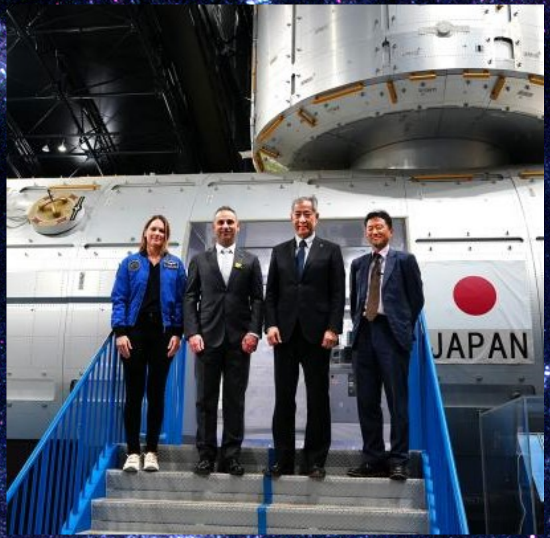
11th UNISEC-Global Meeting

Student Session

Adapting Layered Space Shielding for Ballistic Fragmentation

Jasmine Mari KHUU

Australian Space Agency

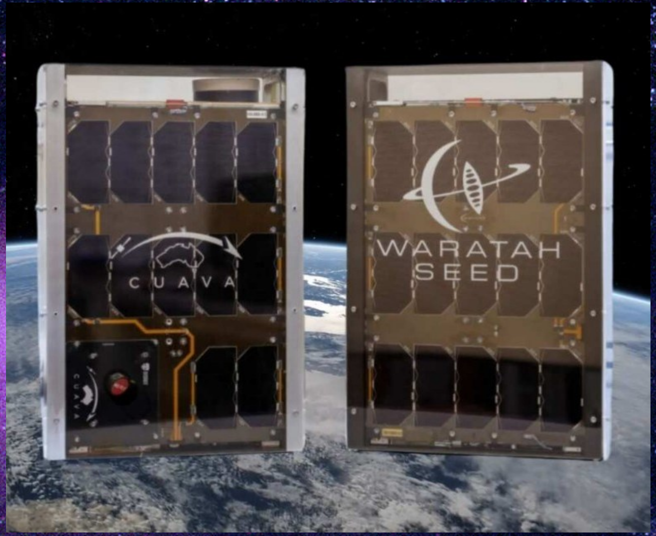


Partnered with JAXA on its Hayabusa2 Return mission. Retrieved an asteroid sample that landed in South Australia's Woomera Prohibited Area in 2020

Katherine Bennell-Pegg

First Australian Astronaut for missions to the International Space Station and beyond in 2024.
University of Sydney alumna

C U A V A



University of Sydney satellites. CUAVA-2 and Waratah Seed-1 CubeSats.
Launched into space aboard SpaceX Falcon 9 rocket, Transporter-11 Vandenberg Space Force Base in California, 16 August 2024, California local time, US

USYD Rocketry Team

Winner of the 2025 International Rocket Engineering Competition (IREC).
Pardalote came first place in the Student Research and Developed (SRAD) Hybrid/Liquid Category

The Problem: IEDs and Civilian Vulnerability

- IED fragments = threat in modern asymmetric conflict
- Civilians & aid workers → unarmoured vehicles
- Existing armour = too heavy / too costly
- Humanitarian protection gap

