Simulation and Physical Testing of an Innovative ‘floating’ Shallow Mount Hostile Vehicle Barrier

Arup

© AVS-Elli

Dr Jon Farley, Arup Australia | Joel Smith, Arup Australia | Dr Dan Aggromito, Arup USA | Luke Pascoe, Arup Australia

October 2022

ARUP

Presentation Overview

- Vehicle as a Weapon attacks
- Test standards
- Vehicle barrier development history
- Problem statement: Protection of bridges
- Development of new product
- Physical testing results

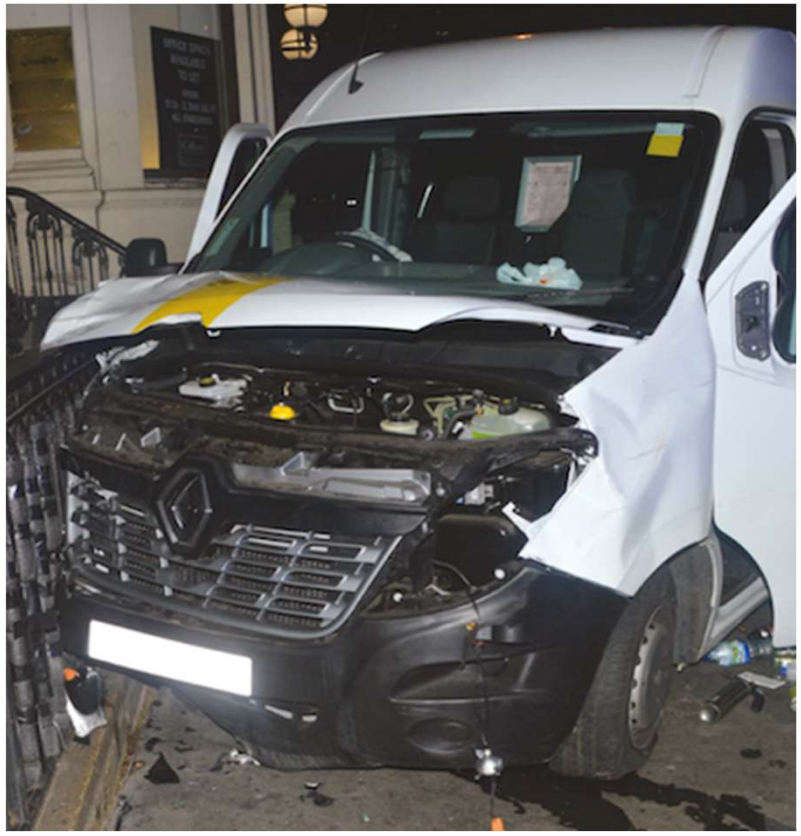
ARUP

Vehicle As a Weapon

Vehicle As a Weapon attacks are a subset of vehicle borne threats – a threat where the use of a vehicle is the primary tool:

Three subsets of Vehicle Threats:

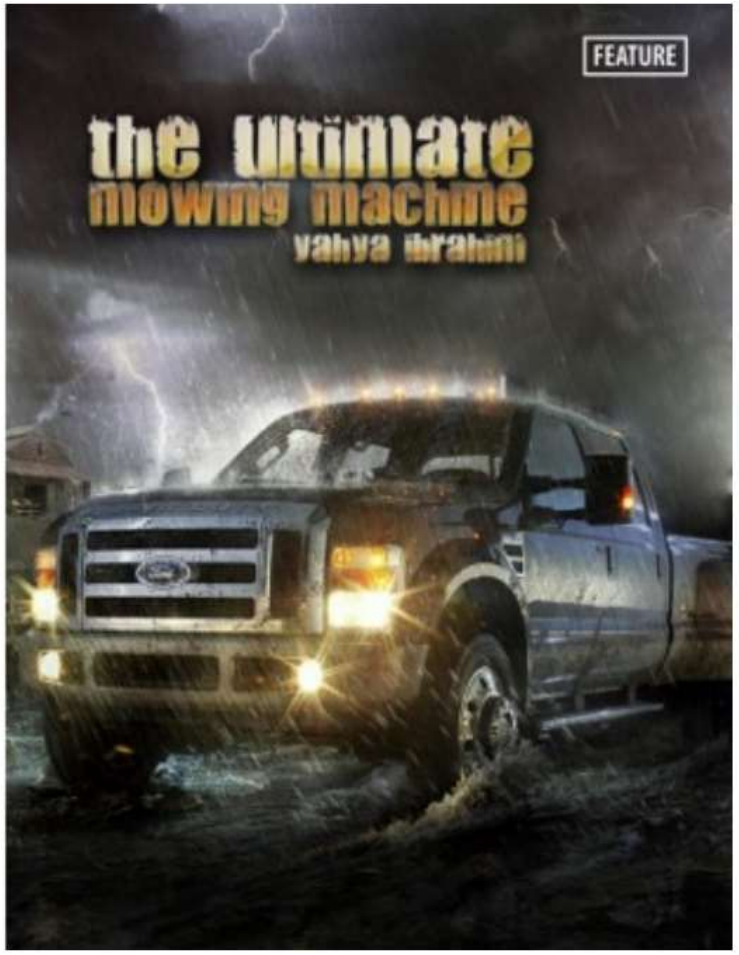
1. Kinetic delivery mechanism (VaW)
2. To deliver an explosive payload (VBIED)
3. To enable a layered attack



