

NP AEROSPACE

ENGINEERING SURVIVAL: THE ROLE OF SIMULATION IN DEFENCE VEHICLE PROTECTION

CONSTRUCTION TELEHANDLER: A CASE STUDY IN BLAST ANALYSIS

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AGENDA

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1. Why Blast Simulation?
2. Blast Analysis Principles:
 - a) Arbitrary Lagrangian Eulerian (ALE) Modelling
 - b) Blast Test Correlation – confirmation of predictions
 - c) ‘Digital Twin’ Success!
3. Case Study – Construction Telehandler:
 - a) Customer Blast Requirements vs Costs & Timelines
 - b) Potential Issues Risk Reduction
 - c) Blast Result Predictions
 - d) Physical Blast Test
 - e) Correlation
4. Summary - Resulting Cost & Time Savings

WHY BLAST SIMULATION?

Cost:

- Typical blast test cost for STANAG 4569 would be ~£0.5M
- Most armoured systems require multiple blast tests, total cost for a construction telehandler would be ~£1.0M (assuming multiple tests are possible per vehicle)

Time:

- Procurement of a vehicle, protection materials, and assembly of the armoured product can take 6-8 months for a new build, and 4-6 months for a repair/rebuild for a re-test

Blast simulation allows for multiple iterations of the design to reduce the risk of failure of the physical blast test. This comes with a substantially reduced cost and timescale compared to purely physical test iterations.



