

Initiation Controlled Multimode Warheads



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Outline

- Introduction & Motivation
 - Multimode warhead

- Theory
 - Computational tool: ANSYS AUTODYN®
 - Underlying physics

- Simulation of an Initiation Controlled Multimode Warhead
 - EFP Mode
 - Jetting Mode
 - Fragmentation Mode

- Summary

Motivation

- Conventional HE warhead types (examples)

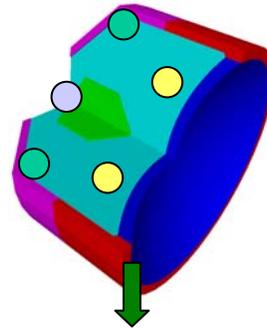
| Warhead | Penetration performance | Standoff | Focus |
|---------------|--------------------------|-------------------------|-----------------|
| SC | High (≥ 10 CD) | Low (~ 6 CD) | Directed |
| EFP | Medium (≥ 1 CD) | High (≥ 150 m) | Directed |
| Fragmentation | Low | Medium | Omnidirectional |

Objective 

1 single multimode warhead that can switch between the three different modes

Motivation

single charge
(e.g. EFP)



multiple points of
initiation

EFP Mode



hard targets
large standoff



e.g. (main battle) tank

Jetting (SC) Mode

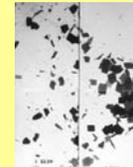


hard targets
small standoff



e.g. main battle tank

Fragmentation Mode



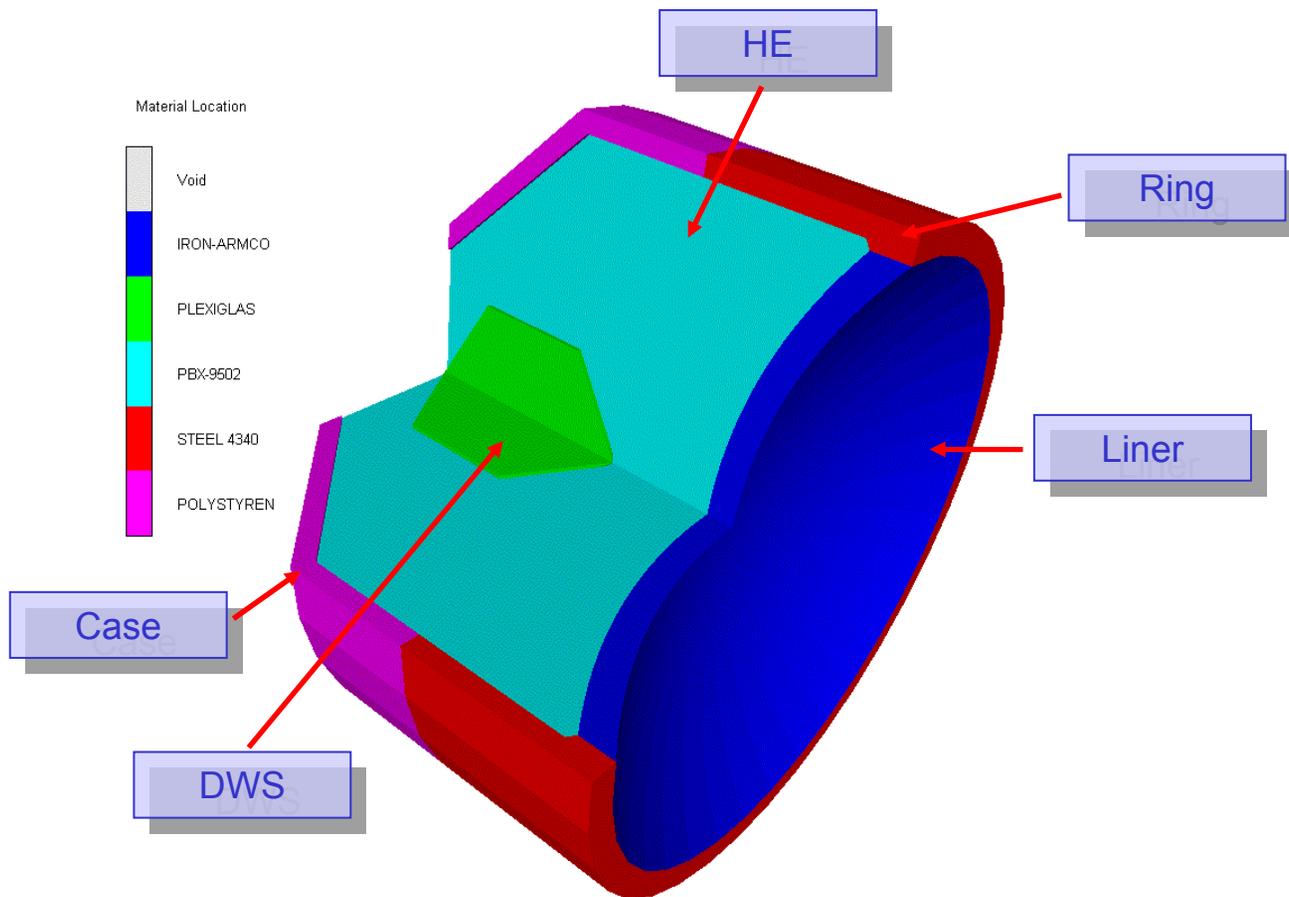
semi hard /
soft targets
medium
standoff



e.g. truck, radar, etc.