ARUP

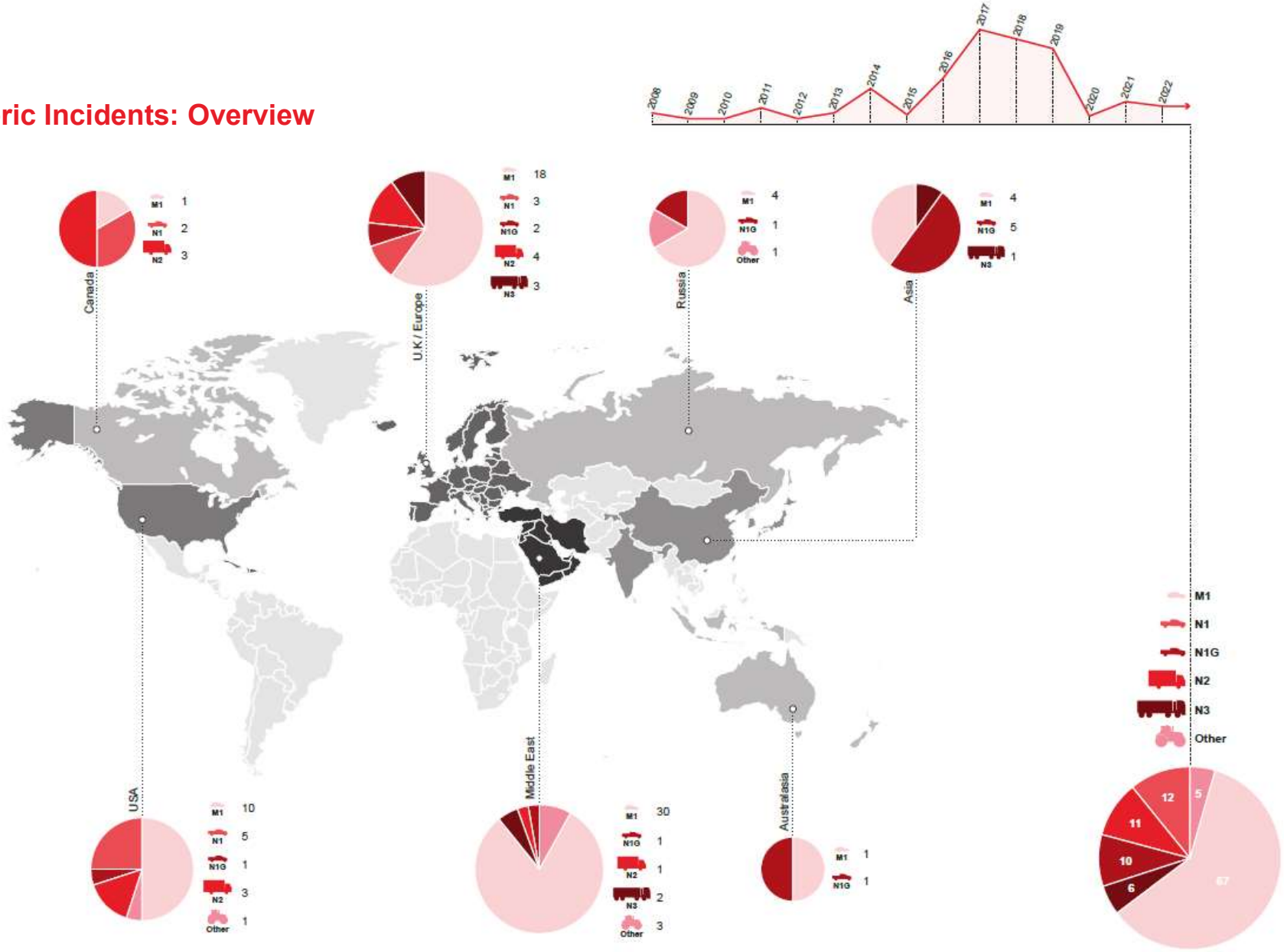

JUST TERROR TACTICS
TRUCK ATTACKS
The Ideal Vehicle
Slightly Raised Chassis and Bumper
Fast in Speed or Rate of Acceleration
Double - Wheeled Load-Bearing Truck
Large in Size Heavy in Weight
How to Acquire a Vehicle
1 Buying
2 Renting
3 Taking from a Kafir by Force or Deception
4 "Borrowing" from a Kafir or Mutadid
Ideal Targets
1 Large Outdoor Festivals, Conventions, Celebrations, and Parades
2 Pedestrian - Congested Streets (High/Main Streets)
3 Outdoor Markets
4 Outdoor Rallies


TARGETS
Hertz
JUST TERROR
TACTICS


FEATURE
the ultimate
mowing machine
yahya ibrahim

Historic Incidents: Overview

ARUP



Testing Standards

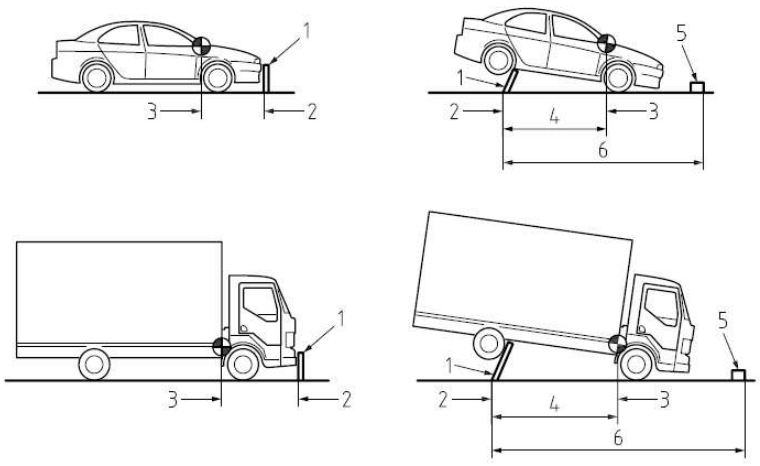
Three Primary Standards:

- IWA 14-1 – Europe
- PAS68 – UK
- ASTM F2656 – USA

Key Features:

- Physical vehicle test (roadworthy)
- Impact at set speeds (30mph, 40mph 50mph)
- Specific vehicle classes and parameters
- Data measurement on post impact penetration
- Tests remain expensive – 50,000GBP

ARUP



a) Pre-impact b) Post-impact

Key

1	VSB (e.g. bollard)	4	vehicle penetration distance
2	VSB datum line	5	major debris
3	vehicle datum point	6	major debris distance

