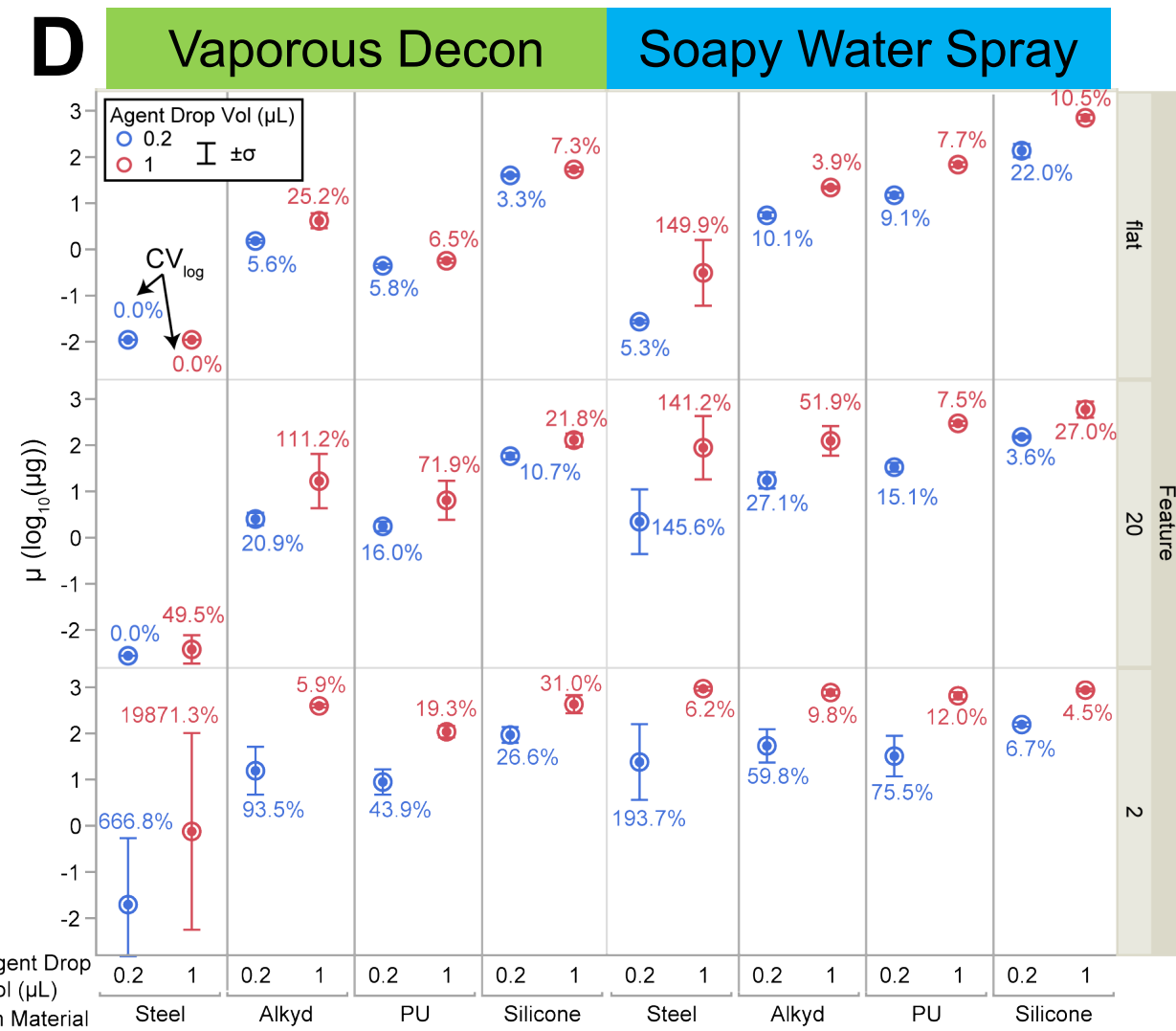
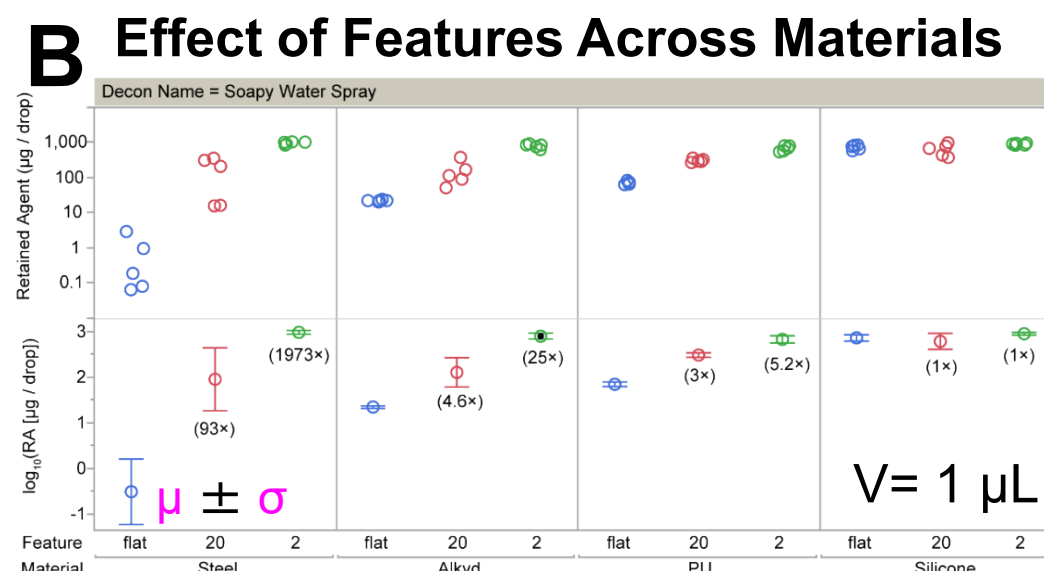
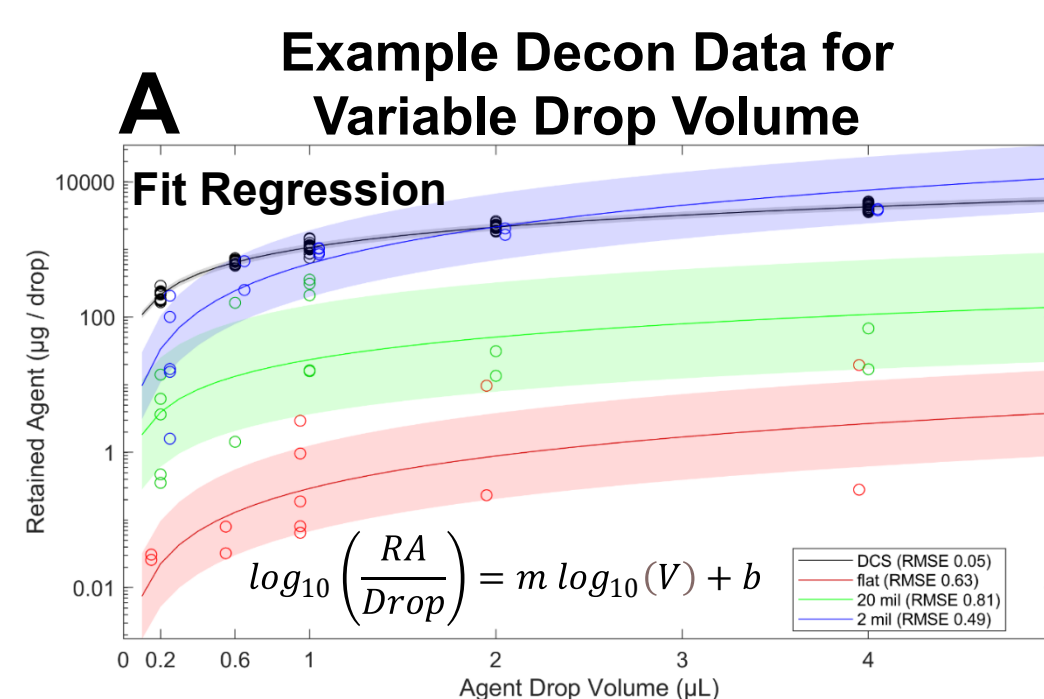
- Measured RA, and decontamination efficacy, vary with agent drop volume, *not with contamination density* (g/m²)
- Scale-up needs to account for variable drop volume contamination
- Mean (μ) and variability (σ , fit RMSE) obtained from fitting (A)