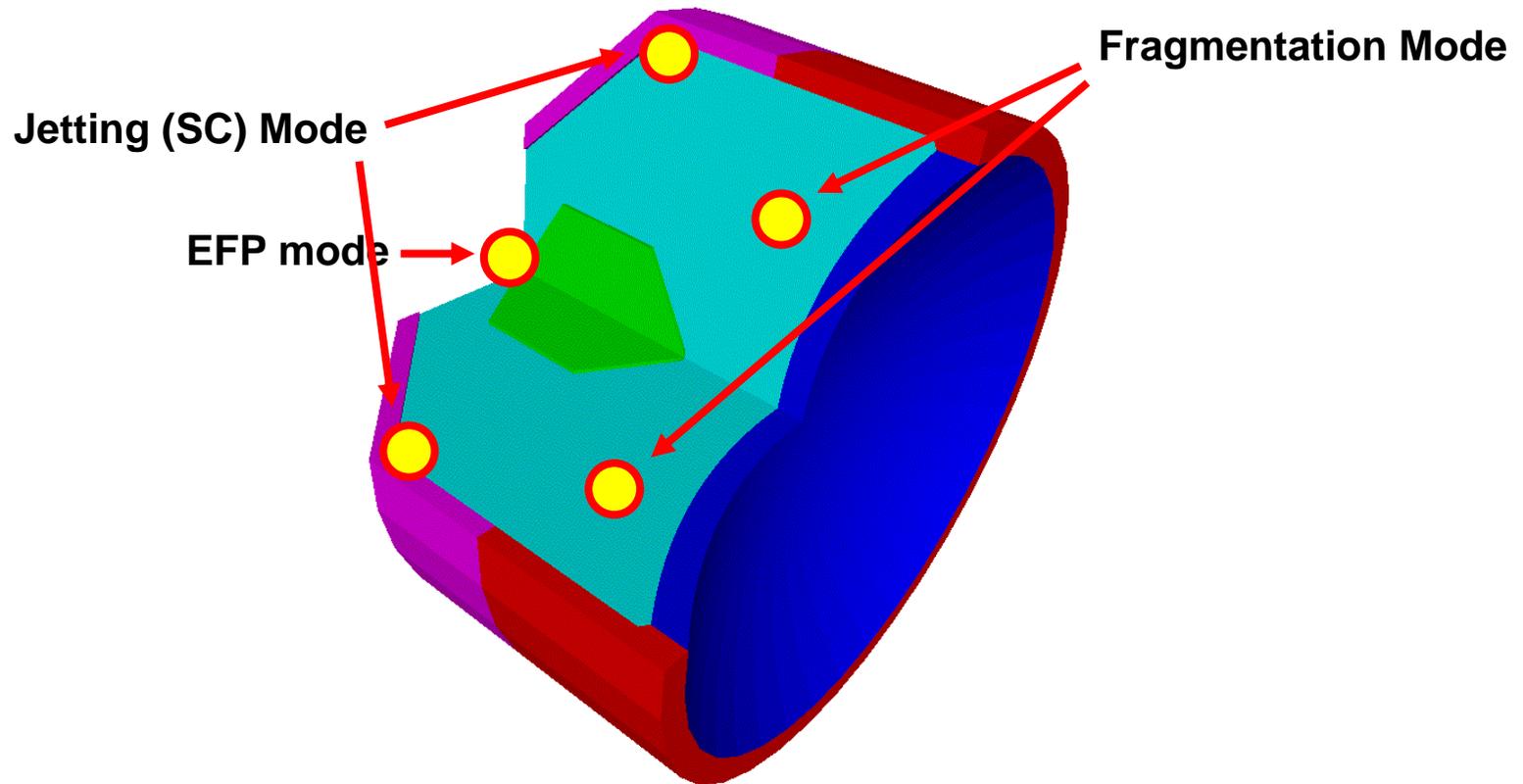
Multimode Warhead

- Basis: EFP warhead



Multimode Warhead

- Choose warhead mode by means of initiation with EFI



AUTODYN®

- Hydrocode simulation with ANSYS AUTODYN®
 - Explicit analysis tool for simulating non-linear short time dynamics of
 - solids, fluids, gases
 - fluid-structure interactions
 - Combined method of
 - finite differences
 - finite elements
 - finite volumes
 - (mesh free SPH)

Underlying Physics

■ Conservation laws

■ Mass

$$\frac{D\rho}{dt} + \rho \sum_{i=1}^3 \frac{\partial v_i}{\partial x_i} = 0$$

■ Momentum

$$\rho \frac{Dv_i}{Dt} = \sum_{j=1}^3 \frac{\partial \sigma_{ji}}{\partial x_j} + f_i \quad (i = 1,2,3)$$

■ Angular Momentum

$$\sigma_{ij} = \sigma_{ji} \quad (i, j = 1,2,3)$$

■ Energy

$$\rho \frac{Dw_{int}}{Dt} = \sum_{i,j=1}^3 \frac{\partial v_i}{\partial x_j} \sigma_{ij} - \sum_{i=1}^3 \frac{\partial q_i}{\partial x_i} + \rho s$$

