

The Use of Hydrocode Modelling in Optimisation of Physical Mitigation Design Solutions for Multiple Weapon Types

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Agenda



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- Introduction
 - Mitigation
 - The stages of problem solving
 - Reaction of a munition to fragment attack
 - Effect of the container and any mitigation
 - Reaction within the stack
 - Reaction between stacks (same or different munitions)
 - Mitigation between stacks
 - Validation
 - Conclusions

Location & Capabilities

SDE

System Approach



ISO 9001/2000
List X

Introduction



- A single large ship's magazine can carry up to 10 different types of munitions, with an NEQ/NEW in excess of 13,000 kg



Introduction



- A single large ship's magazine can carry up to 10 different types of munitions, with an NEQ/NEW in excess of 13,000 kg
- Threats may be external or internal



USS Cole after a terrorist attack

Introduction



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- A single large ship's magazine can carry up to 10 different types of munitions, with an NEQ/NEW in excess of 13,000 kg
 - Threats may be external or internal
 - External threats will be reduced in energy by the magazine boundary, but they may have residual energy that remains a threat.
 - The reaction of any munition to the residual threat (or any internal threat) may cause further sympathetic reactions.
 - Therefore mitigation in the magazine must provide protection from the residual effects of external stimuli and from sympathetic reactions between munitions of different types.

Mitigation



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- There are many types of physical mitigation that may be used to protect munitions.
 - Examples of these are :–
 - sheet metal
 - plywood
 - water
 - aramid fibre
 - Mitigation controls (e.g. stowage plans) can also be used to protect munitions.

The Role of Assessment



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- Research small scale and safety test results to predict munition reactions.
 - Research physical properties to gauge container and mitigation material effectiveness.
 - Down select 2 or 3 mitigation materials to model
 - Use basic tools (Kingery etc) to gauge likely 'safe' distances

The Hydrocode Model



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- The use of Autodyn by Century Dynamics to model
 - Fragment impact on plates and explosives
 - Reaction of explosives to stimuli
 - Blast wave expansion and interaction
 - Fragmentation formed from detonations
 - 2D or 3D setups can be modelled

