Blast effects and risk inside rail transport systems

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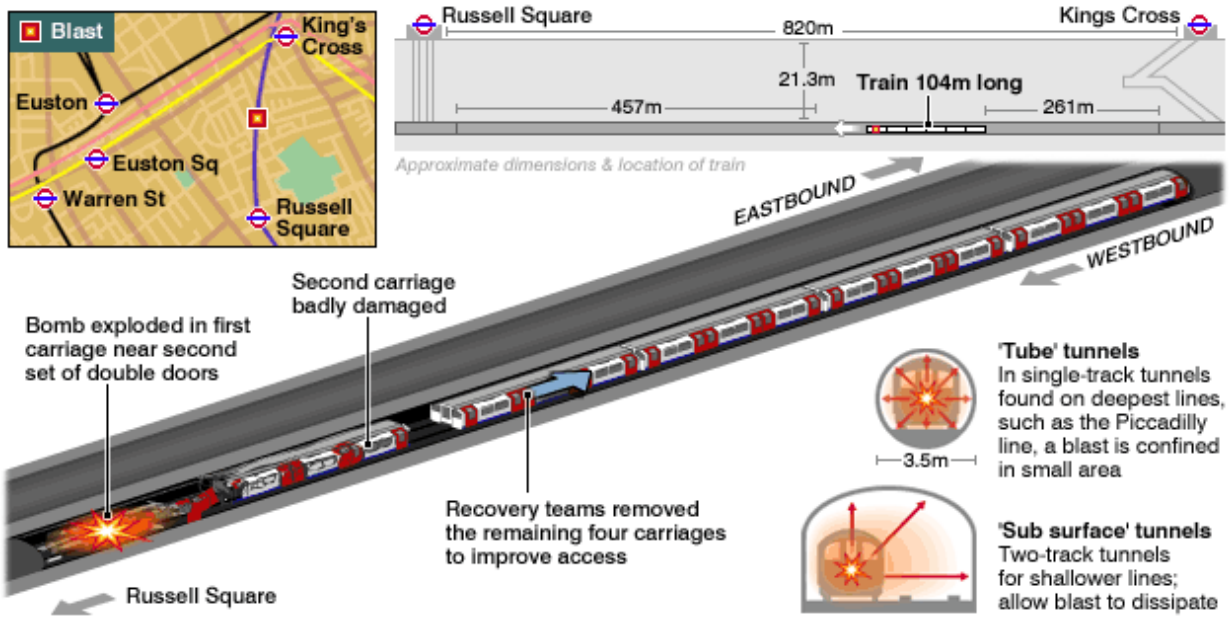
Terrorist Attacks against Trains

Madrid, 11 March 2004

London, 7 July 2005



Source: www.bbc.co.uk

Innovative Technologies for Safer and More Secure Land Mass Transport Infrastructures Under Terrorist Attacks

Problems

- Open security architecture
- No measures comparable to those applicable to civil aviation

Main objectives of the project

- Reduce vulnerability of railway and metro stations to explosion effects
- Make available a simulation tool
- Provide a guideline for safer and more secure trains and stations

Destruction of a Train

Terrorist Attack, Madrid, 11 March 2004

Bag bomb (10 kg)

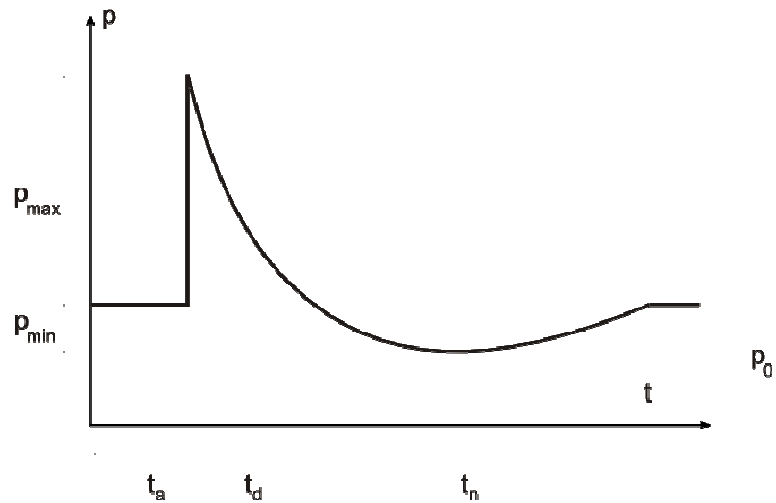
Source: www.spiegel.de

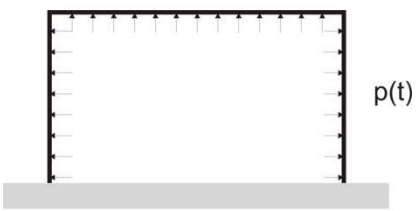
Air Blast Waves, Simulation

Pressure depends on

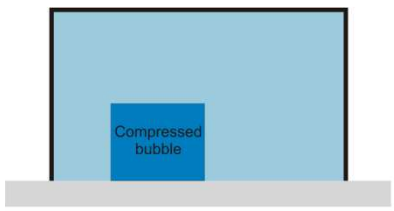
- the distance
- the size of the explosive