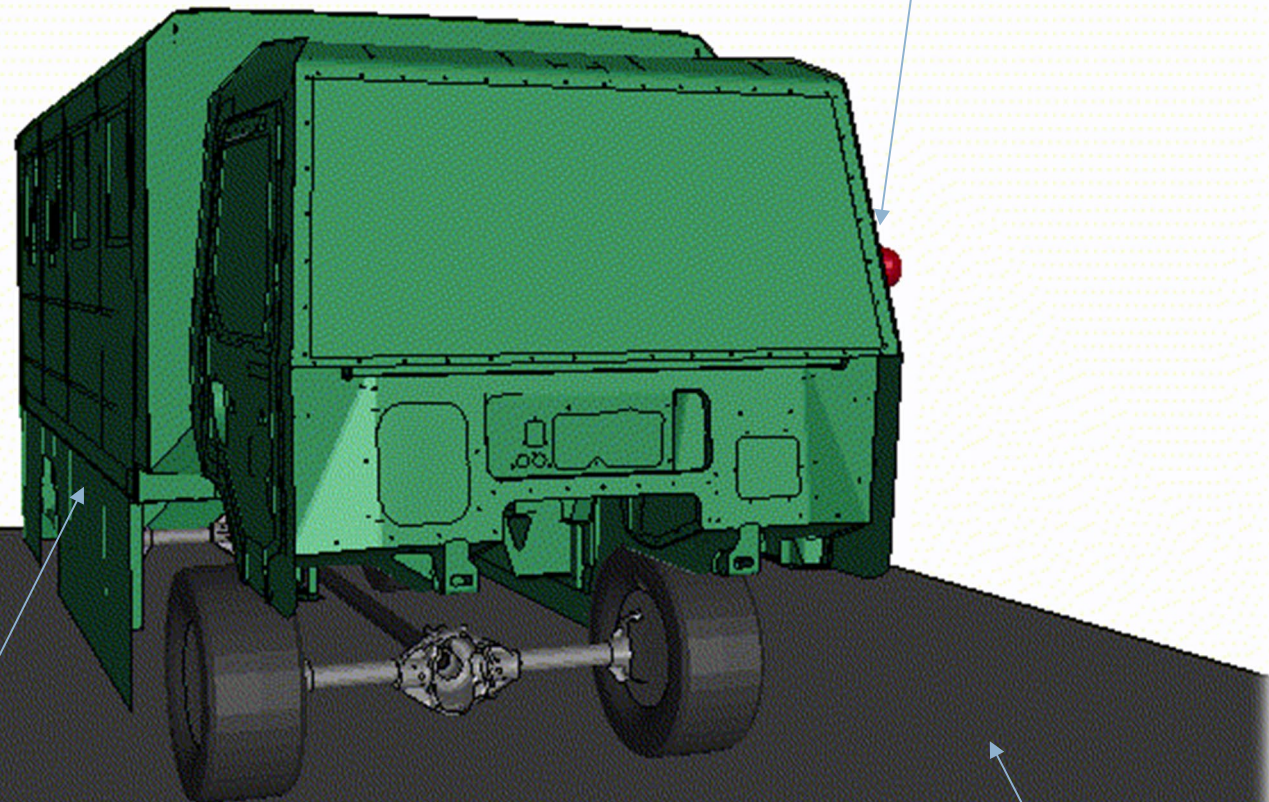
BLAST ANALYSIS PRINCIPLES

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ARBITRARY LAGRANGIAN EULERIAN (ALE) MODELLING

Time = 0

Positioned Charge



Lagrangian Structure

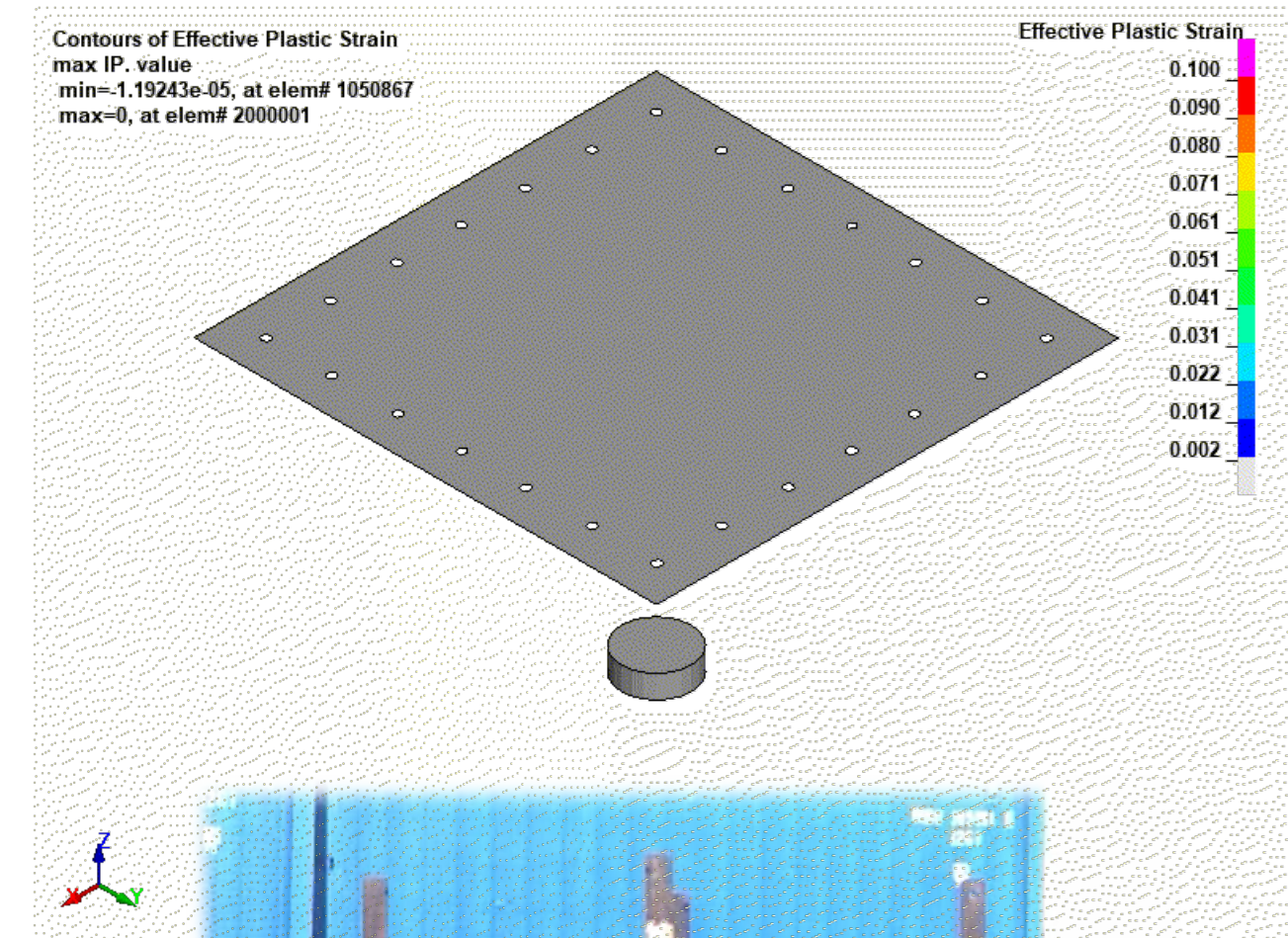
Eulerian Fluid

1. Blast events exhibit high energy events over a short period of time, not a typical CAE structural analysis.
2. This problem is solved using Fluid-Structure Interaction (FSI).
3. How does this work? Using Arbitrary Lagrangian (structure) Eulerian (fluid) modelling, or ALE.

BLAST TEST CORRELATION

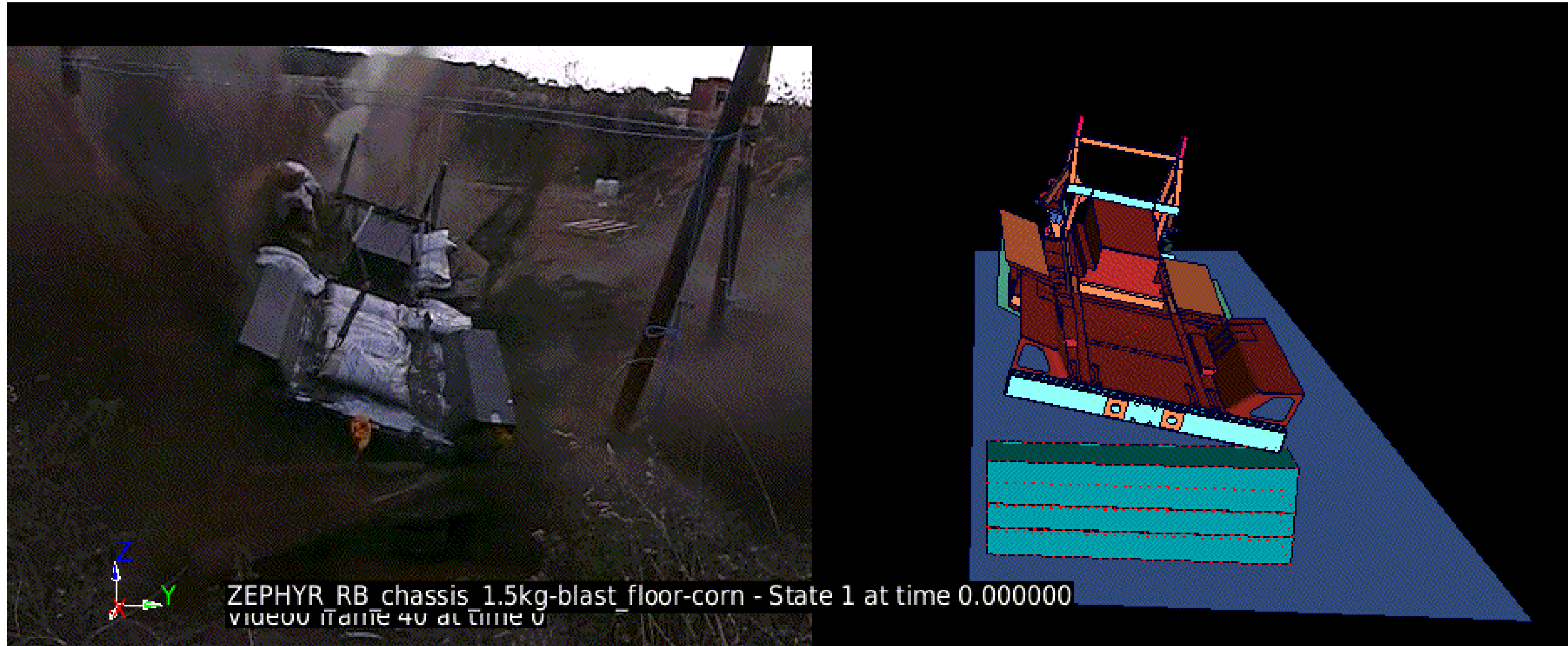
- Early correlation was performed using armour panels mounted on a test rig. This allowed for calibration of charge size and material stiffness.
- Correlation work was expanded to capture strain rate sensitivity and damage modelling to match the performance of the sample in test.

	Simulation	Test
1kg blast: Mobile rig rise	341mm	330mm
1kg blast: Panel dent	35mm	31mm
3kg blast: Mobile rig rise	1.67m	1.51m
3kg blast: Panel cumulative dent	171mm	165mm



'DIGITAL TWIN' SUCCESS

- The model was then further calibrated through application to a physical test vehicle.