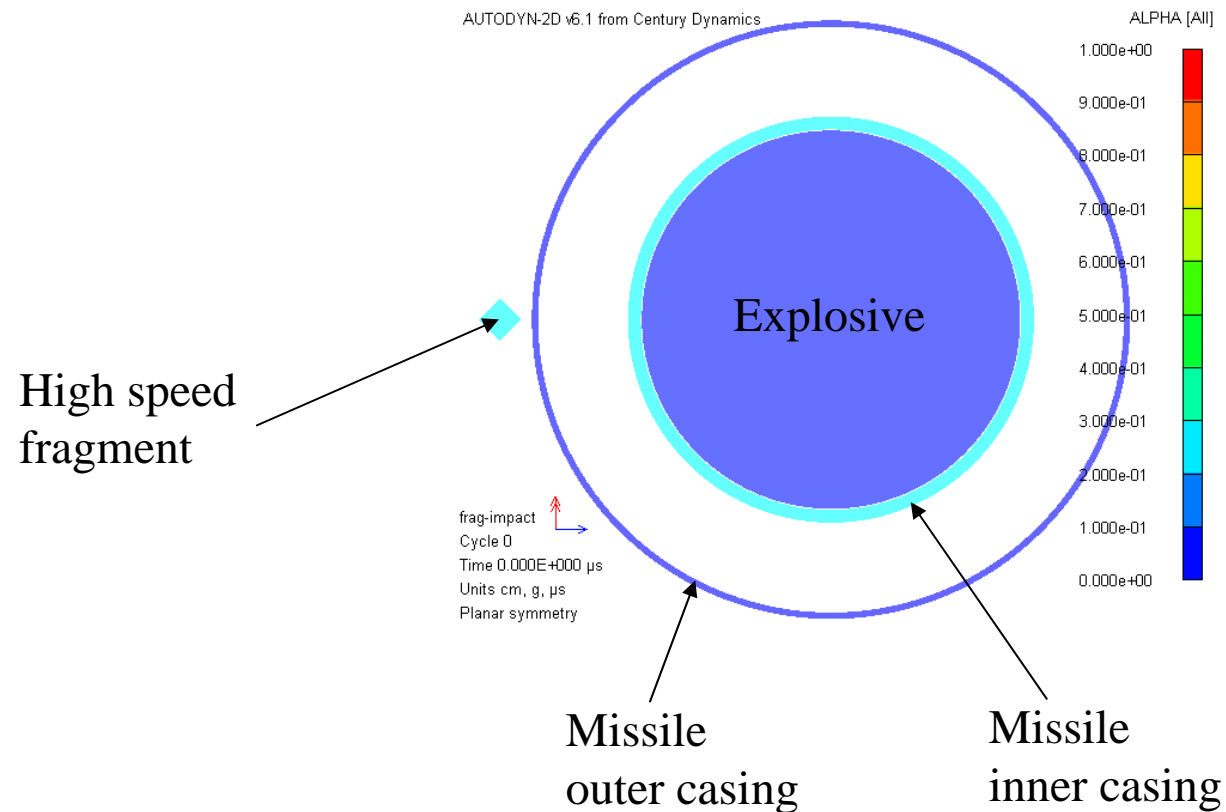
The Problems



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- Problem 1 – Fragment strike on a munition
 - Problem 2 – Sympathetic reaction within stack
 - Problem 3 – Reaction between stacks
 - Problem 4 – Mitigation between stacks

