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UCRL-TR-233414

# Vulnerability and Mitigation Studies for Infrastructure

L. Glascoe, C. Noble, J. Morris

August 7, 2007

## Disclaimer



## Auspices Statement

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

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# Vulnerability and Mitigation Studies for Infrastructure

## General Overview Slides

### DHS Science and Technology

August 3, 2007
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**Charles Noble, Joseph Morris**

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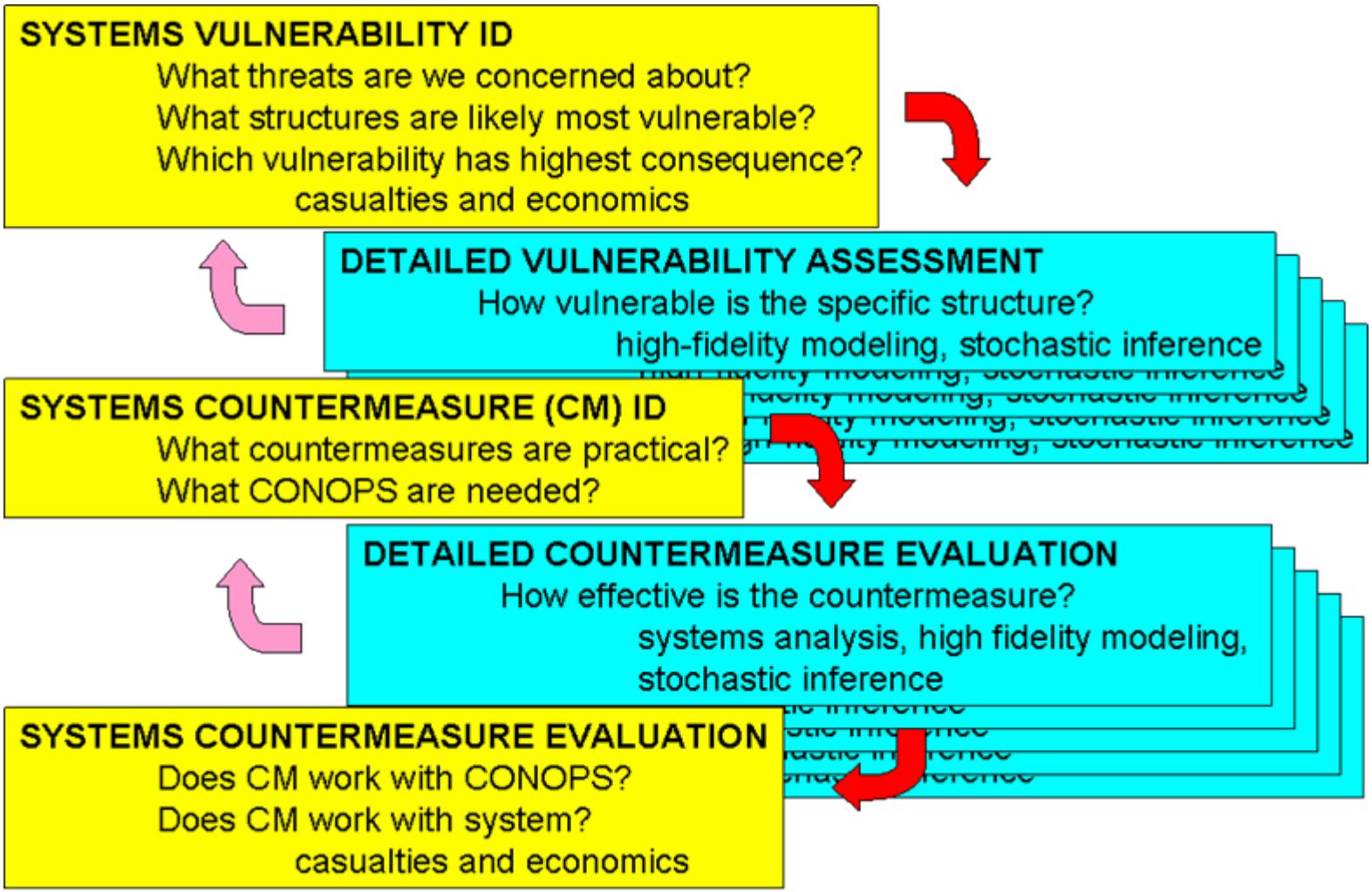
# Overview of Discussion

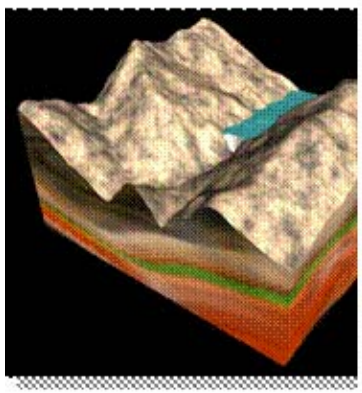
- Our end-to-end approach
- LLNL Capabilities
- Vulnerability analysis details
  - High-fidelity modeling
  - Systems analysis
- Countermeasure details
  - High-fidelity modeling
  - Systems analysis

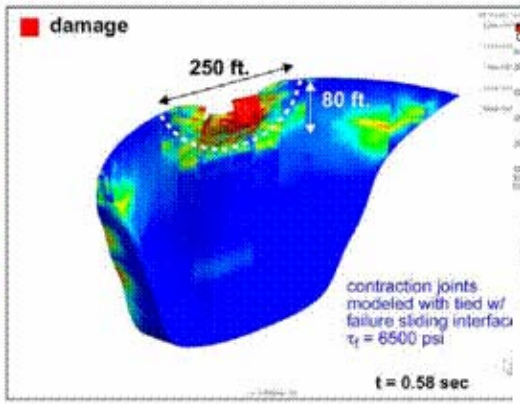
# End-to-end process: threat, vulnerability, and countermeasures

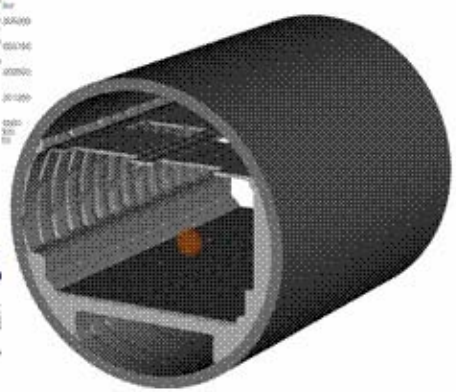


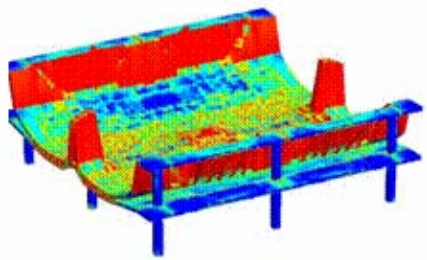
# LLNL has been analyzing infrastructure protection since 1970's