Parameters for spherical conditions from the literature (e.g. Kingery)

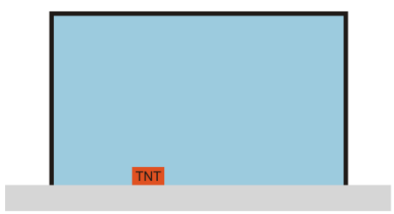




Pressure time curve



Compressed bubble



Solid TNT

Complexity, calculation time

Simulation Code

EUROPLEXUS, developed in collaboration with CEA :

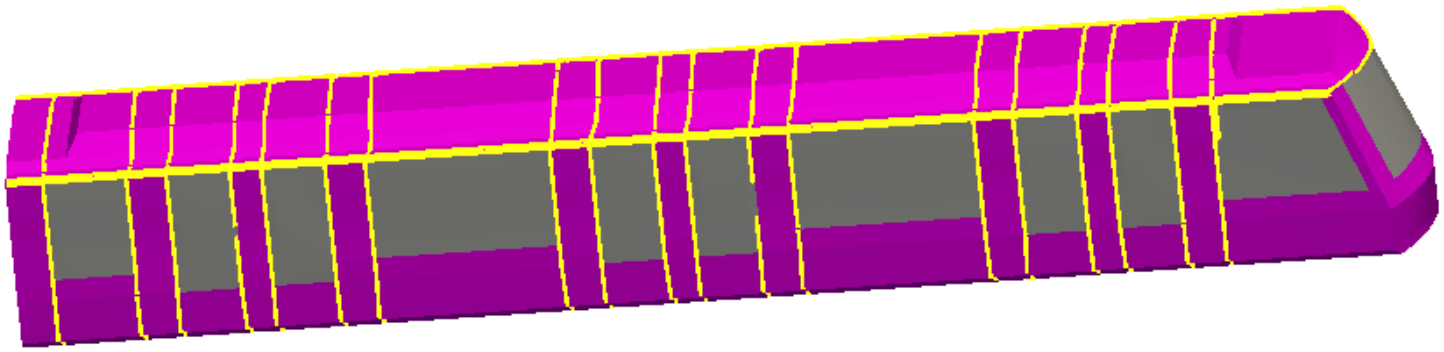
- Explicit finite element code for fast dynamic response of structures (explosions, impacts, crashes, etc)
- Specialized in modelling of Fluid-Structure Interaction phenomena.
- Experience in simulation of safety problems.
- Commercial version available (Samtech SA).

Underground Carriage

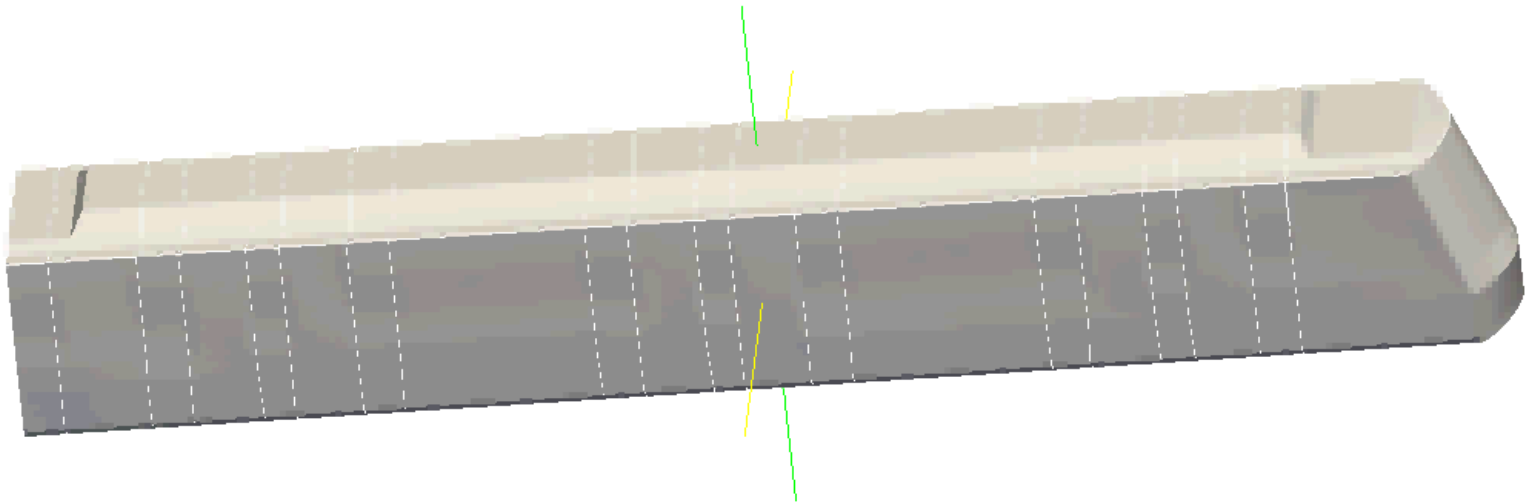
Model of the simulation

- Frame structure
- 3 mm aluminum sheet welded on the frame structure
- Floor fixed
- Explosive in the centre of the carriage