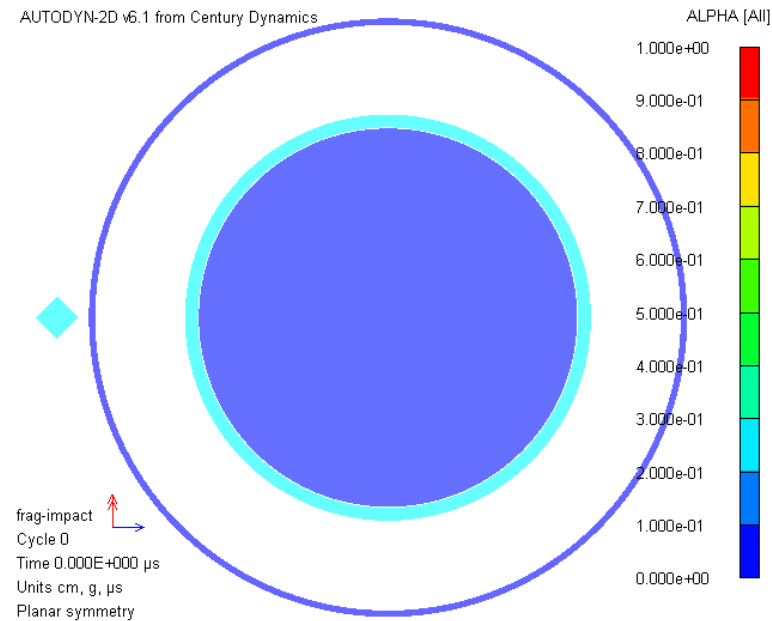
Problem 1

- High velocity fragment impact on bare missile



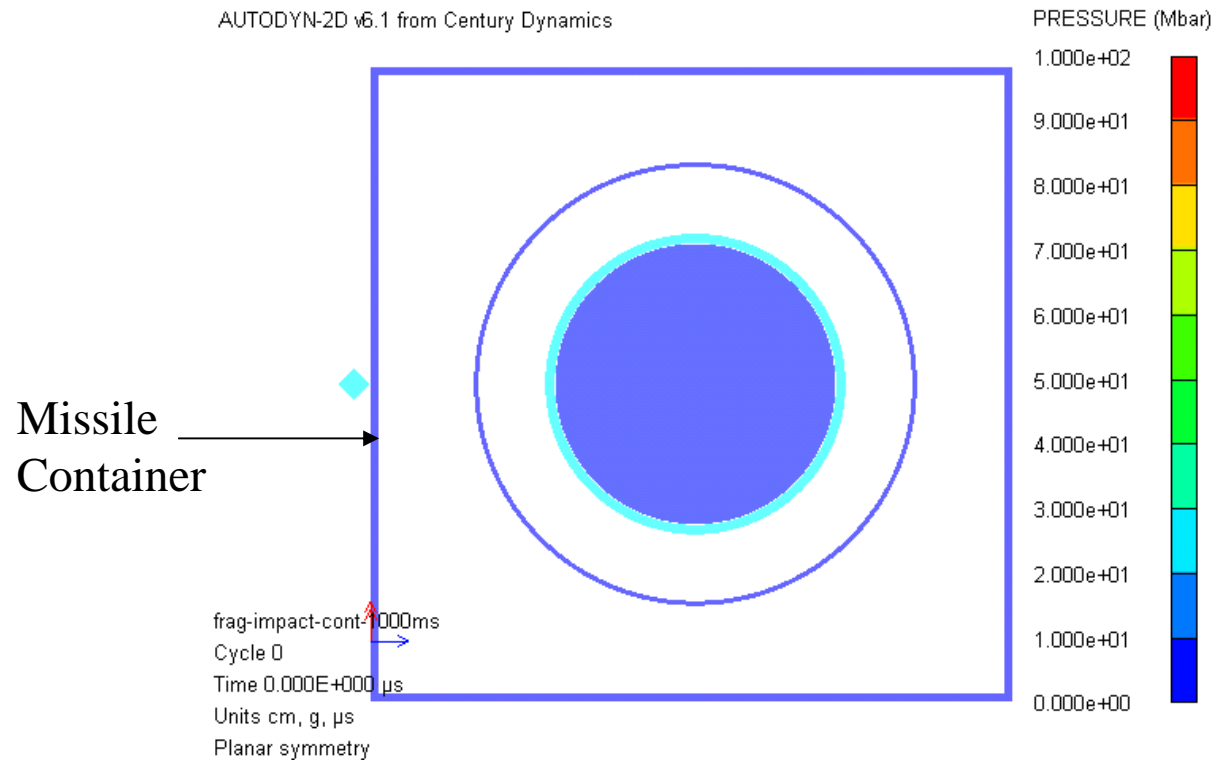
Problem 1

- High velocity fragment impact on bare missile



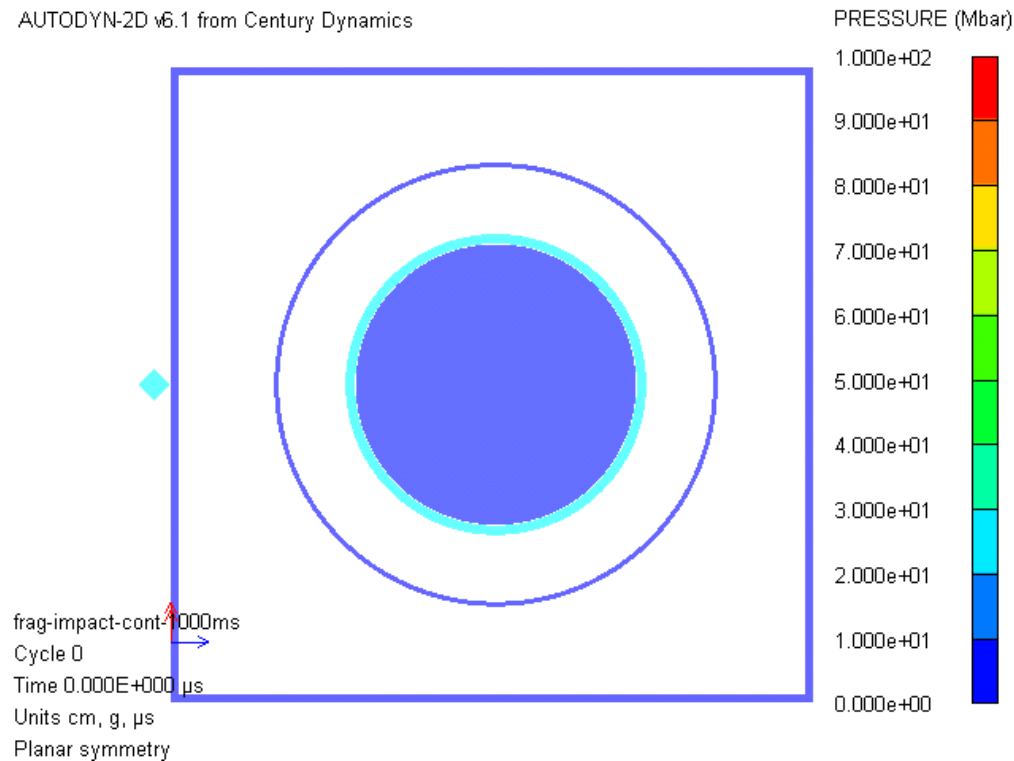
Problem 1

- Effect of container on the fragment



Problem 1

- Effect of container on the fragment



Container not sufficient to prevent initiation

Problem 2

- Sympathetic reaction within the stack
