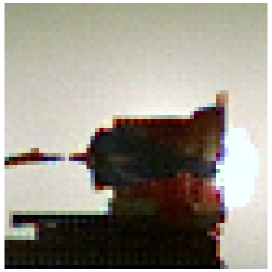
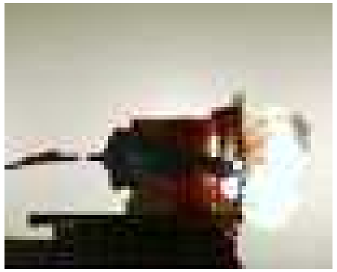
Demonstration of a Predicative Modelling Approach to the Design of Mass Efficient Fragment Mitigation Systems





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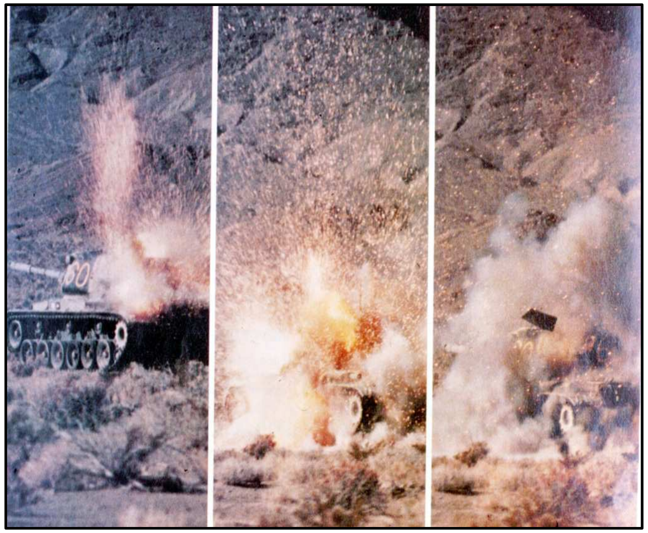
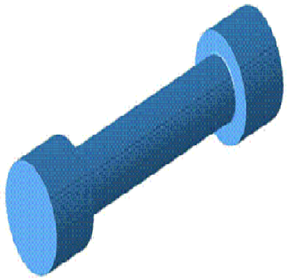


Demonstration of a predicative modelling approach to the design of mass efficient fragment mitigation systems

Aims



Aims of work

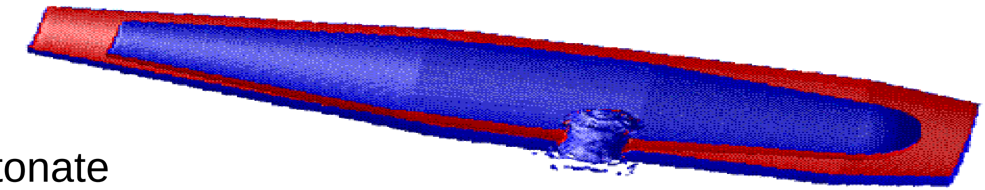
Reduce the risk to assets & personnel arising from warheads

- Improve the “Insensitive Munition” (IM) signature of warheads from fragments
- Ideally case options retro-fit, could imply packaging

Demonstrate potential mass efficiencies of alternative materials

Demonstrate the capability of predicative modelling tools & laboratory tests

Threats



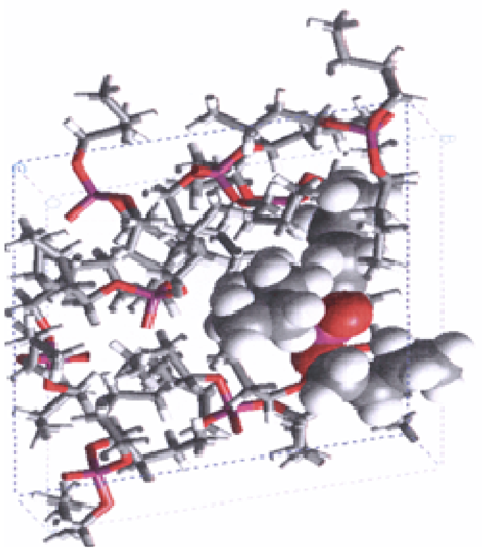
- Enemy Action
- Accidents causing adjacent stores to detonate