Dimensions of the carriage using JRC 3D Reconstructor



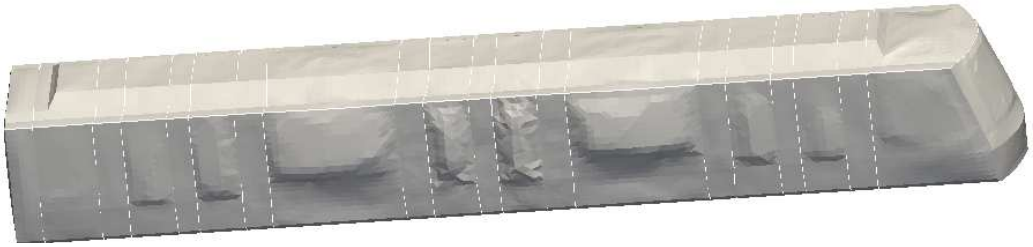
10 kg TNT, frame structure, laminated glass, displacements



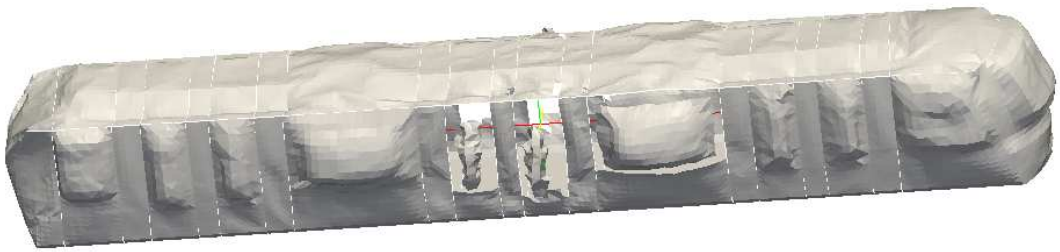
Fluid-Structure Interaction, Charge

Laminated glass, frame structure

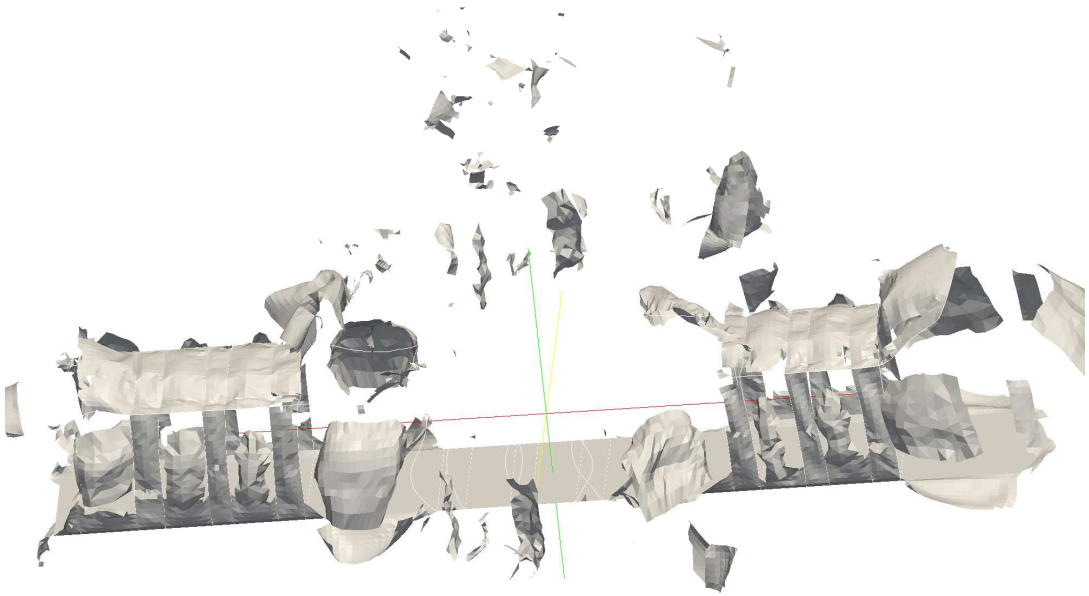
0.5 kg TNT



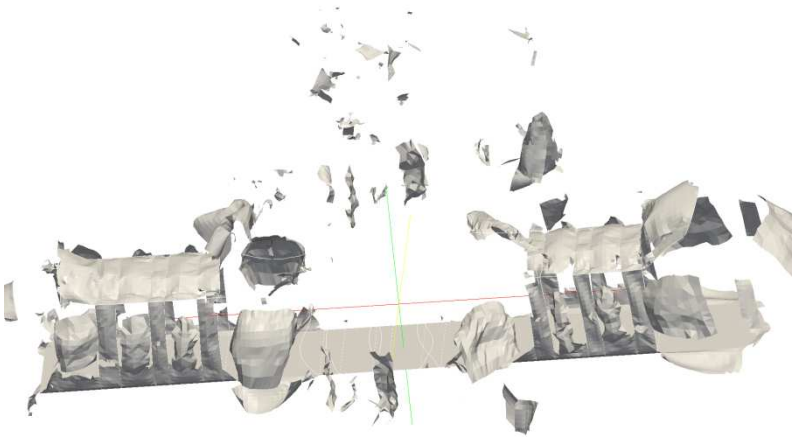
2.0 kg TNT



10.0 kg TNT