t : time

x_i : position

v_i : velocity

ρ : local density

σ_{ij} : stress tensor

f_i : external force density

w_{int} : specific internal energy

s : heat sources

q_i : heat flux

■ Material laws

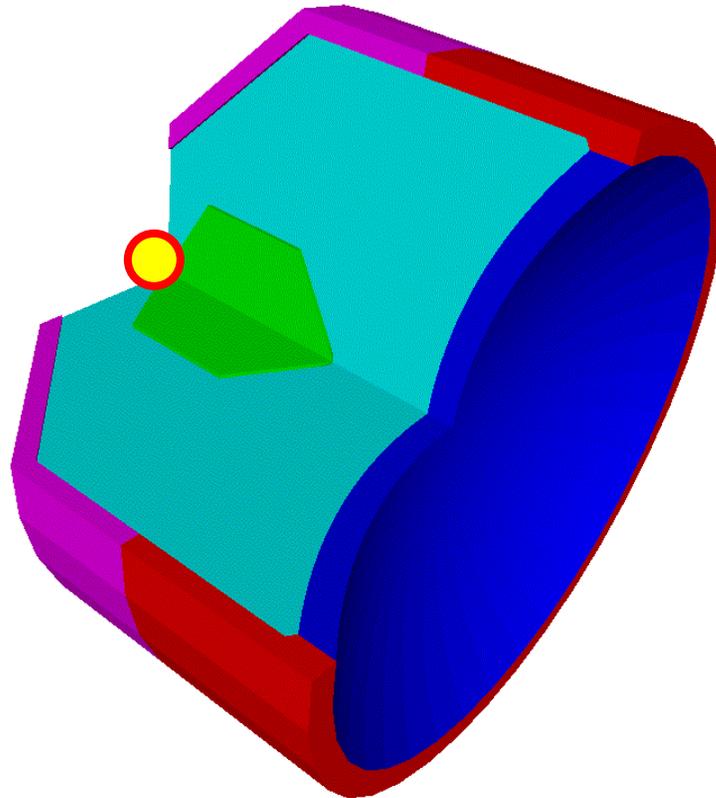