Mohne dam breach in WW II
(allied forces bomb damage assessment photo)

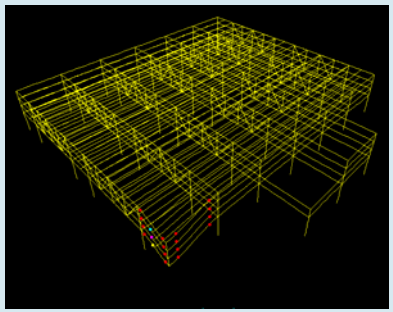
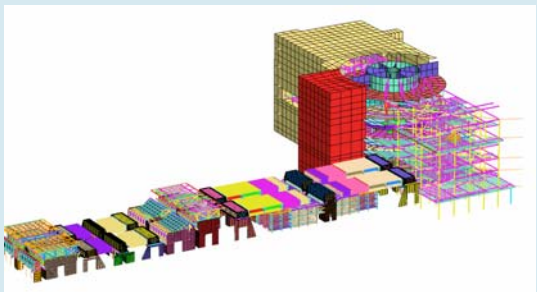
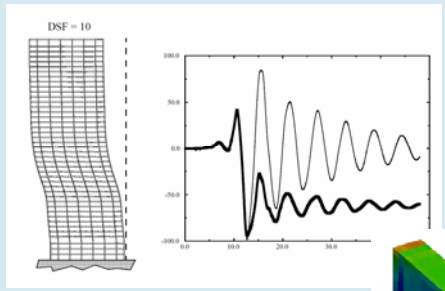
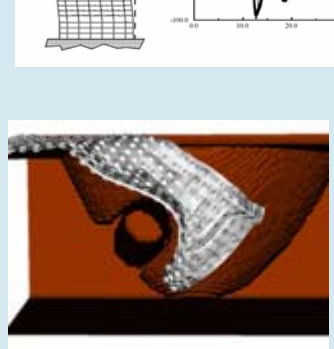
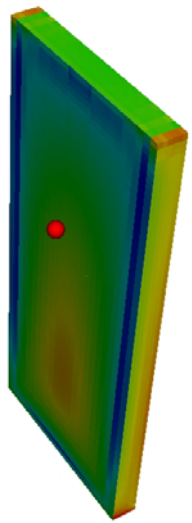
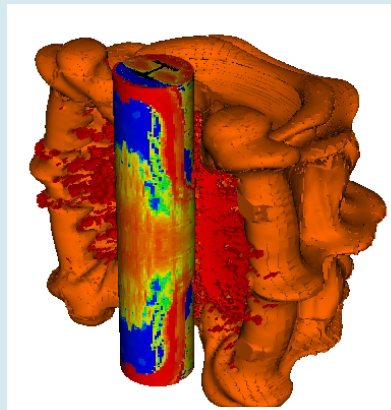






# LLNL's state-of-art computer resources and detailed physics modeling enables high-fidelity simulation

| Linear and Nonlinear Static Systems | Nonlinear Static and Slower Dynamic (~ sec) | Nonlinear Faster Dynamic (~msec) |
|---|---|---|
|   SAP2000 GEMINI |     NIKE3D ALE3D SPH, CFD |   DYNA3D/PARADYN ALE3D |

# LLNL Brings to Table Strong Subject Matter Expertise

Fluids and transport modeling: Lee Glascoe, Joe Morris

Structural analysis: Chad Noble, Ed Kokko, Larry McMichael,

Stochastic analysis: Steve Koutsourelakis, Lee Glascoe

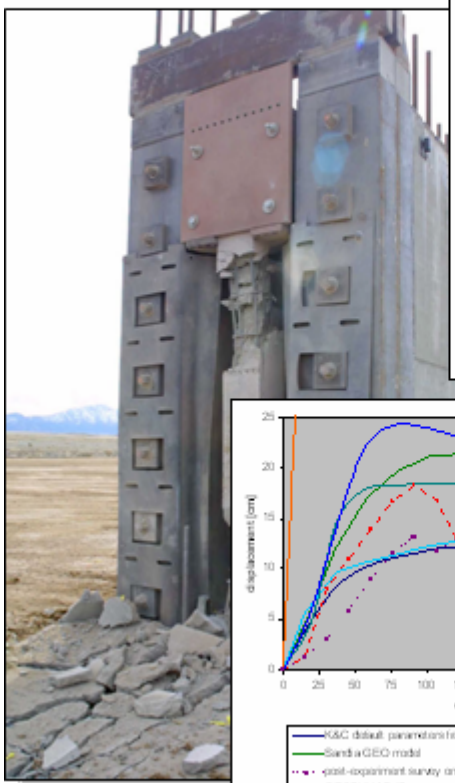
Soil analysis: Joe Morris, Tarabay Antoun, Scott Johnson, Steve

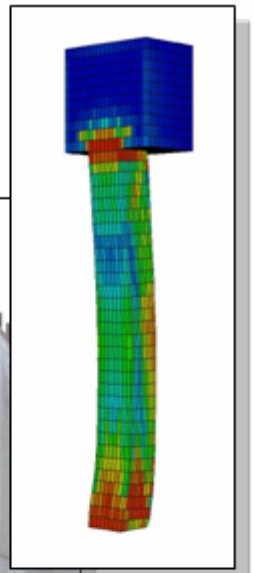
System/vulnerability analysis: Alan Lamont, Carol Meyers, Mackenzie Johnson, John Lathrop