Comparison

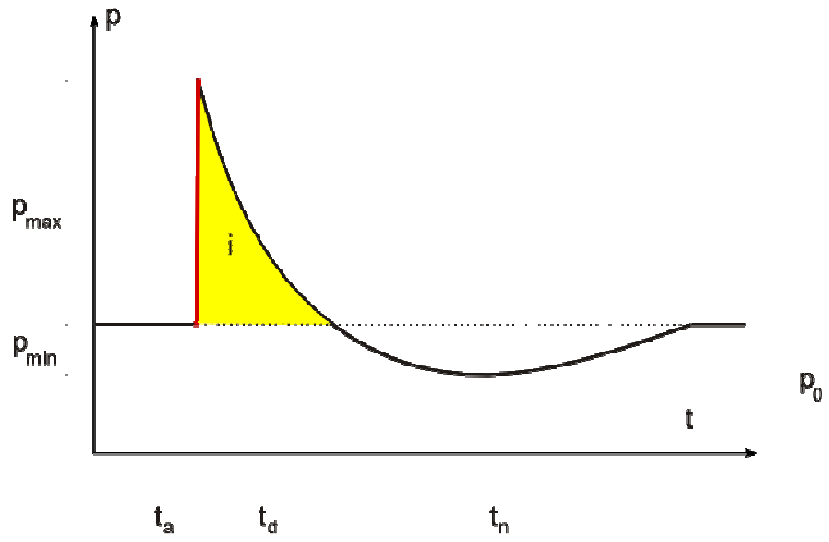


Fluid-structure interaction

Madrid, 11 March 2004

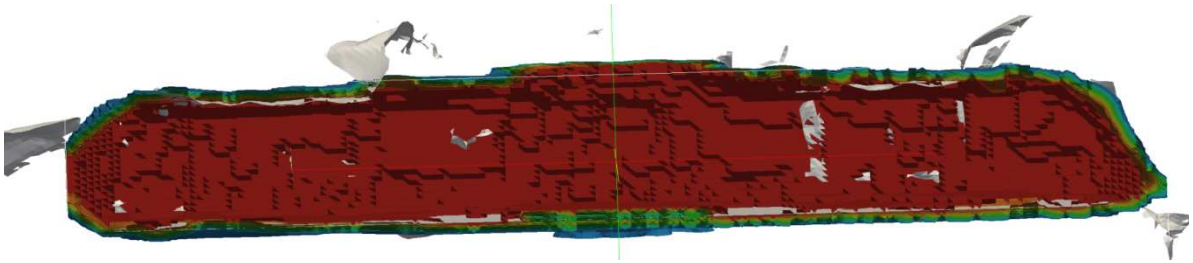
Risk Analysis Formulation

- Combination of impulse, overpressure
- Different levels of fatal injuries:
  - lung haemorrhage
  - head impact
  - whole body impact
- Non-lethal injuries: Eardrum rupture
- Verified using terrorist attack in Madrid



