NUMERICS

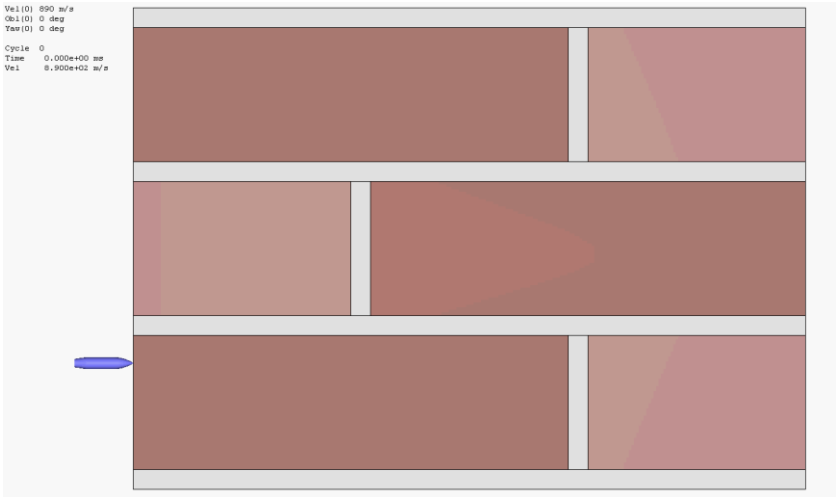
PS3D

Expert System for the Penetration Simulation of 3D Trajectories

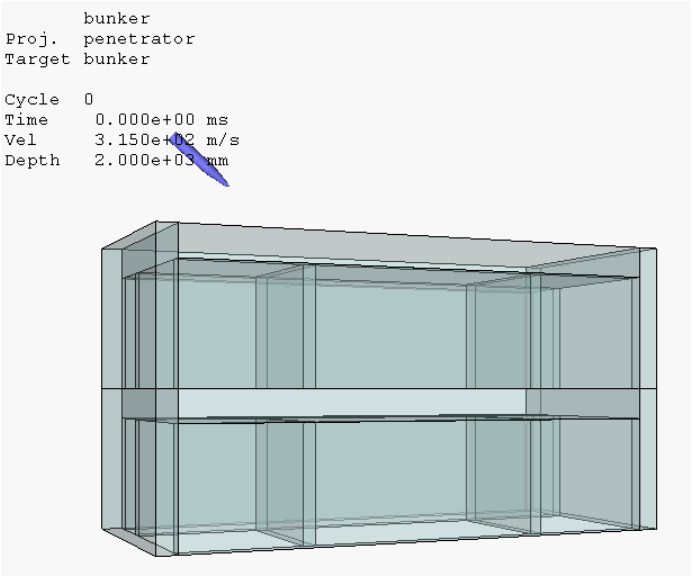
Product information

PS3D Overview

The engineering software PS3D was developed for the study of the penetration process of rigid and deforming penetrators in geological and building materials.



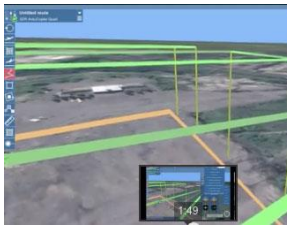
Armor-piercing rifle muition penetrating a mud-brick wall