Simple solutions – thick & therefore heavy metal case backed by rubber

- Parasitic mass
- High collateral damage

Demonstration of a predicative modelling approach to the design of mass efficient fragment mitigation systems

Background

Background - IM

IM Categories

- Type I Response - "Detonation"
  - Extensive case fragmentation, Extensive damage to adjacent structures
- Type II Response - "Partial Detonation"
  - Significant case fragmentation, Significant damage to adjacent structures
- Type III Response - "Explosion"
  - A few case fragments, Still damaging to adjacent structures
- Type IV Response - "Deflagration"
  - Case rupture, Heat and Smoke damage only
- Type V Response - "Burning"
  - Explosive burns, non-violent case splitting, all debris within 15m and non-fatal
- Type VI – “No Reaction”

IM - type IV or better

- To threats identified in risk assessment

Background - Fragment Threat

Defined in STANAG 4496

- Higher velocity 2530ms^{-1} (+/- 90ms^{-1})
- Steel Fragment

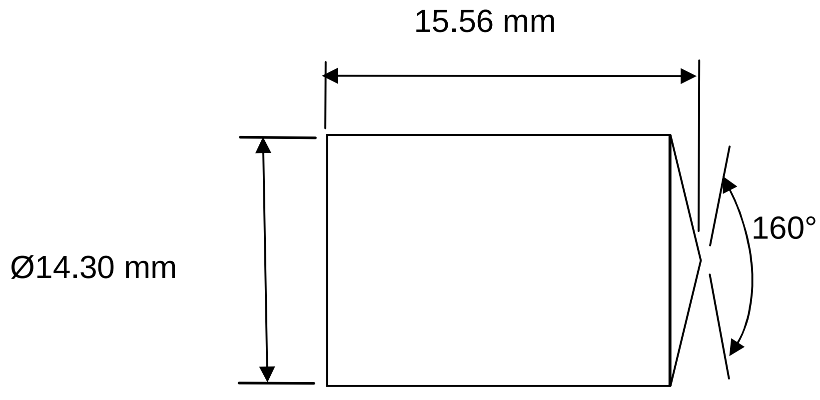
IM Failure mechanisms

- SDT (Shock to Detonation Transition)
- DDT (Deflagration to Detonation Transition)

Experimental configuration defined in STANAG 4496

Simulations apply QinetiQ CHARM model

- Explosive fill known not to DDT
- Investigate SDT



Background - Baselines

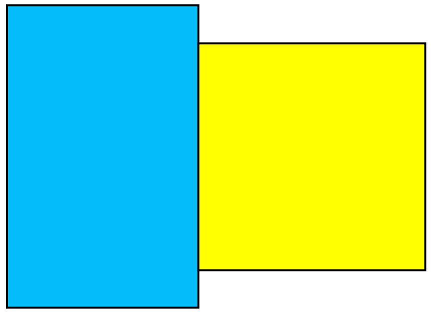
Typical ‘IM’ solution for warheads

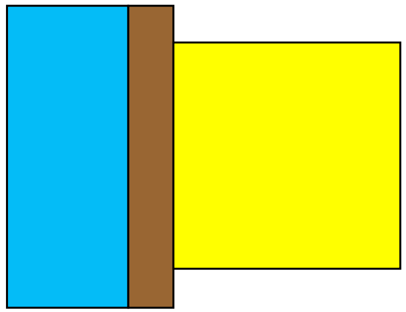
- Air to Ground Systems
- 100mm Diameter

Assume PBX fill (DDT very unlikely)