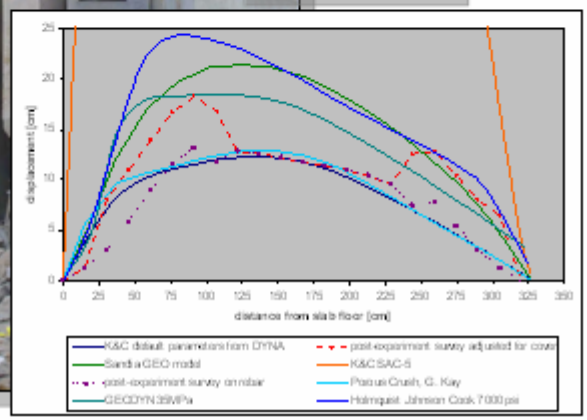
Economists: Alan Lamont, Richard White

# Model Validation is a Top Concern

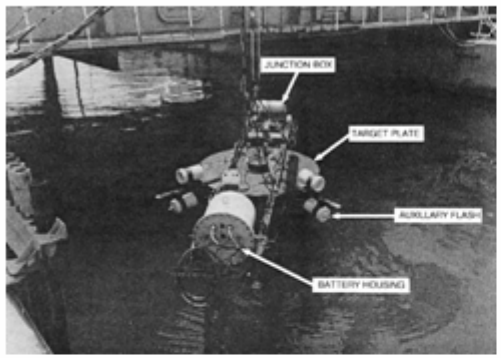
**K&C concrete model validation**

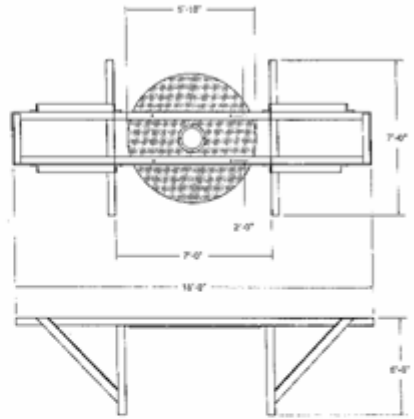


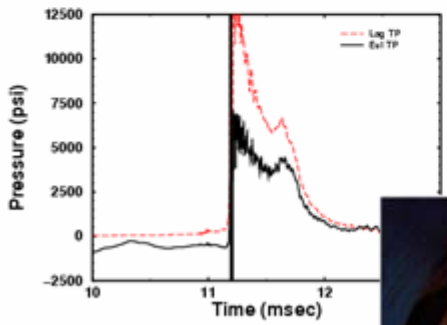


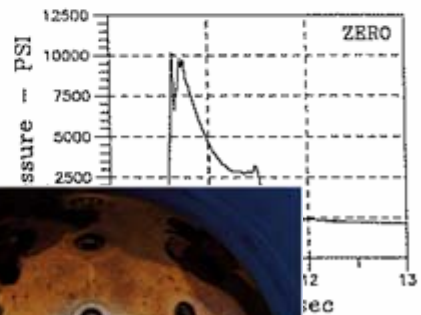


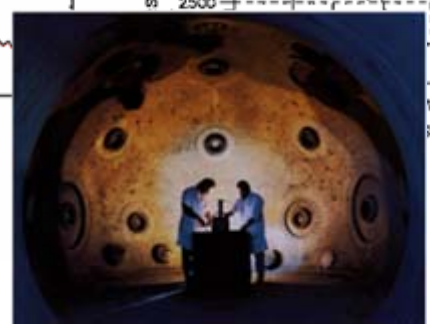

**Experimental Test—NSWCDD/TR-92/482**



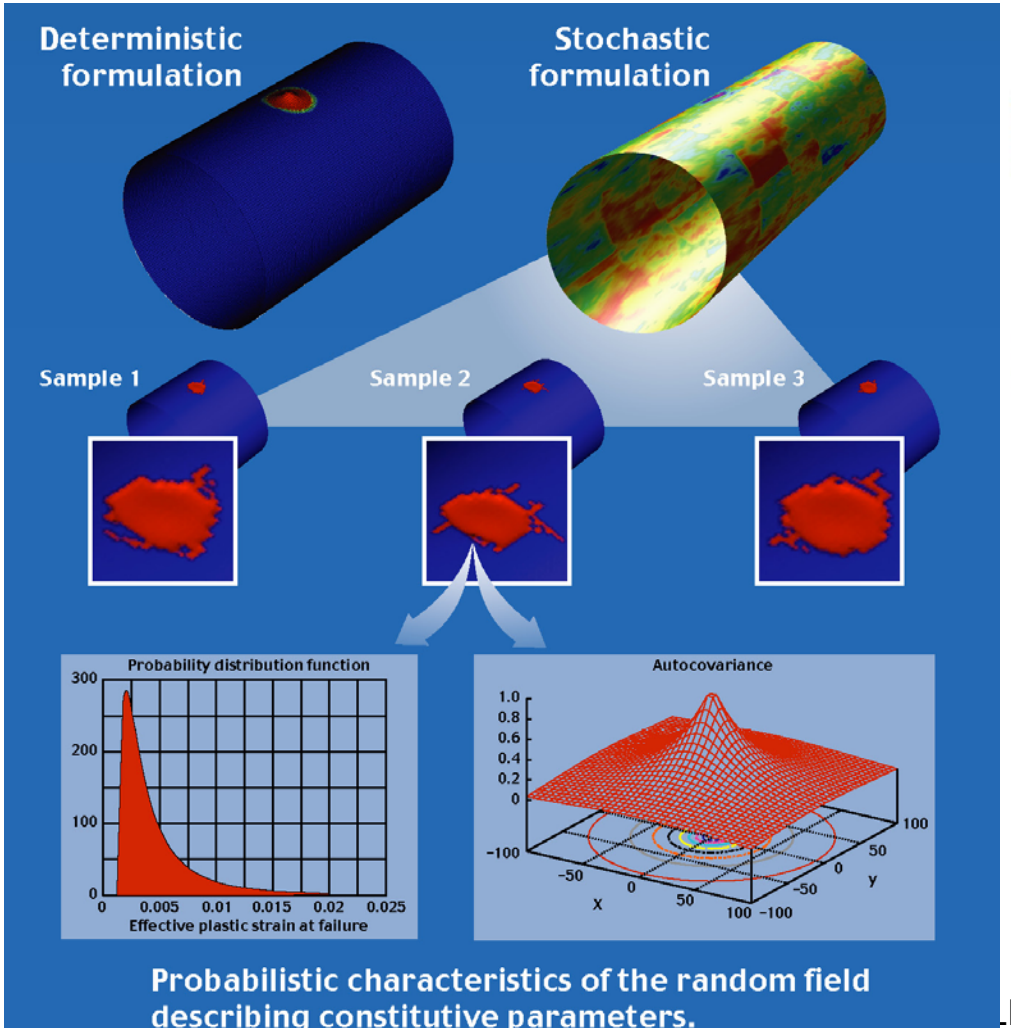


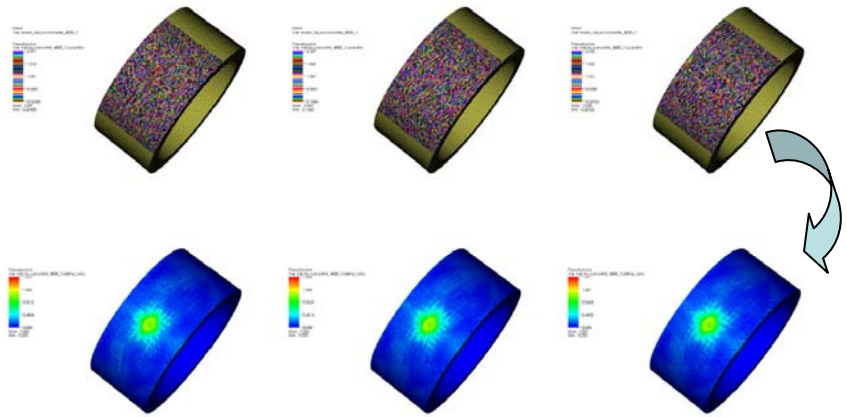
# Stochastic Simulations Enhances Our Variability and Uncertainty Assessment