Bunker-buster attacking an underground structure

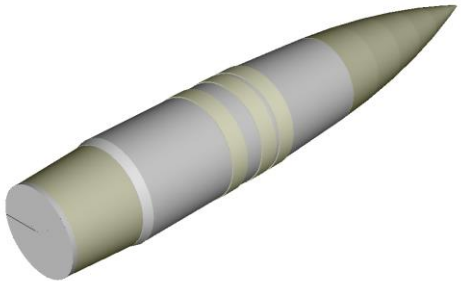
PS3D Overview

Mission Planning

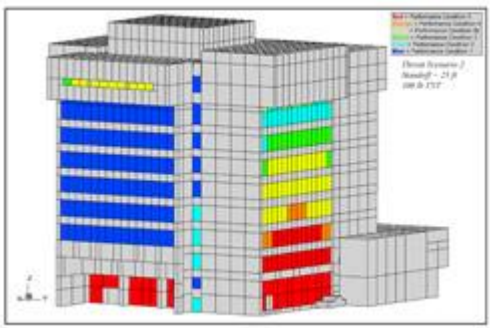


Source: www.defense-update.com, www.directionsmaq.com

Projectile / Penetrator Design



V/L Analyses



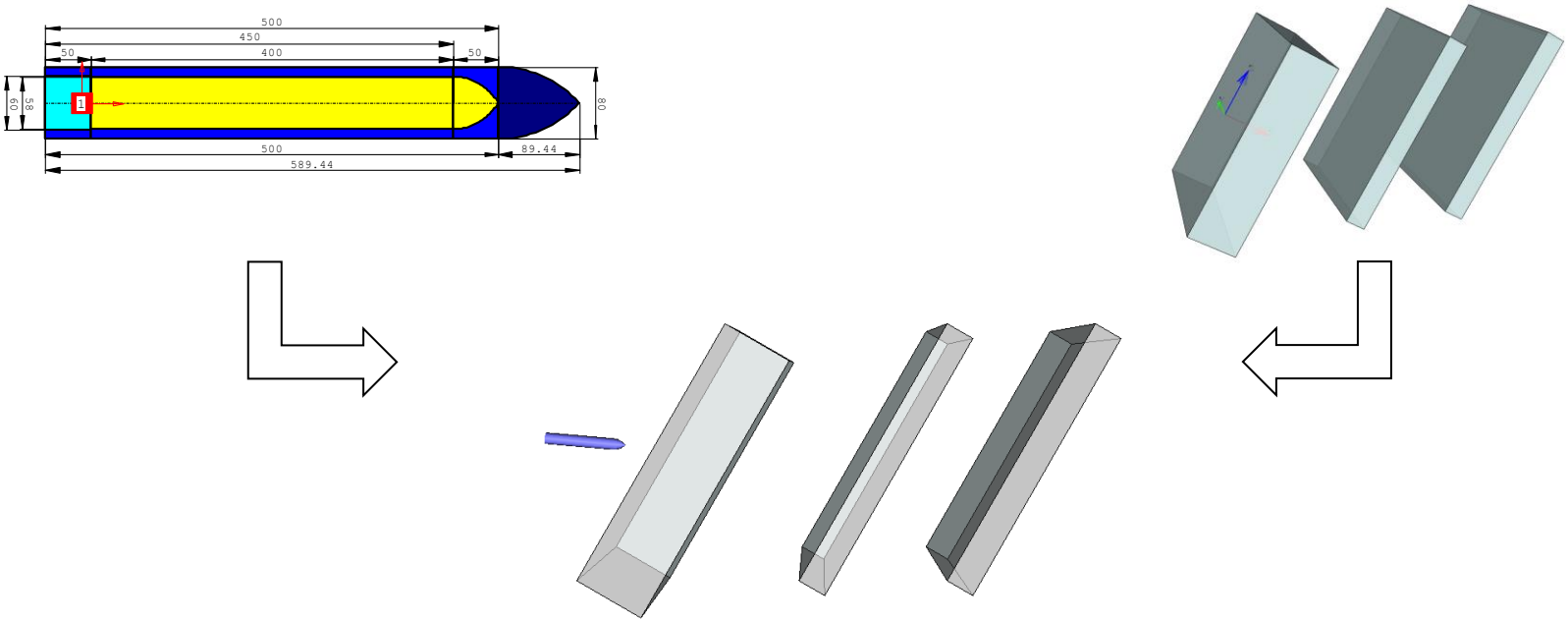
Source: www.ara.com

Protection Layout

Source: www.structural.net

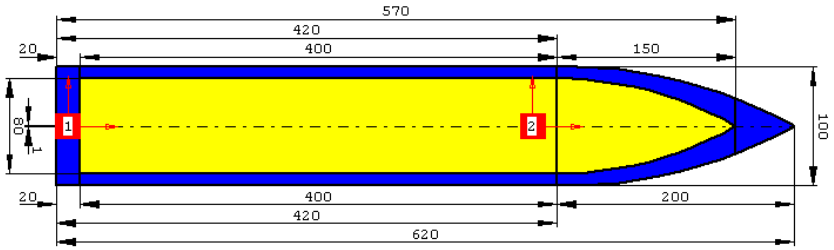
PS3D Overview

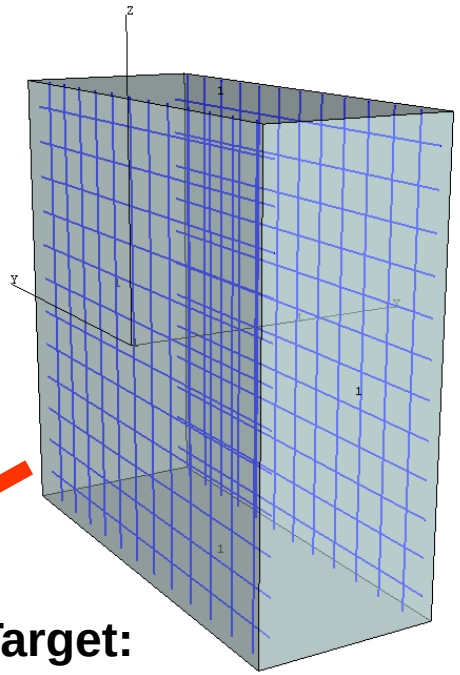
