

Optimizing Cost & Time Effectiveness of Test & Evaluation Using Knowledge-Based Simulations



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Modeling & Simulation will never *replace* Test & Evaluation



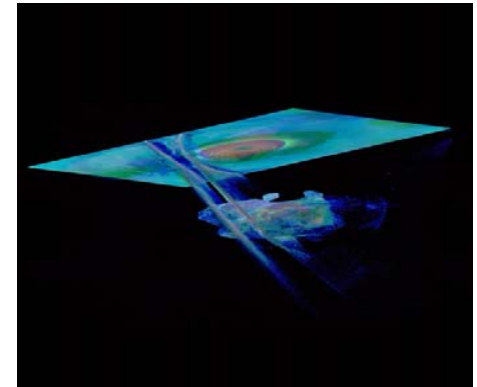
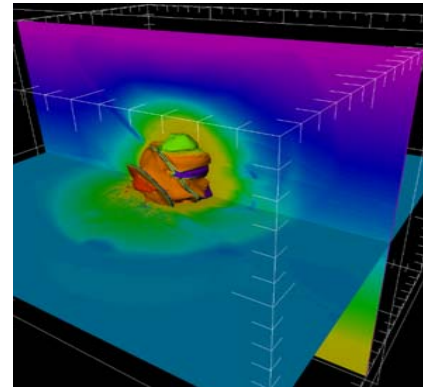
- There is no substitute for experience
- Even the most accurate simulations require understanding that is either obtained or validated by experiment
- Simulations that are not validated (VV&A) are about as useful as testing and evaluation techniques that are not validated

Intelligently applied, knowledge-based simulations can enhance the development and acquisition process

In 1992, the Department of Energy faced a perplexing new challenge



- **PRESIDENTIAL DIRECTIVE: Certify the performance, safety and reliability of the enduring nuclear deterrent WITHOUT TESTING.**



What are knowledge-based simulations?



Empirical Simulations

- *Describe* outcomes
 - Use fits or tables derived from data
 - For quick interpolations between data points when variances are intuitive

Knowledge-Based Simulations

- *Predict* outcomes
 - Use equations derived from understanding of governing mechanisms
 - For reasonable excursions beyond and between data points when variances aren't intuitive

Knowledge-based simulations can enhance test & evaluation in different ways



Design Tests

Where to “look”
What to “look for”
What to vary
Reduce risk for failure

Interpret Tests

Unravel confusing data sets and provide insight about the important phenomena that produce them

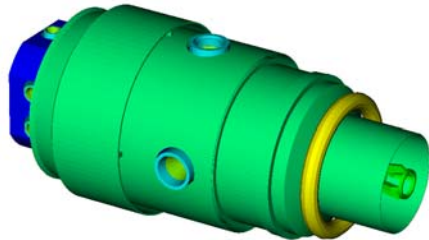
Supplement Tests

Provide insight where experiments are prohibitively expensive or physically impossible

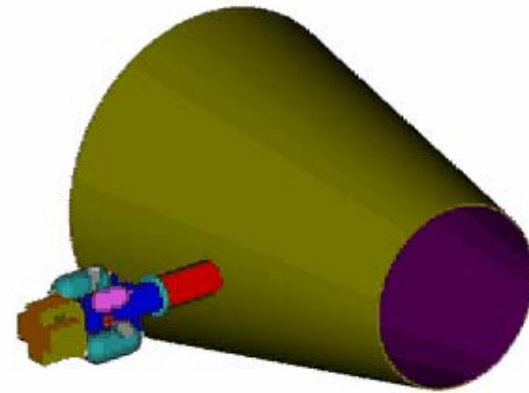
The missile defense community uses knowledge-based simulations to assess kinetic intercept lethality



Standard Missile -3 (SM-3, AEGIS)