Iron variability



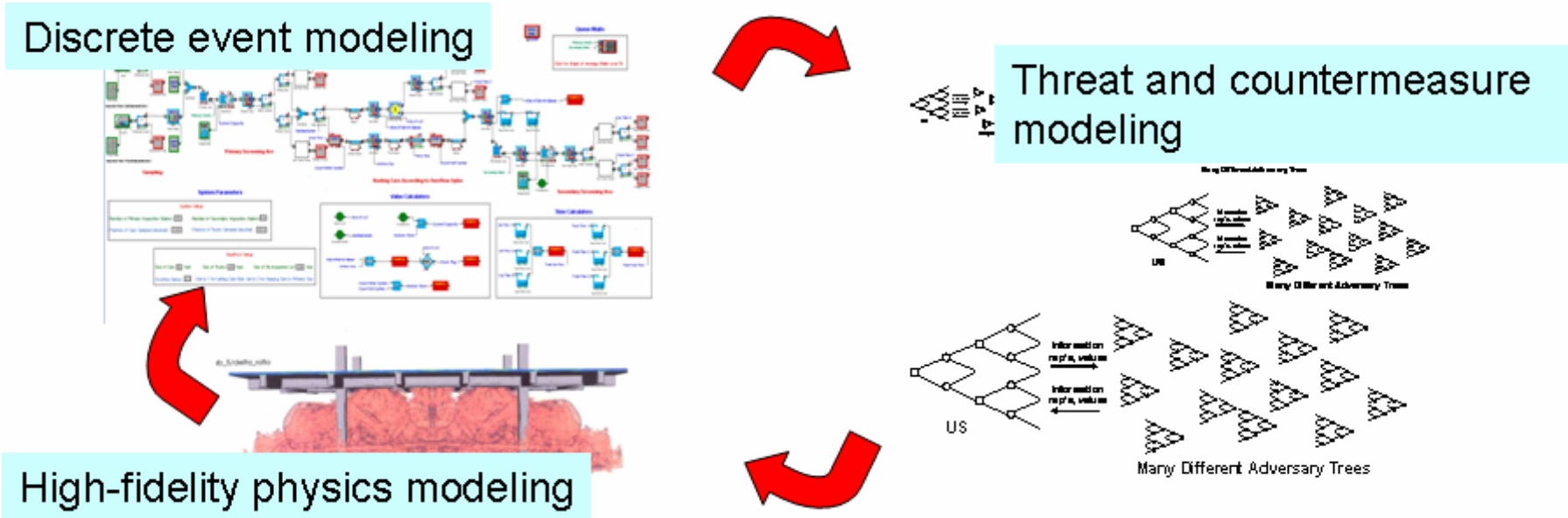

Probabilistic characteristics of the random field describing constitutive parameters.

Concrete variability



# Systems and Risk Analysis Enhances Decision Making

- Systems analysis allows for evaluation of entire systems and overall consequences
- Risk, adversary and consequence analysis allow for prioritization of countermeasures



# Project History

- **Stakeholder approached LLNL to help characterize known vulnerabilities.**
- **LLNL worked with stakeholder**
  - **to secure DHS resources**
  - **to bound the threat-space**
  - **to fully characterize the vulnerability to a threat**
- **LLNL assisted stakeholder with mitigation efforts to protect vulnerable infrastructure.**
- **As a result of these efforts, LLNL is working with other stakeholders to evaluate vulnerabilities and effect mitigation.**
- **Since January 2007 we are working for TSL and stakeholders with DHS and TSA**
- **We look at high consequence threats and vulnerabilities.**

# Sponsor, Customer, and Current Stakeholders

**Department of Homeland Security**

**Transportation Security Administration**

**Systems**

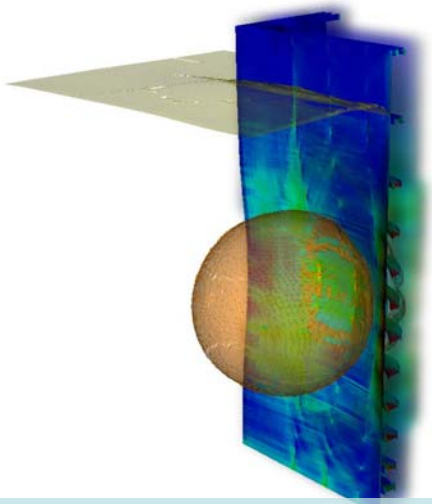
- Stakeholder 1
- Stakeholder 2
- Stakeholder 3
- Stakeholder 4
- Stakeholder 5

**Agencies/Associations**

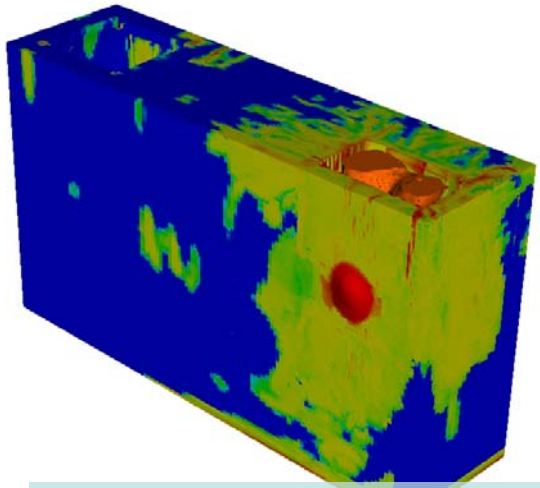
- American Public Transportation Association