- three-dimensional (3D) finite difference code
- applies a differential area force law (DAFL)
- calculate projectile trajectories, deformations and sensor signals
- CPU time frame between seconds and a few minutes



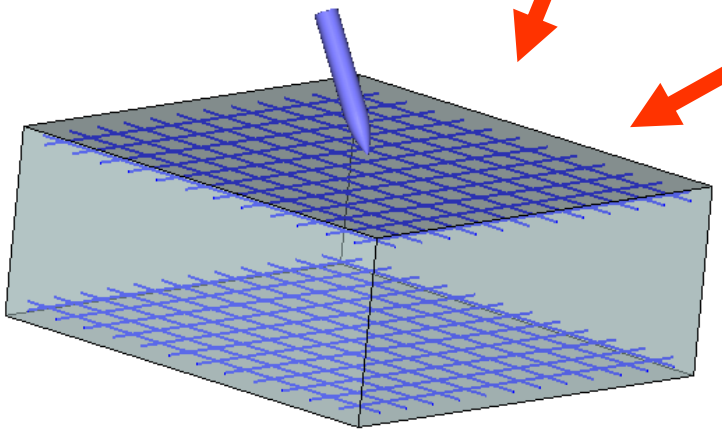
PS3D Overview

Principle of Modeling





Projectile:
geometry, materials,
control parameter,
sensor information, etc.



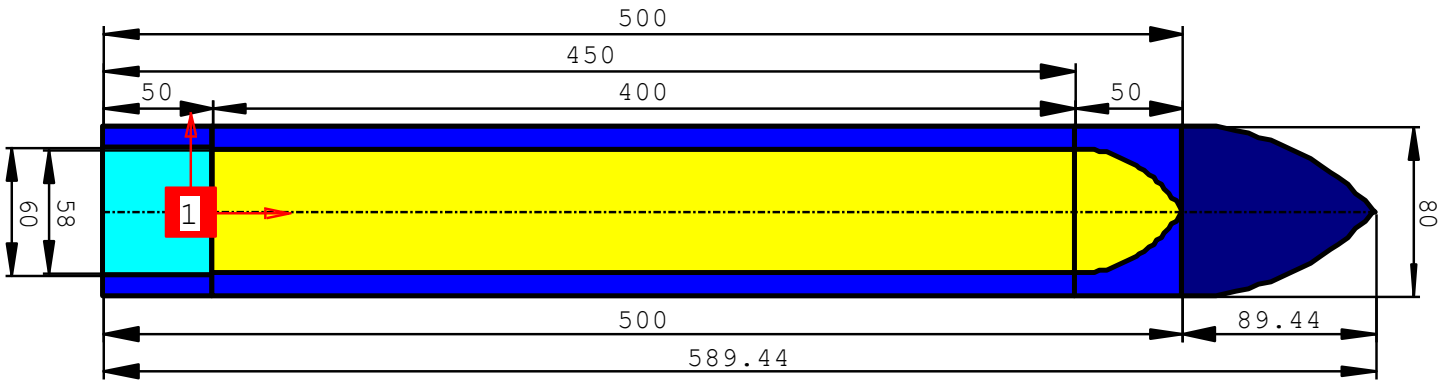
Target:
contains geometry,
materials, amount of
blocks, hole profile, etc.