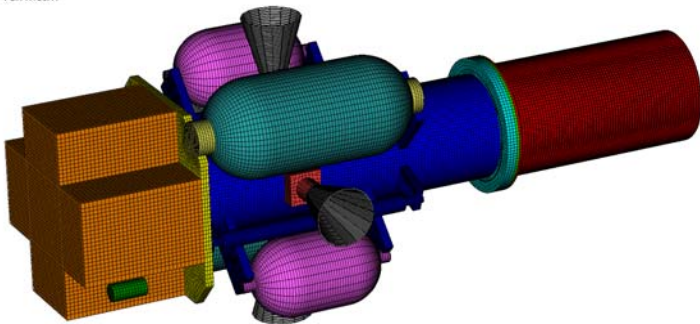


DB: ekv1.vg.mtl
Cycle: 0 Time: 0



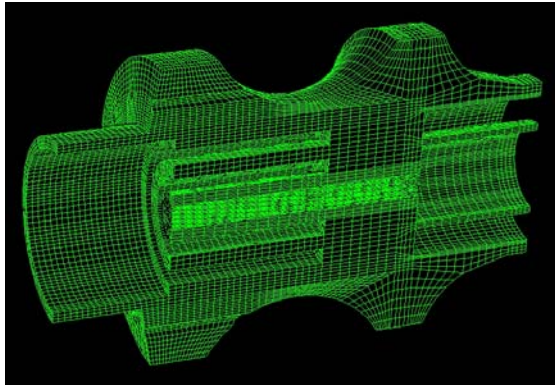
Exoatmospheric Kill Vehicle (EKV, GMD)

rvn01
Vor: mesh1



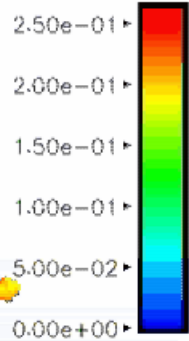
**Simulated Ground-Based Midcourse
Defense (GMD) Intercept**

Debris patterns can be correlated with real-time hit assessment immediately following a flight test



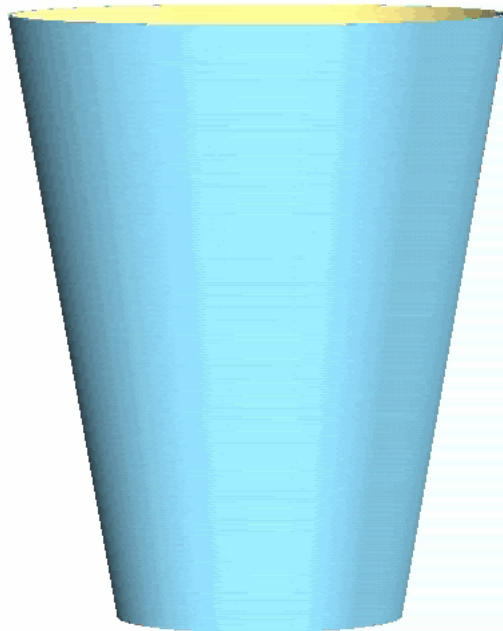
Global Maximum: 3.10e-01, Nodal 19676
Global Minimum: 0.00e+00, Nodal 64213
Displacement Scale: 1.0/1.0/1.0