**We work with TSA, DHS, and the stakeholders for *vulnerability evaluation to effect vulnerability mitigation*.**

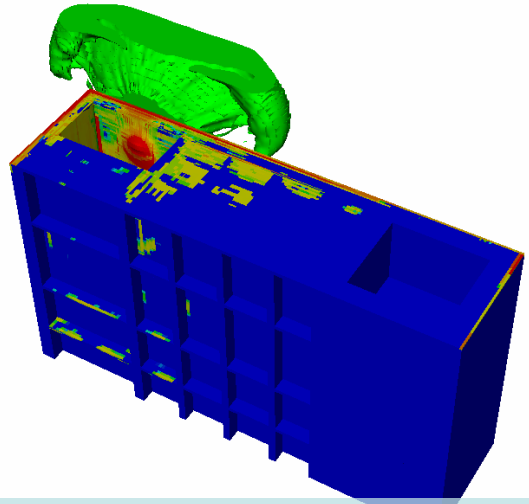
# KV1 Simulation summary



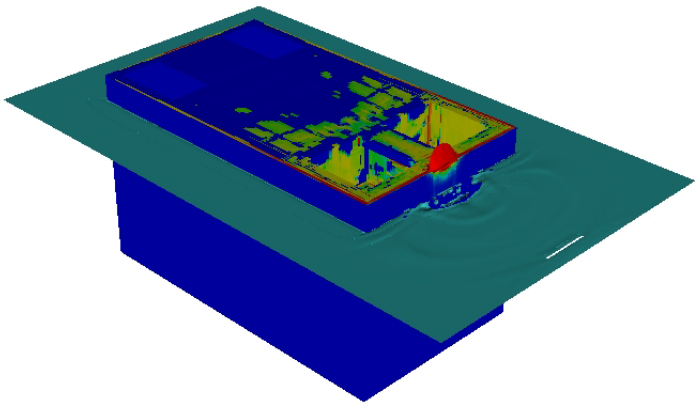
Submerged threats

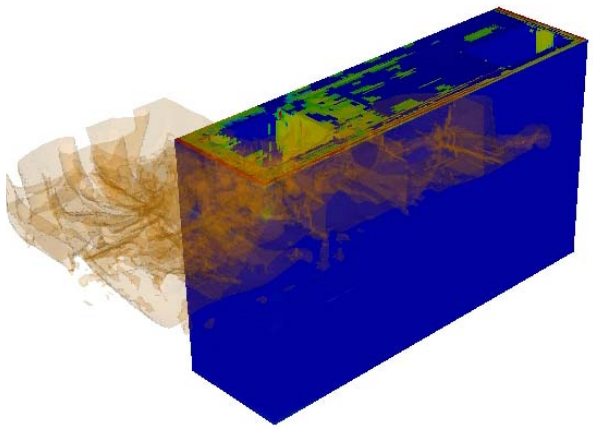


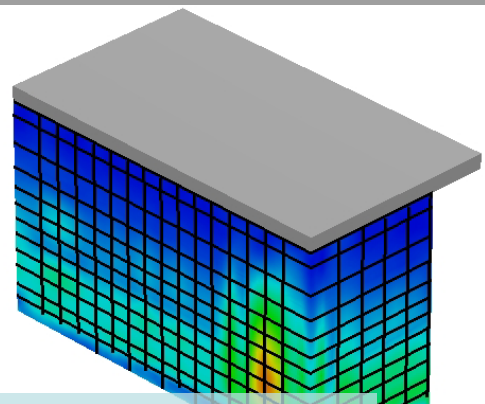
Internal threat



External threats



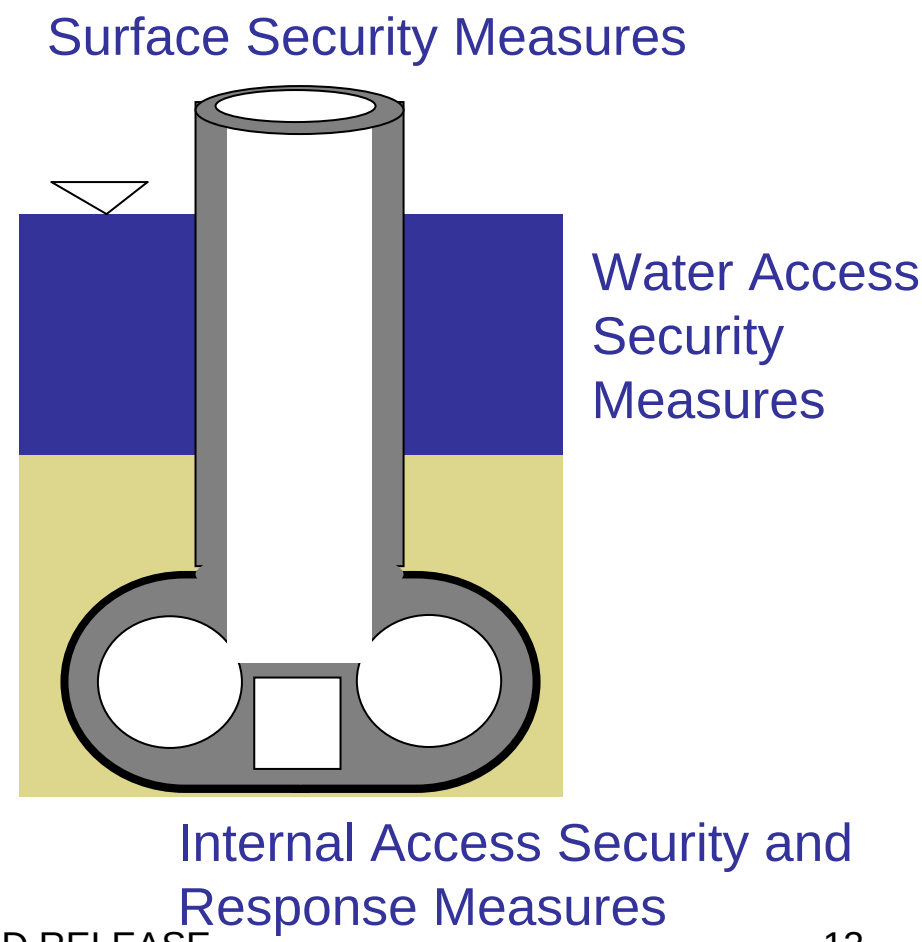




Complete structure analysis

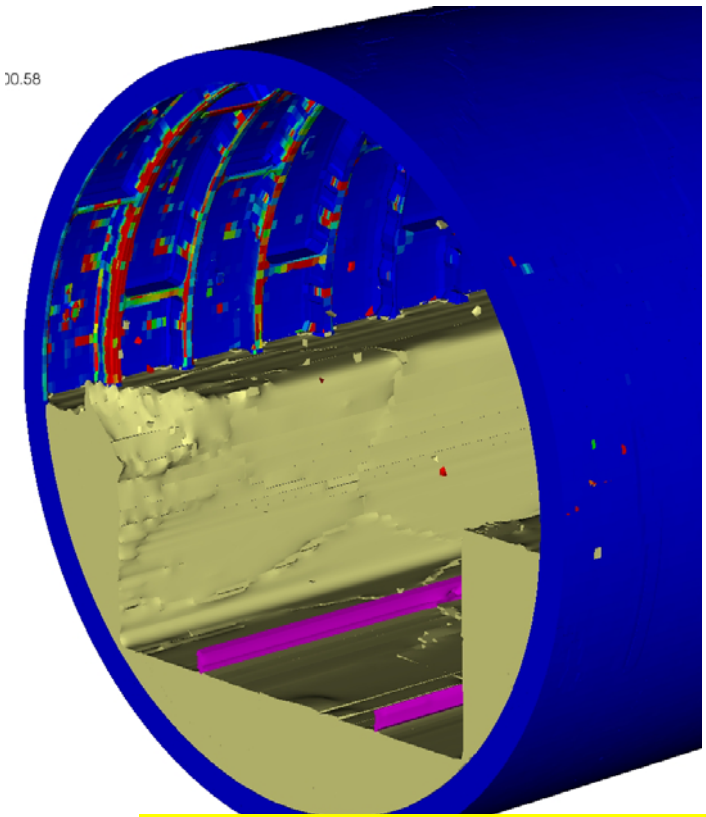
# Vulnerability Evaluation & Effected Mitigation (KV1)