 - An anti tank missile stack

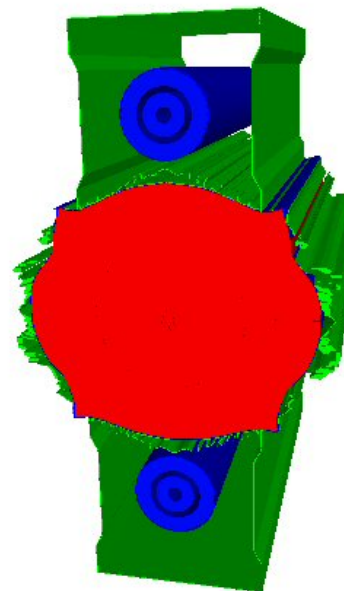


Problem 2

- Sympathetic reaction within the stack
 - An anti tank missile stack

AUTODYN-2D v5.0 from Century Dynamics

trial-none
Cycle 17500
Time 9.193E+001 μ s
Units cm, g, μ s
Planar symmetry



ALPHA [All]

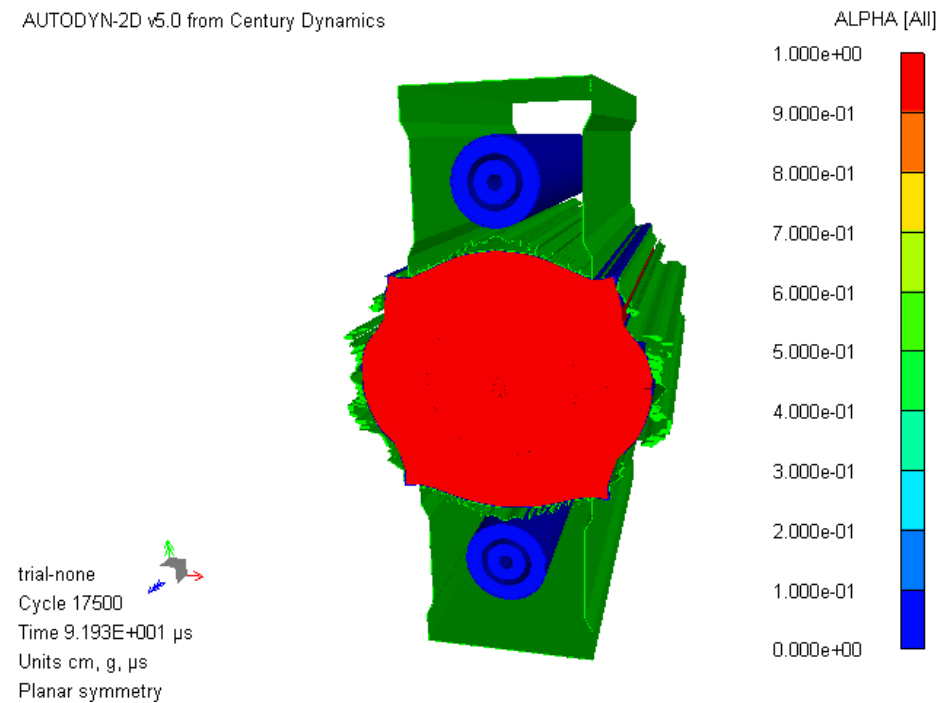
1.000e+00
9.000e-01
8.000e-01
7.000e-01
6.000e-01
5.000e-01
4.000e-01
3.000e-01
2.000e-01
1.000e-01
0.000e+00