Baselines

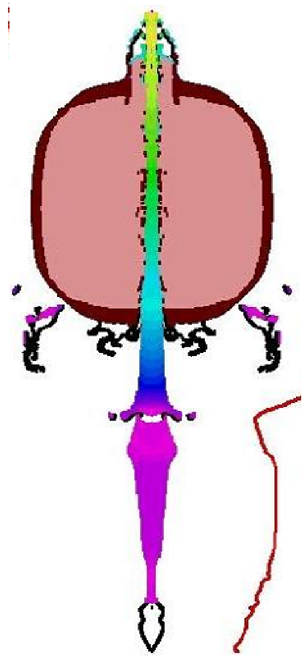
- Thick Steel Case
  - Type IV
- Thinner steel case backed with rubber
  - Type V
- Typical mass 239g/cm
  - Cylindrical form





Demonstration of a predicative modelling approach to the design of mass efficient fragment mitigation systems

Details of study



Study – Approach

Highly efficient design process

Utilises a combination of modelling tools and small scale laboratory tests

Methodology summary:

- Predict the EOS of the candidate materials
  - Where possible validate the EOS
- Identify salient material attributes
  - Energy absorption, shock mitigation and/or strength properties
- Design potential mitigation systems
  - Order material layers to exploit material attributes
- Simulate the fragment impact and estimate the likely response
- Perform an iteration cycle to improve mass efficiency
- Confirm the predictions with CHARM

Study – Example materials applied

Obtain mass efficient designs (<80% baseline)

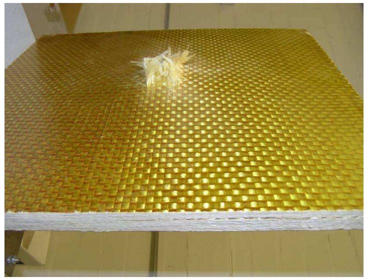
- Minimise volume penalty (<20mm extra)
- Layered structures
- Introduce shock reflection/refractions
- Still backed by steel

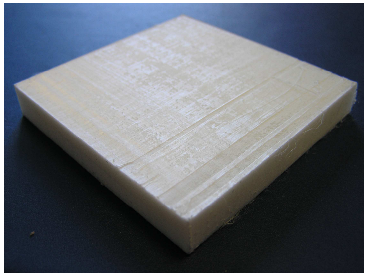
Different material attributes selected

- Impact mitigation
- Energy absorption

Example materials selected

- Dyneema®
- S2 GFRP
- Foamed aluminium
- EPDM foamed rubber





Study – Modelling Requirements

Material properties

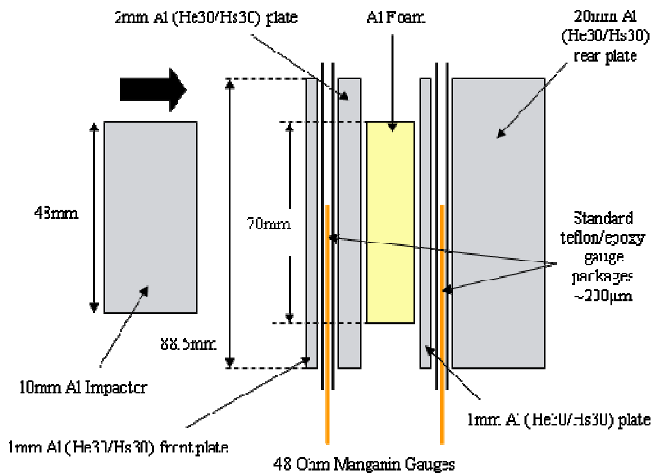
- Strength properties
- Shock properties