Simulation:
simulation control parameters,
analysis options (rigid or elastic-plastic
for projectile), encounter information,
initial values, precursor charge (optional)

PS3D Overview

Projectile Modeling

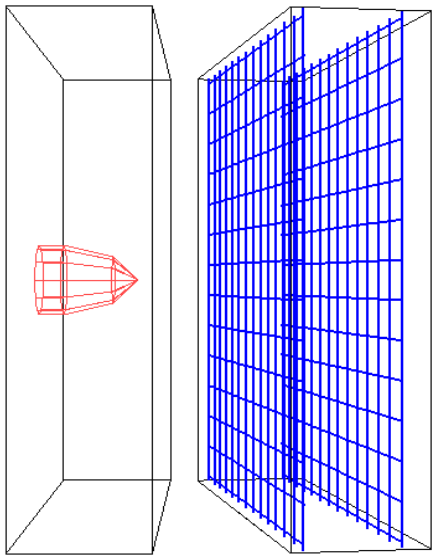
- series of axis-symmetric sections with casing and filler
- cylinder, cone, ogive and inverse ogive
- arbitrary number of accelerometers

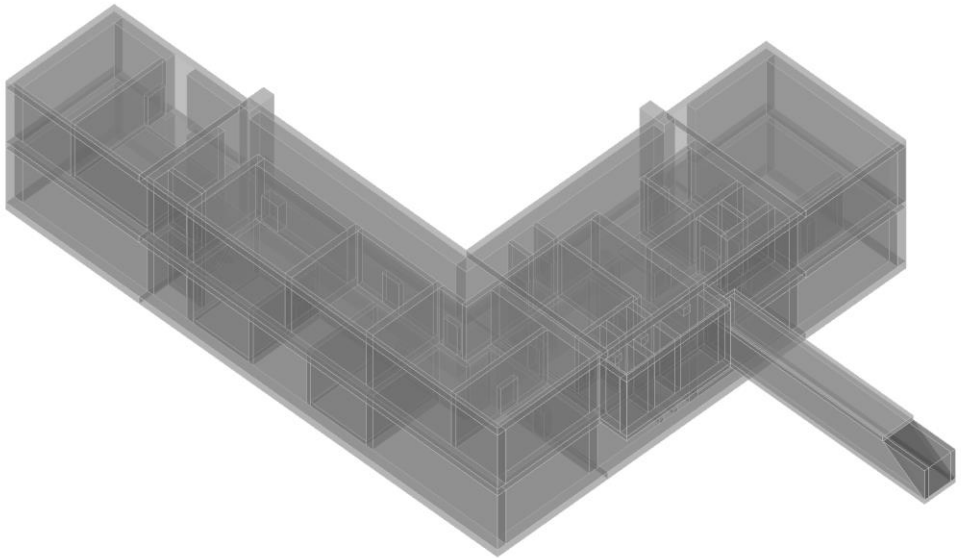


PS3D Overview

Target Modeling

- rectangular blocks (arbitrarily positioned and / or rotated)
- explicit reinforcement modeling
- definition of holes (e.g. from a pre-cursor shaped charge)