Figure 6 — Vehicle penetration distance and major debris distance – Side view

Table 1 — Test vehicle specification

Vehicle classification	M1	N1G	N1	N2A	N2B	N3C	N3D	N3E I)	N3F I)
Type of test vehicle A)	Car	4x4 crew cab pick-up	Day cab vehicles E)						
			Flat bed H)	2-axle rigid	2-axle rigid	2-axle rigid	2-axle rigid	3-axle rigid	4-axle rigid
Test vehicle mass (kg)	1 500	2 500	3 500	7 200			12 000	24 000	30 000
Minimum unladen mass (kg)	1 235	1 700	1 675	3 575	5 200	6 100	6 200	9 750	10 500
Maximum ballast (kg) B), C) Maximum secured Maximum unsecured Tolerance (kg)	265 265 50 ±50	800 800 50 ±50	1 825 1 825 75 ±50	3 625 3 625 100 ±50	2 000 2 000 100 ±50	1 100 1 100 100 ±50	5 800 5 800 100 ±50	14 250 1 000 14 250 ±50	19 500 1 000 19 500 ±50
Test vehicle mass (kg) Tolerance (kg) D)	**1 500** ±75	**2 500** ±75	**3 500** ±100	**7 200** ±400	**7 200** ±400	**7 200** ±400	**12 000** ±400	**24 000** ±400	**30 000** ±400
Vehicle length (mm) E) Tolerance (mm)	4 500 ±360	5 200 ±600	6 200 ±380	7 610 ±1 520	8 340 ±1 670	9 560 ±1 910	8 900 ±1 900	7 640 ±1 200	9 600 ±1 000
Vehicle width (mm) F) Tolerance (mm)	1 760 ±150	1 850 ±200	2 100 ±175	2 400 ±200	2 400 ±200	2 500 ±225	2 500 ±225	2 400 ±200	2 500 ±225
Wheel base (mm) G) Tolerance (mm)	2 700 ±540	3 200 ±500	3 805 ±710	4 310 ±830	5 275 ±1 100	5 910 ±1 250	5 450 ±1 250	5 600 ±500	6 800 ±500
Height from ground to lowest edge of the chassis rail at the front (mm) Tolerance (mm)	n/a	435 ±75	440 ±120	515 ±175	630 ±175	750 ±200	845 ±225	750 ±200	810 ±200

ARUP

Vehicle Barriers Design

- Historic development: lots of steel and concrete
  - Very stiff – vehicle does the deforming
  - Unyielding (elastic methods)
  - Deep foundations to transfer load to ground
- Recently: lighter, shallower, operable
  - Growing need for retrofit (protection of existing infrastructure)
  - Complex ground conditions (services, structures)
  - Vehicle barrier ‘absorbs’ impact

© Heald

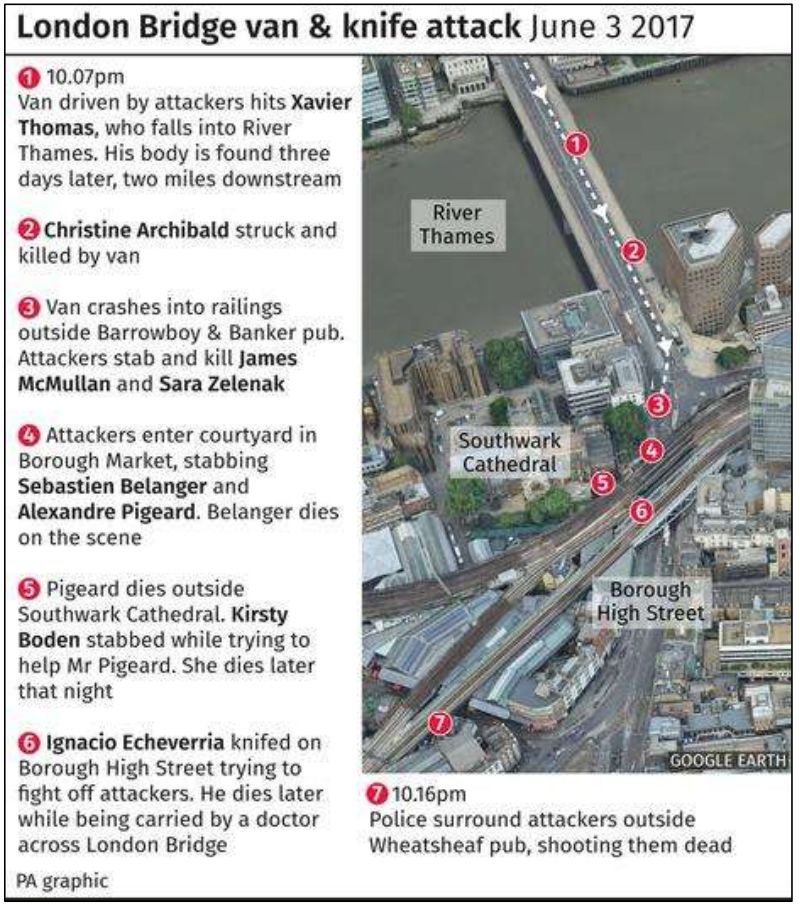
© GPS

ARUP

Problem Statement – Bridge footpath protection

- In 2017 London Bridge attacks occurred
- Bridges were identified as a higher risk (threat deflection)
- Historic structures (+100 years)
- Limited load capacity
- Very limited foundation depths
- Movement / expansion joints