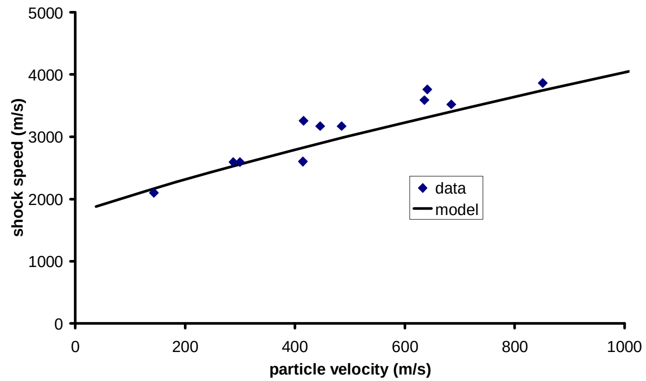
QinetiQ predict data

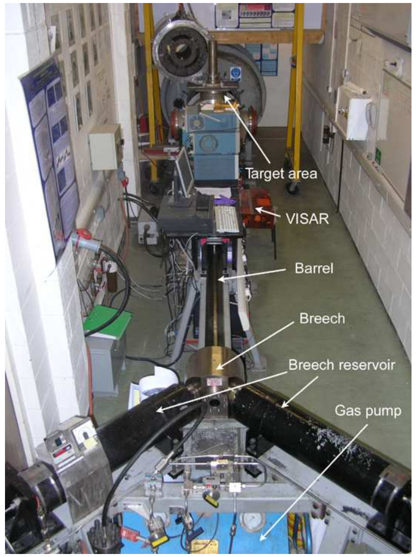
- Porter-Gould QSPM technique

Cavendish plate impact testing

- Validation only







QinetiQ

Study – Modelling Methodology

Understand impact of material properties on mitigation

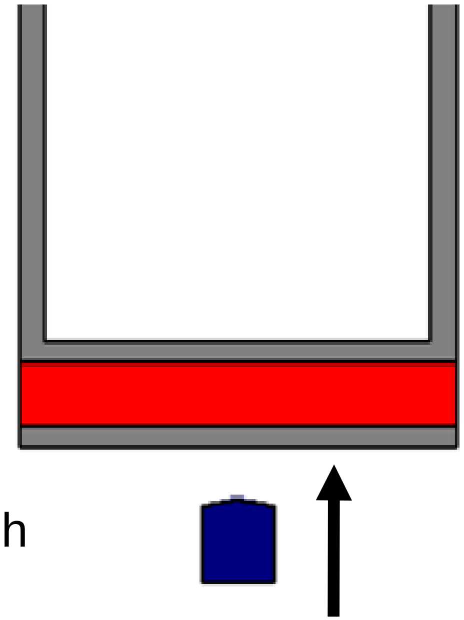
- Develop typical configuration of concepts

Quantify relative performance

- STANAG fragment into each material in isolation
- Highlighted fragment resistance
  - Ignored shock

Quantify relative performance as a filling in a steel sandwich

- STANAG fragment again
- Included shock mitigation



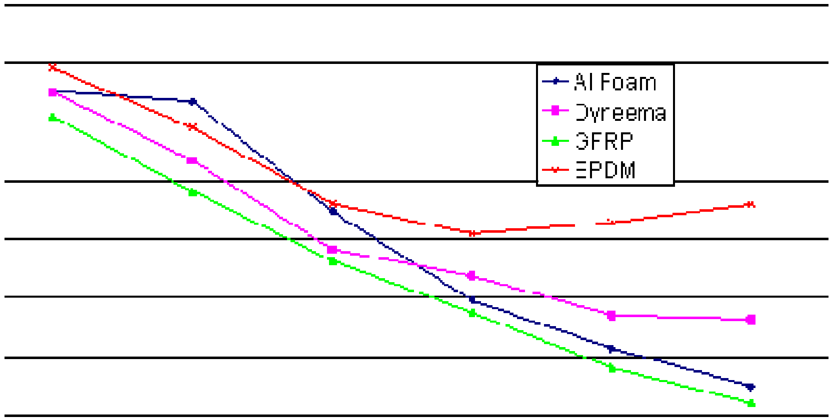
Study – Modelling Methodology

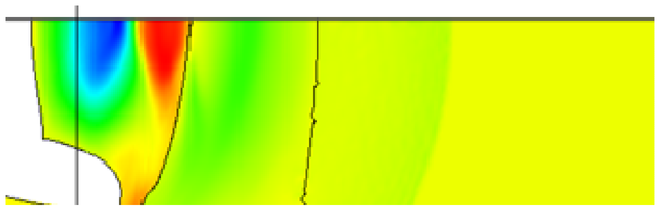
Apply results of simulations

- Form understanding of relative performance
- Determine merits of extra thickness
- Optimise use of each material