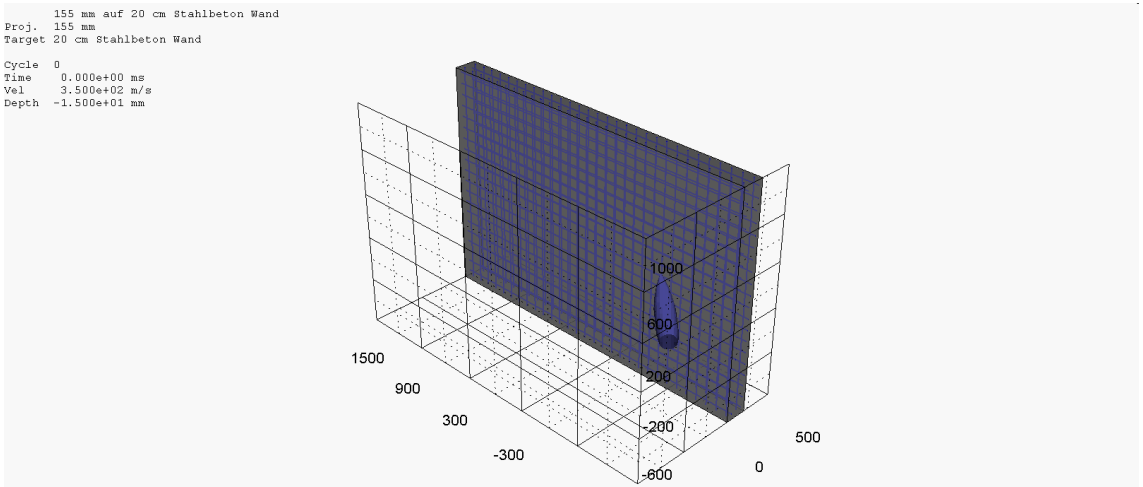




PS3D Overview

Scenario Setup & Analysis

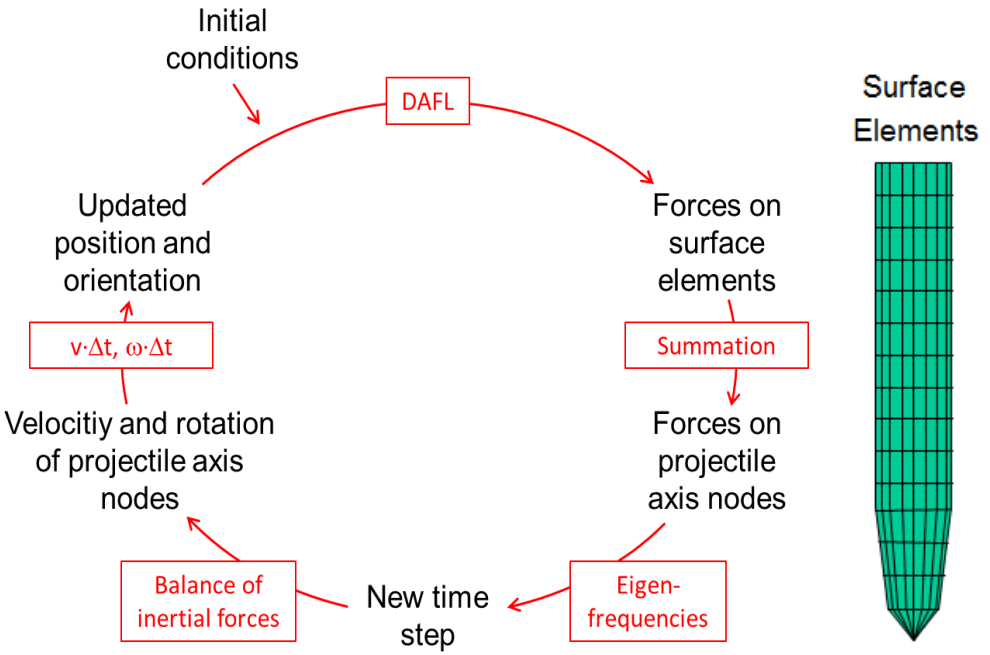
- arbitrary positioning of penetrator and target
- rigid body or beam model calculation
- initial conditions including spin and tumbling rates
- single shot or parametric studies
- Monte Carlo simulations for the hit point



PS3D Overview

PS3D calculation cycle

- 3D DAFL solved in a FD scheme
- Discretization of Projectile surface
- DAFL to determine forces on each element
- Forces are summed up
- New velocity and/or rotation rate
- Projectile position advanced by 1 time step



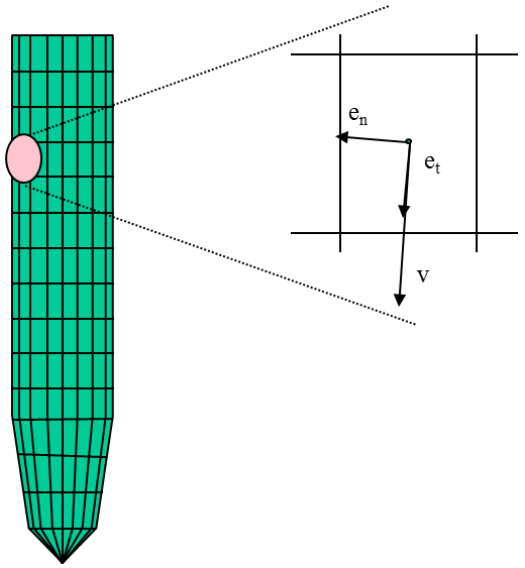
PS3D Overview

Targets are considered to be static, they do neither deform nor change their properties during penetration.