Fit - Per-drop Regression

$$\mu_{fit}(V) = m \log_{10}(V) + b$$

m is the slope
 b is the intercept
 μ is the mean mass per drop (log₁₀(μg))
 V is the agent drop volume (μL)

- Source terms acquired for flat panel and shim panels of different thickness (2, 20 mil) and different materials
- Decon efficacy varied by ~2000 × from flat to small shim gap (B)
- Panel orientation (Horizontal vs. Vertical) was insignificant compared to entrained agent in shim panels (C)
- Two decon treatments were characterized, showing efficacy and reproducibility across materials and feature types (D)



Scale-Up Demonstration

Representing an operation asset in relevant condition must address several factors

- Efficacy can vary by > 4 orders of magnitude (2,000x) based on the material (steel vs. elastomer) and features (flat vs. shim panel)
 - Validation used: controlled laboratory contamination**
- Agent mass after treatment varies with agent drop volume (V)
 - Controlled agent drop volume**
- Contamination distribution on assets are random
 - Use highly controlled contamination of asset**
- Treatment process has inherent variability
 - Account for process variability (σ)**

Addressed with random sampling (Monte Carlo) techniques

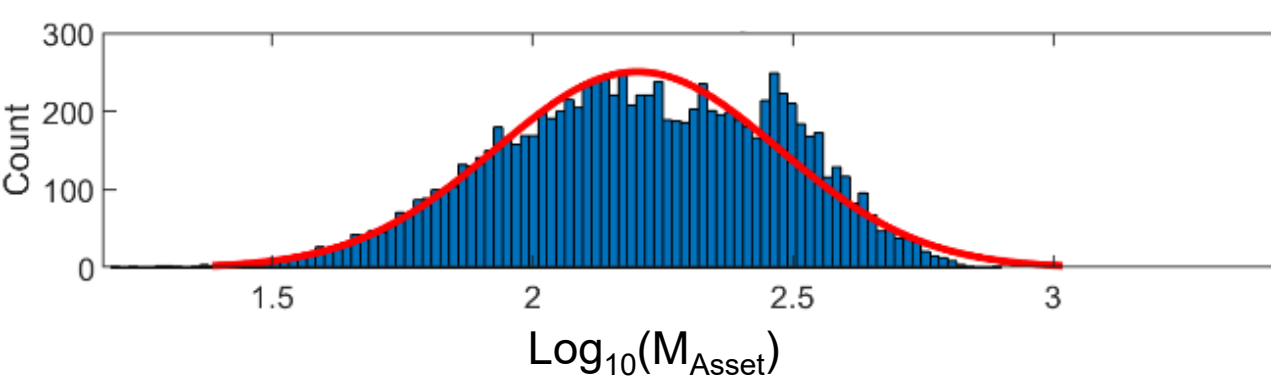
Highly Controlled Contamination



Distribution of Asset Mass after 10,000 iterations of sampling

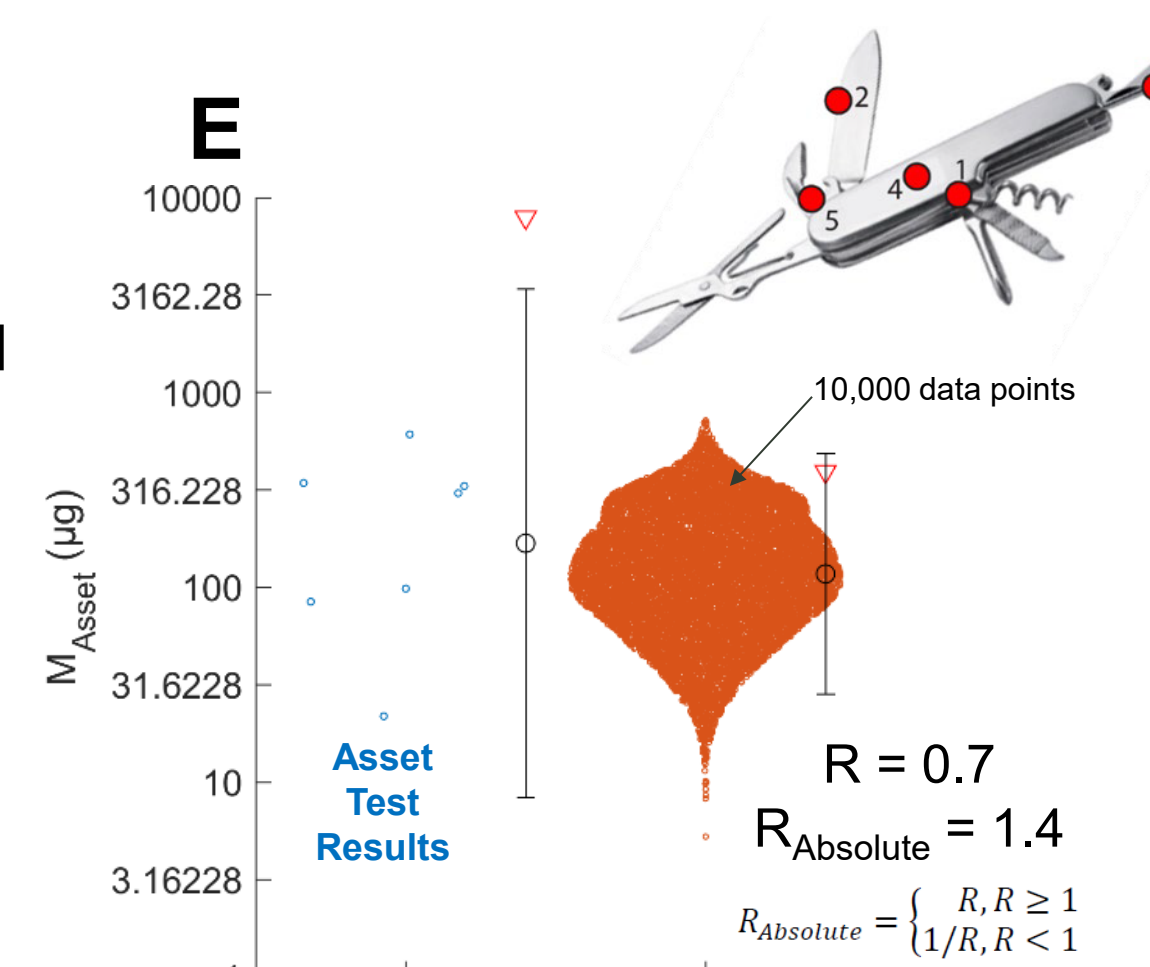
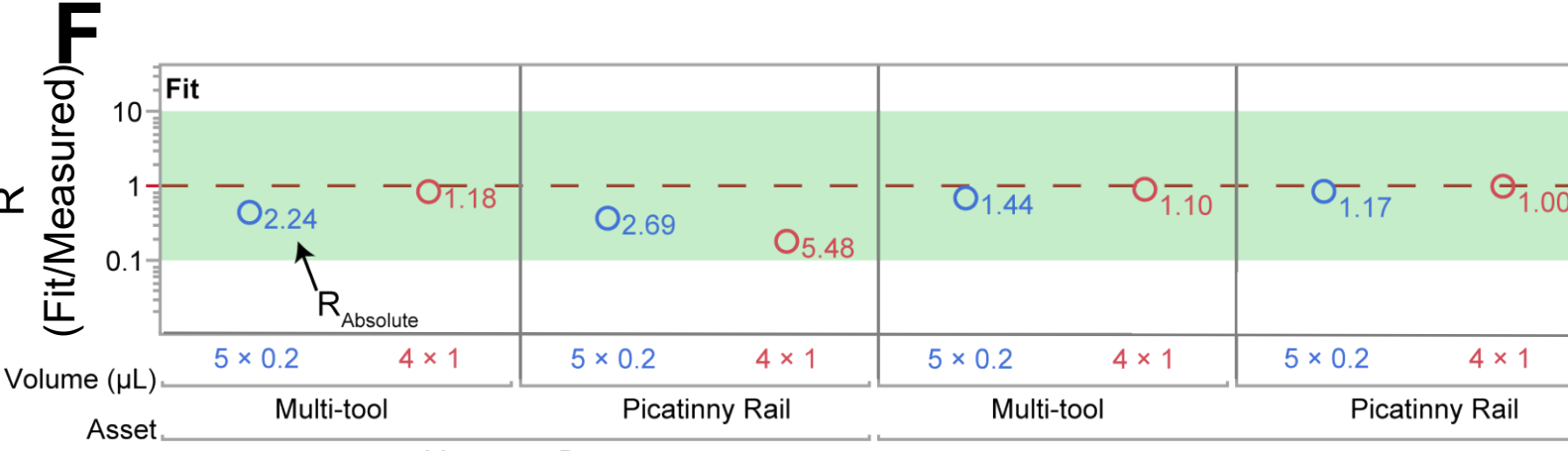
$$M_{Asset} = \sum_{k=1}^K \text{antilog}(\text{randn}() * \sigma_k + \mu_k(V_k))$$