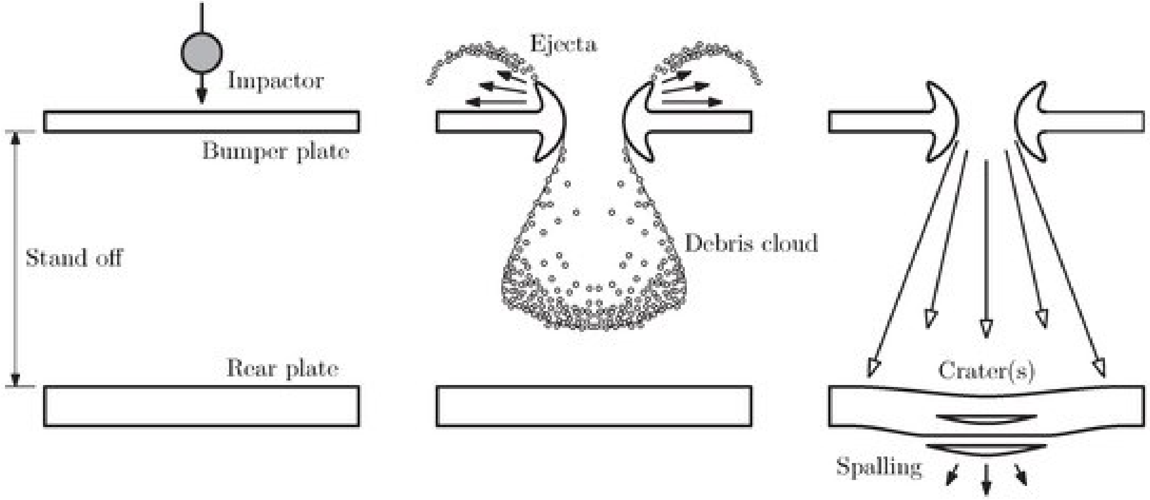
IED examples

Aftermath of an IED explosion

Bushmaster Protected Mobility Vehicle

Inspiration from Space

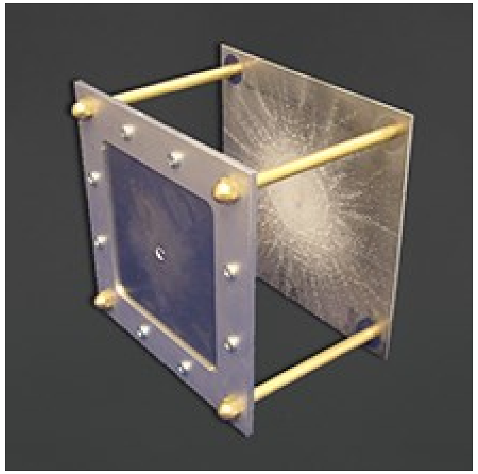
- Space debris > 7 km/s
- Whipple Shield → lightweight, layered system
- Break, absorb, disperse, stage energy dissipation
- Proven for ISS → adapt for IED fragments?