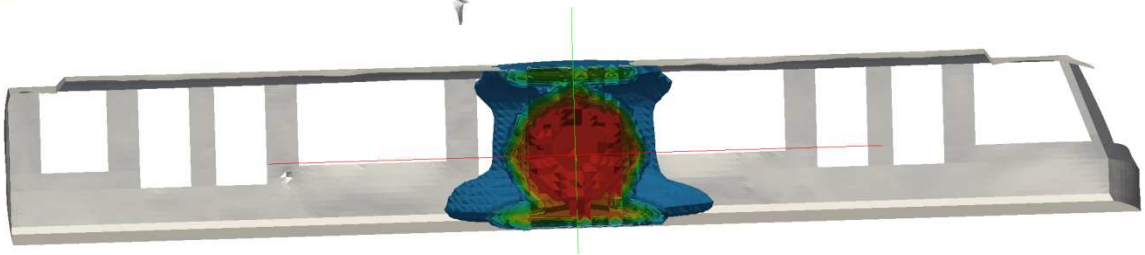
Risk inside the Carriage

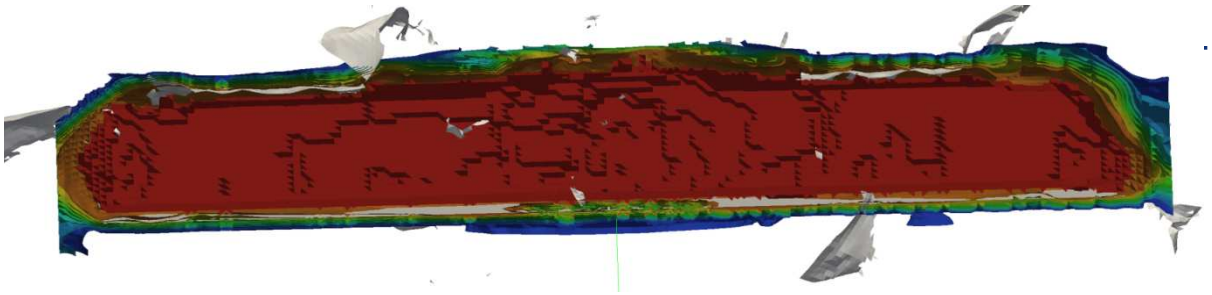
10 kg TNT



Risk of death

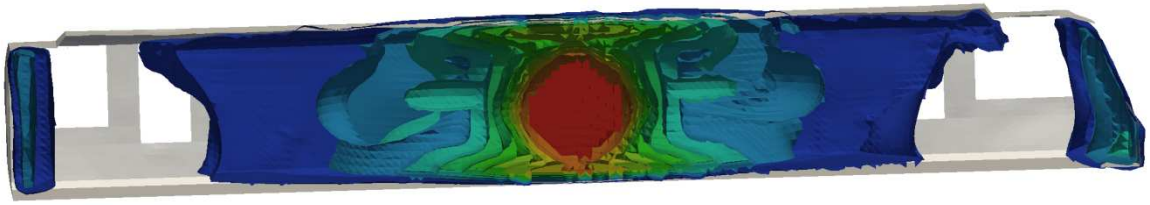
0.5 kg TNT





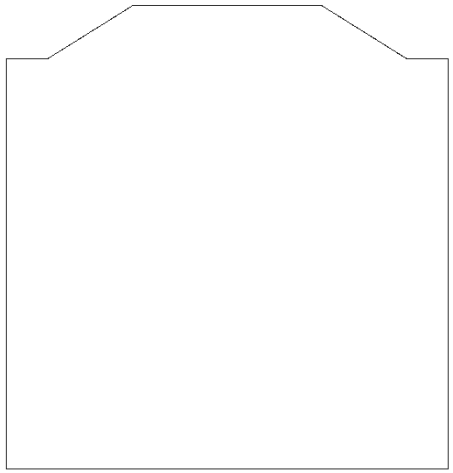
Risk of eardrum rupture