Propose layered configurations

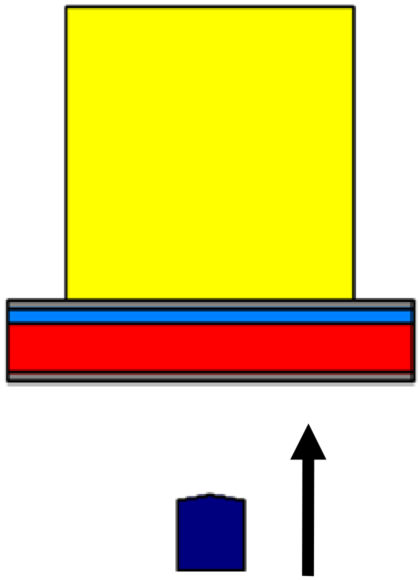
- Backed by steel
  - Avoids compatibility issues
- Simulate fragment impact
  - Assess transmitted pressure & energy profile
- Apply CHARM





Study – Configurations Shortlisted

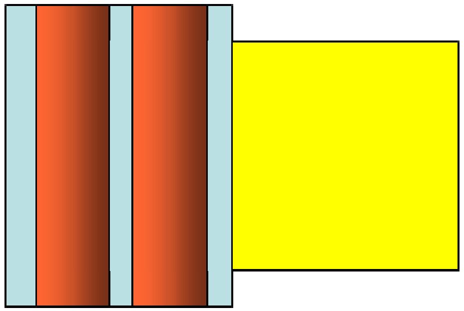
Design	Materials	Thicknesses (mm)
1	Steel/Foam/Steel/Foam/Steel	2.0/5.0/1.5/5.0/1.5
2	Steel/Foam/EPDM/Steel	2.0/10.0/2.0/2.0
3	Steel/Dyneema/Steel	1.5/20.0/1.5
4	GFRP/Steel/Dyneema/Steel	10.0/1.5/7.5/2.0
5	GFRP/EPDM/Foam/Dyneema/Steel	7.0/1.5/7.5/5.0/1.5
6	Steel/Dyneema/Steel	1.5/5.0/1.5