Problem 2

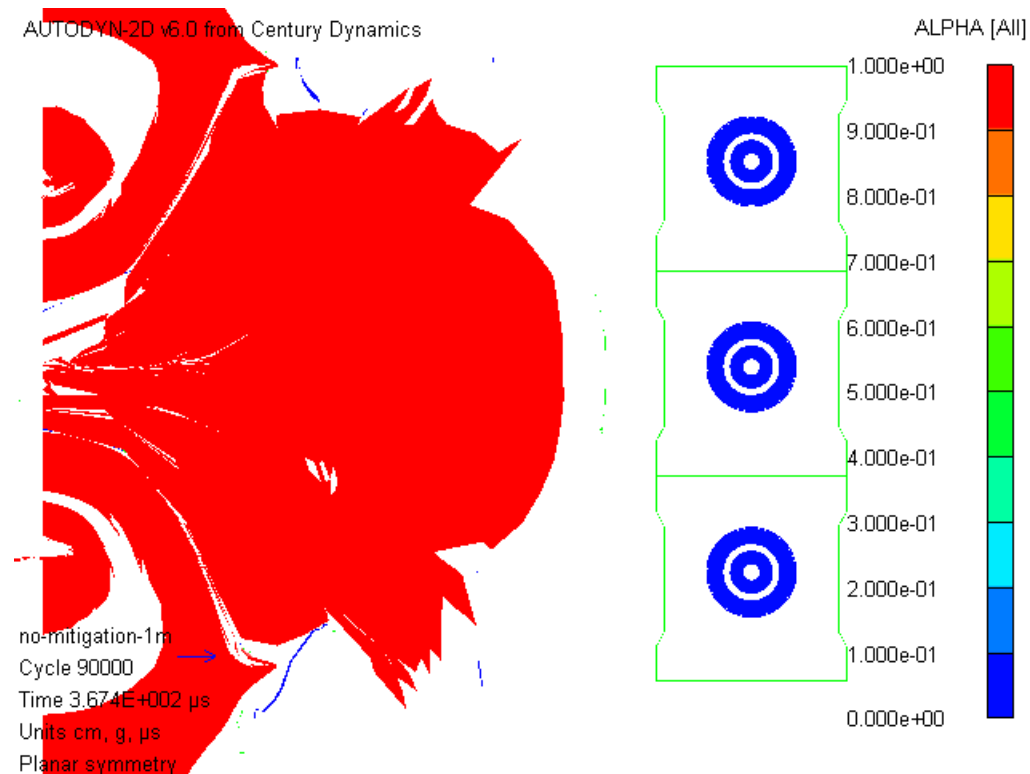
- Sympathetic reaction within the stack
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AUTODYN-2D v5.0 from Century Dynamics



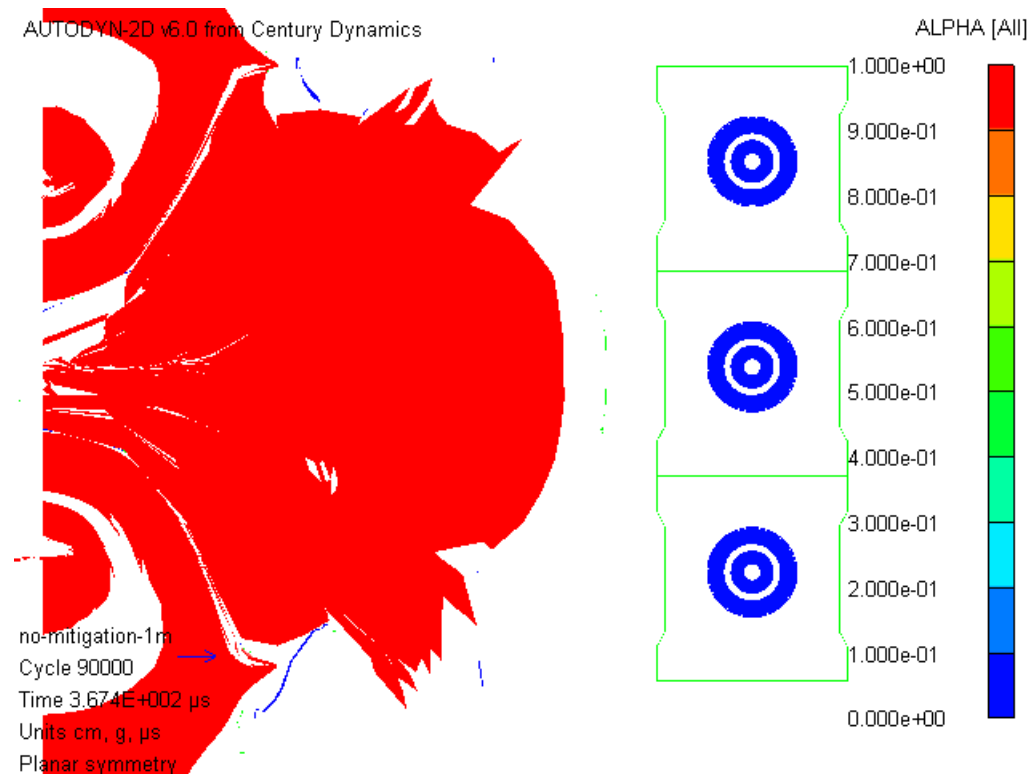
Problem 3

- Transfer to the adjacent stack of a like munition
 - Anti tank missiles with 1m stack separation