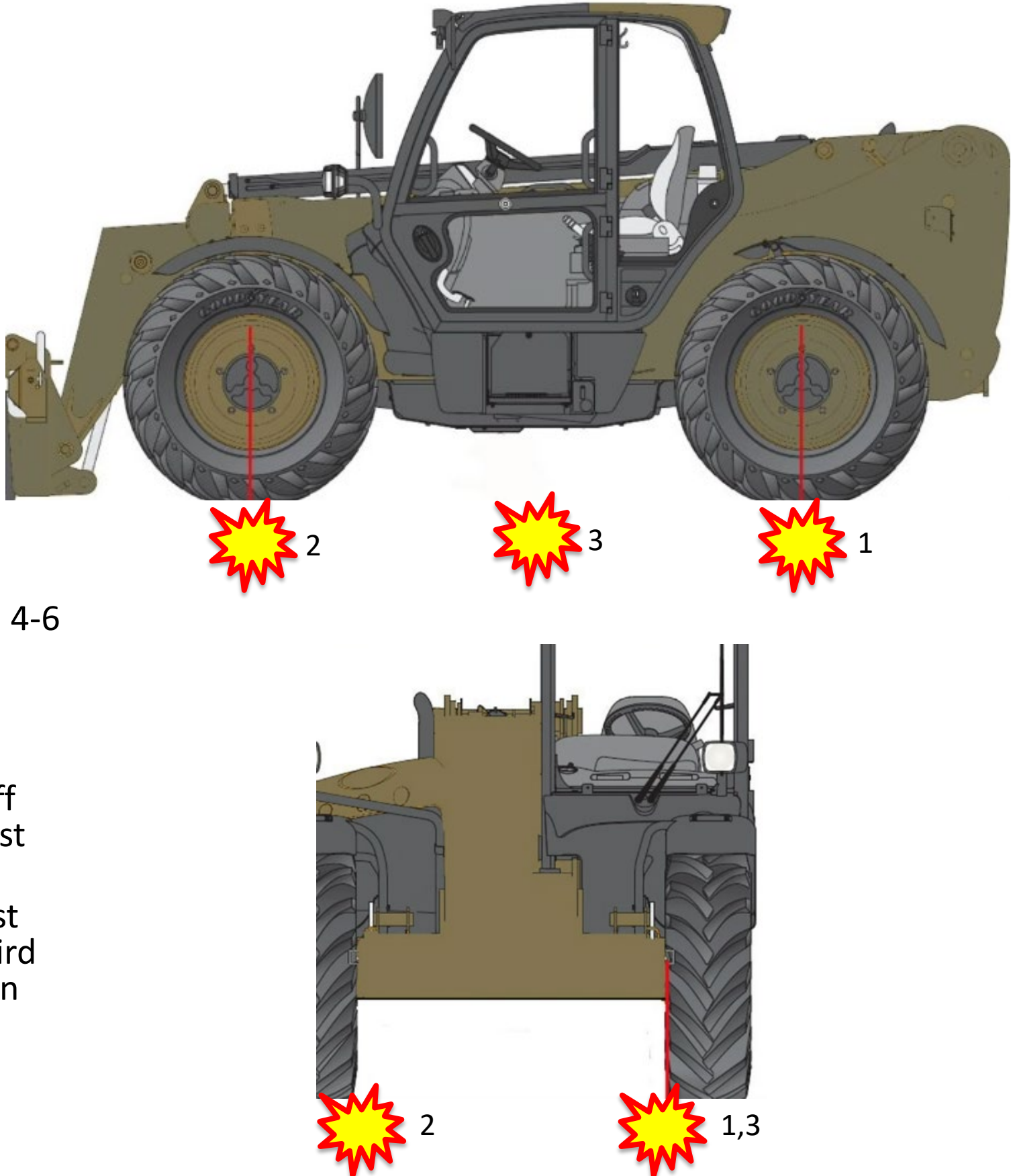
- The analysis captured identical flip mechanics and vertical displacement; thus a 'digital twin' for the blast conditions and the armour material was achieved.

CASE STUDY – CONSTRUCTION TELEHANDLER

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CUSTOMER BLAST REQUIREMENTS VS COSTS & TIMELINES

- **Requirement:**
 - Three underbody blasts signed off via physical blast tests
- **Pass Criteria:**
 - Dynamic Response Index (DRIZ) < 17.7
 - Pelvis Z acceleration < 23g for > 7ms
 - Lumbar Spine Compression < 6.7kN
 - Tibia Load < 5.4kN
- **Issue:**
 - The second blast costs an additional ~£50K
 - The third blast means a vehicle repair/rebuild before re-test which takes an extra 4-6 months rebuild/retest and an additional cost of ~£0.25M
- **Objective:**
 - To convince the customer that the second and third blast tests could be signed off through blast simulation rather than the added time and cost for the physical blast tests
 - It was agreed that if 'blind' simulations were done for all three blasts, and the first blast simulation correlated to the first physical blast test, then the second and third physical blast tests would not be necessary, and would be signed off by simulation only, thereby saving both time and cost for the project



POTENTIAL ISSUES RISK REDUCTION

- Potential Issues Identified:
 - Occupant injuries above threshold
 - Attachment of cab to chassis compromised
 - Ingress of blast debris & pressure into the cab
 - Minimise intrusion into the cab due to the blast

Cab Main Structure:



Finished Protected Cab:



POTENTIAL ISSUES RISK REDUCTION

- **Occupant Injury Prevention:**

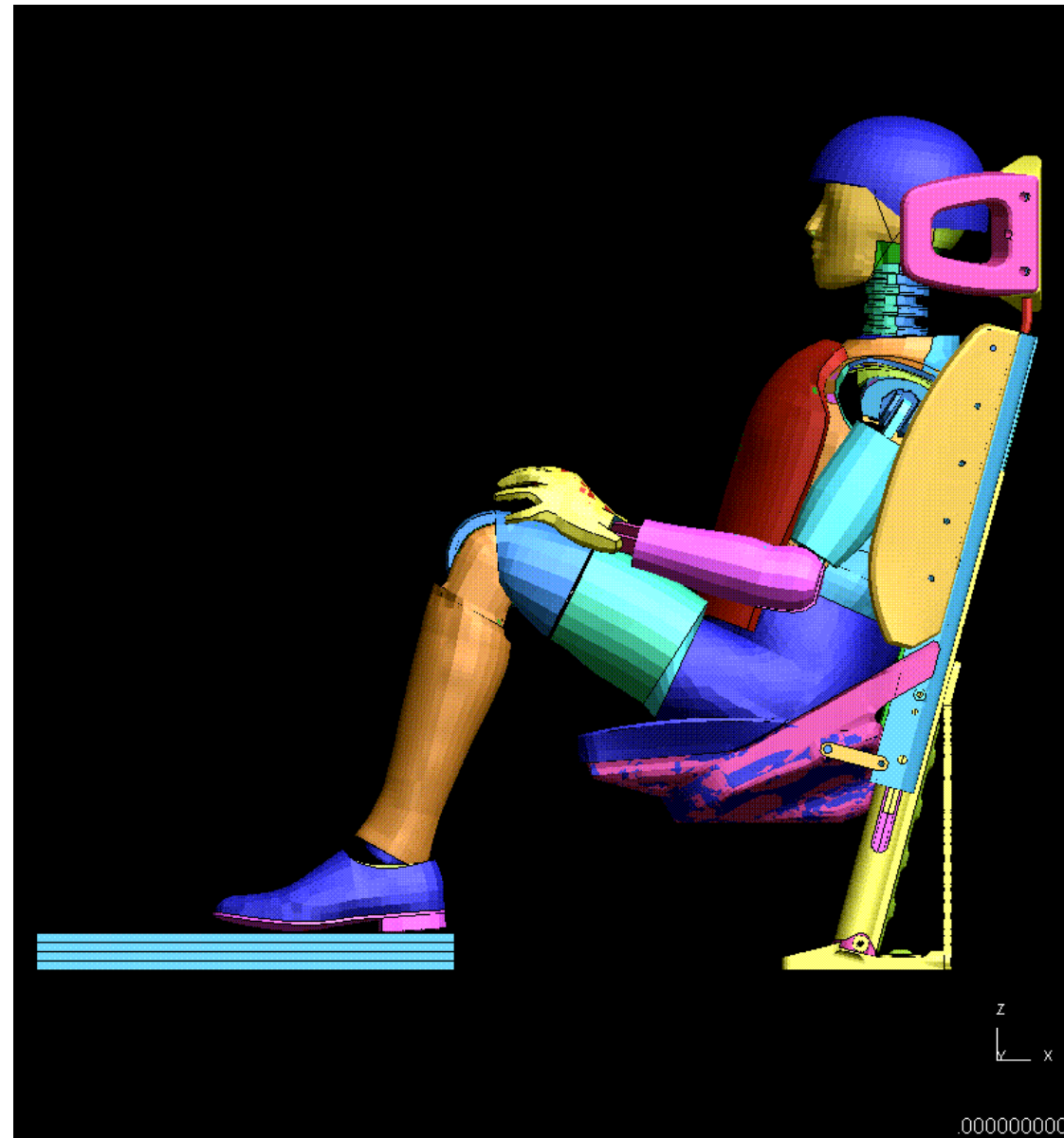
- Blast Mitigating Seat for:

- DRlz
- Pelvis Z-Acceleration
- Lumbar Spine Compression

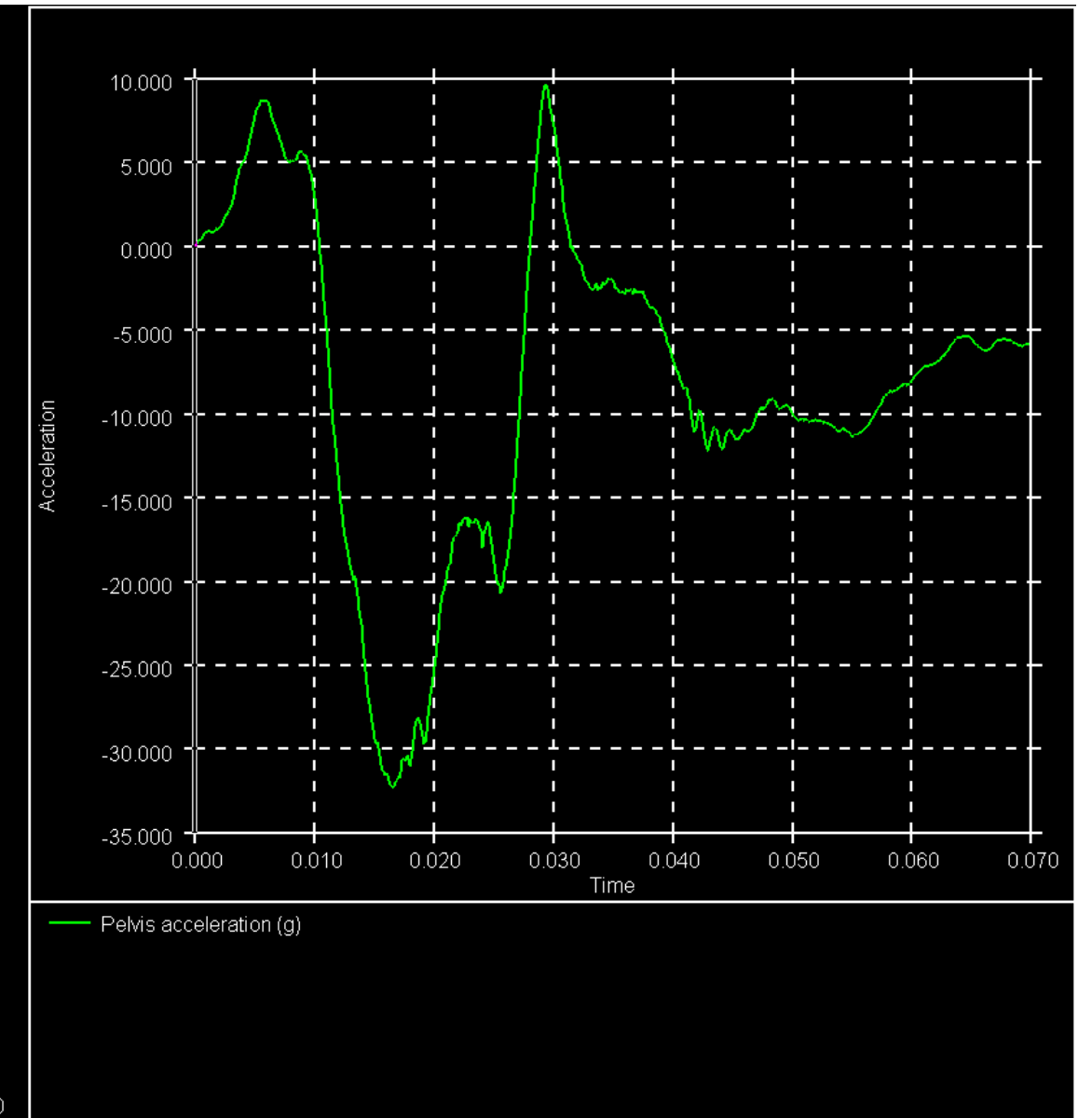
- Footpad for:

- Tibia Loads

Blast Seat Attenuation:



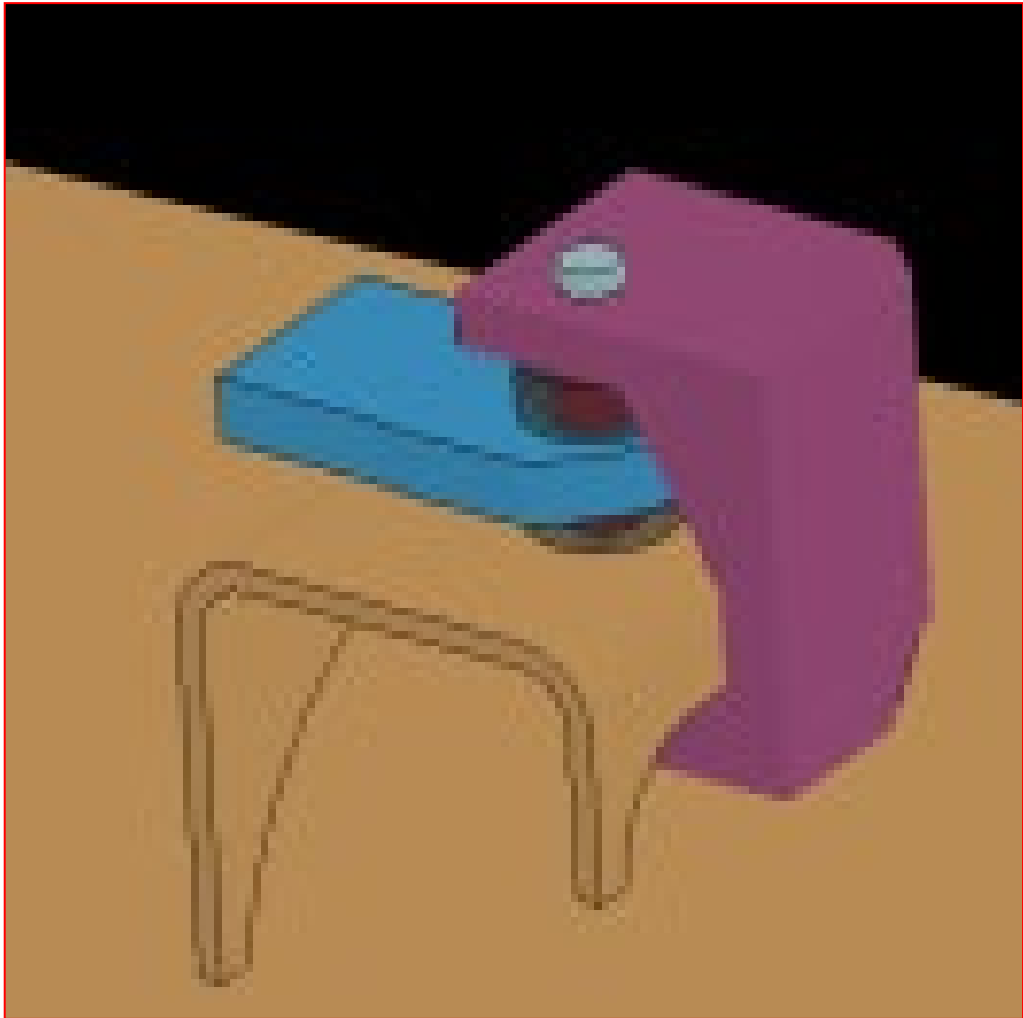
Pelvis Z-Acceleration:



POTENTIAL ISSUES RISK REDUCTION

- **Cab to Chassis Retention:**
 - Retention Bracket added

Bracket in Purple Added:



Simulation Showing Cab Retention:



POTENTIAL ISSUES RISK REDUCTION

Blast Intrusion Minimisation:



Double Walled Floor

Blast Debris & Pressure Minimisation :



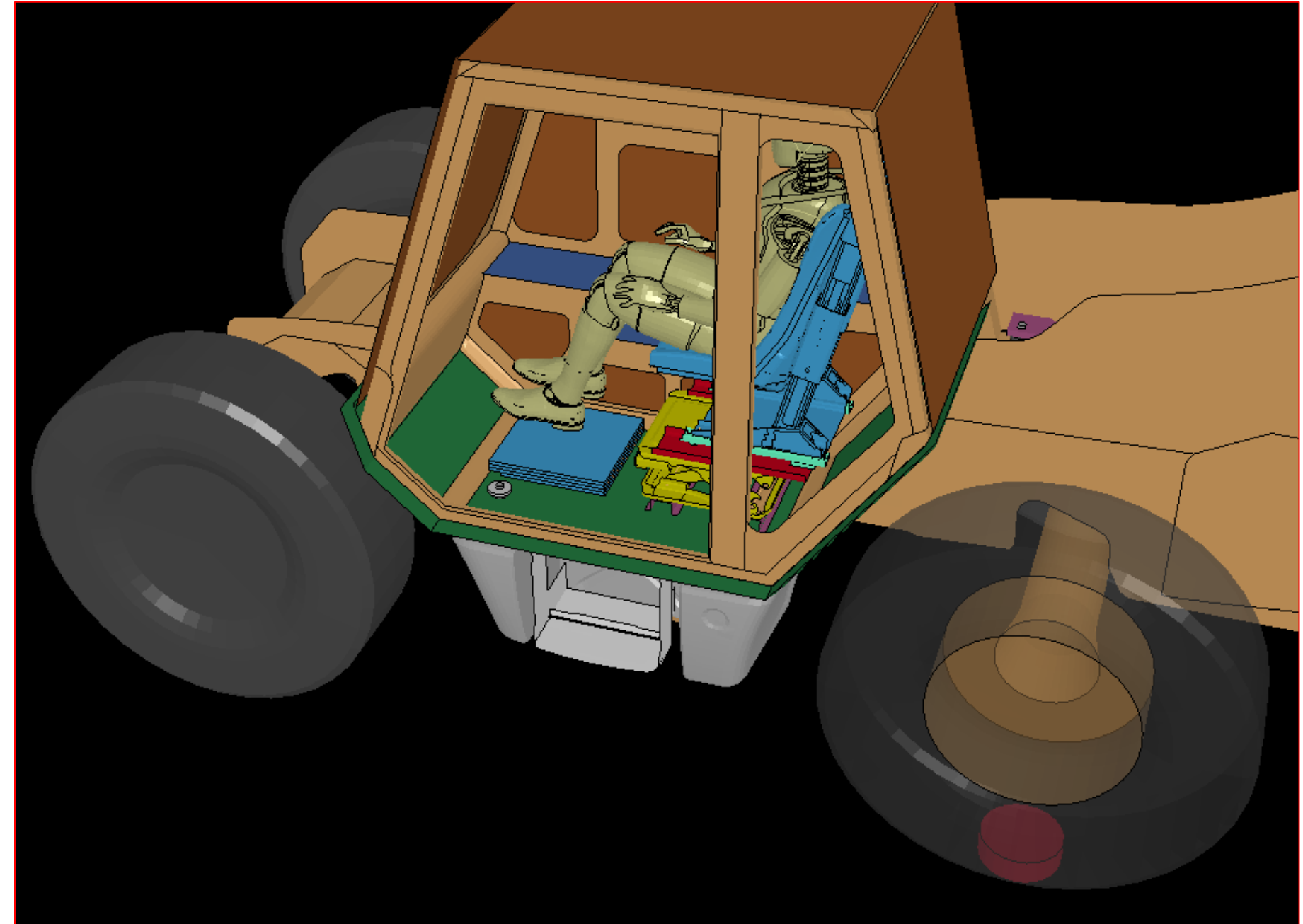
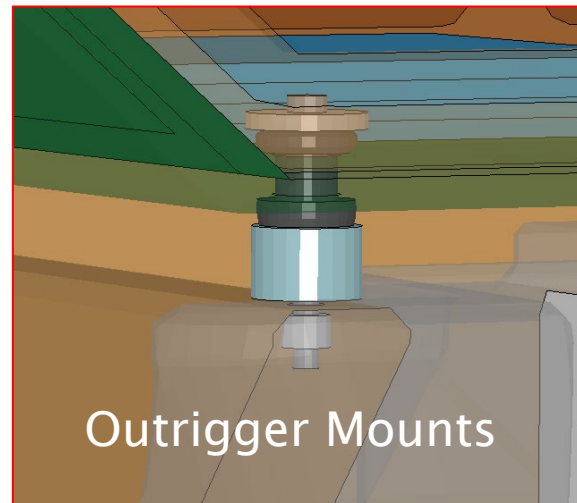
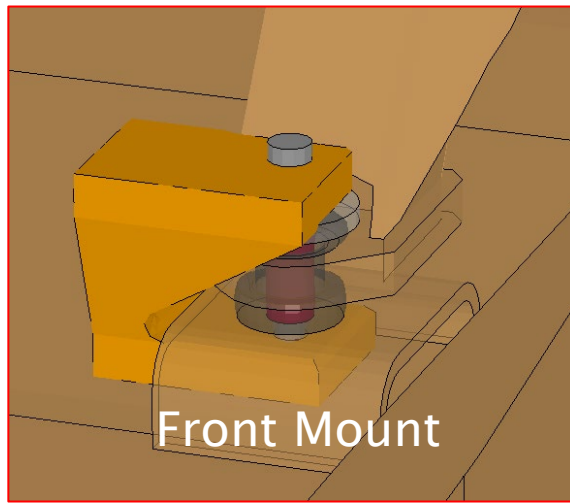
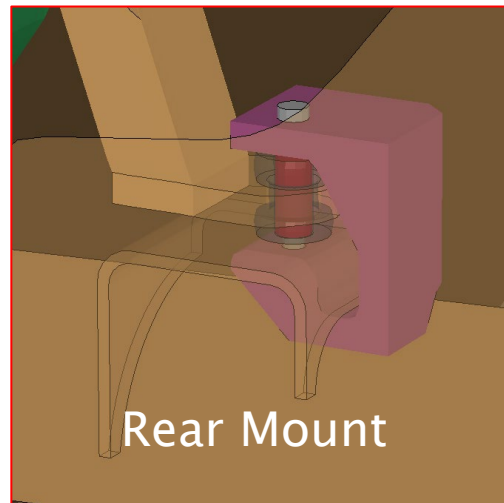
Effective Joint Sealing