■ Equation of State

■ Material strength

■ Material Failure

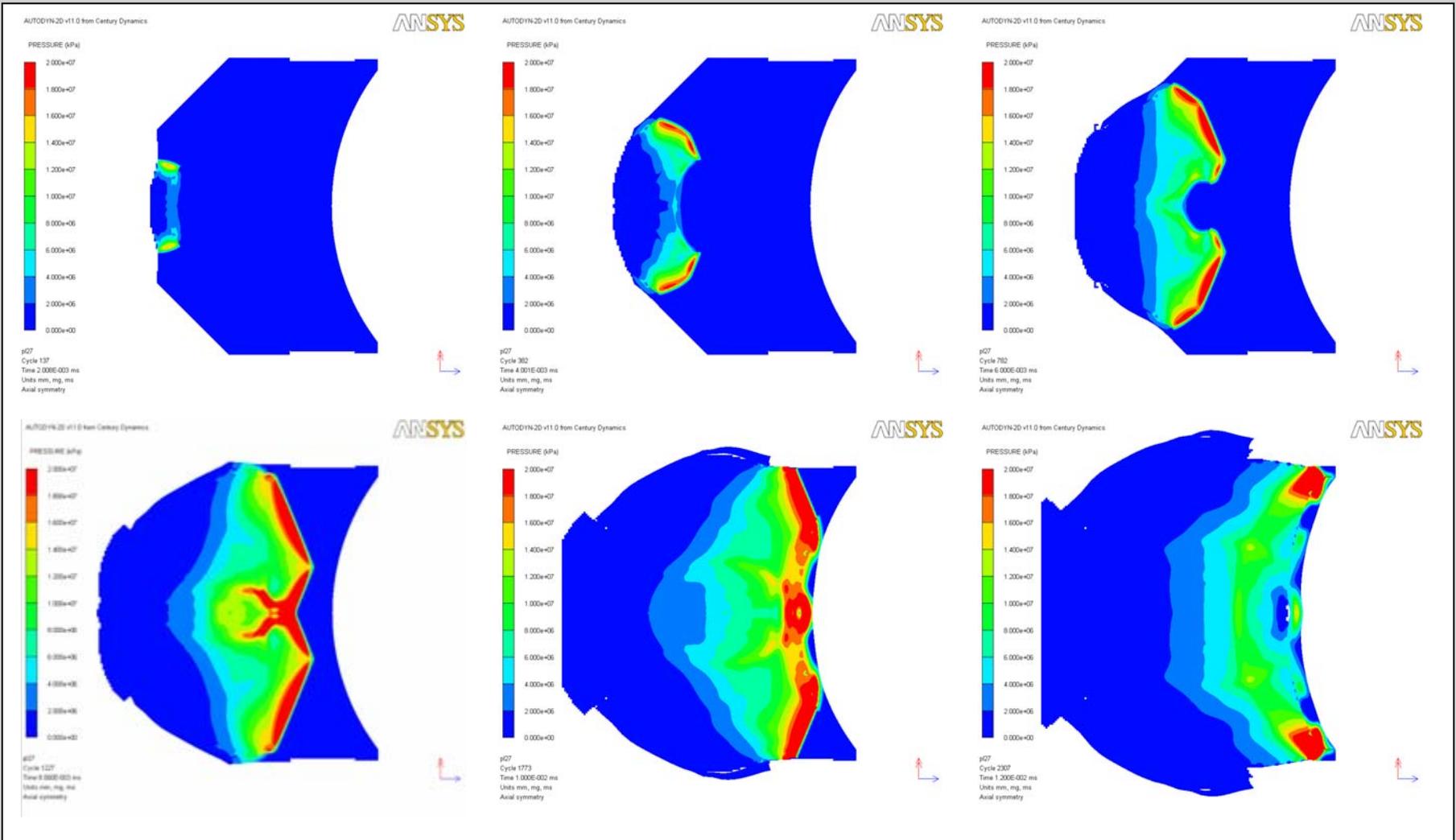
EFP Mode

- Initiation point in front of DWS

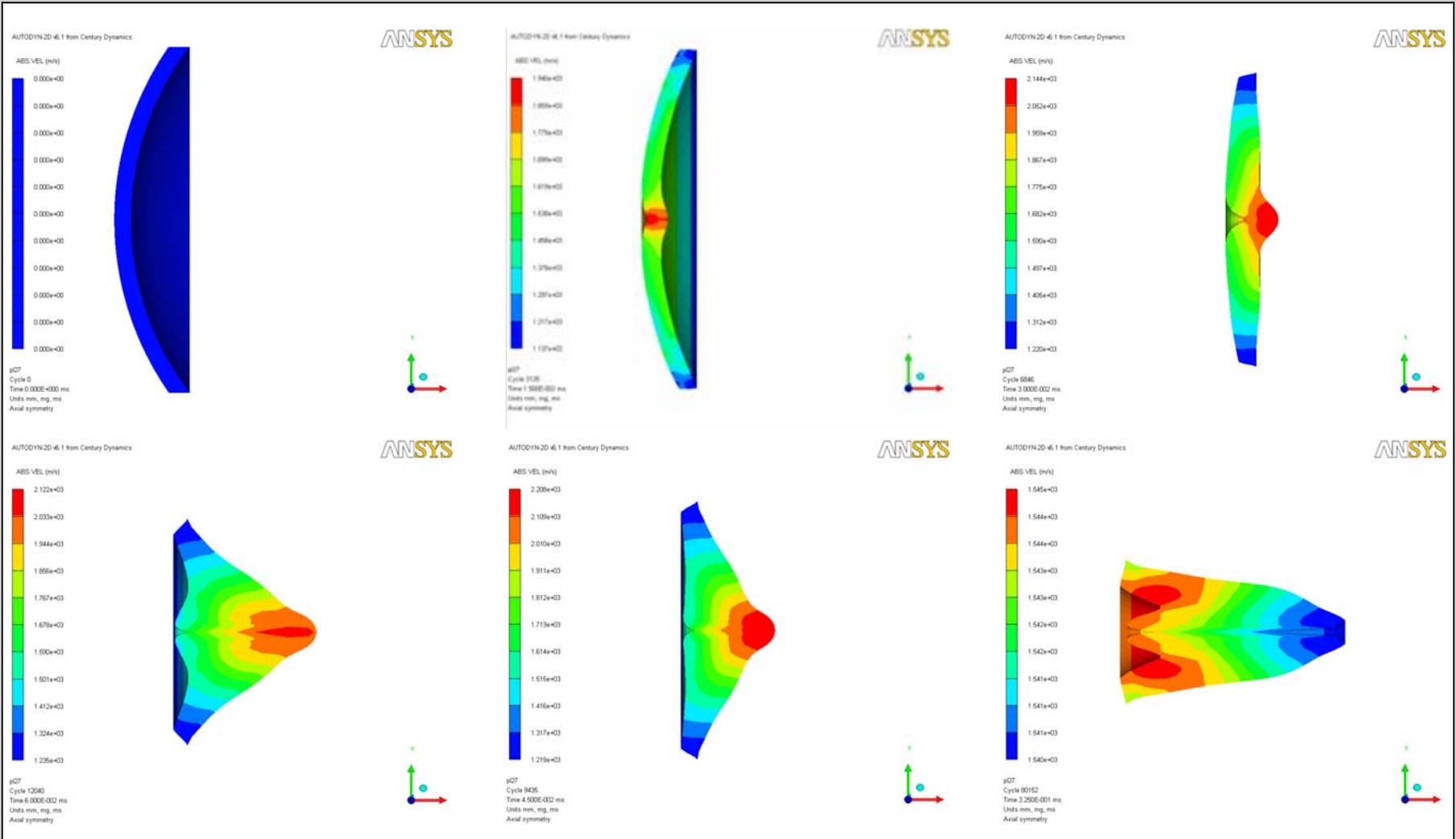


Initiation Controlled Multimode Warheads