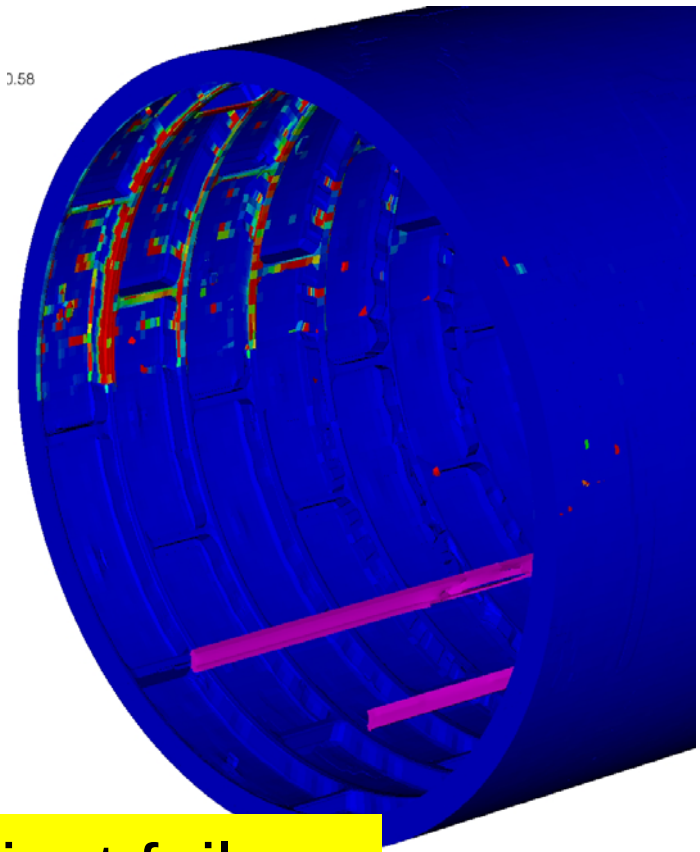
- **LLNL did systems vulnerability and upgrades assessment**
- **LLNL assisted stakeholder with mitigation**
- **Based on LLNL analysis stakeholder implemented countermeasures**



KV2

# Contact Threat with Standoff

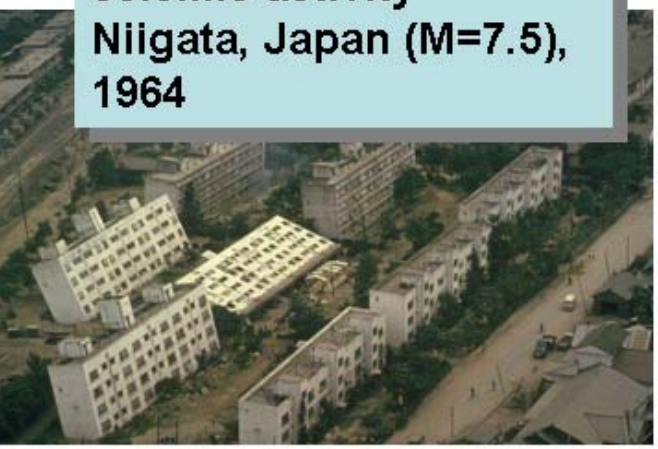


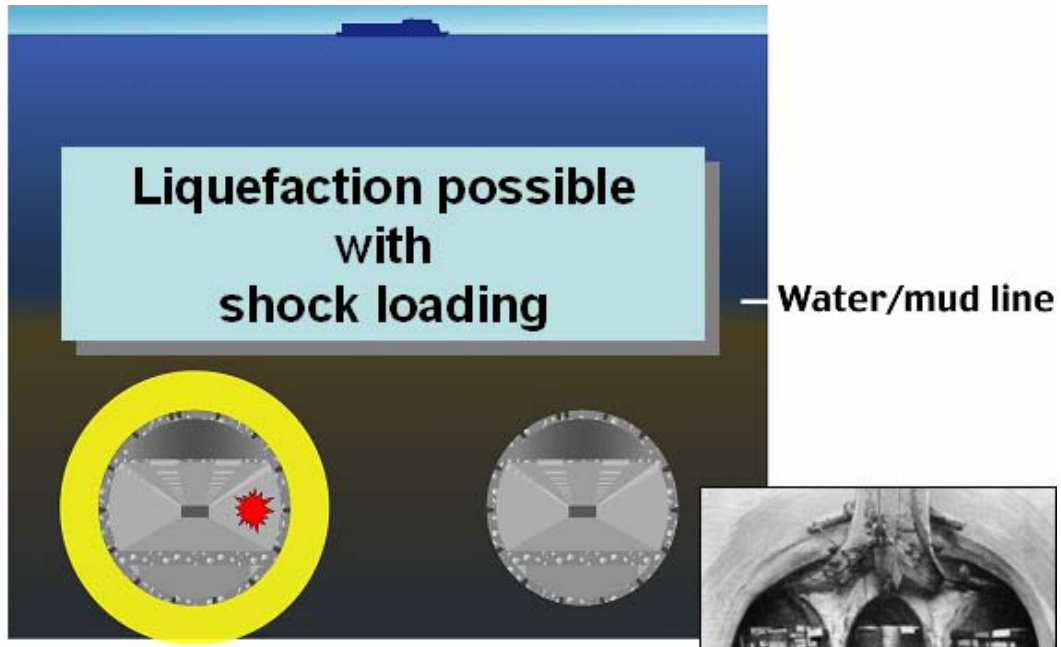


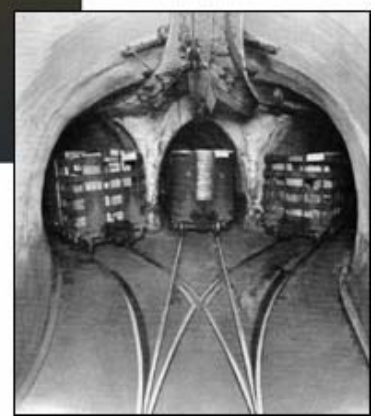
Standoff mitigates against failure.

# Causes and Consequences of Soil Failure

Question: What happens after breach occurs? Does the mud fail with resultant flow into breach?