BLAST RESULT PREDICTIONS

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BLAST RESULT PREDICTIONS – REAR WHEEL

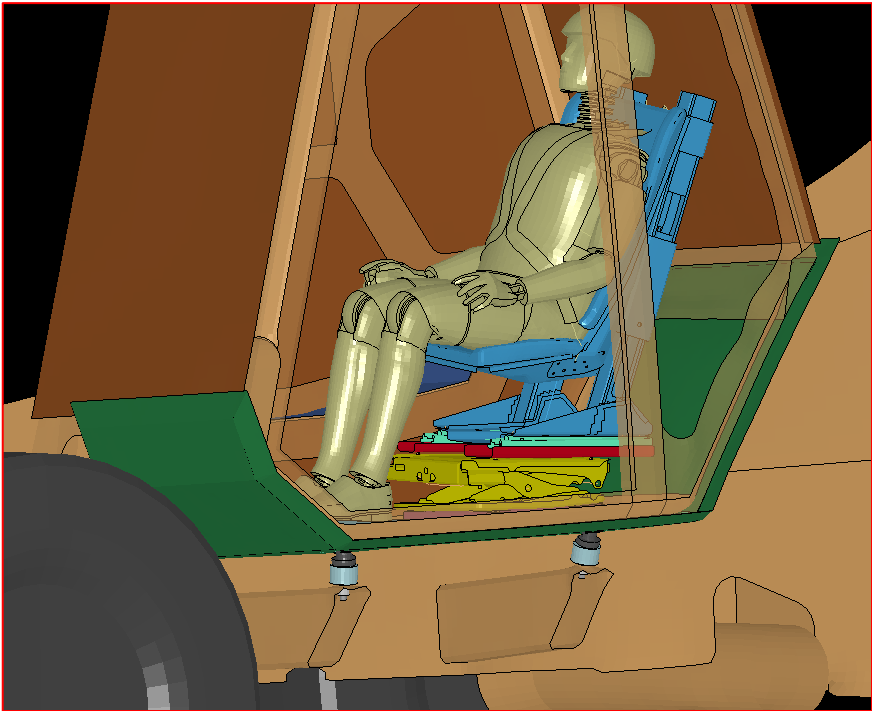
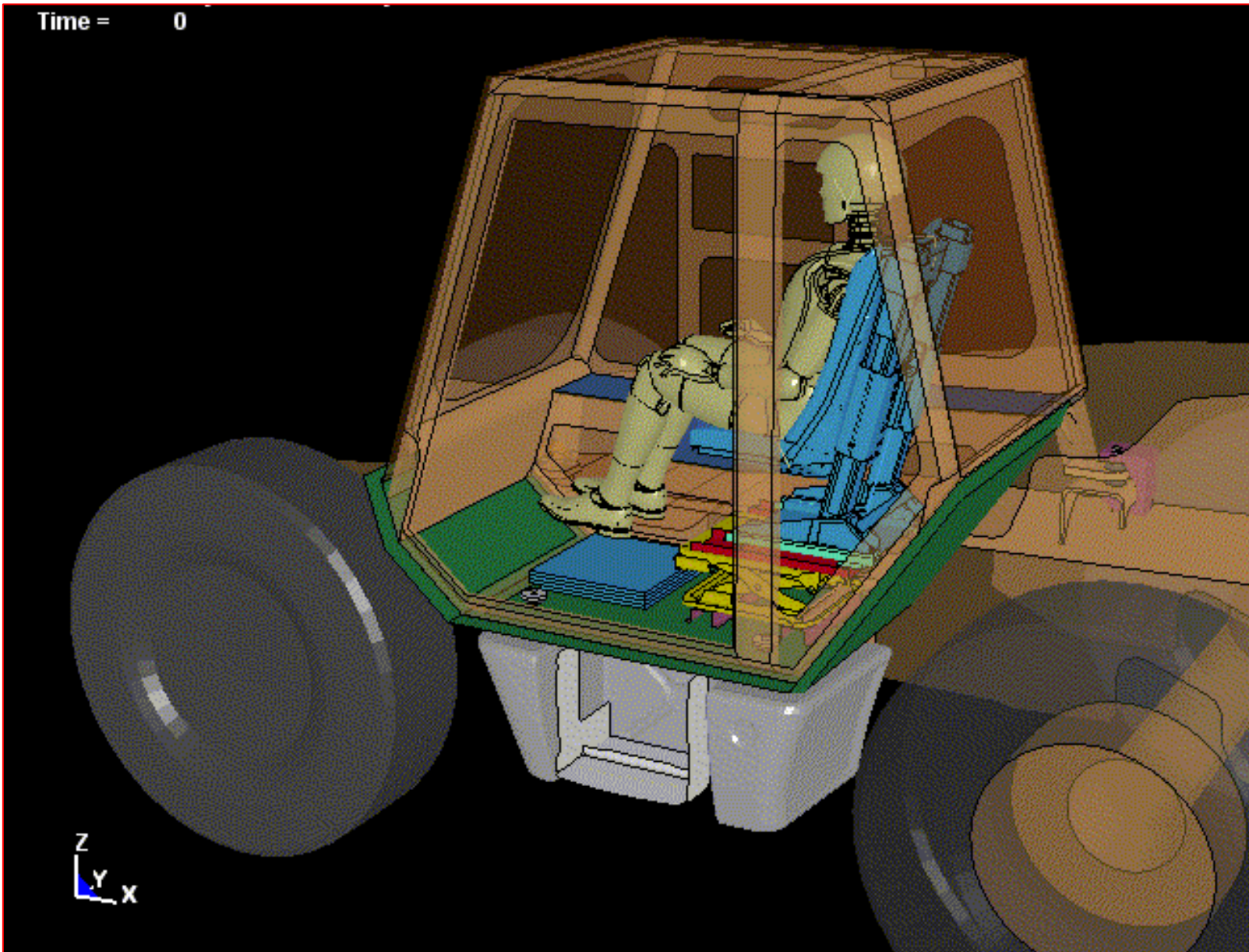
- Objective – test prediction when the charge is positioned under the rear wheel
- Confirm performance of the mounting interface for the cabin
- Validate injury performance for ATD under blast conditions



BLAST RESULT PREDICTIONS – REAR WHEEL – STRUCTURAL INTEGRITY

Cabin Integrity

- Peak cabin intrusion = 45mm.
- Structural integrity remained uncompromised.