International Space Station

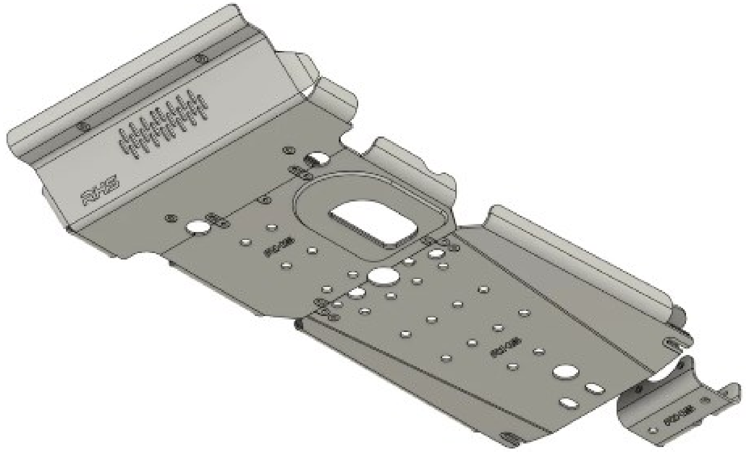
Monolithic Shield

Whipple Shield



Concept: Bringing Whipple Shields to Earth

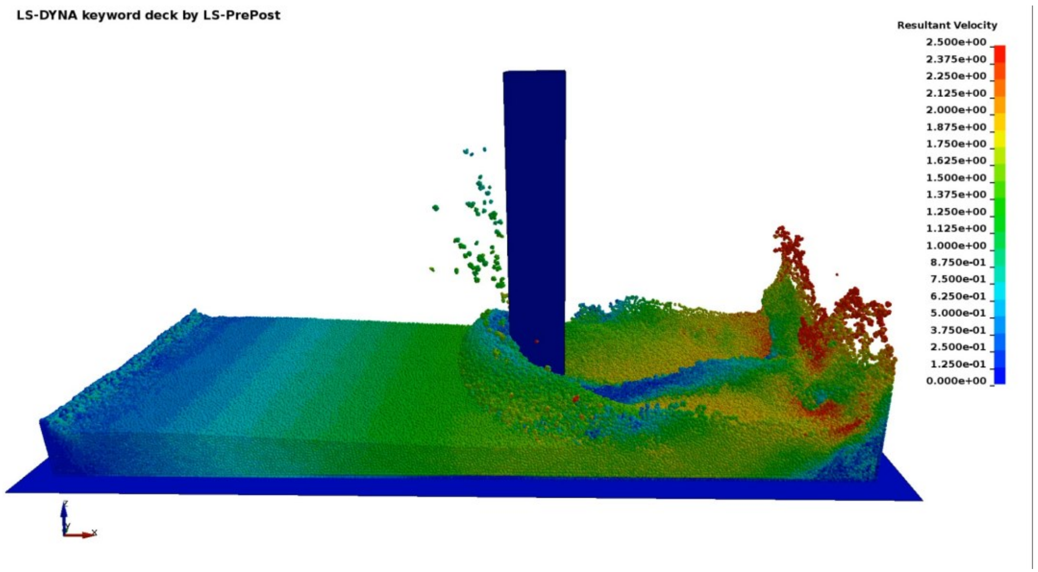
- Underbody shield using Whipple principle
- Slower velocities → less spallation, more intact fragments (still deadly)
- Aluminium & mild steel → common and affordable
- Lightweight, bolt-on, modular



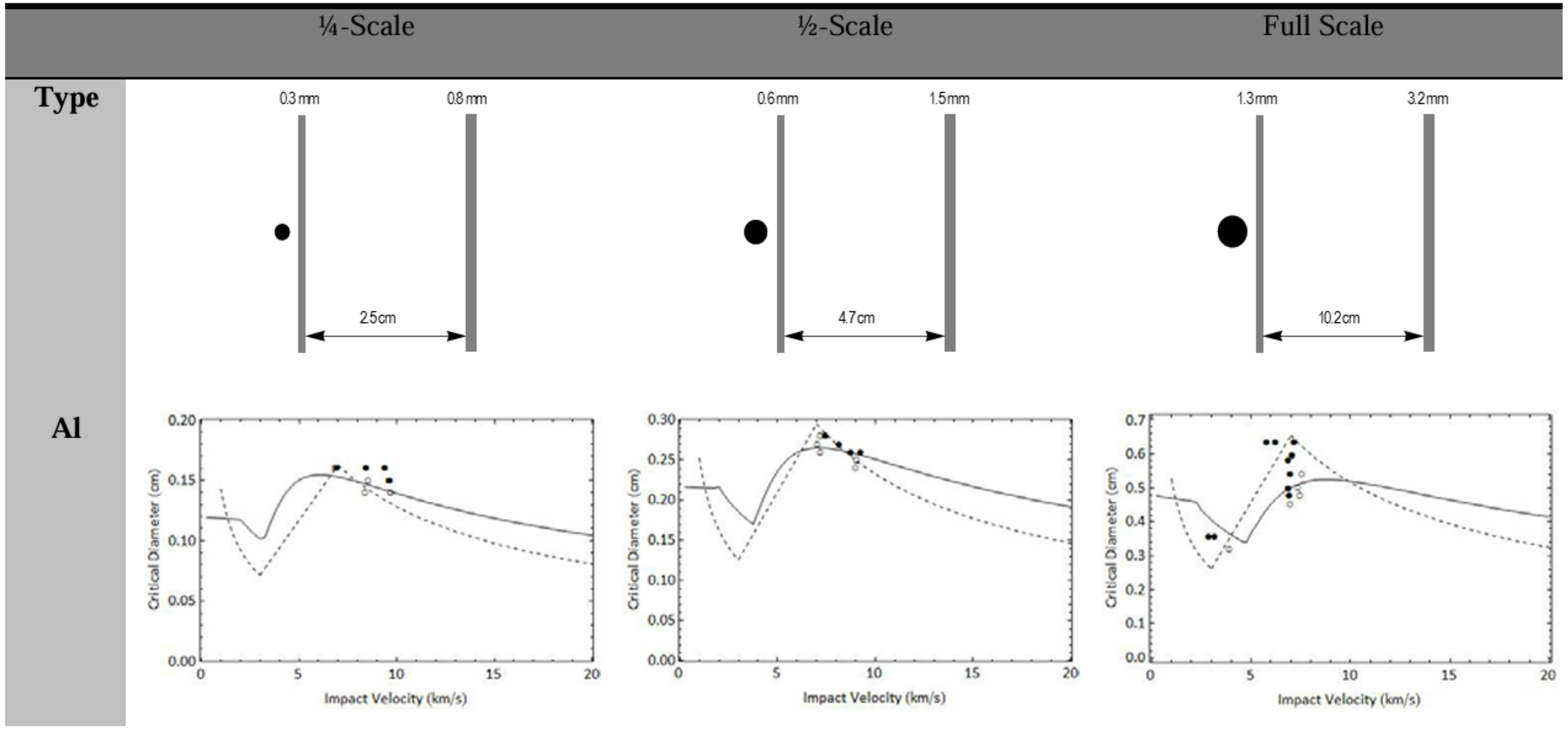
Visualisation of plates with existing bash plates