EFP Mode

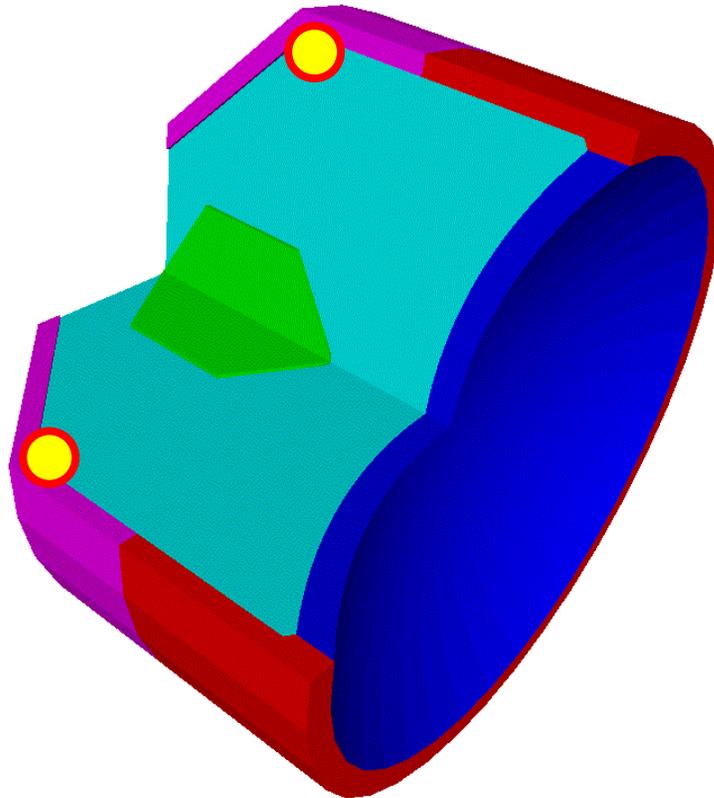


EFP Mode

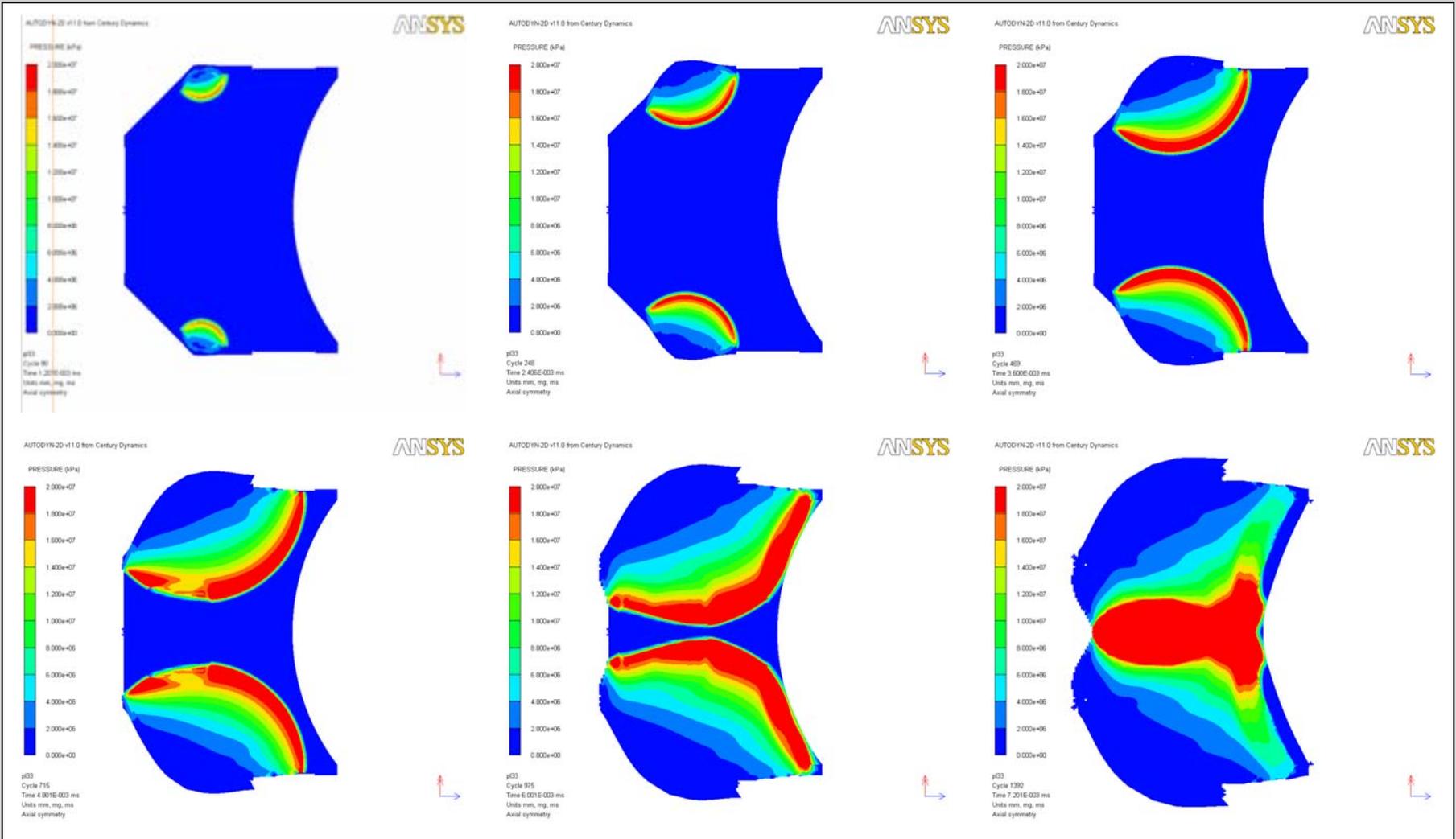


Jetting (SC) Mode

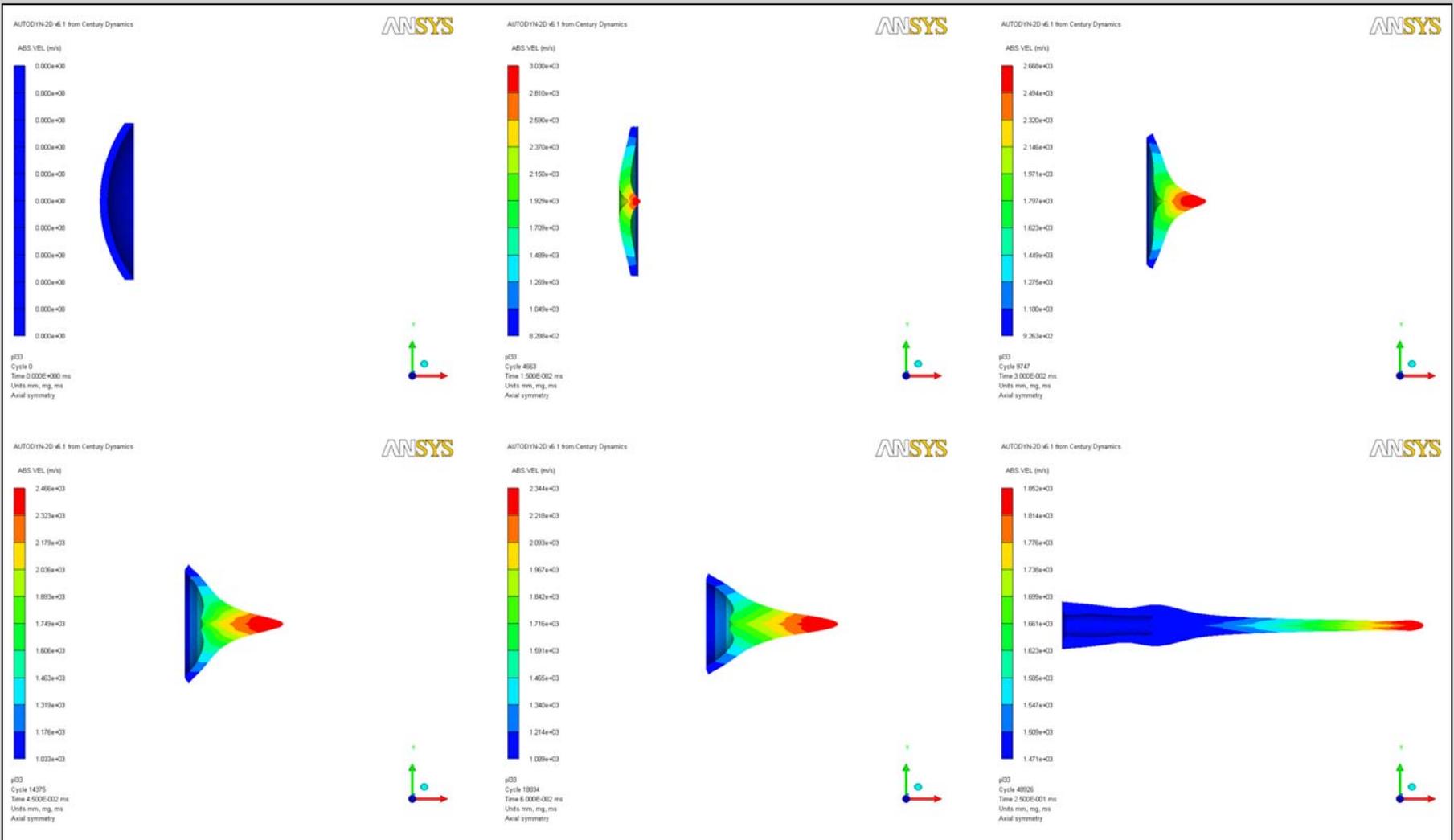
- Multiple initiation points around circumference of warhead case