k (Drop ID)	RA _k (source terms)	Drop Volume V _k (μL)	μ _k (V _k) (log ₁₀ (μg))	σ _k (V _k) (log ₁₀ (μg))
1	Steel 20 mil	0.2	Lab Data	Lab Data
2	Steel 20 mil	0.2	...	...
3	Steel 2 mil	0.2	...	...
4	Steel flat	0.2	...	...
5	Steel 2 mil	0.2	...	...

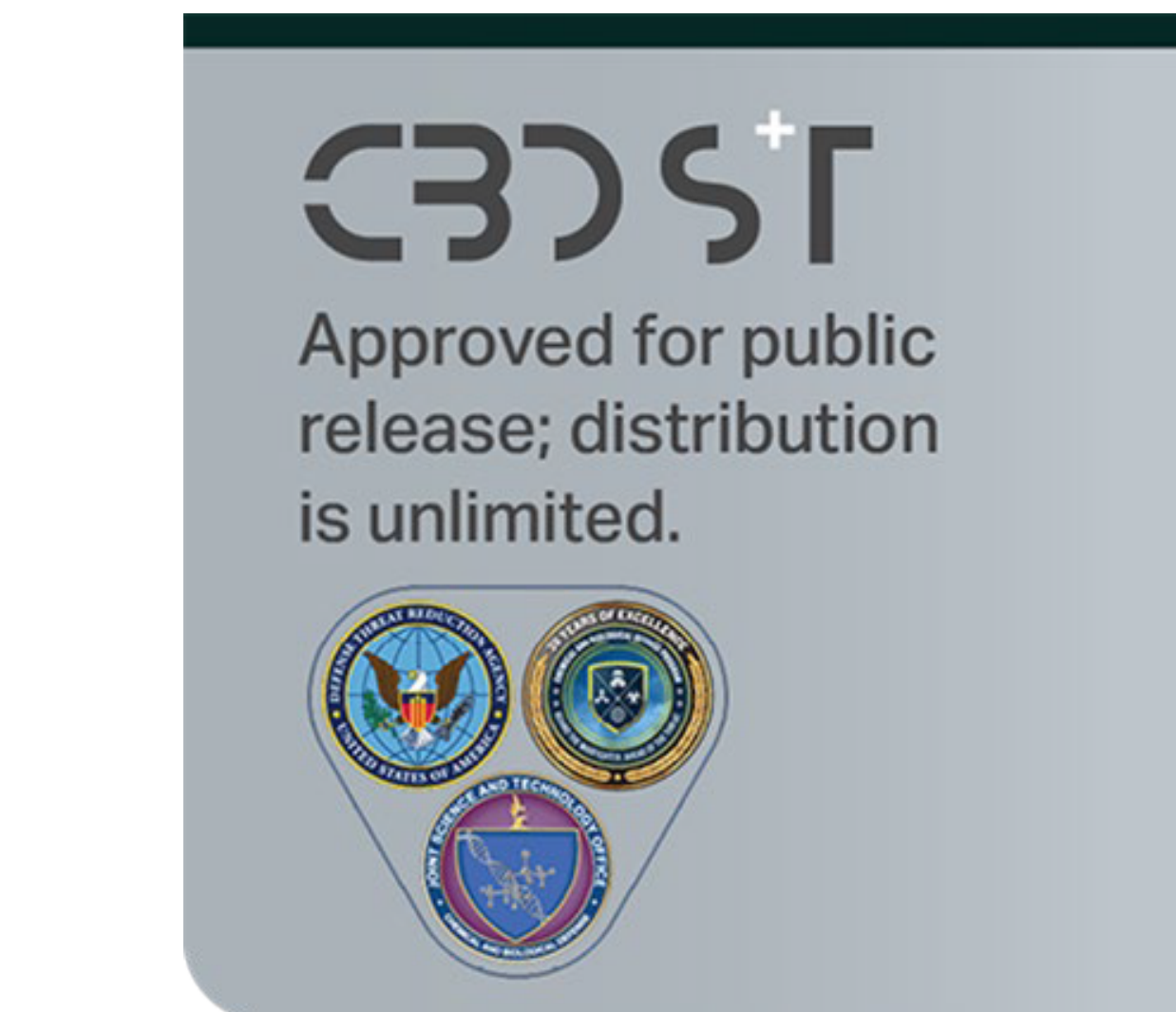