Methodology

Capability of LS-DYNA using SPH

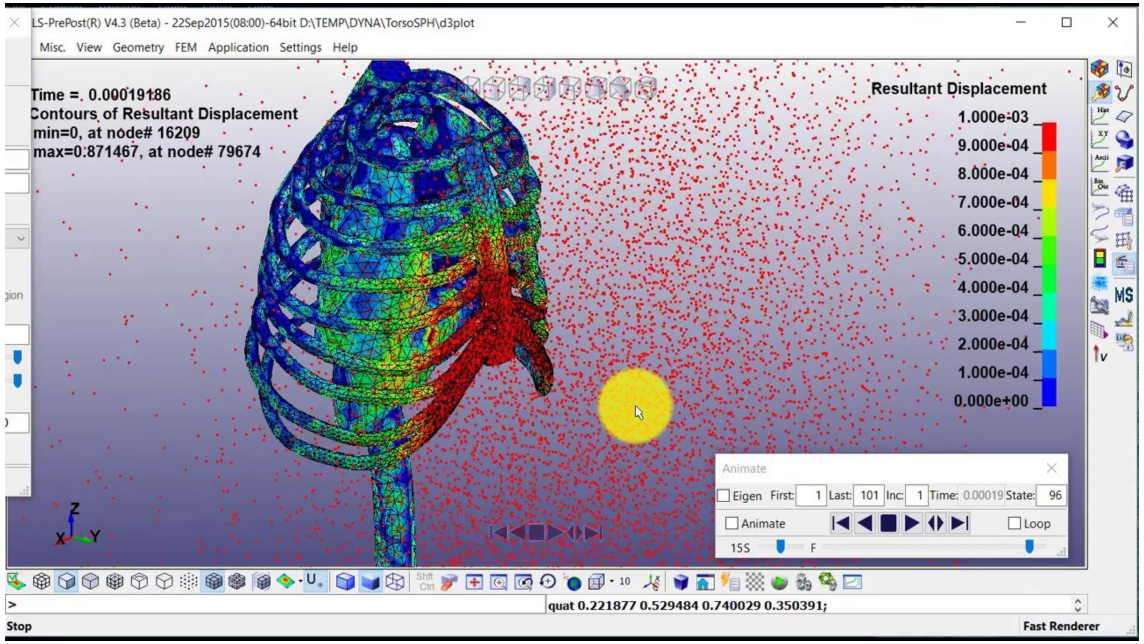


- Test feasibility with LS-DYNA (SPH) as it captures fragmentation, spallation, and deformation
- Little done research for Mild Steel shields.
- 12 simulations at 3.5–5.5 km/s
- Single layer → fundamental impact behaviour



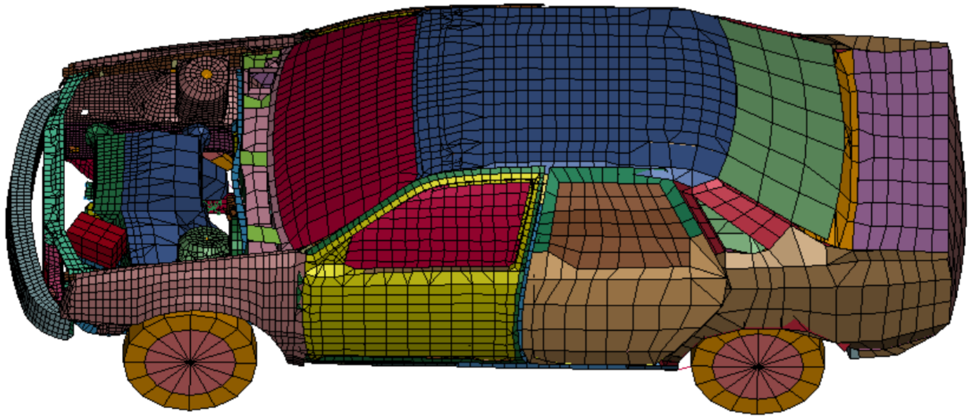
Why Simulation?