Jetting (SC) Mode



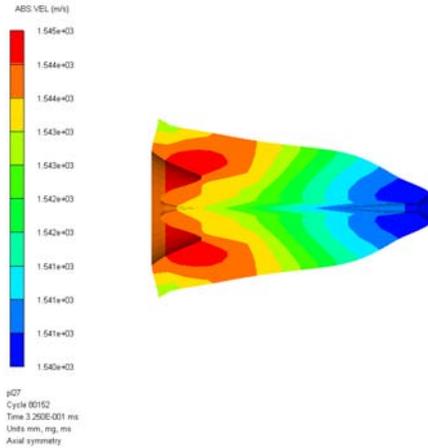
Jetting (SC) Mode



Comparison of EFP and SC Modes

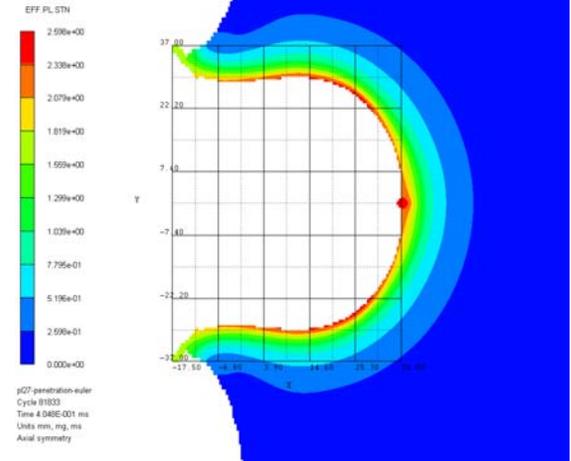
AUTODYN2D v6.1 from Century Dynamics

ANSYS



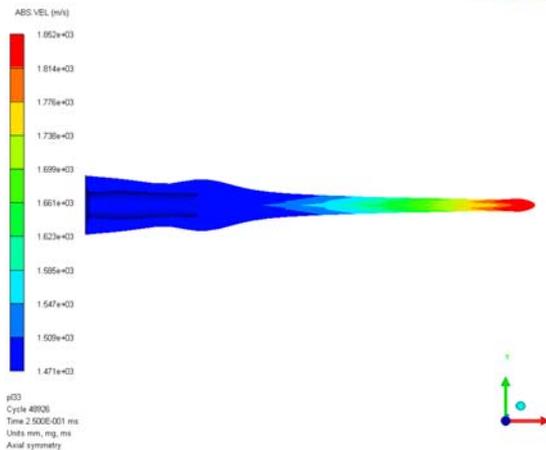
$v = 1540 \text{ m/s}$
 $L/D = 1.6$
 $P_{\text{Steel}} = 0.4 \text{ CD}$

AUTODYN2D v11.0 from Century Dynamics



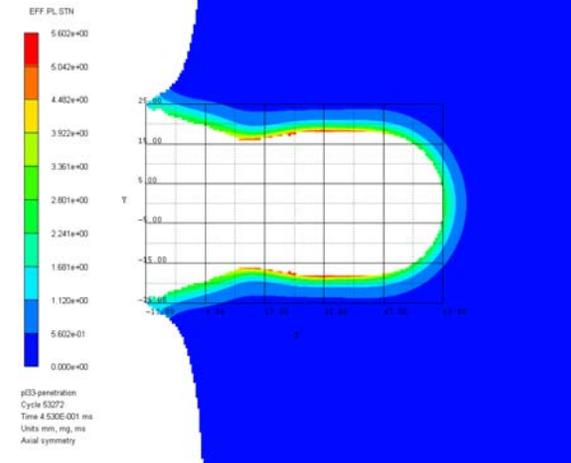
AUTODYN2D v6.1 from Century Dynamics

ANSYS



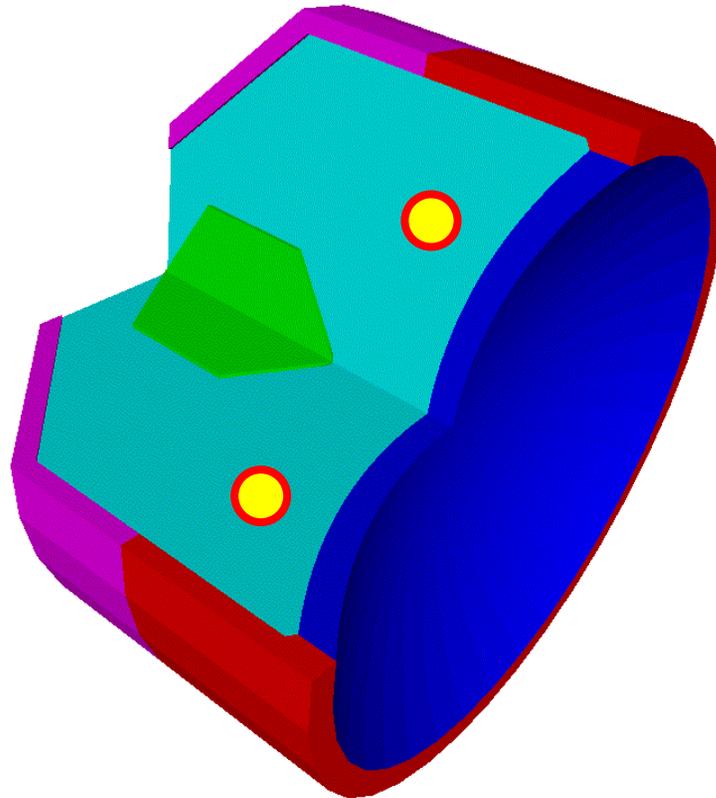
$v = 1850\text{-}1470 \text{ m/s}$
 $L/D = 7.6 \text{ (}t=250\mu\text{s)}$
 $P_{\text{Steel}} = 0.7 \text{ CD}$