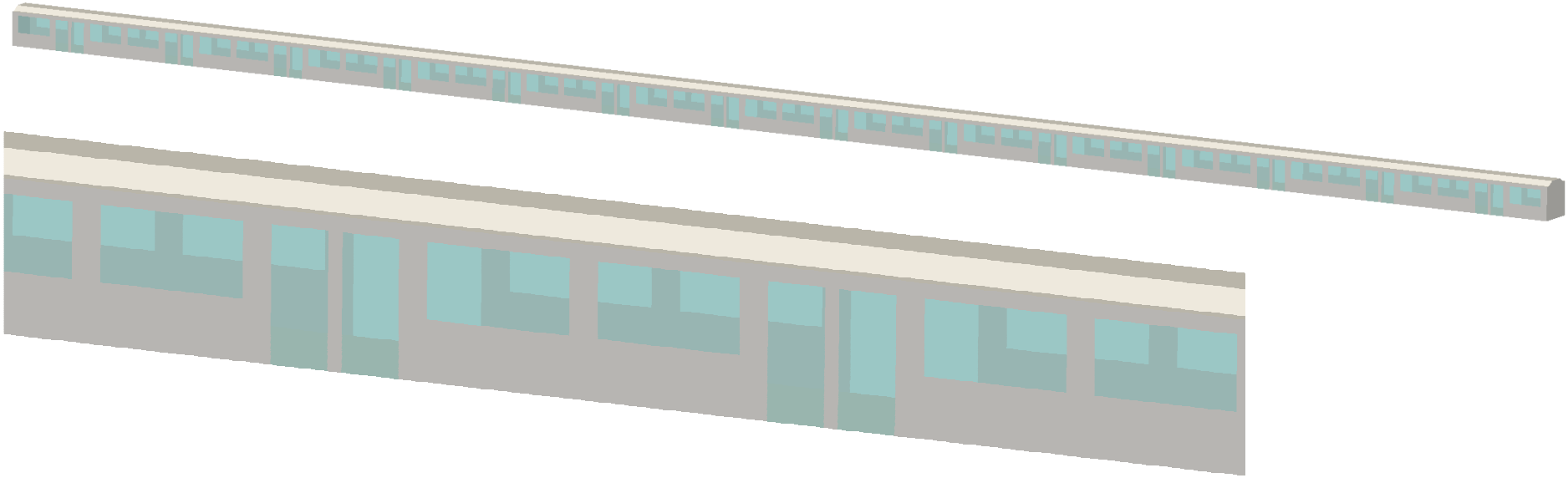
0.5 kg TNT



Risk in longer trains

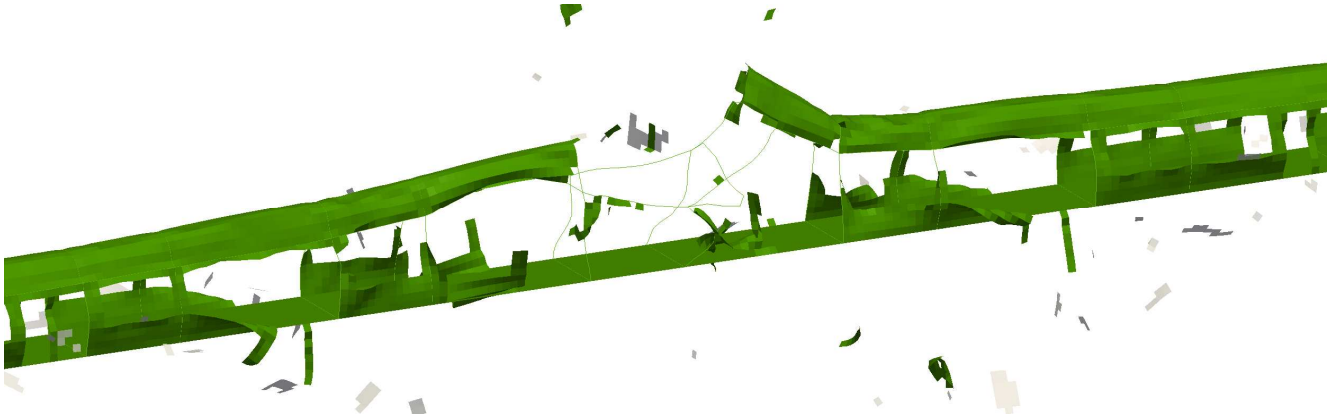
- 96 m length, coarser mesh
- Cross section similar to one of the carriage
- Spherical conditions ↔ explosion in a tunnel
- Empty train ↔ train with passengers/chairs