Problem 3

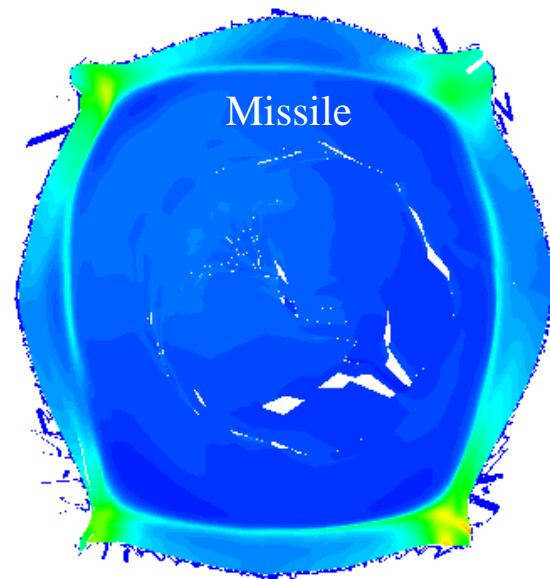
- Transfer to the adjacent stack of a like munition
 - Anti tank missiles with large stack separation



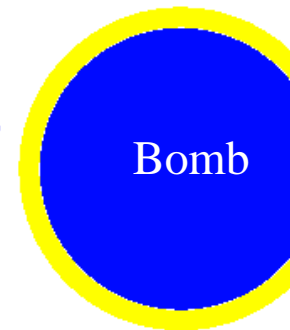
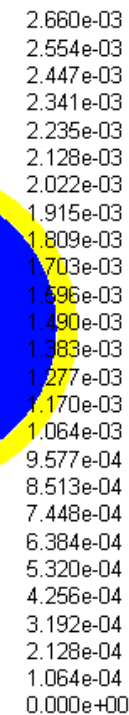
Problem 3

- Transfer to the adjacent stack of a different munition
 - Anti tank missile adjacent to large bomb

AUTODYN-2D v6.0 from Century Dynamics



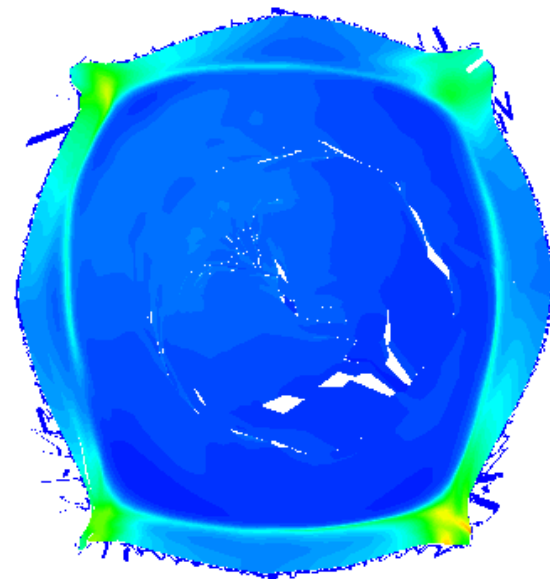
PRESSURE (Mbar)



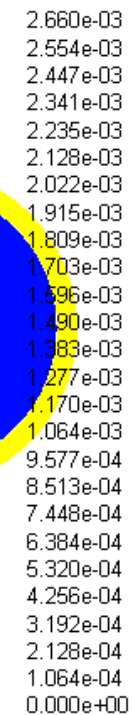
Problem 3

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AUTODYN-2D v6.0 from Century Dynamics