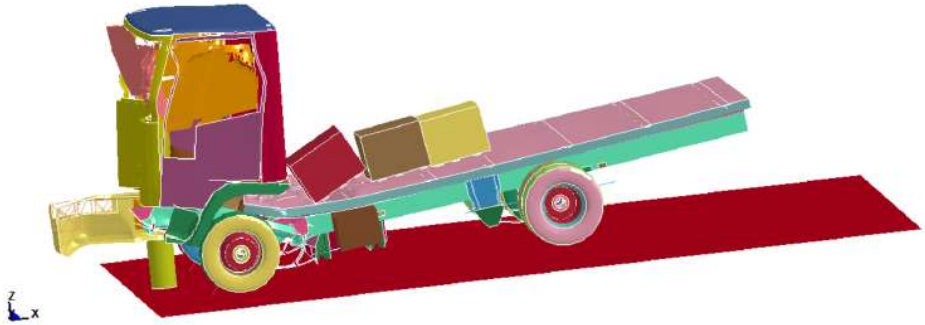
Very few products exist in the market

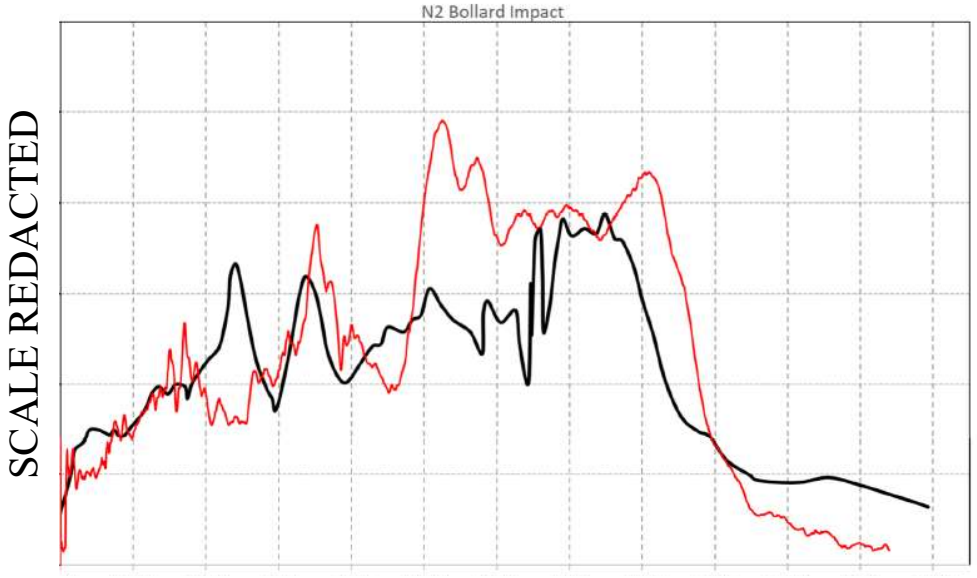


ARUP

Vehicle Model Validation

N2A Vehicle Validation



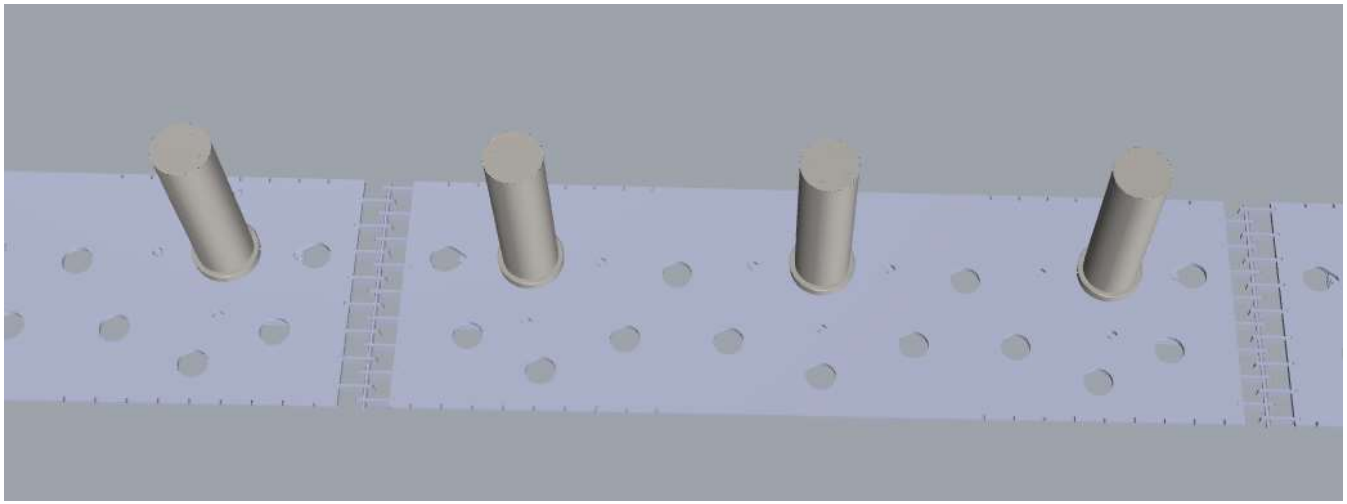


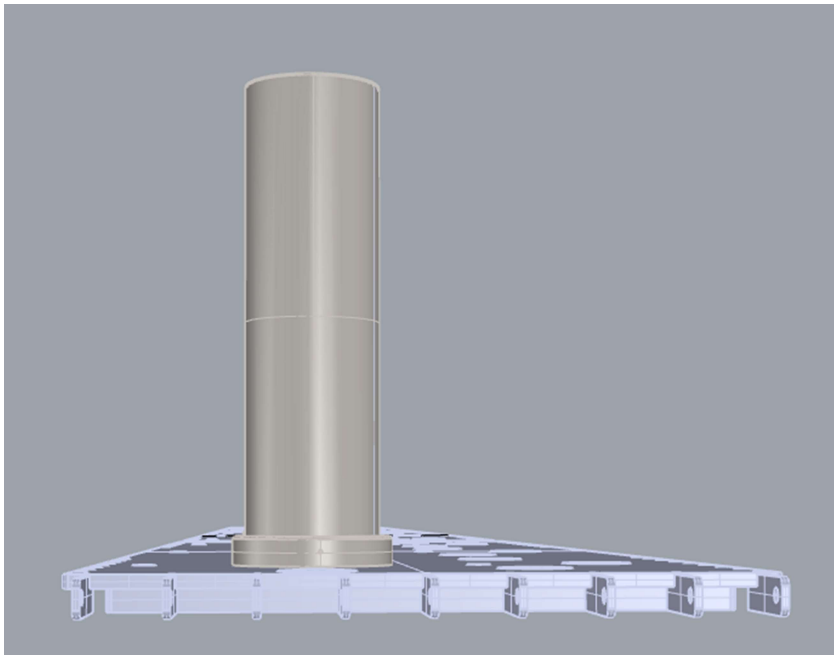
Typical Values at 48kmh impact:

Peak Force:	**1250kN**
Impact Duration:	**180ms**
Impulse:	**100kNs**

ARUP

Developed Solution



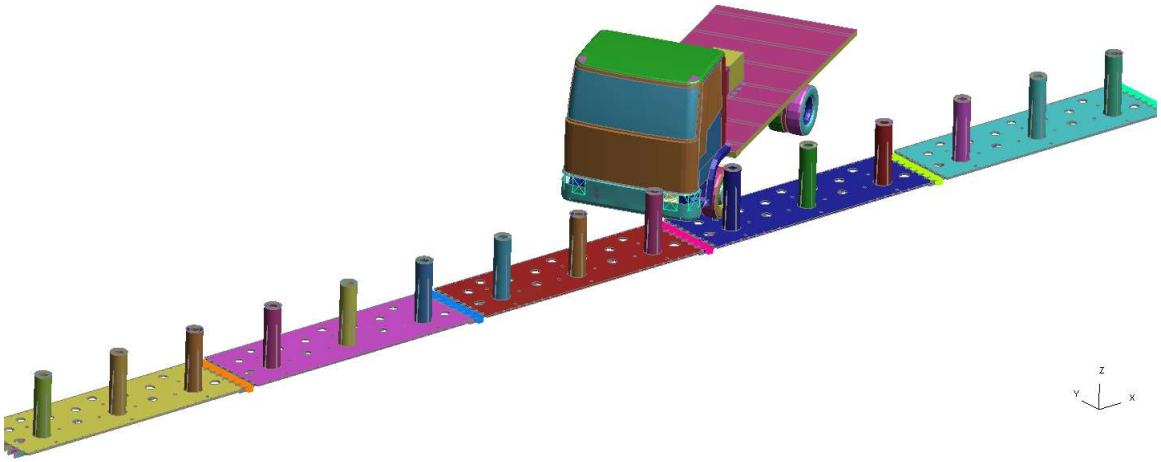


- Linear array of bollards connected through base plate
- Bollards designed with internal absorption structure
- Base plates connected via tabs and reo-bar

ARUP

Barrier Simulation

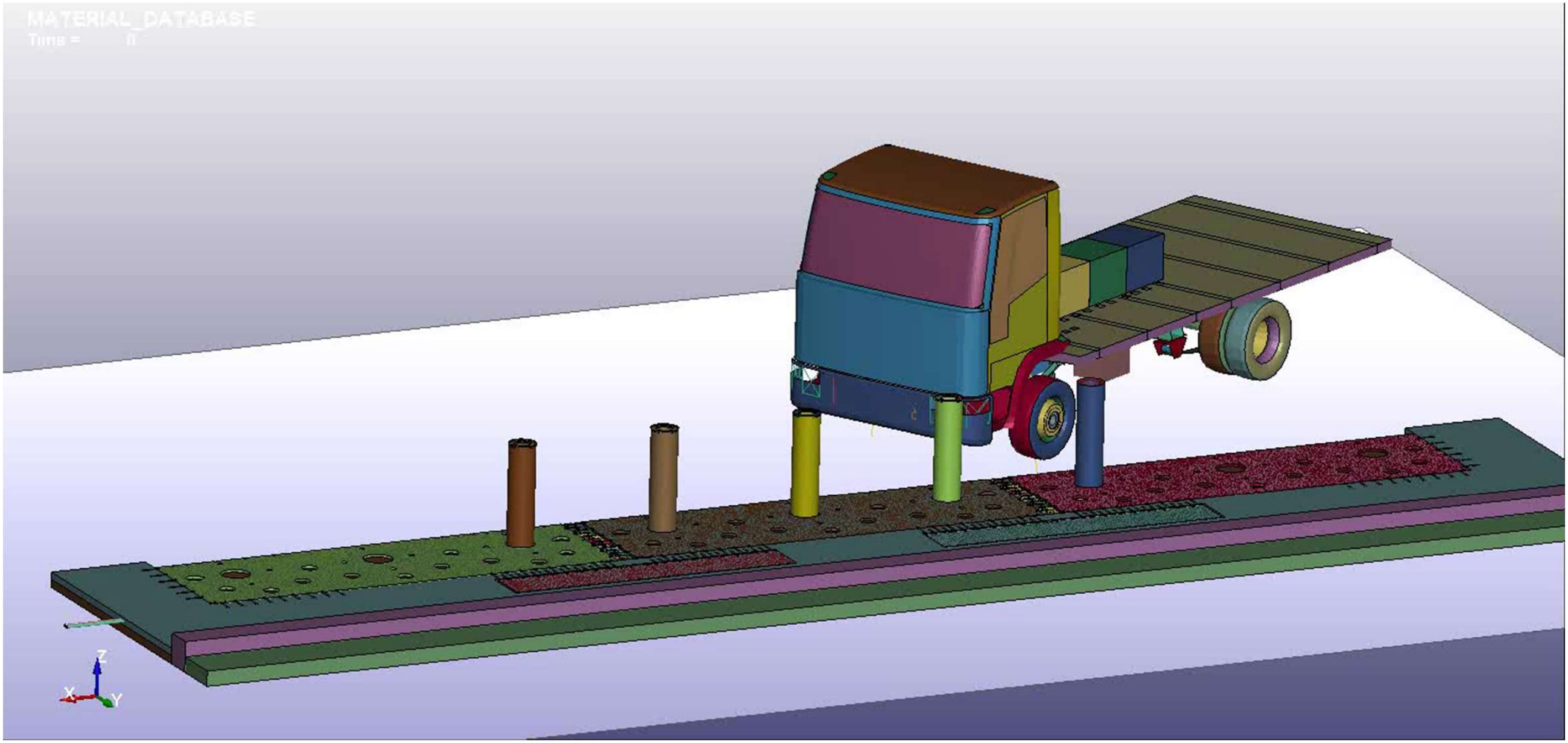
- Linear Bollard Setup:
  - 5 x Base Plate Assembly
  - 15 x Bollard Assembly
  - 15 x Internal Stiffener Assembly