Velocity Magnitude



Materials

- 1 ■
- 2 ■
- 3 ■
- 4 ■
- 5 ■



fr10h: 6.8 km/s
t = 0.00000e+00

fr10h: 2 km/s
t = 0.00000e+00



Missile intercept simulations contribute in all three categories



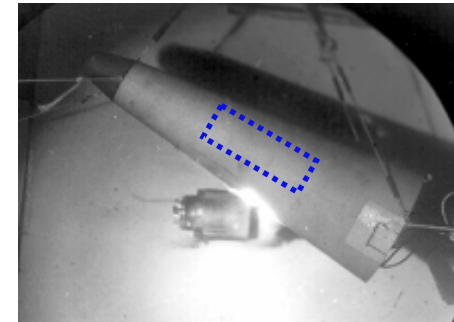
Design of Experiments

Full-Scale Sled Track Test

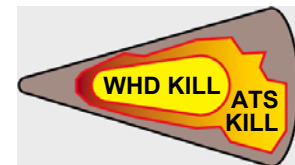


Interpretation of Experiments

Scaled Light Gas Gun Test



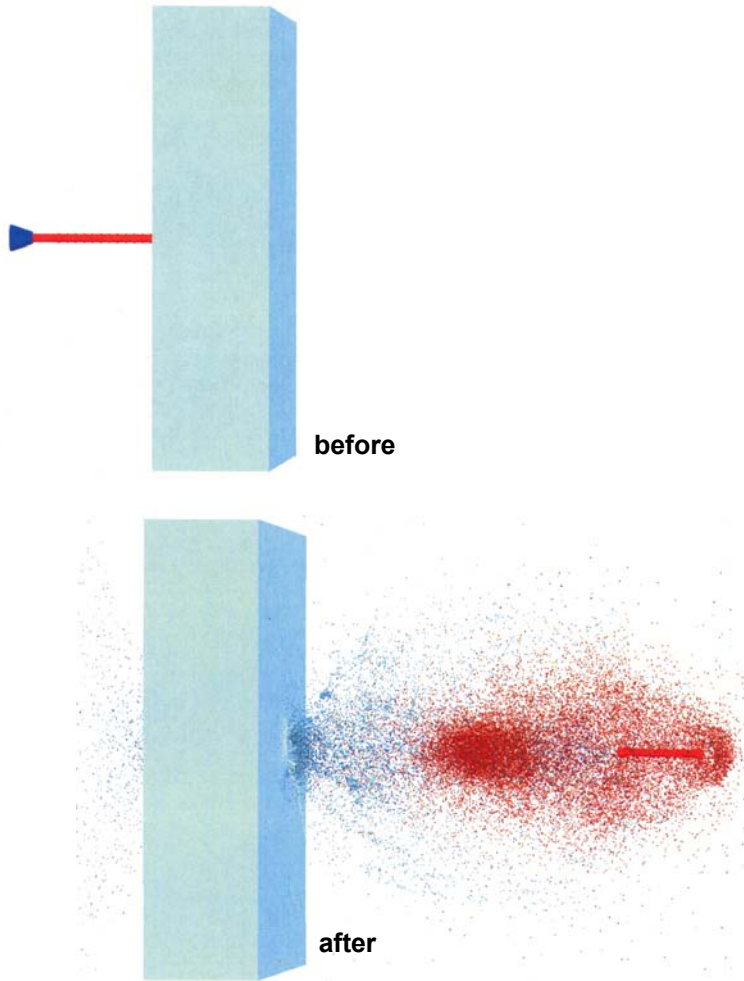
Supplement Experiments



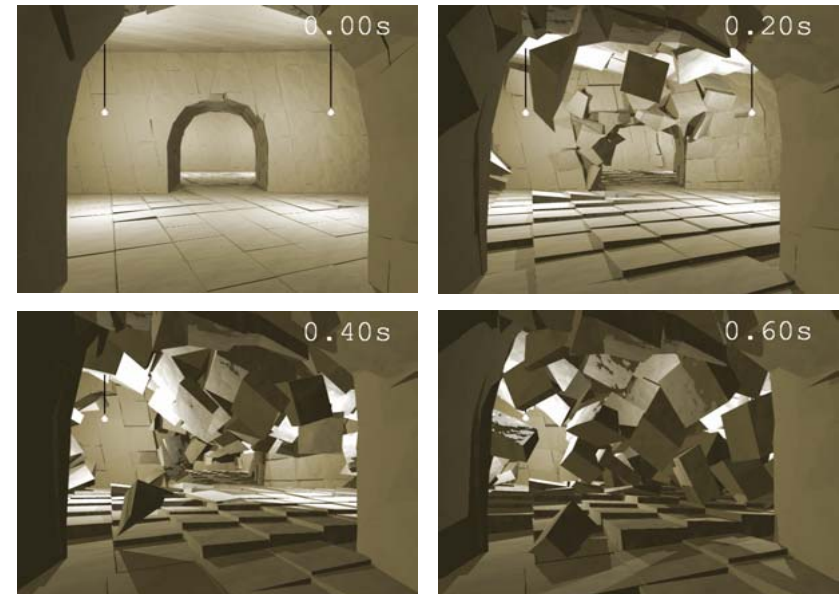
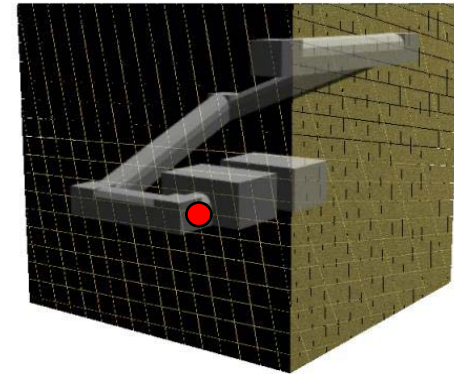
Penetration continues to be an important mechanism in weapon lethality