Scale-up Validation

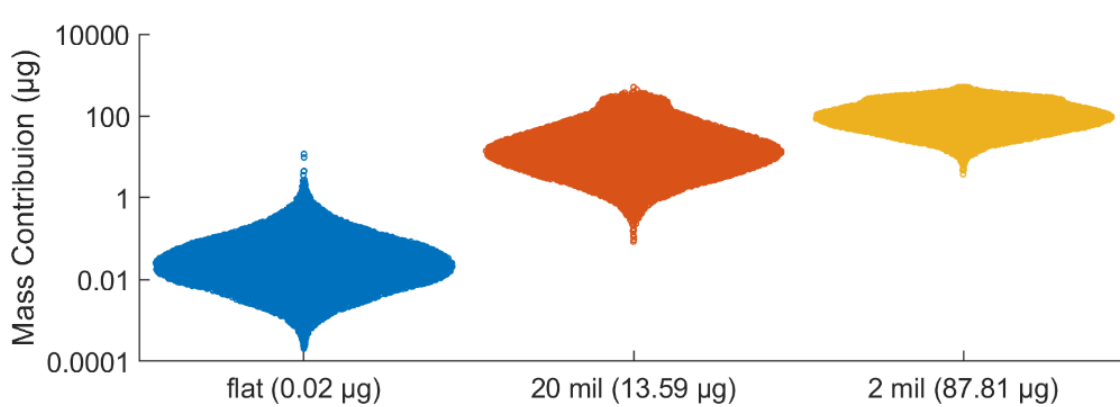
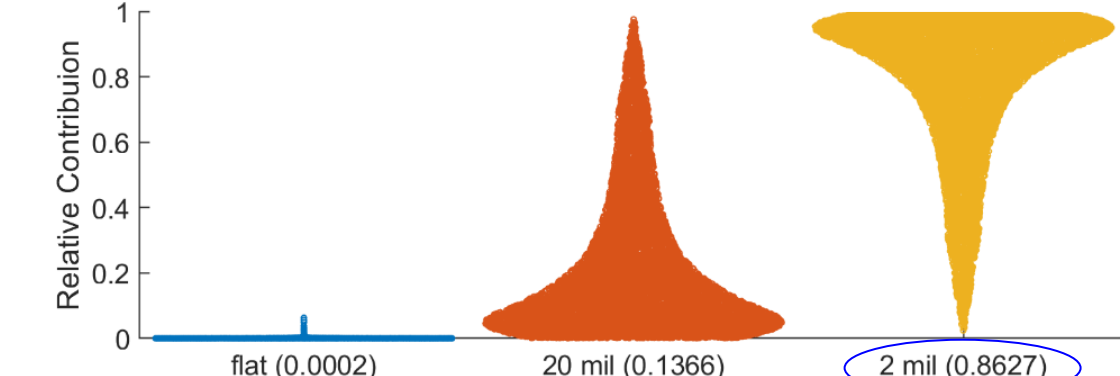
- Test real assets, predict response using panel data, demonstrate similarity of prediction to test result (E)
- Accuracy of prediction evaluated as R = Fit / Measured
- Accuracy of scale-up within ~5 × (F)