- N2 Vehicle:
  - Speed: 48 km/hr
  - Mass: 7.5 tonne
  - Angle: 30 degrees from x-axis (about z-axis)

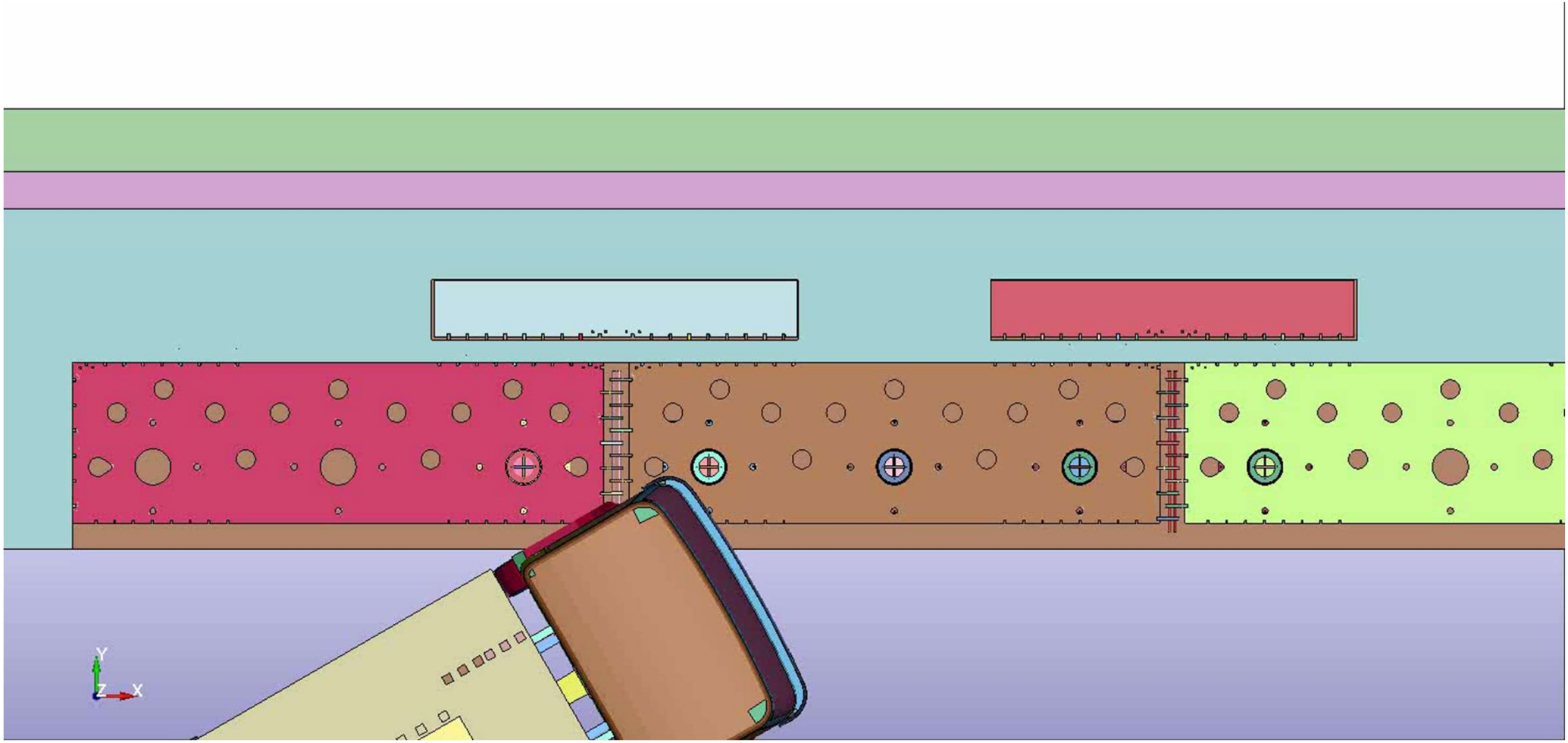
ARUP

Barrier Simulation



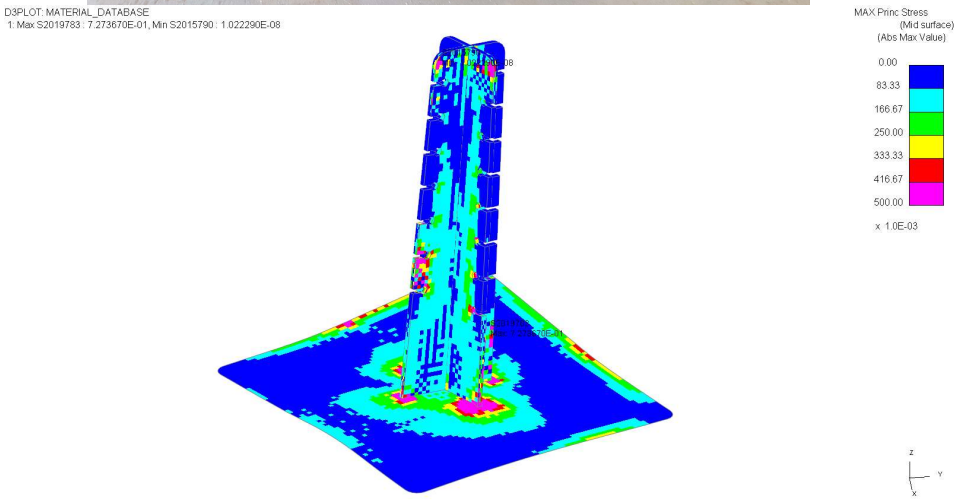
ARUP

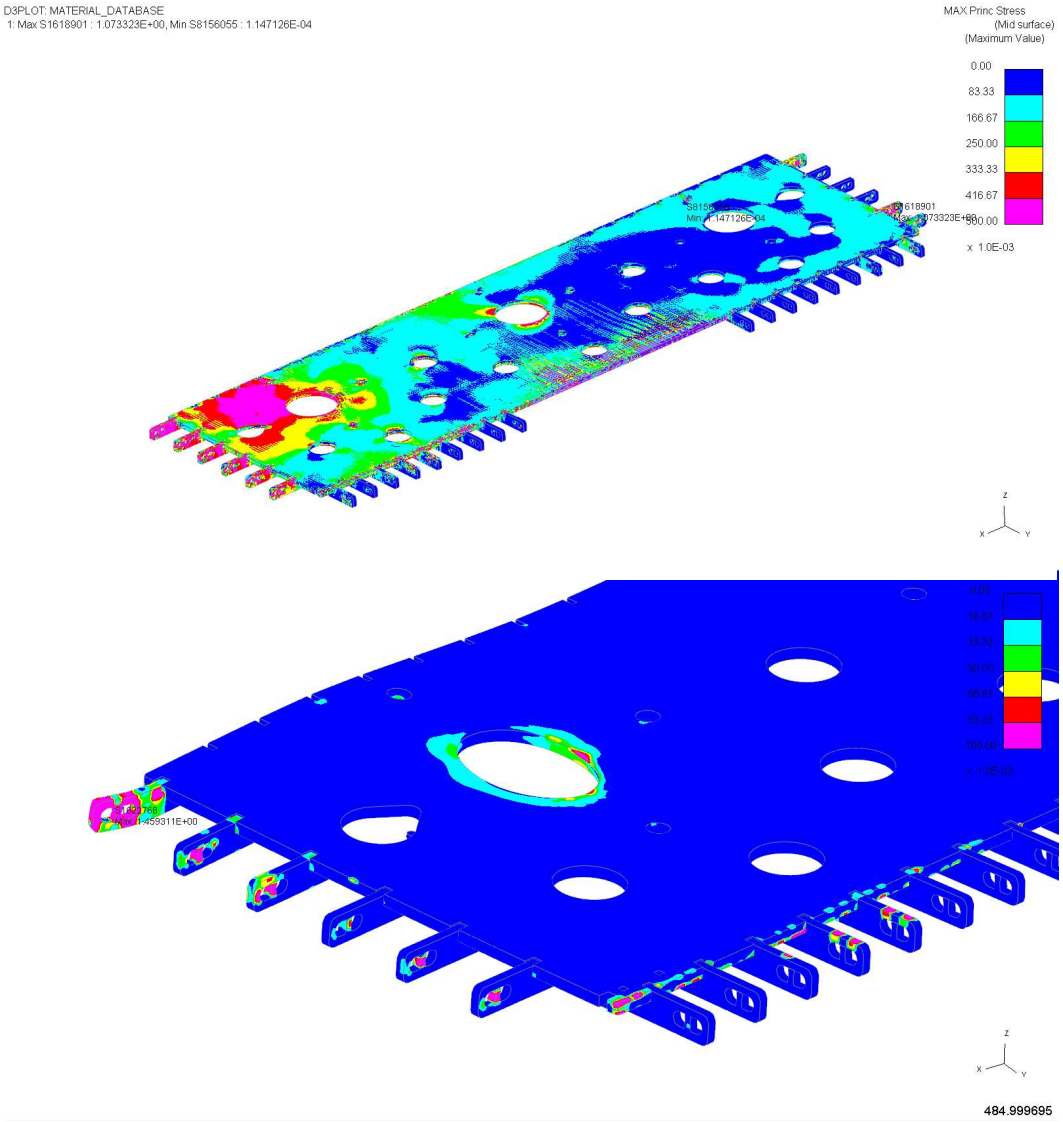
Barrier Simulation



Barrier Simulation

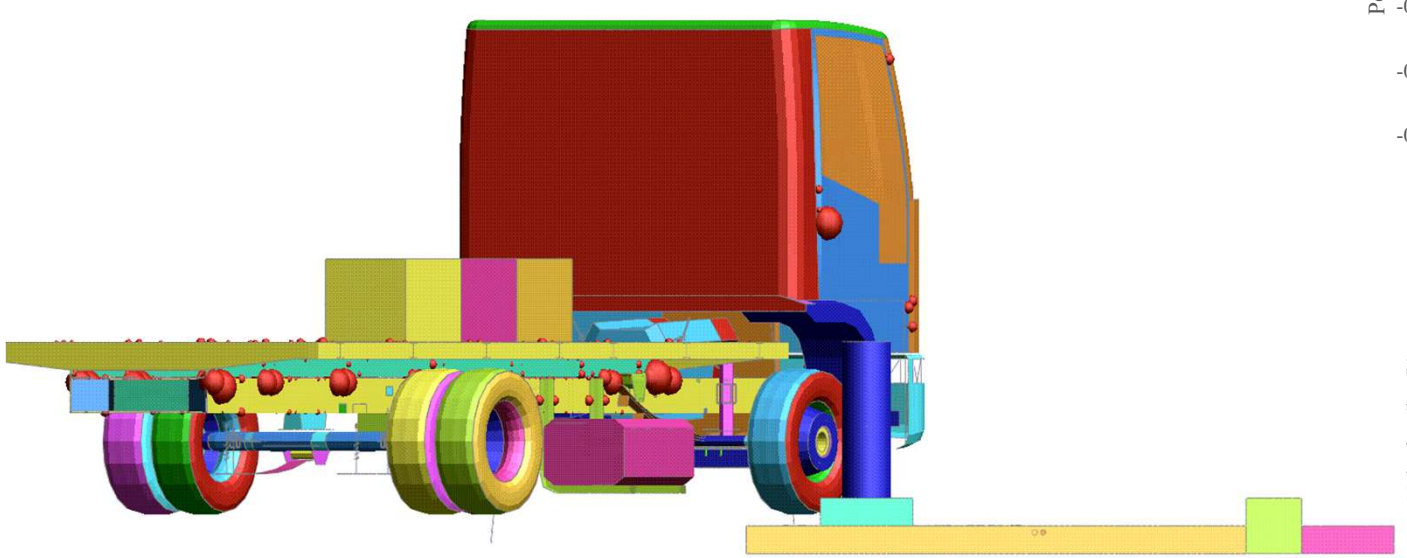
ARUP

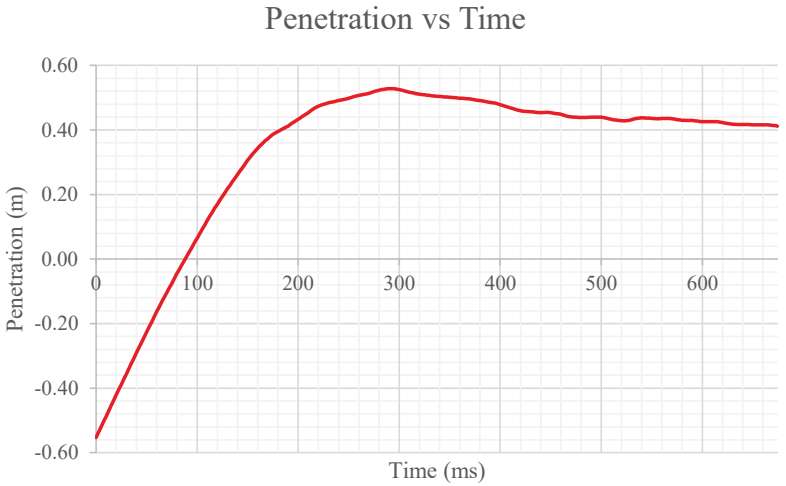


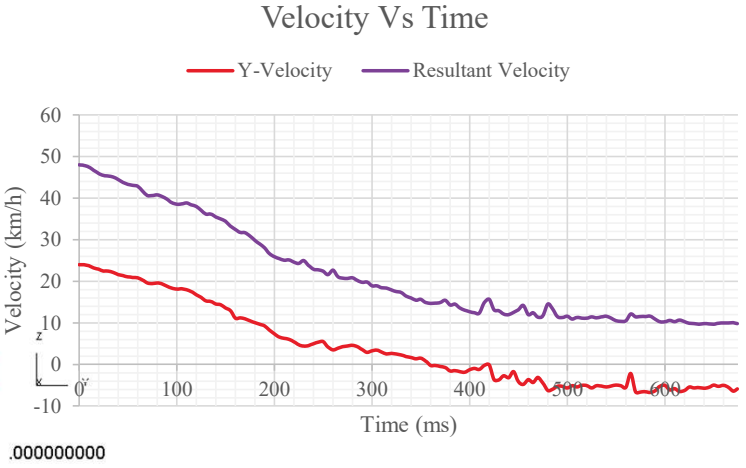