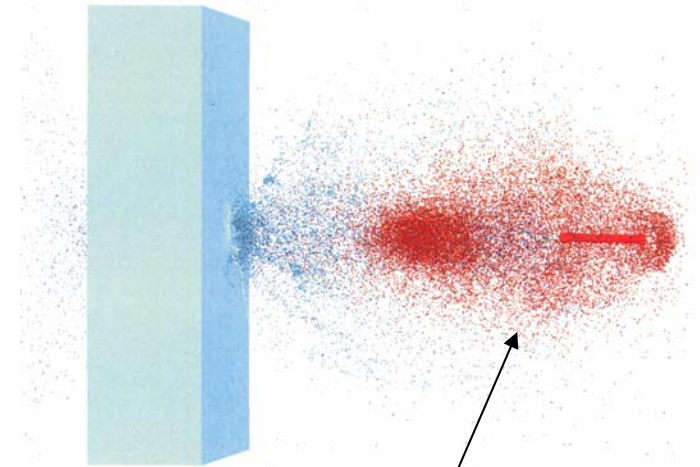
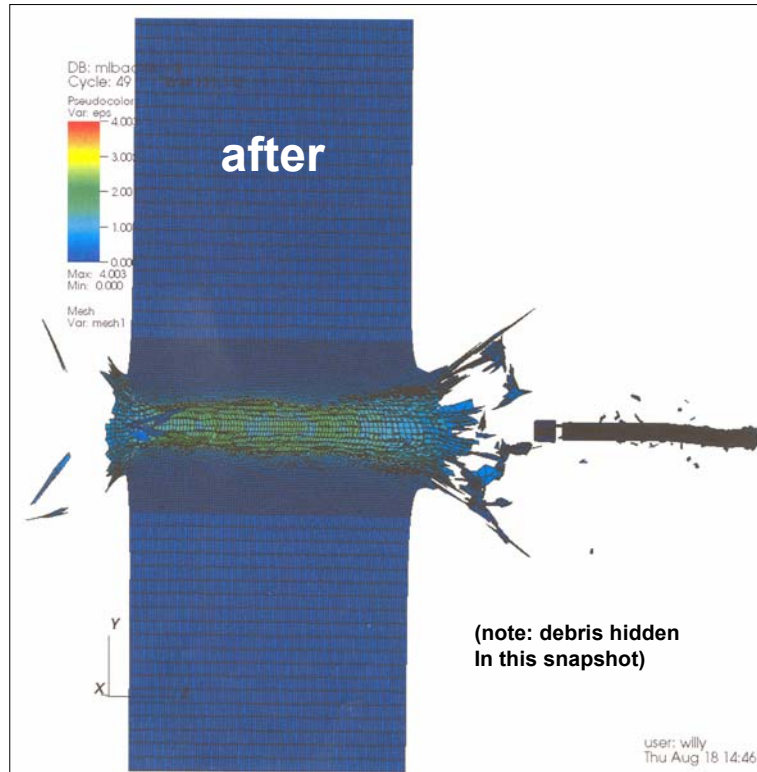
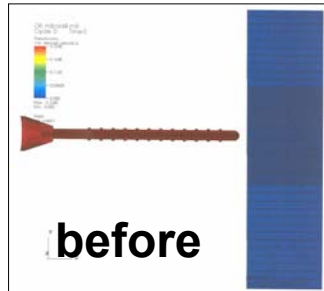
Penetration of Armor