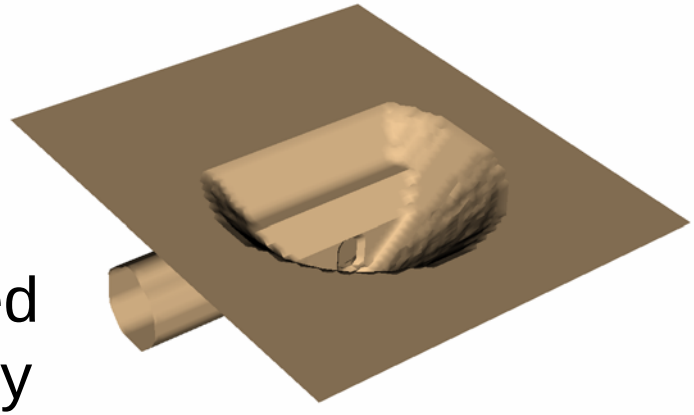


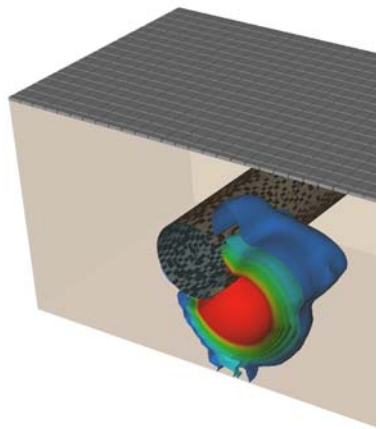



# Vulnerability Evaluation & Effected Mitigation (KV2)

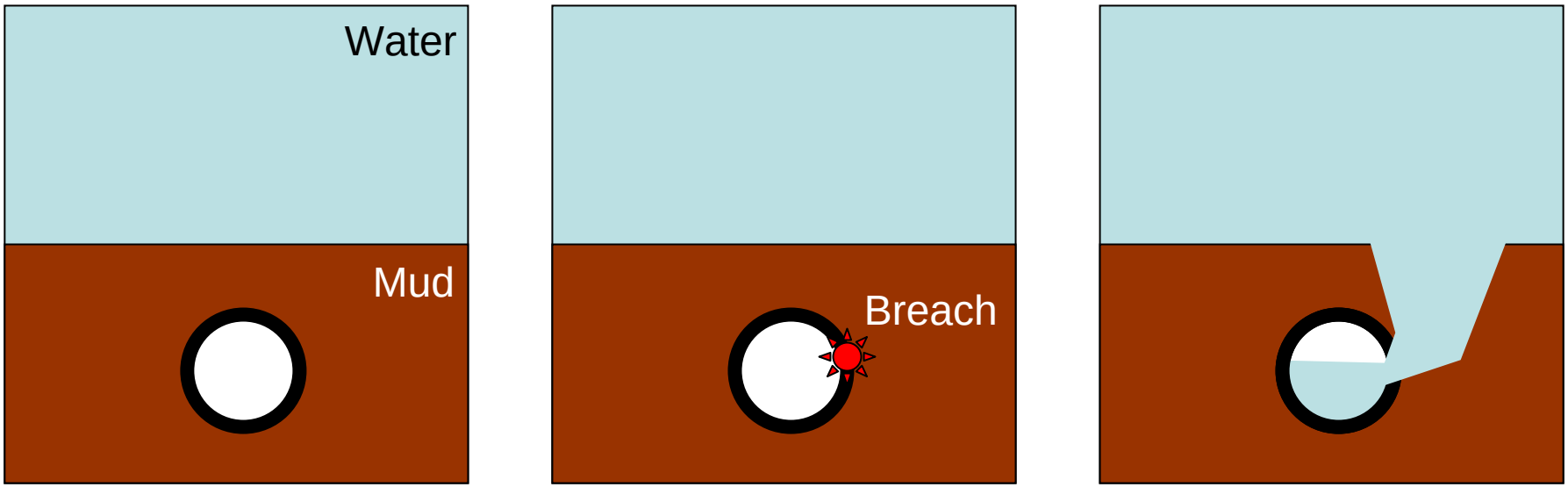
- KV2 tunnel structure summary
  - Stronger structures need enhancement of security & response
  - For weaker structures we work with stakeholder
    - on vulnerability bounding
    - on actionable mitigation strategies
    - On countermeasure assessment





# Strategies for Mitigating Consequence of Breach

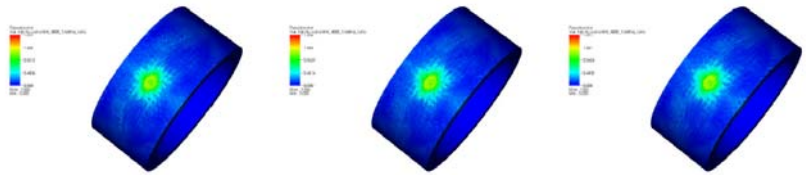
- Consider a submerged tunnel, possibly under a layer of mud:



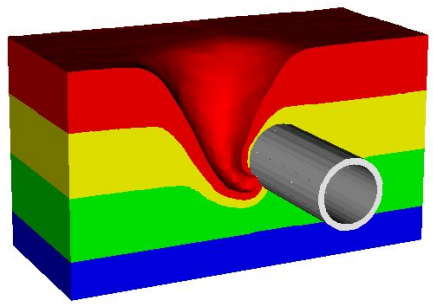

- Mitigation strategies:
  - Structural hardening – costly and disruptive
  - Stand-off – May not be practical
  - Alternative mitigation strategies – Cheaper, little or no disruption in service?

# Adopted a 2-stage approach: ALE3D and LDEC w/ Mud Model

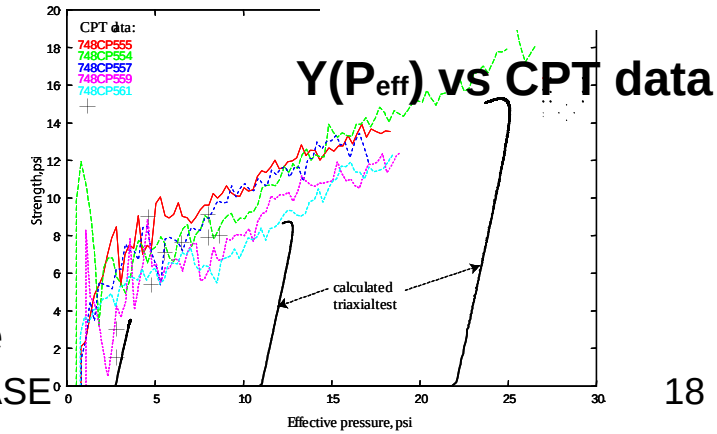
- ALE3D: Simulate milliseconds out to seconds
  - Structure modeled in detail
  - Timesteps are short
  - Mud/mat slide surfaces may develop numerical issues over long runtimes



- LDEC Smooth Particle Hydrocode (SPH): Simulate seconds to minutes
  - Quasi-incompressible approach to achieve larger timestep
  - Robust fully Lagrangian meshfree method
  - Soil can 'soften' and be of varying strength