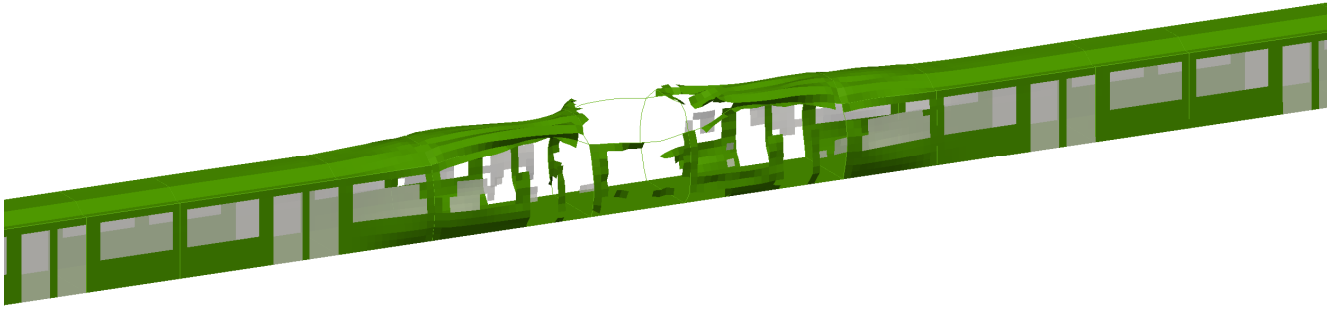


Long train: failure

2 kg, free field

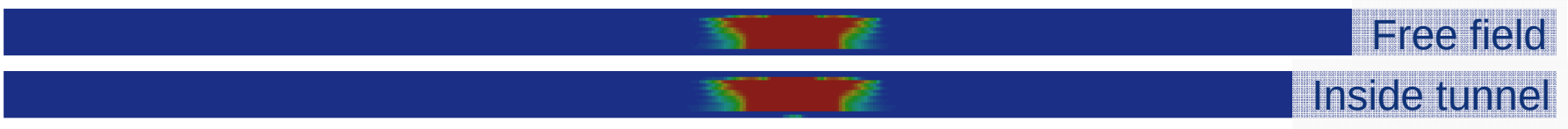


10 kg, free field

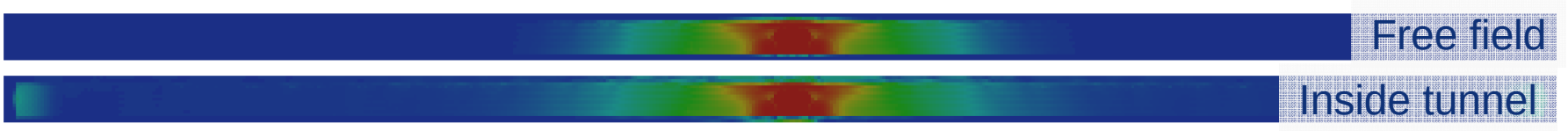


10 kg, inside tunnel

2 kg, annealed glass

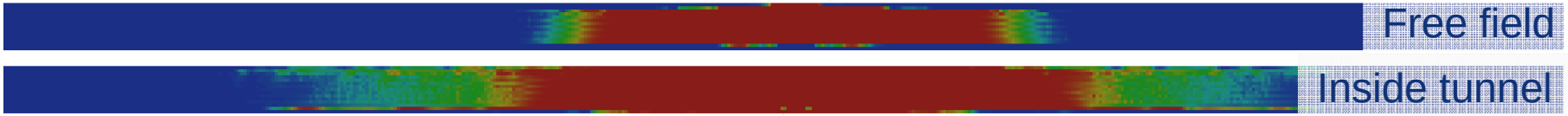


Risk of death

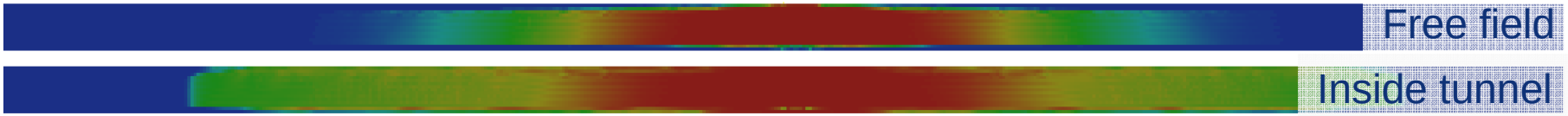


Risk of eardrum rupture

10 kg



Risk of death



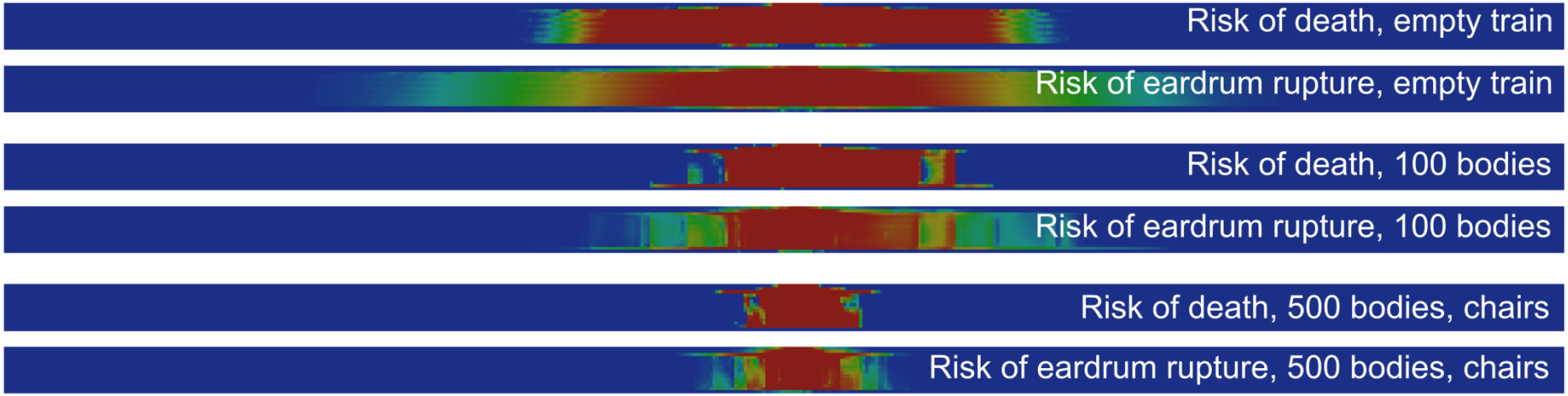
Risk of eardrum rupture

Influence of Passengers, Chairs

- Simple model with shell elements
- Thickness 10 cm
- Similar weight, density of 1400 kg/m^3
- Stiffness 40 10^6 N/m^2
- Failure criterion 20 % strain
- 100/500 persons randomly in the train
- No contact