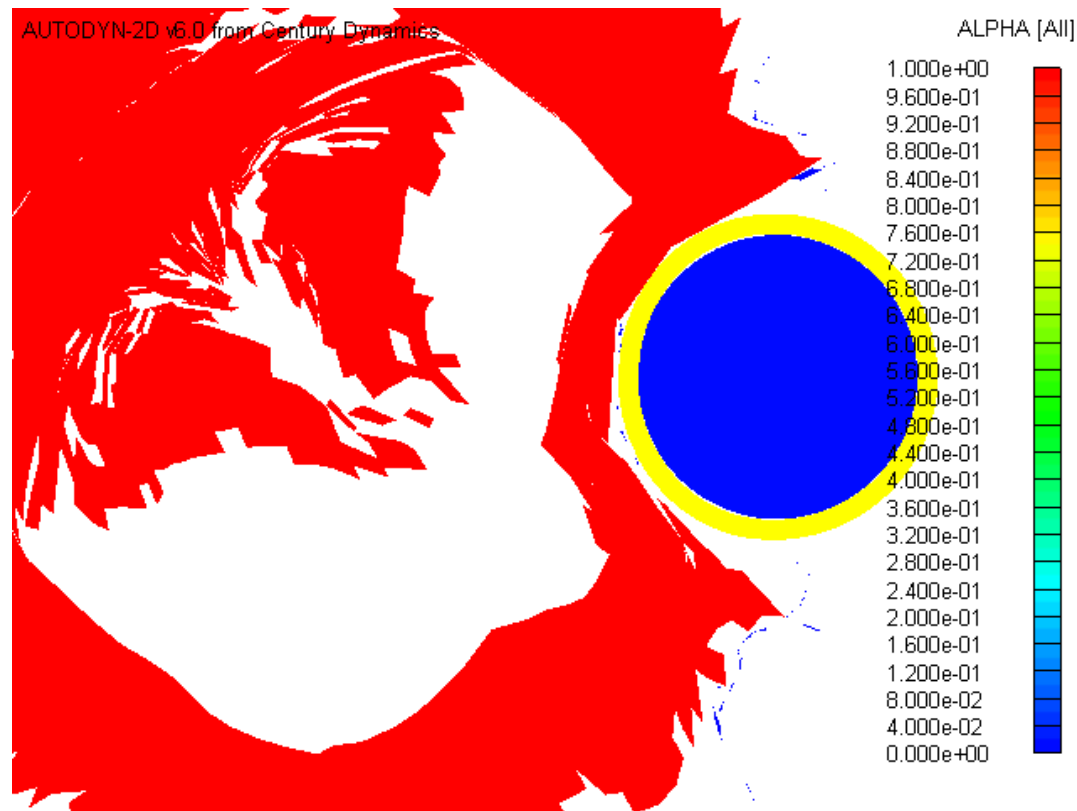


PRESSURE (Mbar)



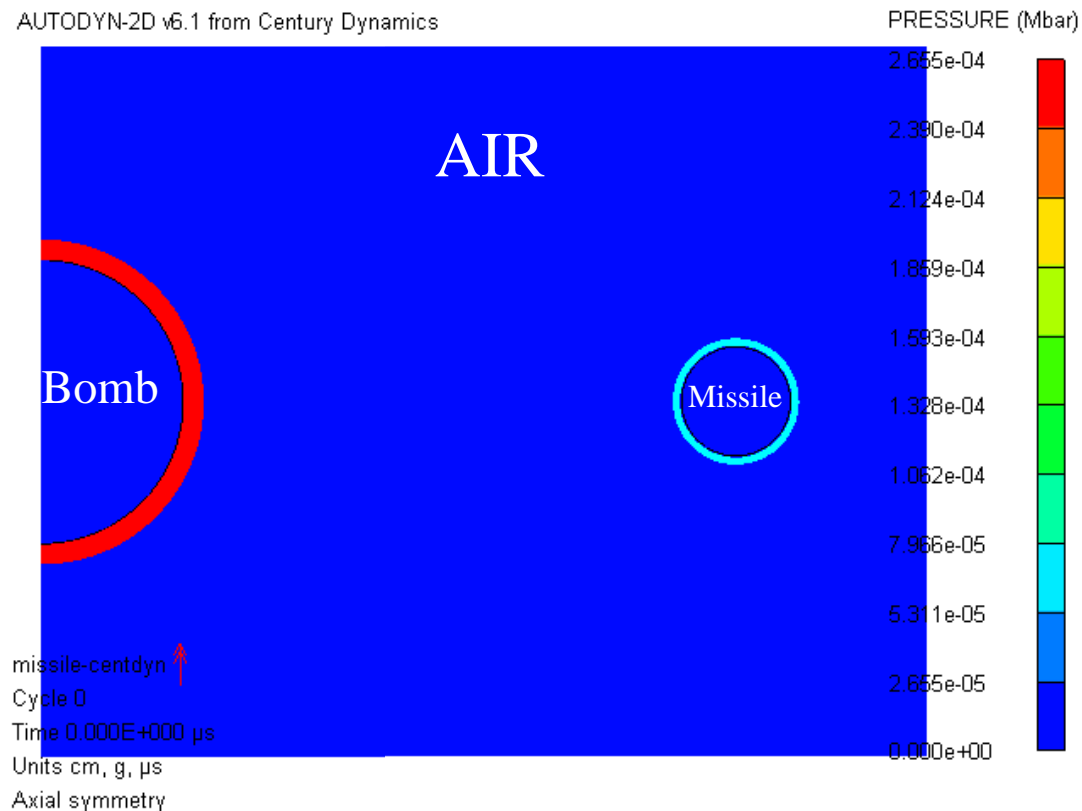
Problem 3

- Transfer to the adjacent stack of a different munition
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Problem 3