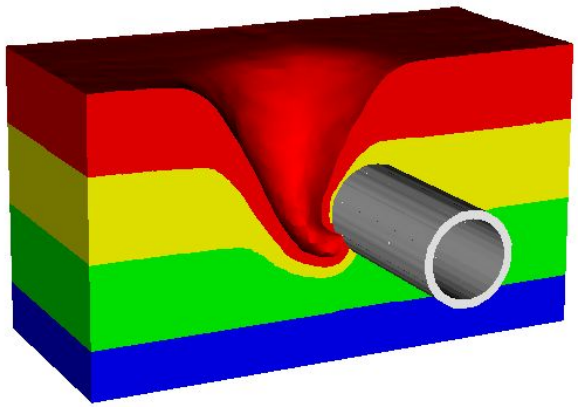
- Mud model for river sediment
  - Developed and used for both models
  - Based on effective stress theory
  - Reproduces CPT data
  - Valid for pressures 1bar-200 kbar
  - Can be used with wide range of equations of state




**$Y(P_{eff})$ vs CPT data**

# Coupling of Capability

University of California
Lawrence Livermore National Laboratory

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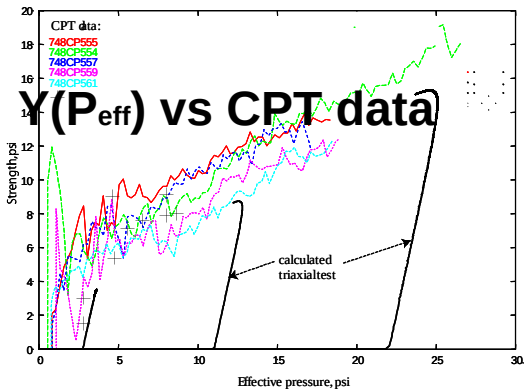


**Y(P$_{eff}$) vs CPT data**

# Coupling of Tools: Comparison of mud flow with experiment

University of California
Lawrence Livermore National Laboratory

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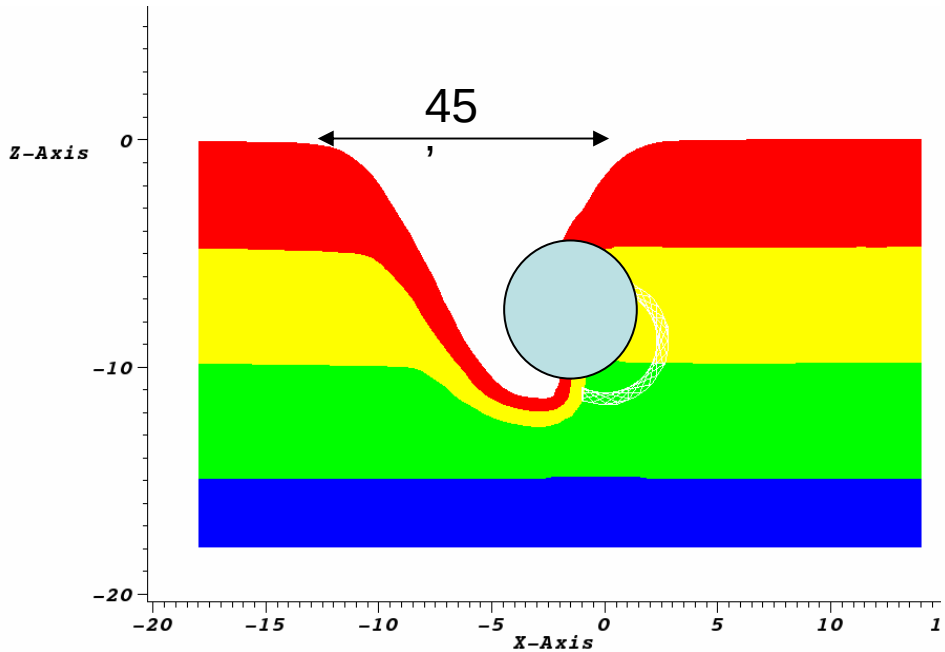


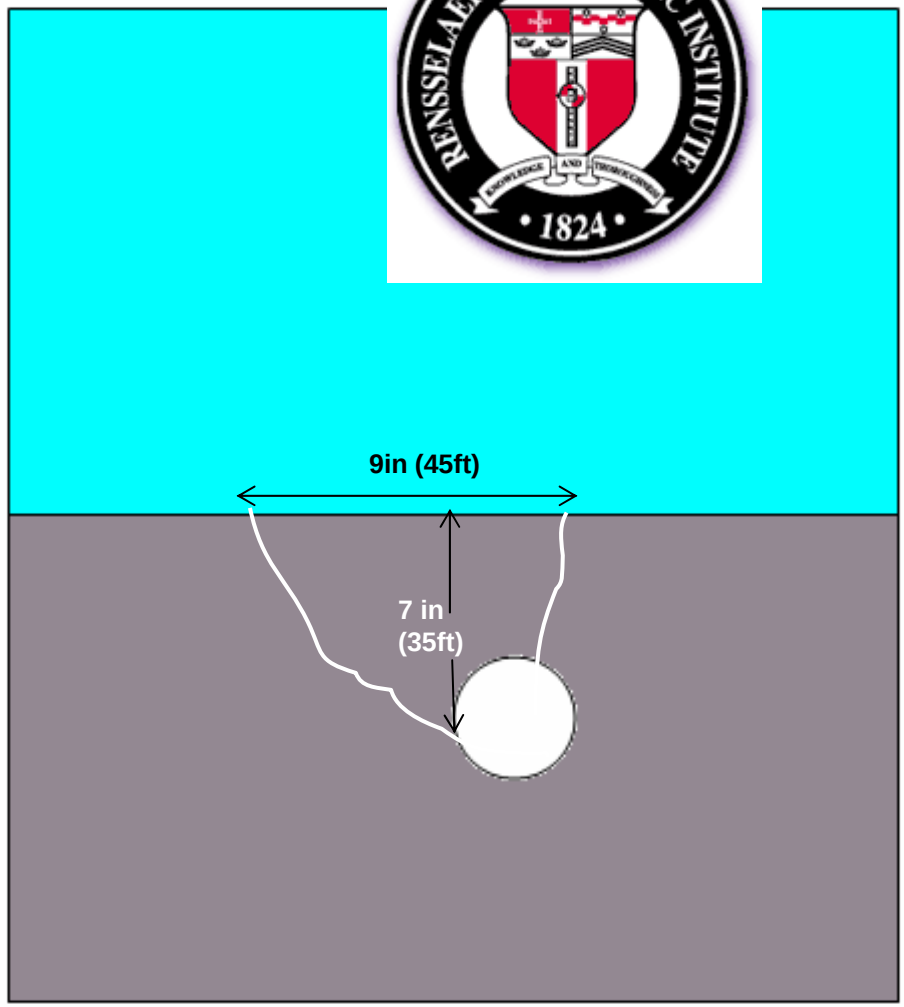

# Summary

- We do end-to-end systems analysis for infrastructure protection
- LLNL brings interdisciplinary subject matter expertise to infrastructure and explosive analysis
- LLNL brings high-fidelity modeling capabilities to infrastructure analysis for use on high performance platforms
- LLNL analysis of infrastructure provides information that customers and stakeholders act on