The behavior of the target is completely defined by the forces it exhibits on the surface of the projectile:

$$\vec{f}_S = \sigma_n \cdot \vec{n} + \sigma_t \cdot \vec{t}\left(\vec{v}, \vec{n}\right)$$

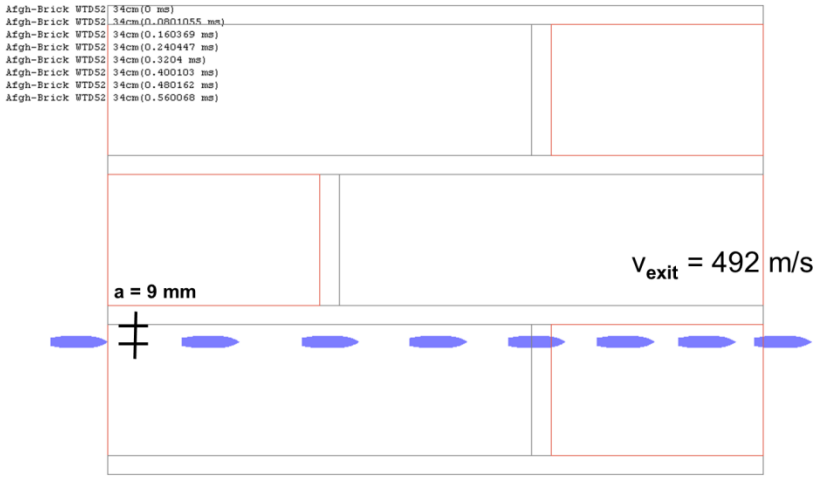
$\vec{f}_S$	=	force per unit area acting on the projectile due to interaction with the target
σ_n	=	normal stress at the projectile surface
σ_t	=	tangential stress at the projectile surface
$\vec{n}$	=	unit vector normal to the surface
$\vec{v}$	=	local velocity at the projectile surface
$\vec{v}_n = \vec{n} \cdot \left(\vec{v} \circ \vec{n}\right)$	=	normal velocity at the projectile surface
$\vec{v}_t = \vec{v} - \vec{v}_n$	=	tangential velocity at the projectile surface
$\vec{t}\left(\vec{v}, \vec{n}\right) = 0$	=	null vector, if $\vec{v}_t = 0$
$\vec{t}\left(\vec{v}, \vec{n}\right) = \frac{\vec{v}_t}{\lvert\vec{v}_t\rvert}$	=	unit vector tangential to the surface, if $\vec{v}_t \neq 0$



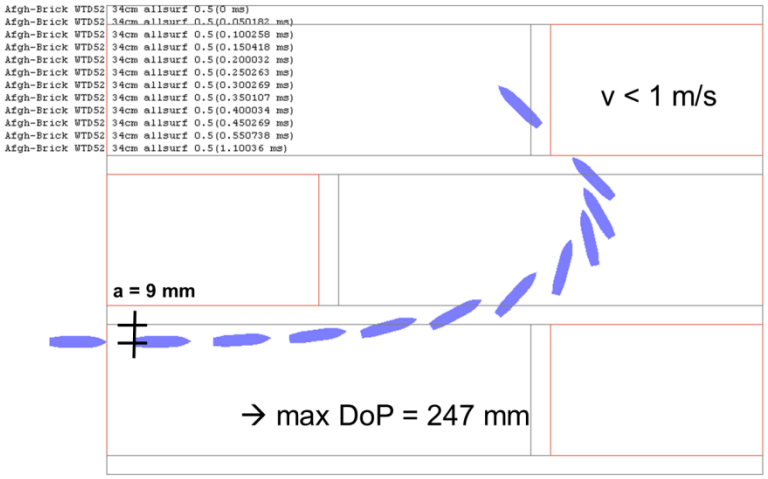
PS3D Overview

Surface Effects

The vicinity to a target block surface can have significant influence on the penetration resistance and thus on the projectile trajectory, velocity, etc.