- Aluminium chairs, thickness 3 mm

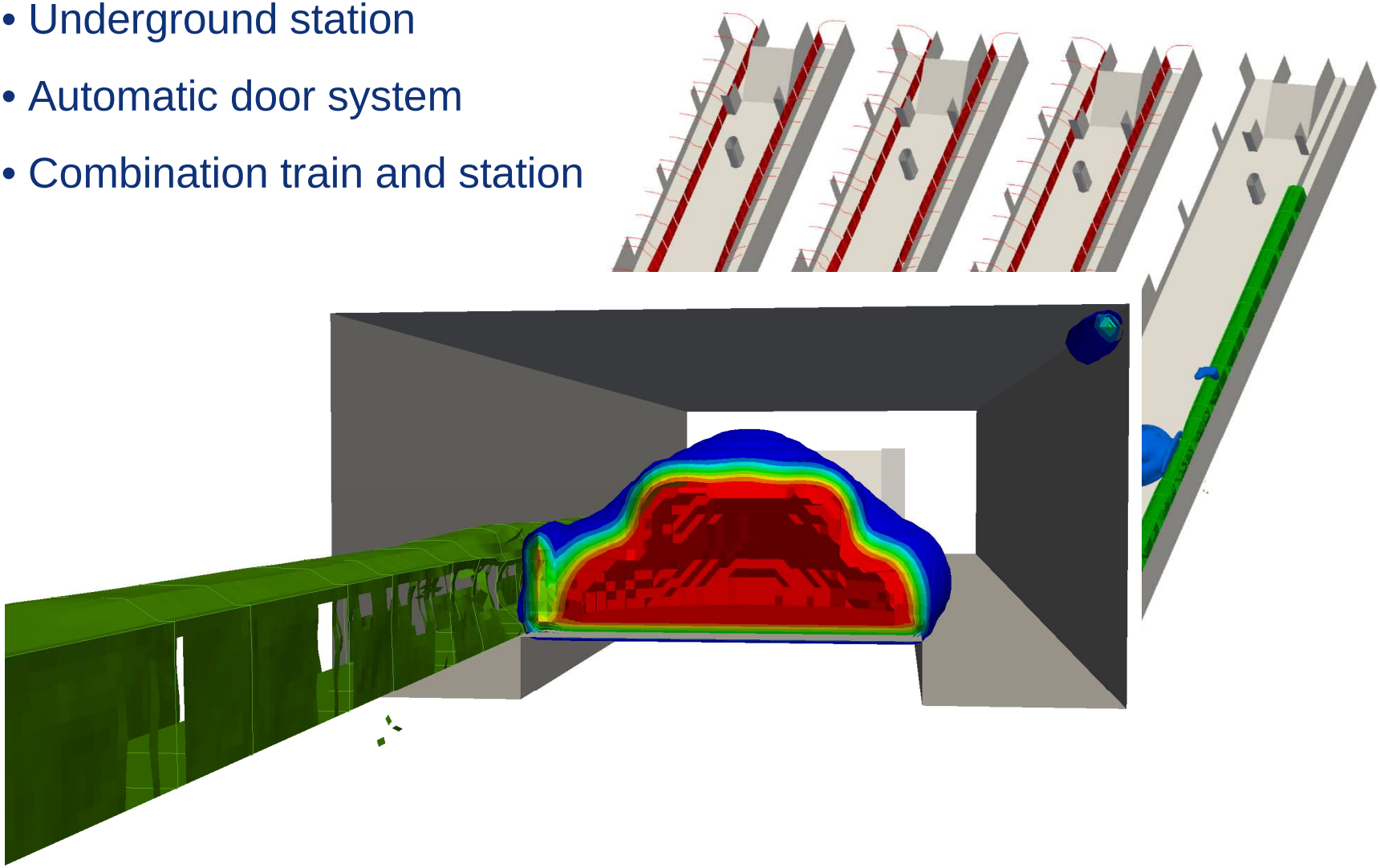
10 kg, including passengers, chairs



Chairs	Number of passengers	Length of high death risk zone [m]	Number of affected passengers
No chairs	0	27.4	0.0
No chairs	100	13.2	12.7
No chairs	500	7.9	41.1
Chairs	0	17.6	0.0
Chairs	100	10.0	9.6
Chairs	500	7.6	36.5

10 kg, including passengers, chairs

- Underground station
- Automatic door system
- Combination train and station



Conclusions

Model

- Allows determination of risk inside structures
- Fluid-structure interaction needed
  → channelling
  → risk

Risk

- Small influence of the structure of the carriage on the risk (frame - sandwich)
- Failure of the structure could reduce the risk due to pressure venting areas.
- Influence of windows (venting areas) is small in case of the failure of the shell.
- Internal walls, windscreens, chairs, passengers have a high influence on the risk, but can become fragments.

Recommendations

- As much material inside as possible
- Reduce the size of the charge!