- Live tests = dangerous and expensive
- Numerical simulation = safe + repeatable
- LS-DYNA - high strain rate problems (car crashes to bullet impact)



SPH for Blast Effect on Torso

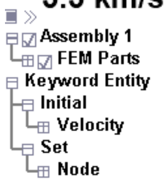
IED blast



LS-DYNA used for car crash simulations

METHOD

5.5 km/s aluminium projectile and aluminium shield



$$p = \frac{\rho_0 C^2 \mu \left[1 + \left(1 - \frac{\gamma_0}{2}\right)\mu - \frac{a}{2}\mu^2\right]}{\left[1 - (S_1 - 1)\mu - S_2 \frac{\mu^2}{\mu+1} - S_3 \frac{\mu^3}{(\mu+1)^2}\right]^2} + (\gamma_0 + a\mu)E,$$

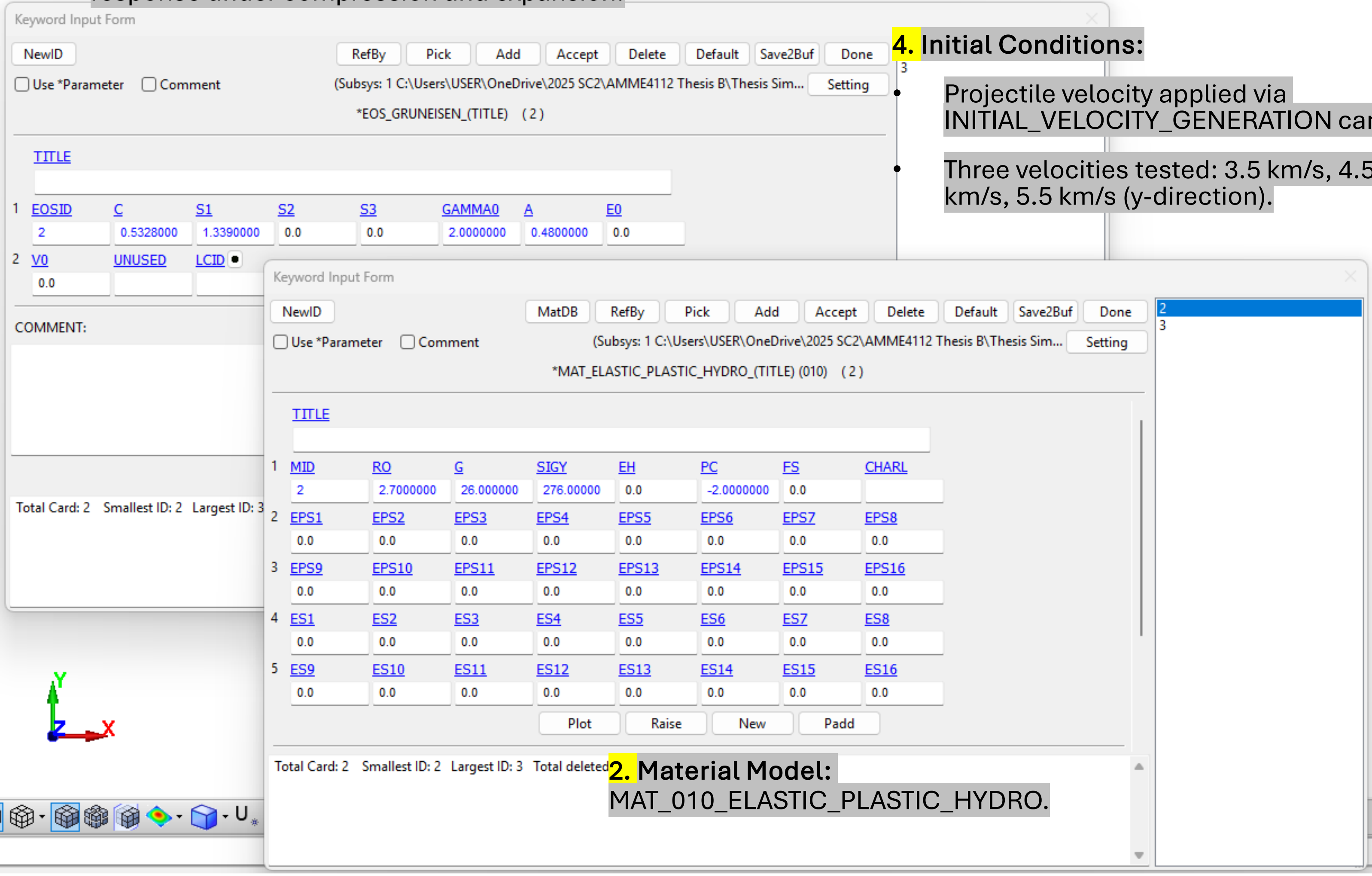
1. Geometry, Meshing & SPH Setup:

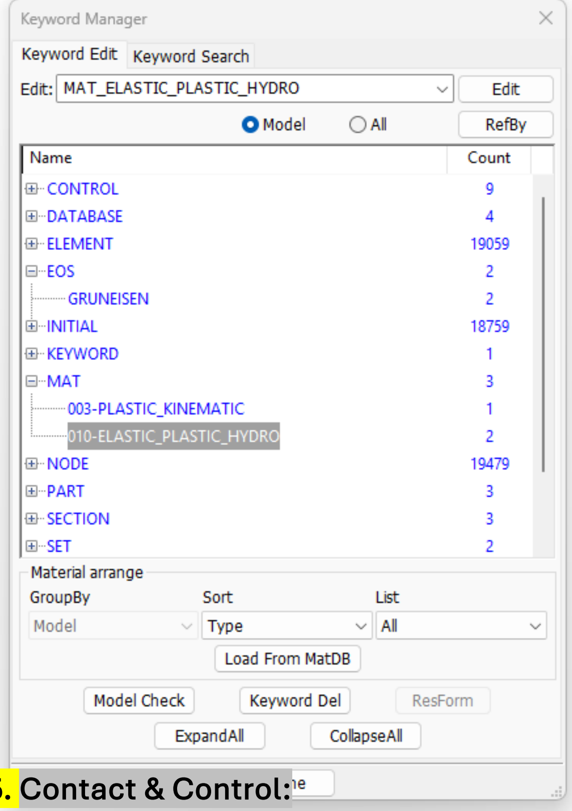
- Shield: cylindrical plate, radius × 0.4 cm, centred at (0, 0, 0). Grid: NumX = 50, NumY = 6, NumZ = 50,
- Projectile: SPH sphere, radius 0.5 cm, initial position (0, –0.7, 0). Grid: NumX = 30, NumY = 30, NumZ = 30

3. Equation of State: Grüneisen EOS, modelling shock response under compression and expansion.

4. Initial Conditions:

- Projectile velocity applied via INITIAL_VELOCITY_GENERATION card.
- Three velocities tested: 3.5 km/s, 4.5 km/s, 5.5 km/s (y-direction).