AUTODYN2D v11.0 from Century Dynamics

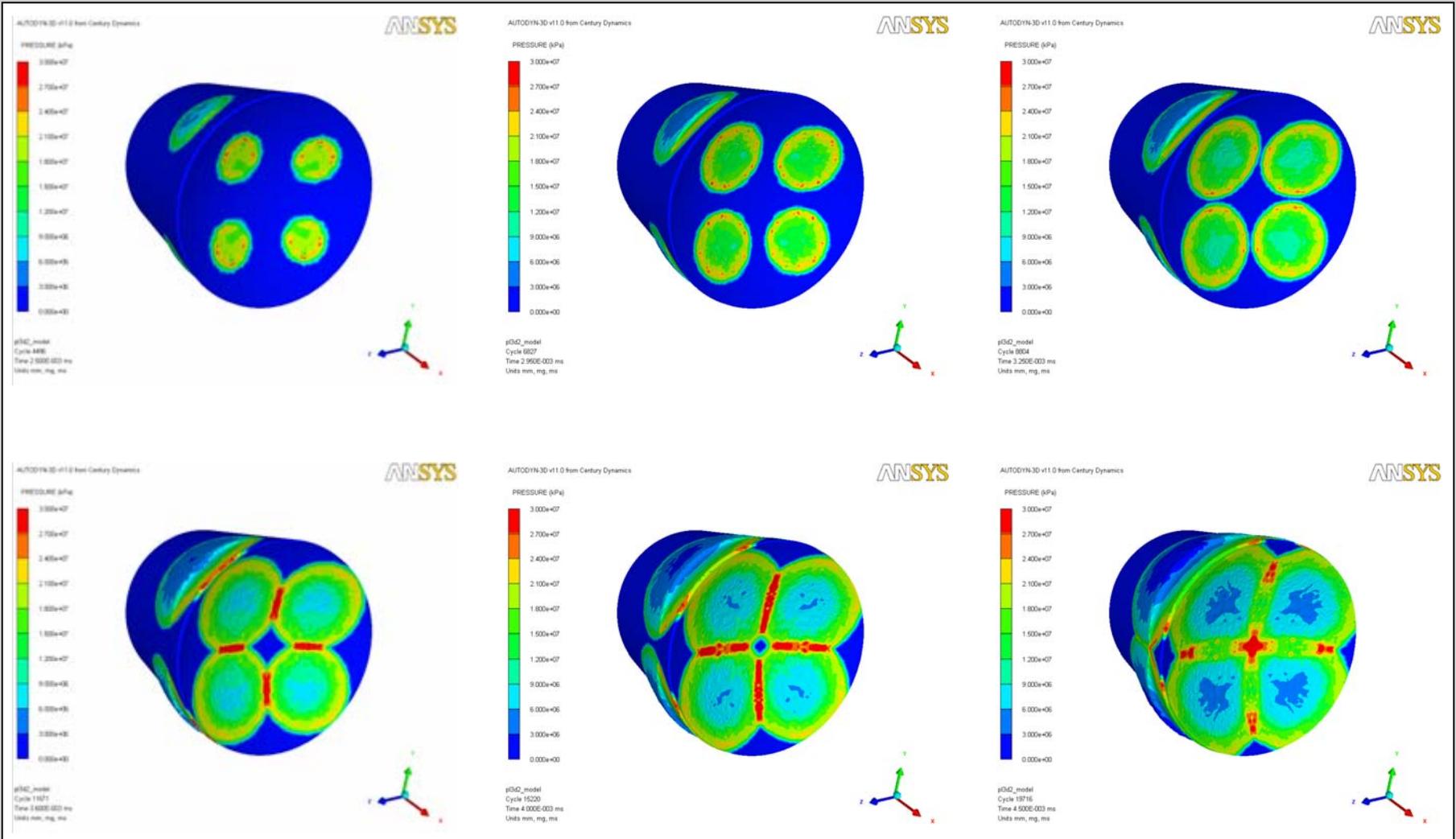


Fragmentation Mode

- Few initiation points in front of liner

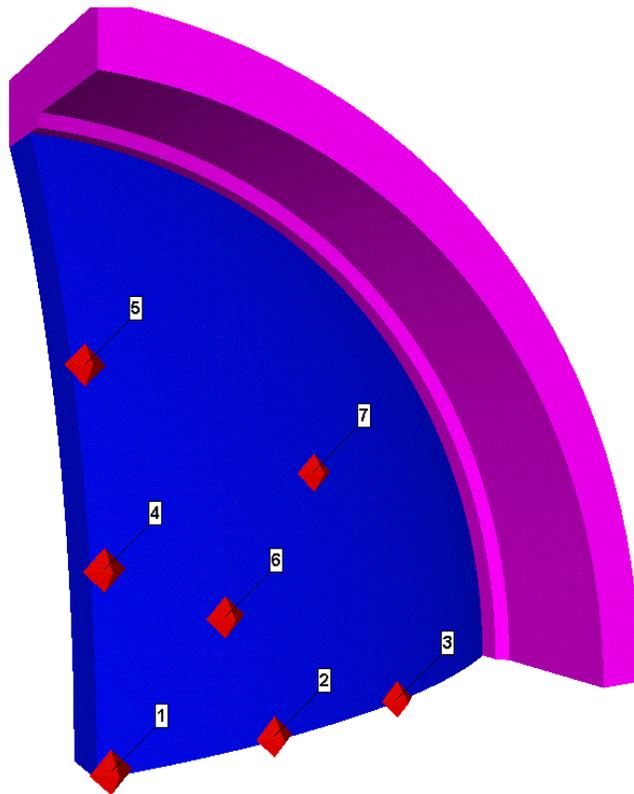


Fragmentation Mode with 4 Initiation Points



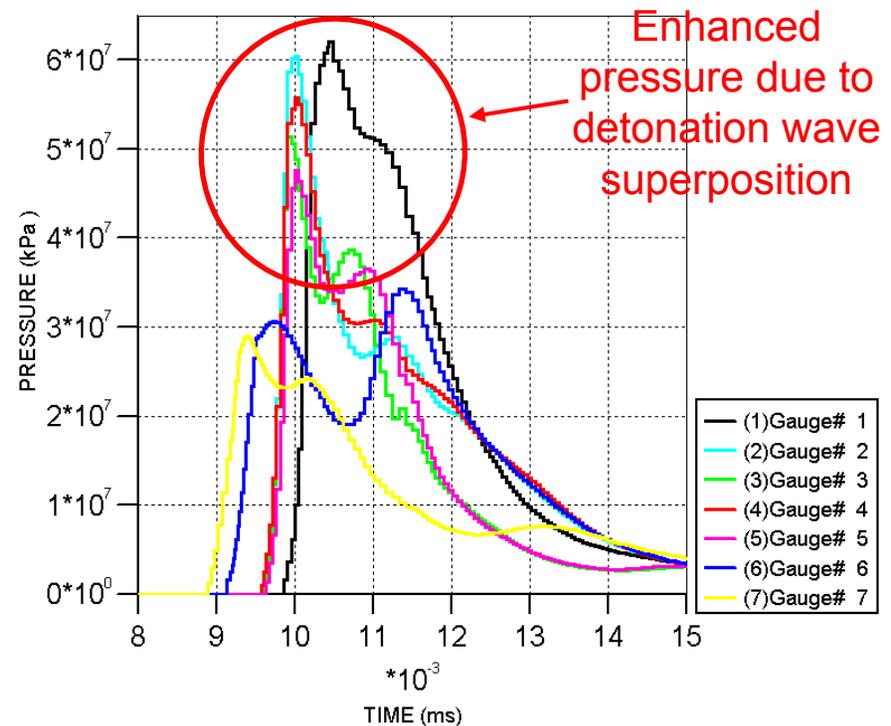
Fragmentation Mode

- Fragmentation of liner due to detonation wave superposition
 - Superposition of detonation waves lead to high local impulse densities
→ local failure of liner material



Fragmentation Mode with 4 Initiation Points

*) different initiation points than in previous figure



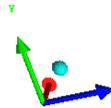
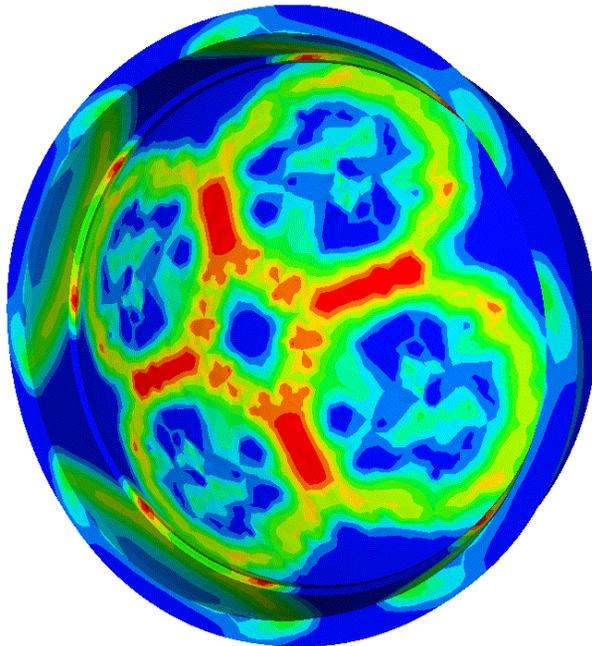
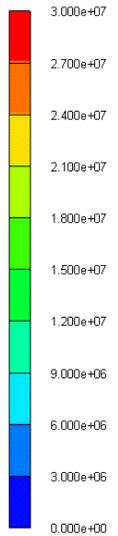
Fragmentation Mode

- Formation of liner fragments

AUTODYN-3D v11.0 from Century Dynamics



PRESSURE (kPa)

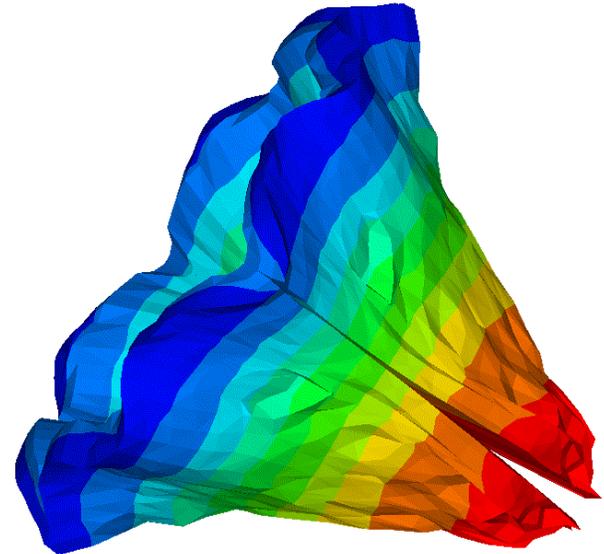
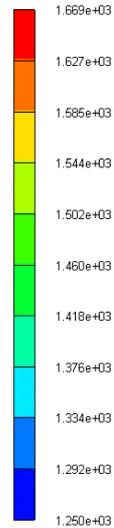


pl3d4
Cycle 2859
Time 4.000E-003 ms
Units mm, mg, ms

AUTODYN-3D v11.0 from Century Dynamics



ABS VEL. (m/s)



pl3d11
Cycle 51629
Time 8.236E-002 ms
Units mm, mg, ms

Limits of Initiation Controlled Multimode Warheads

- Optimum performance only for original warhead mode, i.e.
 - EFP mode for EFP based multimode warhead
 - SC mode for SC based multimode warhead

- EFP basis
 - Thick liner → low collapse velocity → no high velocity SC jet

- SC basis
 - Low liner mass, small opening angle → no EFP
 - Low liner mass → only low mass fragments

Summary

- Operating modes of initiation controlled multimode warhead demonstrated by simulation
- EFP charge with multiple initiation points
 - EFP mode: Single initiation point in front of DWL
 - Aerodynamically stable projectile → hard target defeat at long standoffs
 - Jetting (SC) mode: multipoint initiation along warhead circumference
 - Stretched projectile → enhanced penetration performance at small standoffs
 - Fragmentation mode: few initiation points in front of liner
 - Fragments → defeat of semi-hard and soft targets at medium standoffs
- Functionality of EFP and Jetting (SC) mode verified by experimental tests
- Fragmentation mode under current experimental investigation

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