without consideration of surface effects



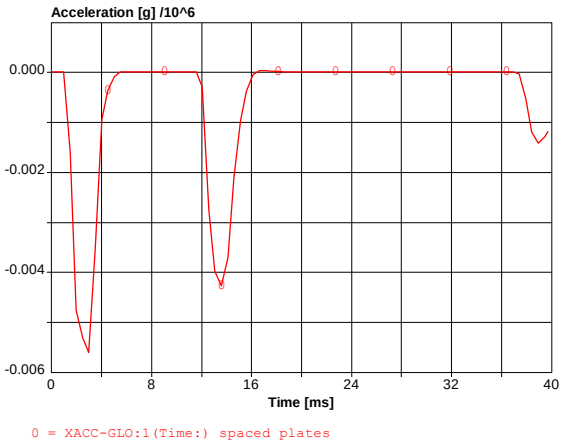
with consideration of surface effects

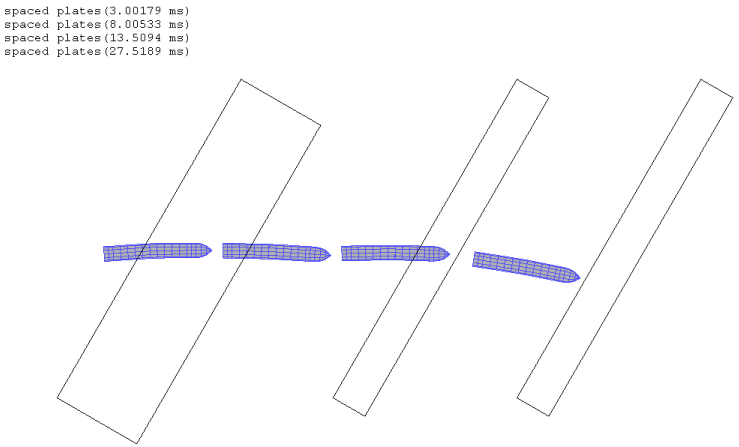
experimentally proven result

PS3D Overview

Post-Processing

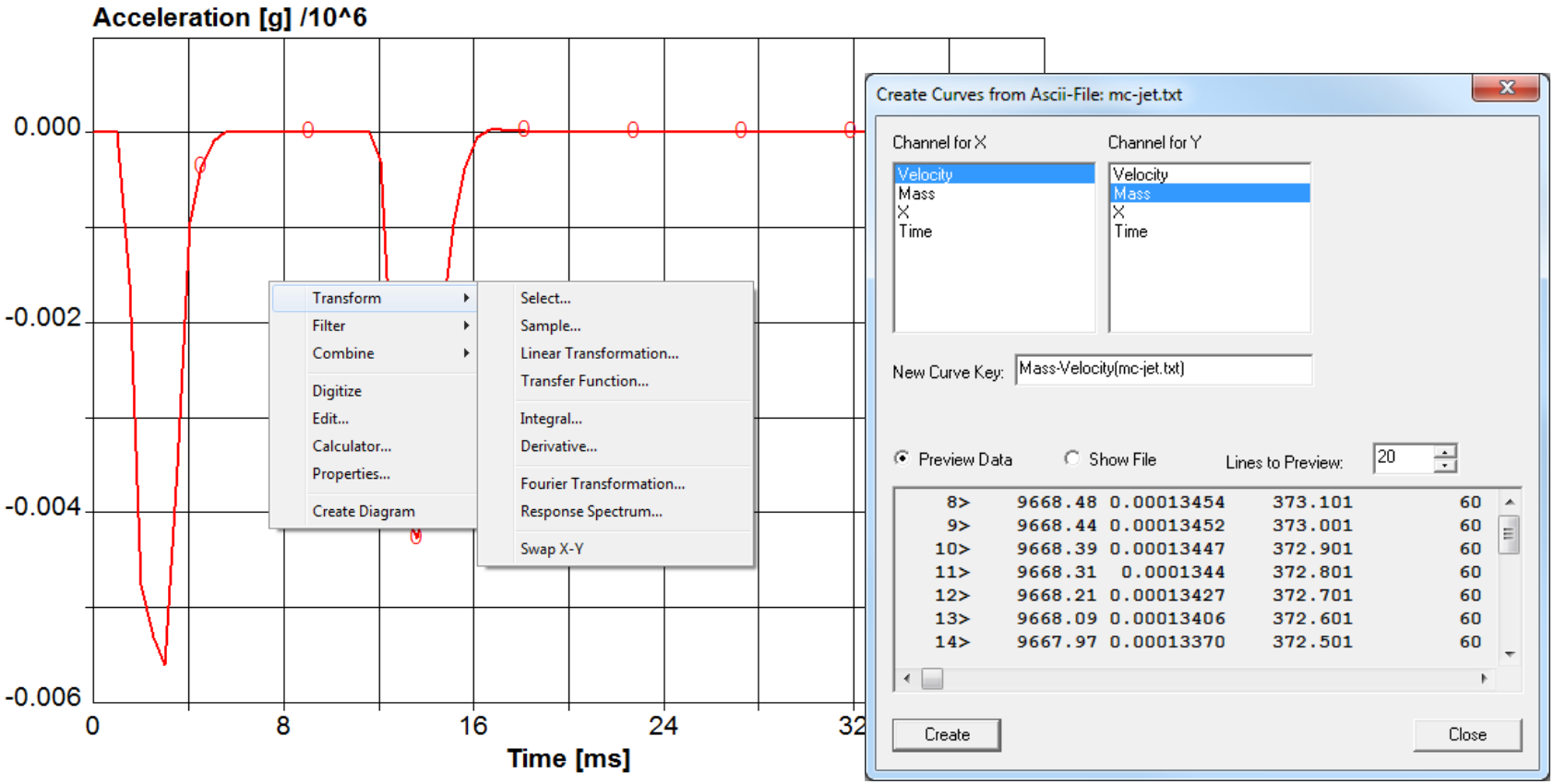
- depth of penetration / residual velocity
- sensor (accelerometer) data time-histories
- elastic / plastic strain, stresses, forces and momenta profile plots for each time of the penetration process (beam model)
- display and overlay of single states of the simulation
- animation and movie creation