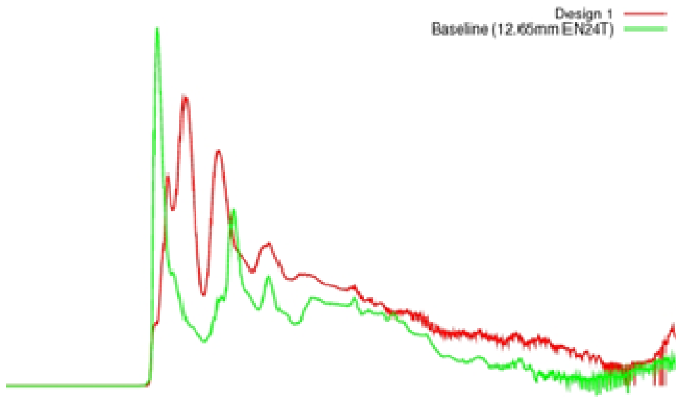


Study – Results 1

Mass Saving

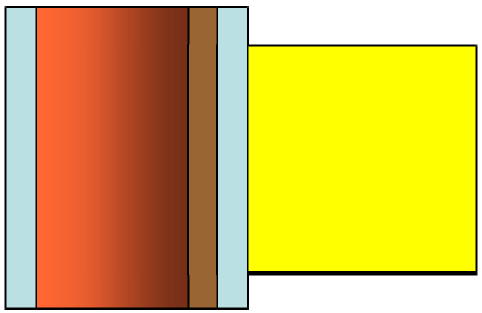
1

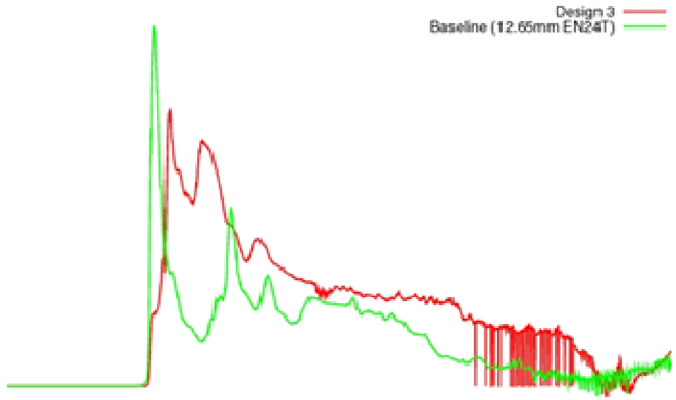




-21%

2





-25%

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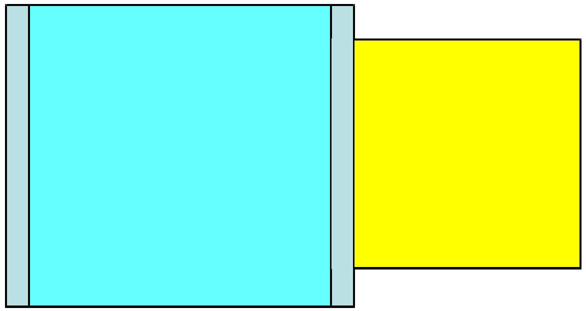
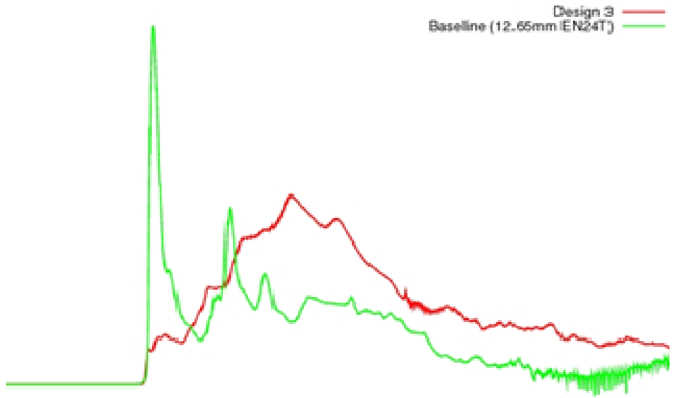
Study – Results 2