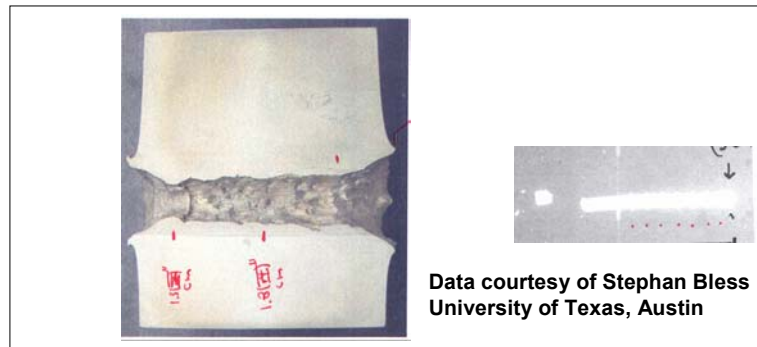
Defeat of Hard & Deeply Buried Targets



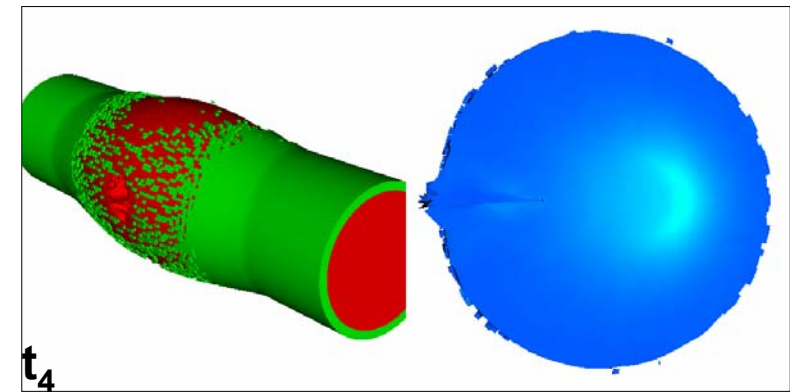
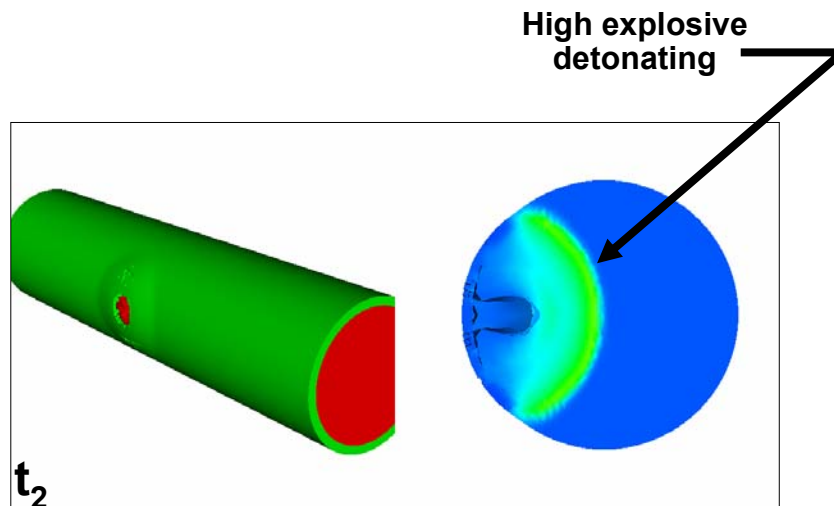
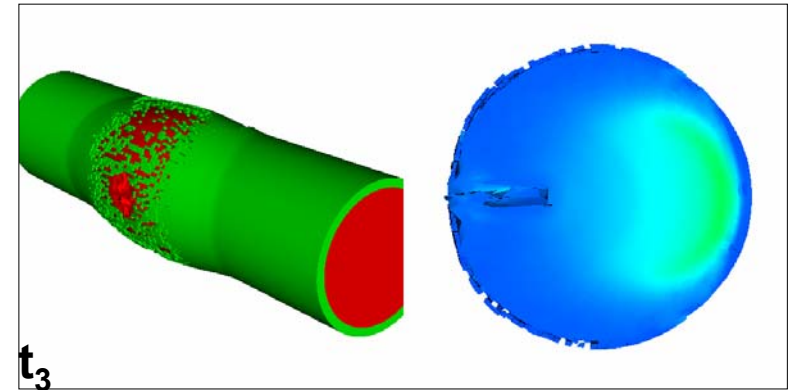
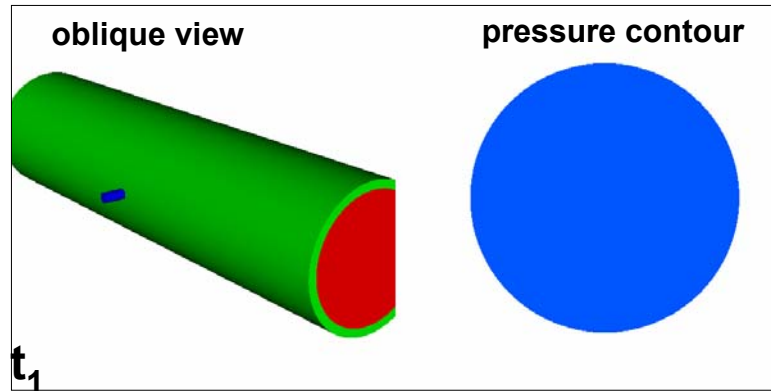
Predicting lethality requires predicting debris