PS3D – Features

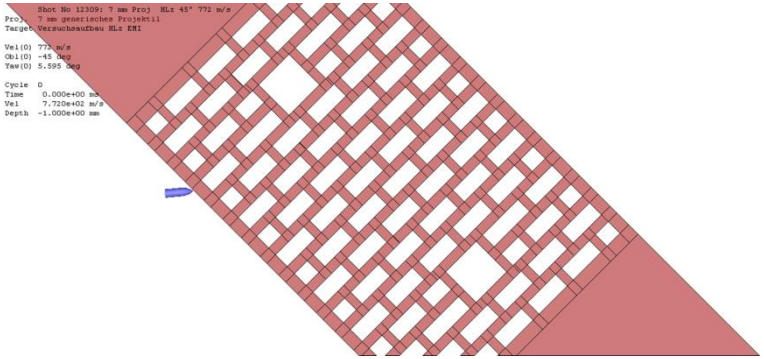
Post-Processing



0 = XACC-GLO:1(Time:) spaced plates

PS3D – Application Example

AP rifel projectile perforating a hollow brick (experiment by EMI)



Impact conditions:

- v_0 = 772 m/s
- 45° impact angle
- -5.1° yaw
- -2.3° pitch

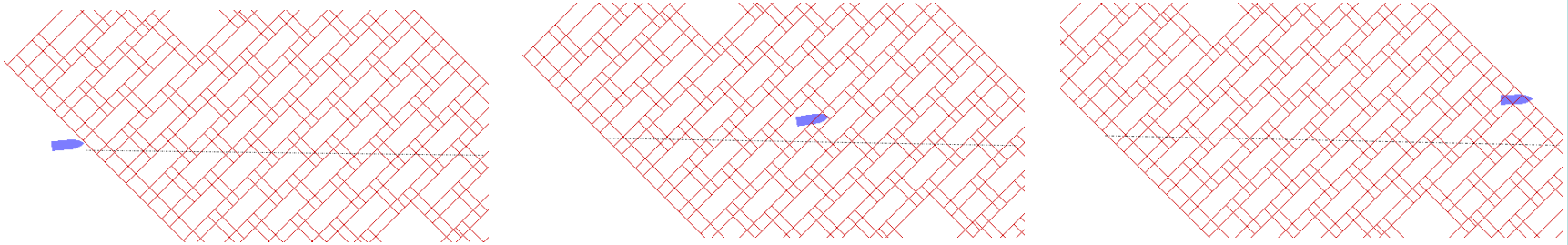
PS3D – Application Example

AP rifel projectile perforating a hollow brick (experiment by EMI)

t = 0 µs

t = 720 µs

t = 1440 µs



Penetration process and projectile trajectory match exactly

(Calculation time: < 10 sec.)

Summary

- PS3D permit to generate good results while requiring only little calculation time → standard for conceptual design, test layout, V/L analyses and mission planning
- PS3D is characterized by outstanding performance and is unique on the commercial market
- PS3D is fully validated by open literature experimental data
- NUMERICS engineering tools are used by industry and governmental agencies in more than 20 countries world-wide

→ PS3D is offered either as stand-alone software or as a part of customized tailored solutions

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