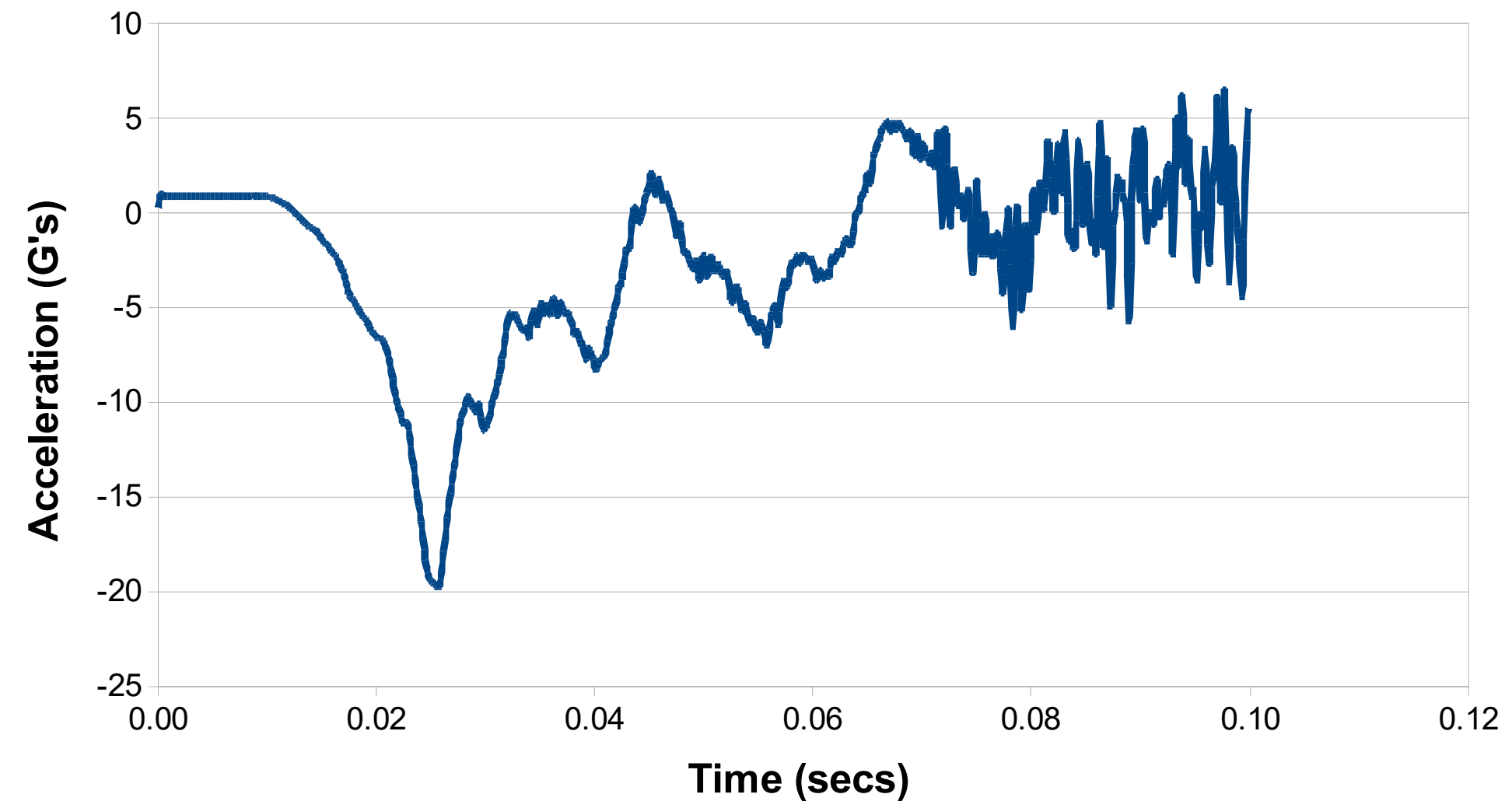
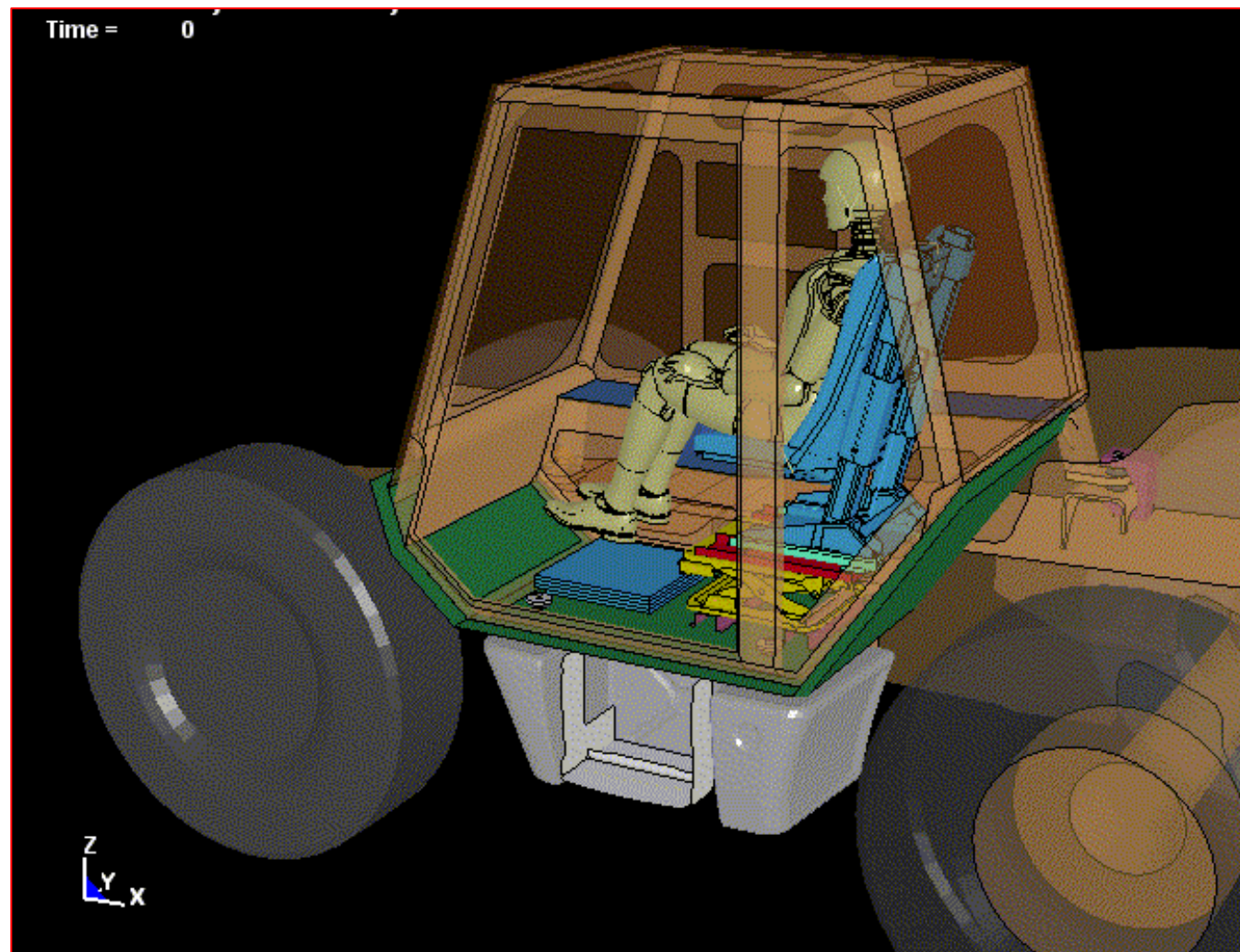
Mount Integrity