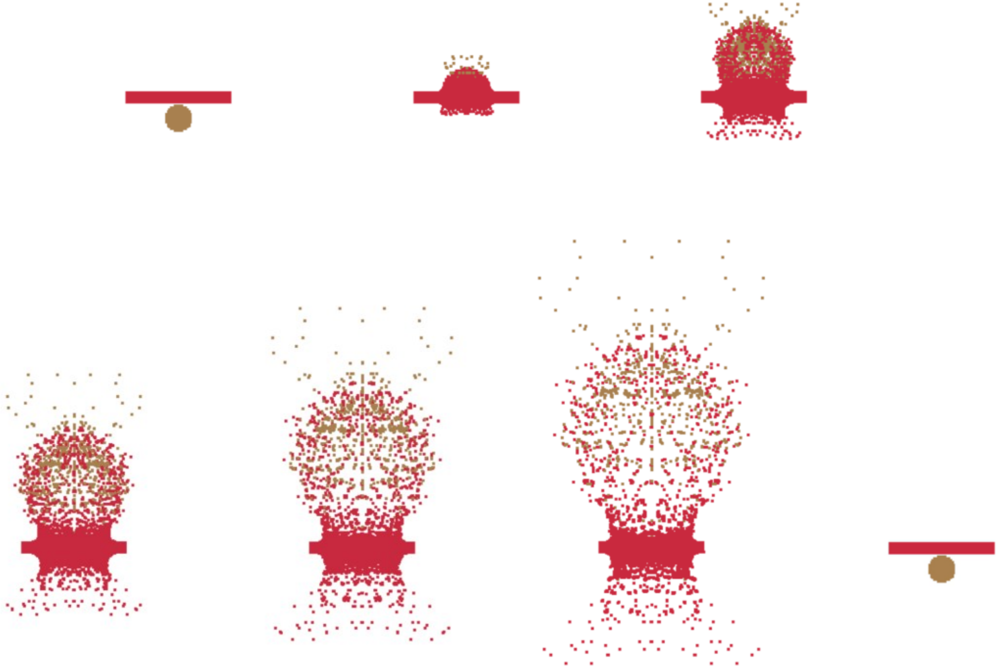
2. Material Model: MAT_010_ELASTIC_PLASTIC_HYDRO.

5. Contact & Control:

- Contact defined using automatic surface interaction with adjusted penalty and penetration settings.
- DT = 0.05
- Total time = 20 micro seconds

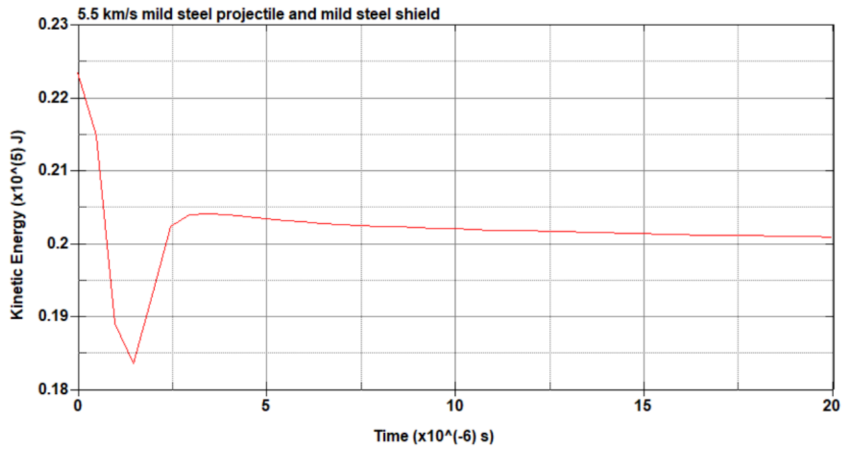
Results

- All 12 simulations, mild steel absorbed more energy than aluminium.
    - Steel’s higher density and toughness explain its superior energy absorption.
- The initial sharp kinetic energy drop = energy absorbed by the shield.
- The later plateau = energy carried by surviving fragments.

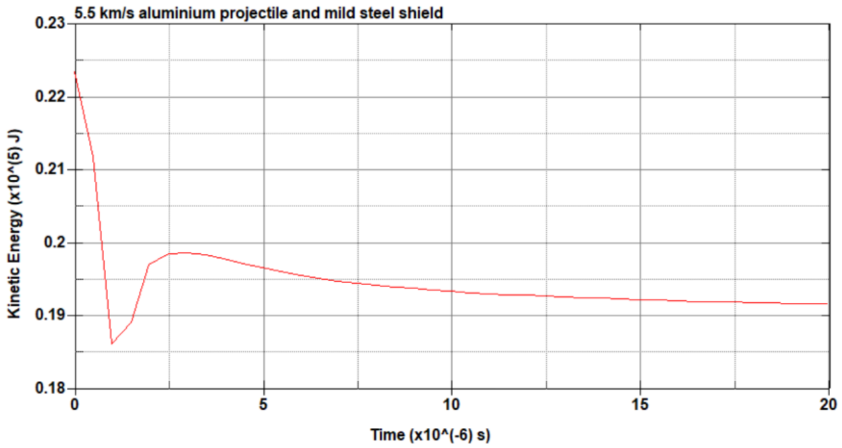


Example of spallation from an Aluminium ballistic against an Aluminium shield at 5.5 km/s