This debris is usually what kills



Generating and propagating fragments is necessary to assess collateral effects

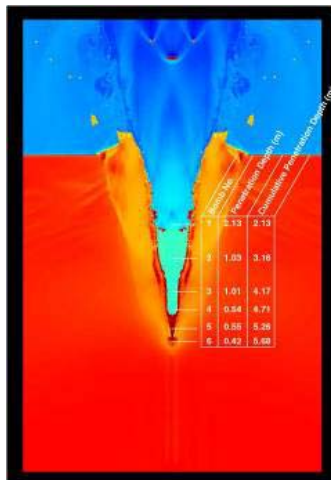


Ground shock (lethality) is significantly enhanced in a buried detonation

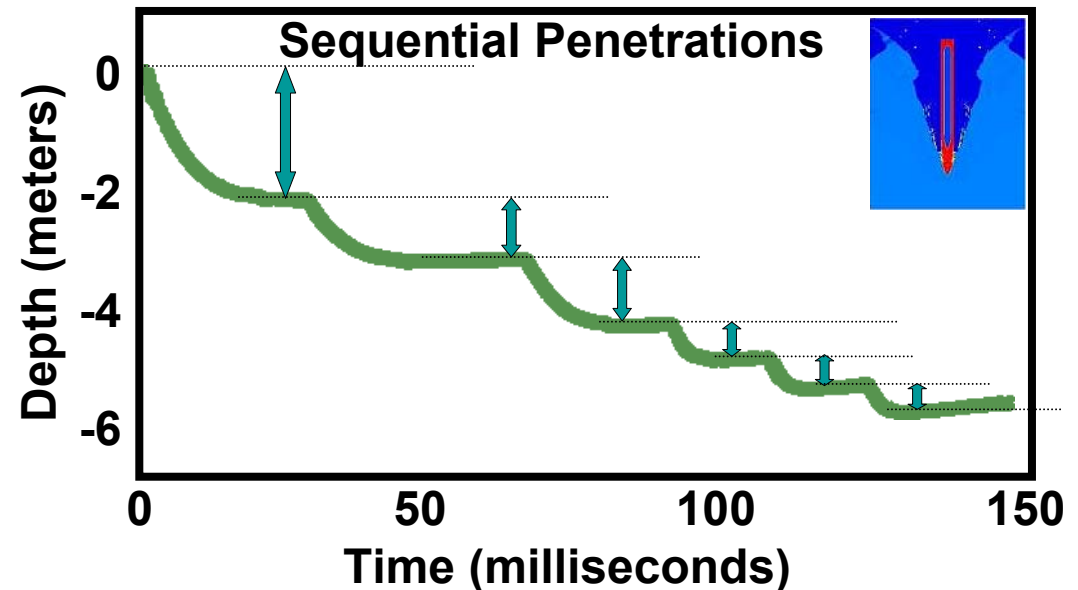


–BLU 116 Advanced Unitary Penetrator

- Length: 2.4 m
- Diameter: 25.4 cm
- Thickness: 50 mm
- Weight: 770 kg
- HE weight: 65 kg



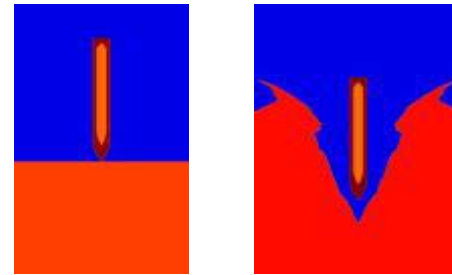
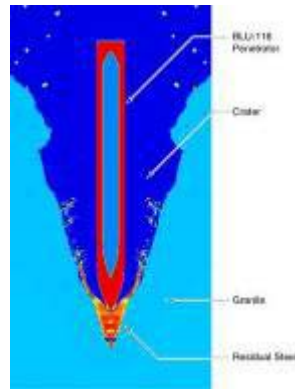
- Consider the scenario of sequentially delivered penetrators
- Penetration is less effective with successive attempts
- **Can this process be optimized?**



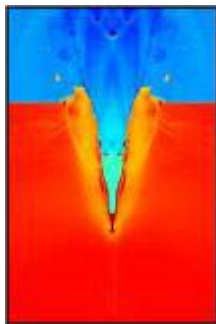
Insight gained from knowledge-based simulations suggests a modified approach



“Clearing”
bomb debris
from the crater
led to a factor of
1.5 increase in
penetration



Penetration at the
surface is **4** times
deeper than penetration
inside a crater.



Penetration depth in shock-conditioned granite
was **3** times greater than it was in virgin rock

**Alternating penetrators with conventional bombs
may be more effective**

Knowledge-based simulations provide true value for defense acquisition



- **Though M&S cannot replace T&E, they provide enhancements by**
 - **Optimizing the design of developmental and operational tests**
 - **Provide guidance in interpreting the results**
 - **Augment data sets when a test-only approach is cost-prohibitive, time-prohibitive or physically impossible**
- **These enhancements permit an additional means for exploring alternatives, modifications and “what if’s”**
- **Intelligently applied, knowledge-based simulations can accelerate discoveries and minimize risks in the development process**