Mass Saving

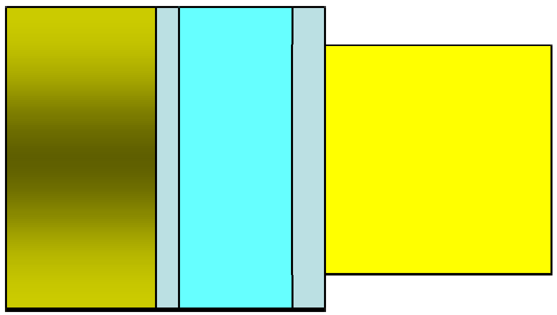
3

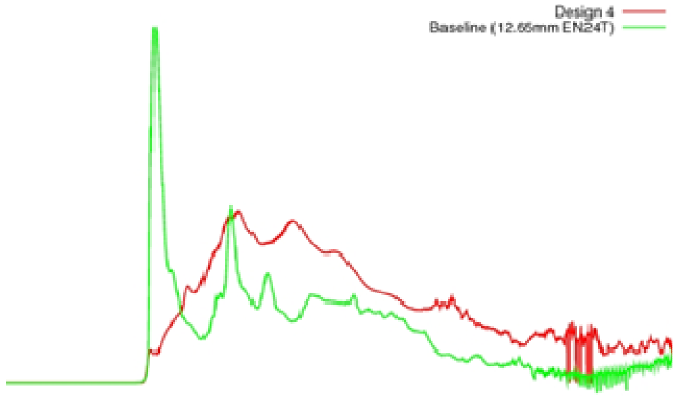




-32%

4





-21%

Study – Results 3

Mass Saving

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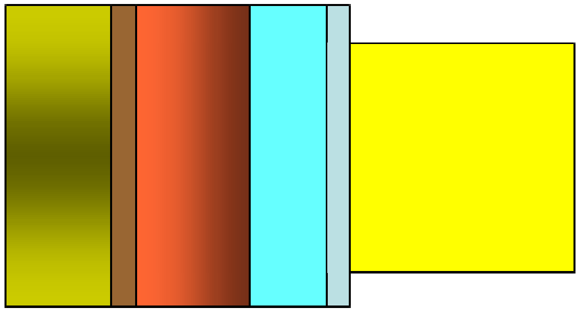
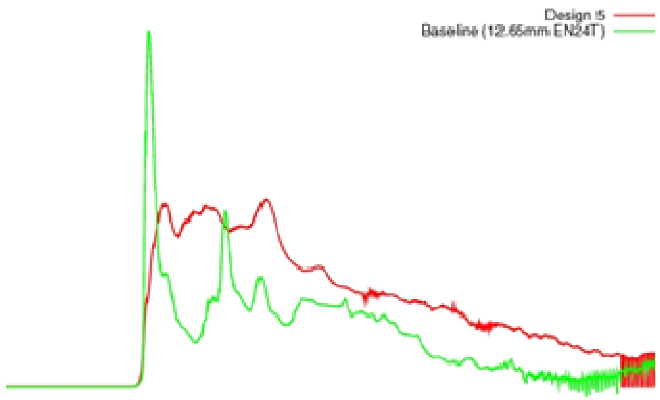
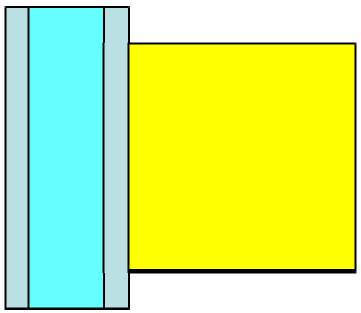
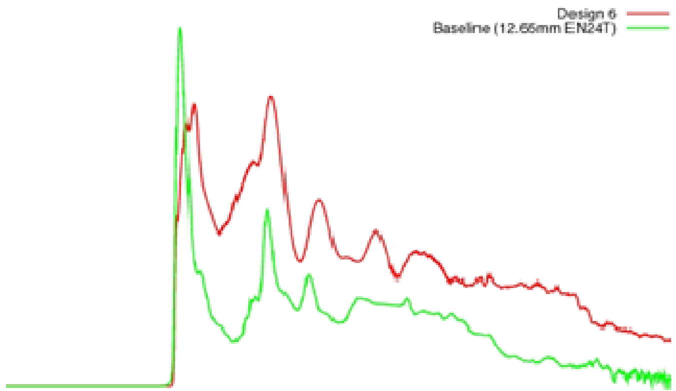