- Transfer to the adjacent stack of a different munition
 - Large bomb to air-to-air missile

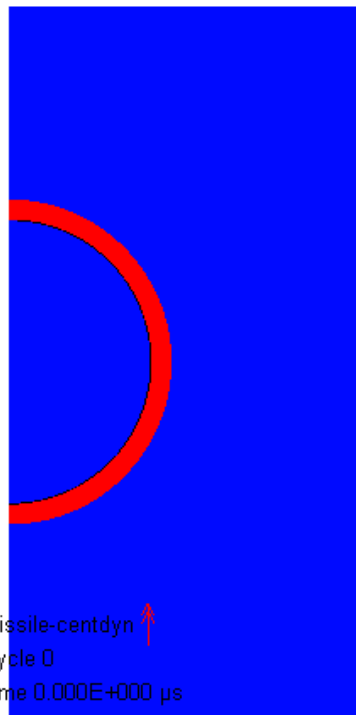


Problem 3



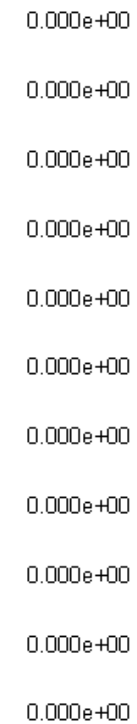
- Transfer to the adjacent stack of a different munition
 - Large bomb to air-to-air missile

AUTODYN-2D v6.1 from Century Dynamics



missile-centdyn ↑
Cycle 0
Time 0.000E+000 μs
Units cm, g, μs
Axial symmetry

PRESSURE (Mbar)

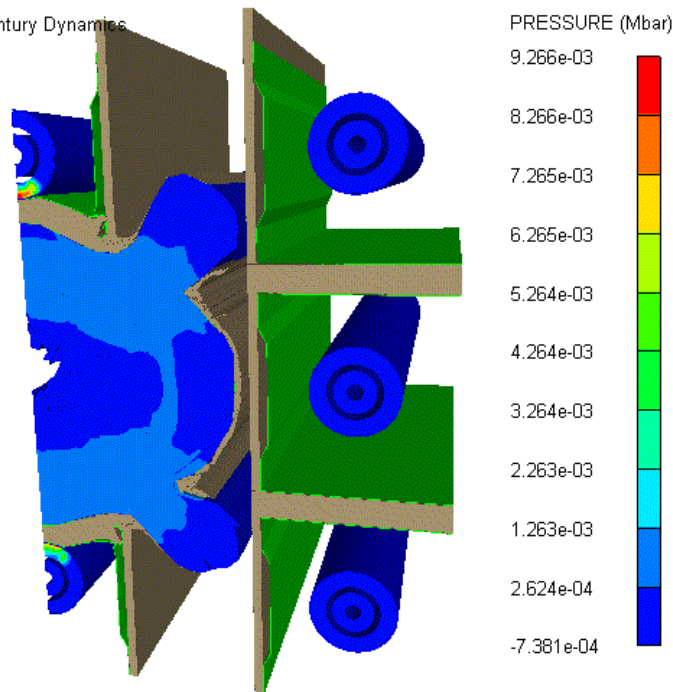


Problem 4

- Provision of mitigation in order to reduce risk and maximise stowage capability

- The addition of mitigation has reduced the stack spacing by 67%

AUTODYN-2D v6.0 from Century Dynamics



- Therefore tripling the stowage capacity

Small Stack separation

Validation



- Compare trial firings of single fragments at several velocities with models of new mitigation and container materials.
- Compare munition reaction model results with Large Scale Gap Test, Fragment Attack Tests/Assessments and Sympathetic Reaction test results.
- If practicable and affordable, carry out full-scale demonstration of model result for confidence building.



Photos courtesy of Ratheon

Summary



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- Munition response to fragment impact can be determined through modelling.
 - The probability of sympathetic reaction within stack can be calculated.
 - The effect of the separation distance can be determined and potentially this is the most effective form of 'mitigation'. Less sensitive munitions can be used as a form of mitigation.
 - By the addition of mitigation, the separation distance between the stacks can be significantly reduced, thus maximising the stowage capacity of the magazine.

Questions?