- The contribution from each feature type was tracked (G)
- Relative contributions show that 2 mil shim was typically responsible for 86% of the M_{Asset} (most significant source)
- Flat and 20 mil shim contributed ~14% of the total agent
- Entrained agent effects may dominate post-decon hazards and are very hard to decontaminate



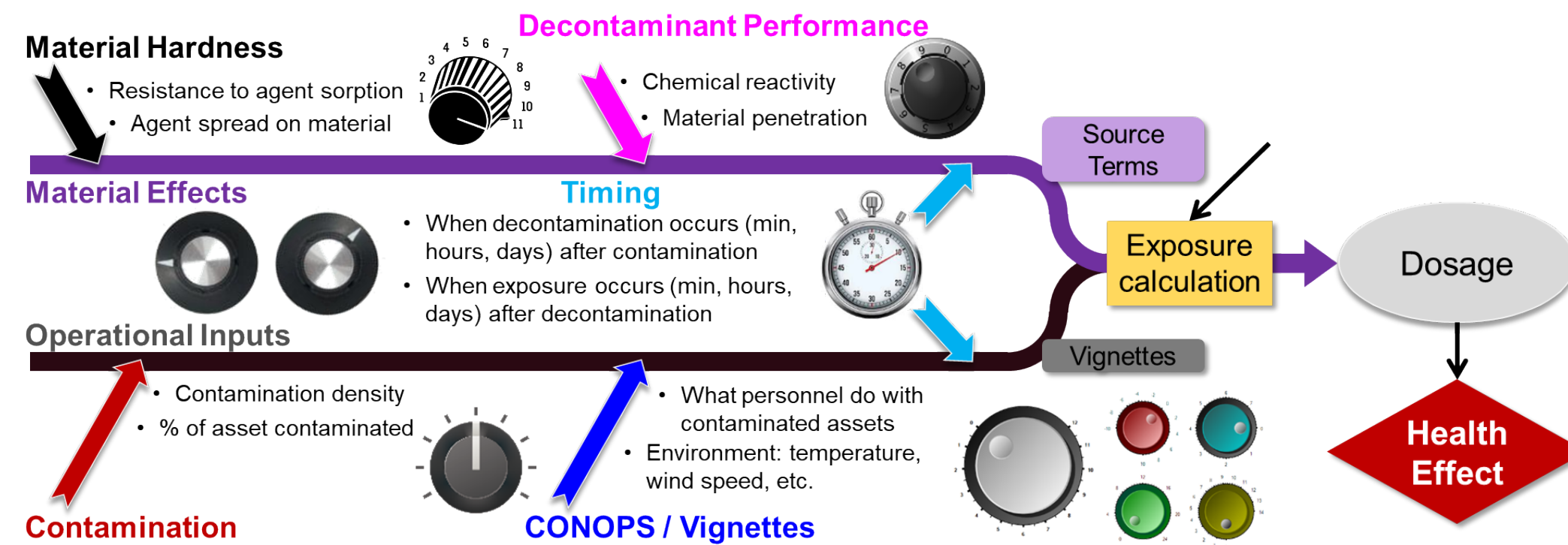
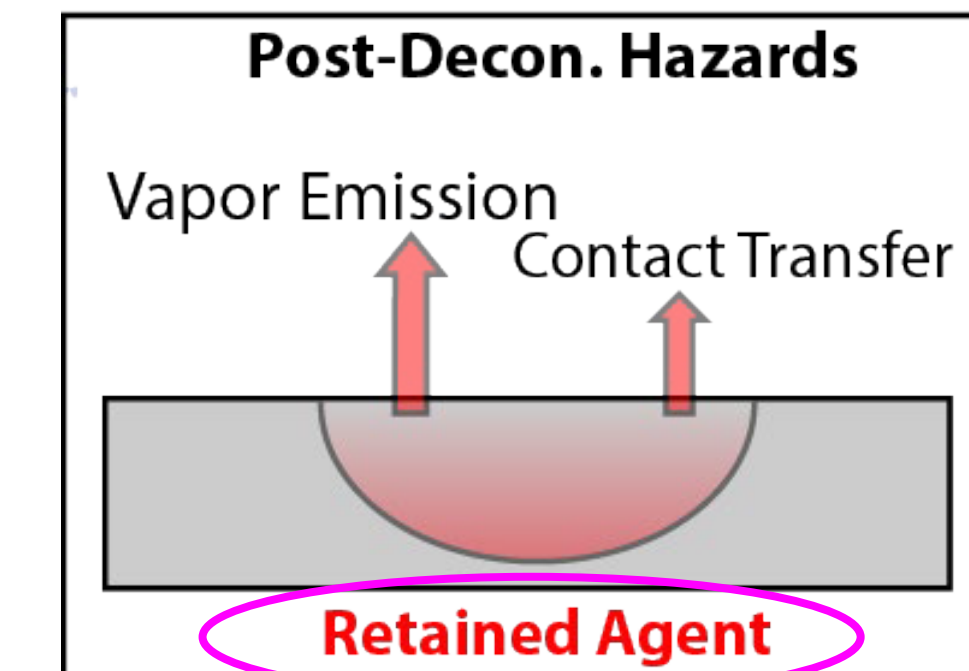
Relative Feature Contributions



Maximum Potential Dose

RA testing is high throughput and low burden (~20x) compared to vapor emission or contact testing to provide a worst case upper bound estimate for potential exposure to personnel

- Retained Agent Context:** Total mass that could produce exposure
- Maximum Potential Dose (MPD):** Upper Bound estimate of exposure source terms
 - Contact:** assume all M_{Asset} results in exposure dose
 - Vapor:** assume steady-state vapor emission of all M_{Asset} over specified time duration
- Enables the use of RA data to estimate operational exposure dose to provide initial characterization of the impact of a given technology or factor
- Use source terms in vignette calculations to estimate upper bound exposure dose



Health effects are a result of many **systems interactions**

- How the operational assets are contaminated
- Hazard mitigation technology efficacy and application of multiple technologies over time
- Material contamination hardness (agent resistance)
- Timing, TTP, CONOPS, Vignette (what personnel do with assets)

Estimating operational health effects depends on the accuracy and resolution of ALL inputs – in a Systems Level Analysis

Conclusions

- Approach to use panel data to represent operational assets demonstrated
- Developed new shim panel to enable simple laboratory characterization of agent entrainment effects and enabled variable contamination analysis using per drop normalization
- Characterized reproducibility and demonstrated methodology (DEVCOM CBC TR-1873, public release)
- Implemented new methodology for use in Test and Evaluation (DEVCOM CBC TR-1890, public release)

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