Barrier Simulation

ARUP







.000000000

ARUP

Physical test results – Vehicle Bollards

IWA 14-1 | N2A, 48kmh, 30degs

ARUP

Physical test results – Vehicle Bollards

IWA 14-1 | N2A, 48kmh, 30degs

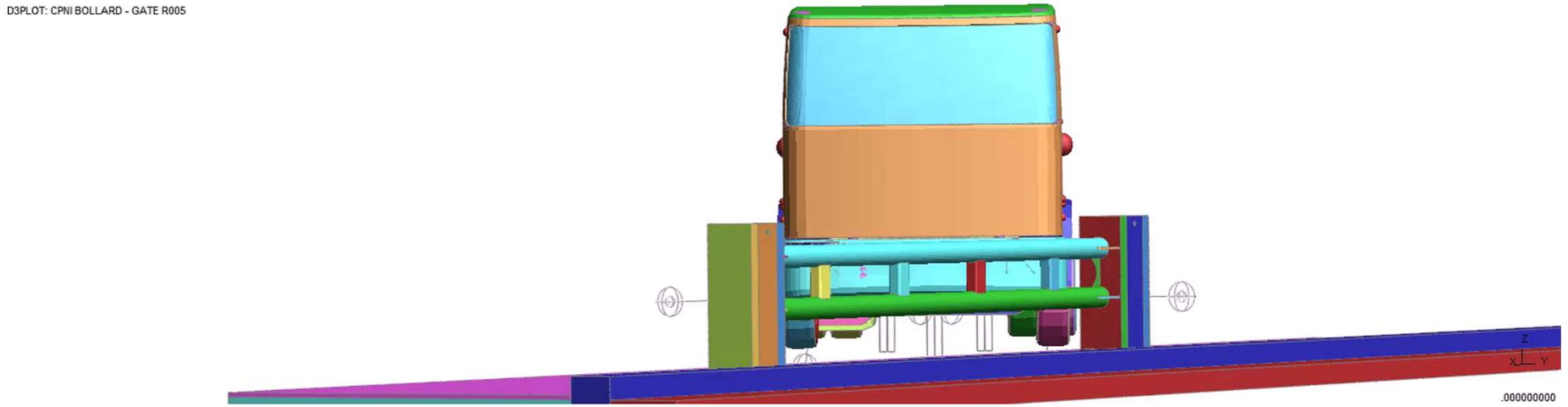
ARUP

Physical test results – Vehicle Bollards

IWA 14-1 | N2A, 48kmh, 30degs

ARUP

Test Results – Vehicle Barrier



ARUP

Lessons Learnt

- Simulation work enabled both products to achieve a test pass first time
- Validation set remains very small!
- Global model response is reasonable
- BUT detail lacking for systems response (cab, suspension failure)
- Product sales numbers are small, development budgets are tight

ARUP

Thanks

Quick thankyou to collaborators:

Nigel Buckley – AVS Elli (Designer & Manufacturer)
Dr Dan Aggromito – Arup San Francisco
Joel Smith – Arup Melbourne
Luke Pascoe – Arup Melbourne

ARUP