- No outrigger failure recognised.
- Safety factor for fasteners was 1.73 for M16 x 2.0, 12.9 grade.

Predicted Pass

BLAST RESULT PREDICTIONS – REAR WHEEL – INJURY METRICS

- Peak pelvis acceleration = 19.8g
- This resulted in a DRlz predicted of 8.6, the target for which is 17.7, and therefore this was considered a pass



Predicted Pass

PHYSICAL BLAST TEST

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PHYSICAL BLAST TEST



Before:



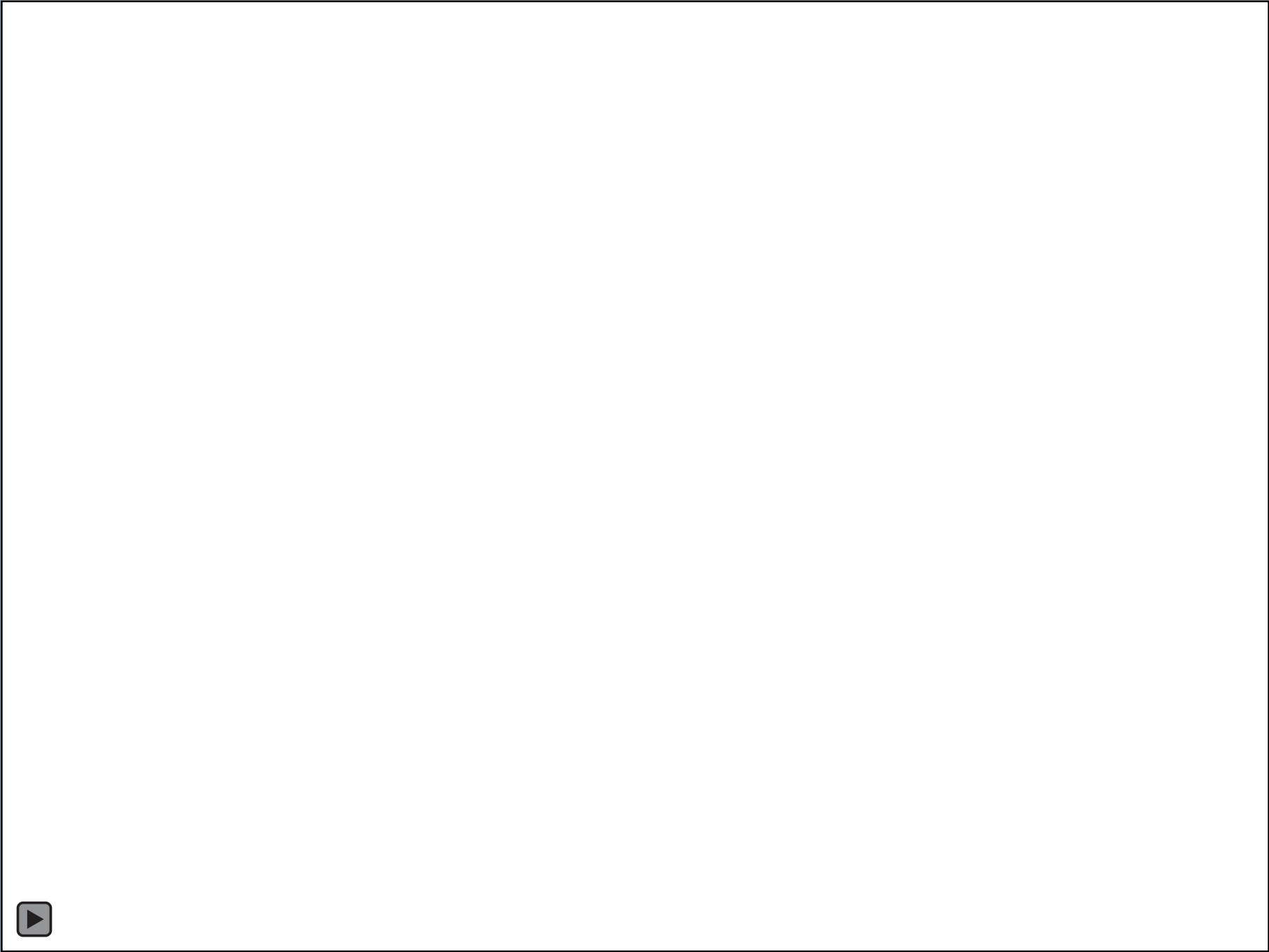
After:



CORRELATION

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CORRELATION – PHYSICAL BEHAVIOUR



CORRELATION – INJURY METRICS

Injury Metric	Metric Limit	CAE Result	Test Result
DRiz	<17.7	8.6	6.4
Pelvis Z Acceleration	<23g >7ms	19.8g	17.4g
Lumbar Spine Compression	6.7kN	4.2kN	3.7kN
Tibia Load	5.4kN	LH = 3.10 kN RH = 1.21 kN	LH = 2.55 kN RH = 0.85 kN

- Blast seat mechanics captured in model
- Results demonstrated close correlation with slightly conservative predictions for injury



SUMMARY – RESULTING COST & TIME SAVINGS

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SUMMARY – RESULTING COST & TIME SAVINGS

- The blast simulation is done irrespective to reduce the risk of failing the physical test sign-off – this means that physical testing does not remove the need/benefit of blast simulation
- It was agreed with the customer that if the first blast simulation was done 'blind', and this correlated to physical blast test result, then they would accept the other simulation results as sign-off against the requirements
- This resulted in a cost saving of £0.3M and timeline benefit of 6 months