Kinetic energy of the overall system



Mild Steel Ballistic fragment vs Mild Steel Shield at 5.5 km/s



Aluminium Ballistic fragment vs Mild Steel Shield at 5.5 km/s

Results

- Aluminium projectiles fragmented easily; steel projectiles were harder to stop.
- At 3.5 km/s, less fragmentation.
- At 5.5 km/s, rear-side spallation increased, reducing protection effectiveness.
- At lower velocities, projectiles act more like solid chunks.
- Lower-speed impacts aren't safer: fewer but heavier fragments increase lethality.
- No single layer was sufficient for full protection = need for Whipple shields.

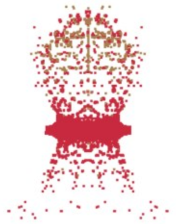
Al sphere Al shield at 3.5km/s

Al sphere Steel shield at 3.5km/s

Al sphere Al shield at 5.5km/s

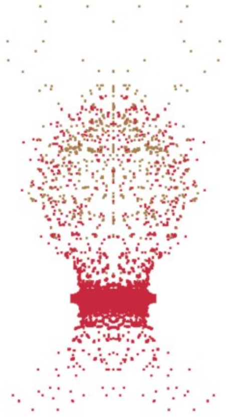
Al sphere Steel shield at 5.5km/s

Steel sphere Al shield at 3.5km/s



Steel sphere Steel shield at 3.5km/s

Steel sphere Al shield at 5.5km/s



Steel sphere Steel shield at 5.5km/s

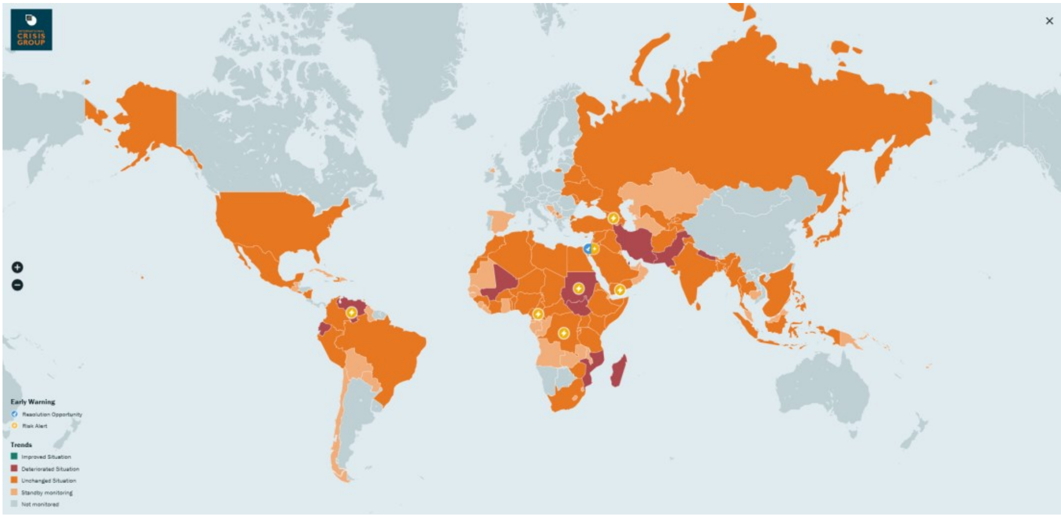
Conclusion and Future Work

- Study tested whether space shielding physics could inform lightweight ballistic protection
- Simulations showed single-layer shields cannot fully stop hypervelocity fragments
- Single layers still absorb significant energy via deformation and fragmentation
- Mild steel identified as a feasible material for shields
- Findings support multi-layered, spaced shielding for improved protection

- Future work with multi-layer configurations & spacing
- Include blast + fragment coupling using ALE (Arbitrary Lagrangian Eulerian)
- Experimental validation

- Protect civilians & aid workers
- Bolt-on, low-cost, replaceable
- Reduce injury severity → save lives

Current conflicts in OCT25



QUESTIONS?

Adapting Layered Space Shielding for Ballistic Fragmentation

A shield that began in space - to protect lives on Earth