-41%

6





-60%

Study – Trials

QinetiQ Shoeburyness

QinetiQ 40mm Gun

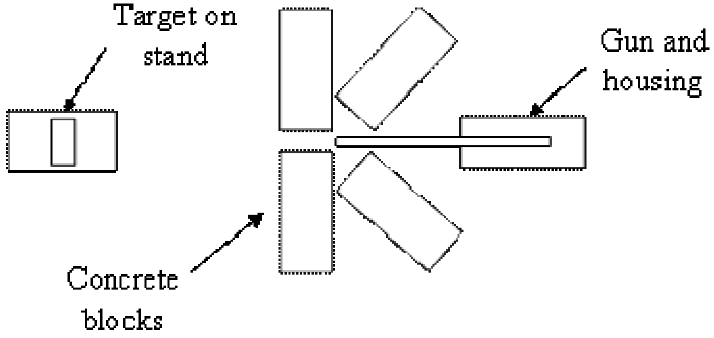
STANG 4496 format trials

75mm square barrier plates

60mm diameter L/D cylinder

Instrumentation

- VISAR
- High speed video
- Witness plates



Study – Trials Results

All designs produced IM responses

- Ranged from type IV to VI

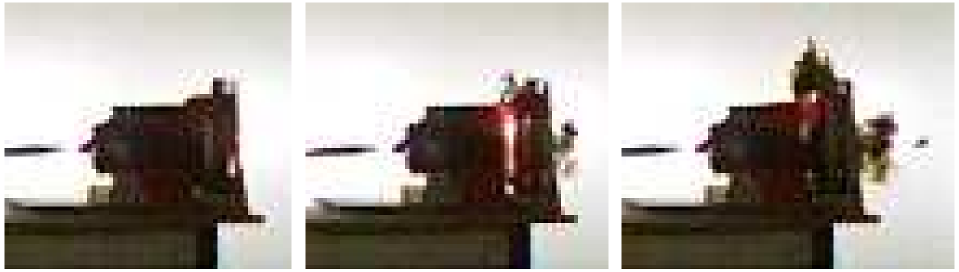
Other observations

- Al foam often ignited

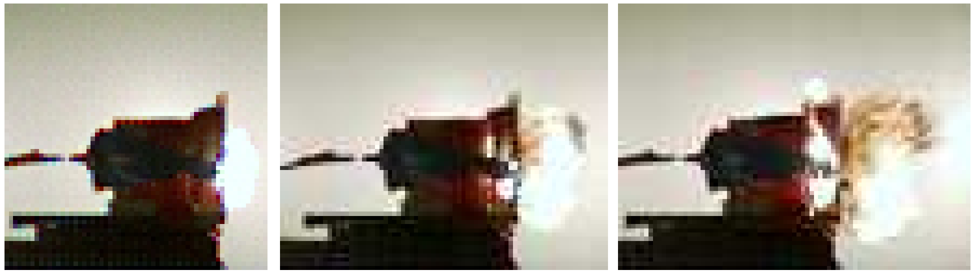
Ranking of responses

Design	Response	Mass
4	VI / V	-21
5	V	-41
1	V / IV	-21
3	V / IV	-32
2	V / IV	-25
6	V / IV	-60

Type V



Type IV



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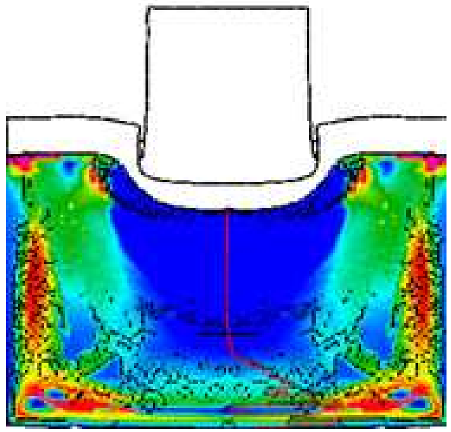
Conclusions & Recommendations



Conclusions

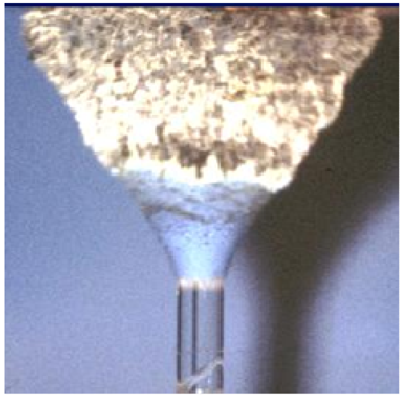
Potential of significant mass savings – and still achieve IM status

- Some also reduce volume
- Principles of the operation of layered mitigation/armour systems understood

QinetiQ QSPM produced excellent material property predictions

Modelling methodology demonstrated and validated

- Predict material characteristics & understand salient attributes
- Design layered mitigation systems
- Model & iterate design with QinetiQ GRIM/DYNA/CHARM
- Select preferred choices & validate



Optimisation still required for individual application

Research still required to predict ignition/violence as well as SDT

This work is currently at Technology Readiness Level (TRL) 3/4

Recommendations

Next steps:

- Employ this toolset on an actual system
  - Need to establish which weapon systems would most benefit
  - Need to avoid compromising performance
- Need to address
  - Effect on munition lethality
  - Any potential compatibility issues between the explosive and mitigation materials

Developments required

- Ability of instrumentation to accurately identify reaction types
- Predictive capabilities to distinguish between IM reaction types III, IV & V

Exploitation

- Able to inform the design of cases for future weapon systems
- Able to inform the design of packaging for existing and future systems

Acknowledgements

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