Vulnerability of Rail Transport Infrastructure to Blast Loading

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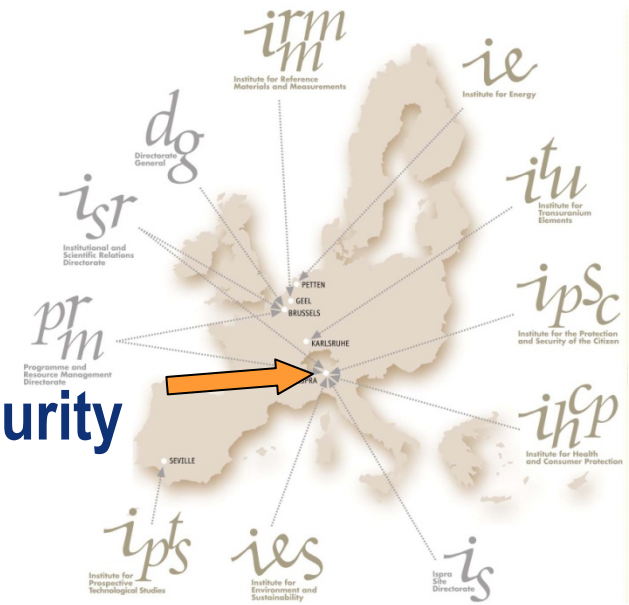
The EC Joint Research Centre

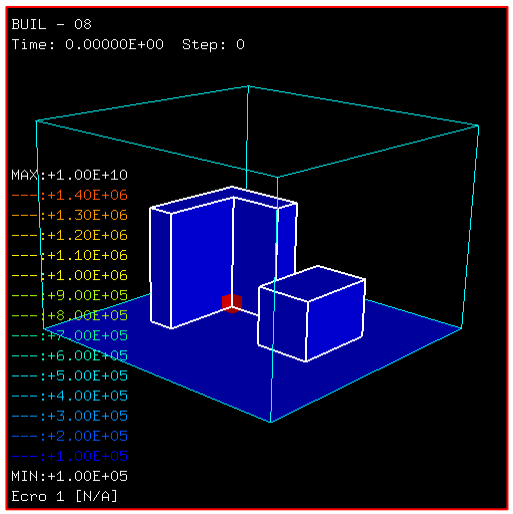
- Provides customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies

- Functions as a centre of science and technology (S&T) reference for the EU, independent of commercial and national interests

7 Institutes in 5 Member States



Institute for the Protection and Security of the Citizen (IPSC) – Ispra, Italy



European Laboratory for Structural Assessment (ELSA)

Mission :

- To provide research and contribute to European Standards harmonization in construction,
- To perform vulnerability assessment of buildings and civil infrastructures for risk mitigation,
- To develop appropriate methodologies through integrated use of experimental testing and numerical modelling in Structural Mechanics.

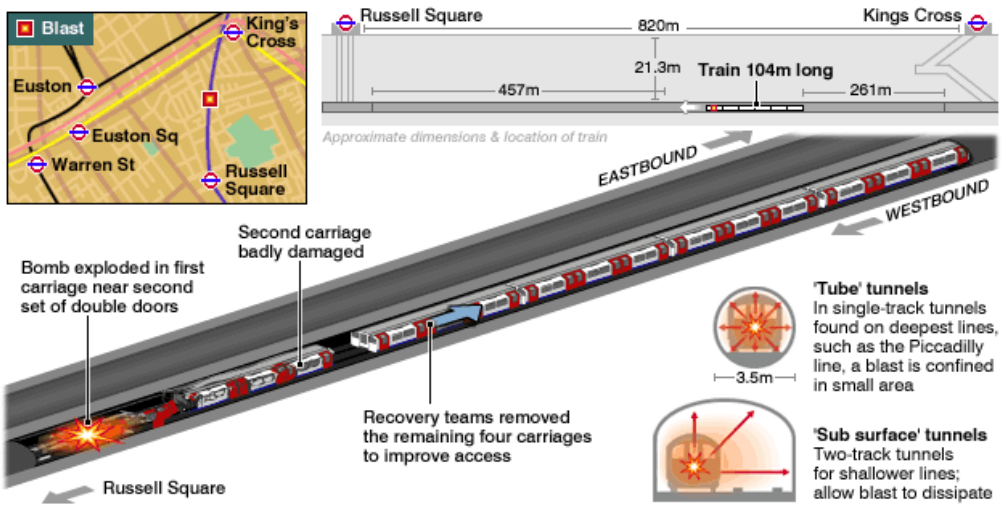
Characteristics of land mass passenger transport :

- Accessible, dynamic, with open security architecture and widely dispersed assets
- No measures comparable to those applicable to civil aviation or to maritime transport
- Not possible to completely eliminate the hazard and secure all assets that make up the land mass passenger transport system

Inherently vulnerable to terrorist attacks

Madrid, March 2004 :
Fatalities 191
Injured 1200

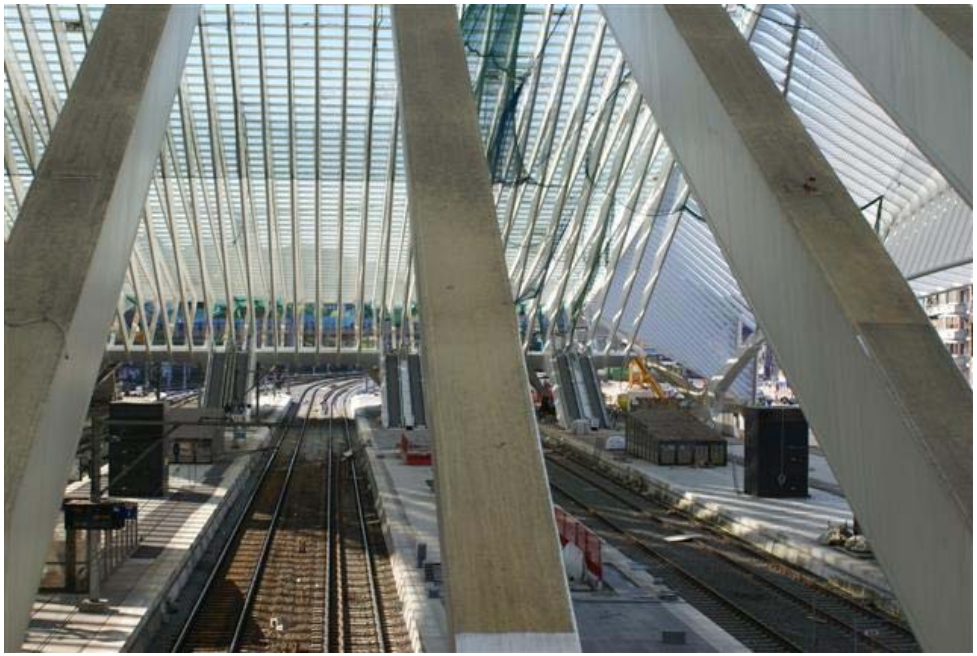
London, July 2005:
Fatalities 50
Injured 700



Source: www.bbc.co.uk

Older stations

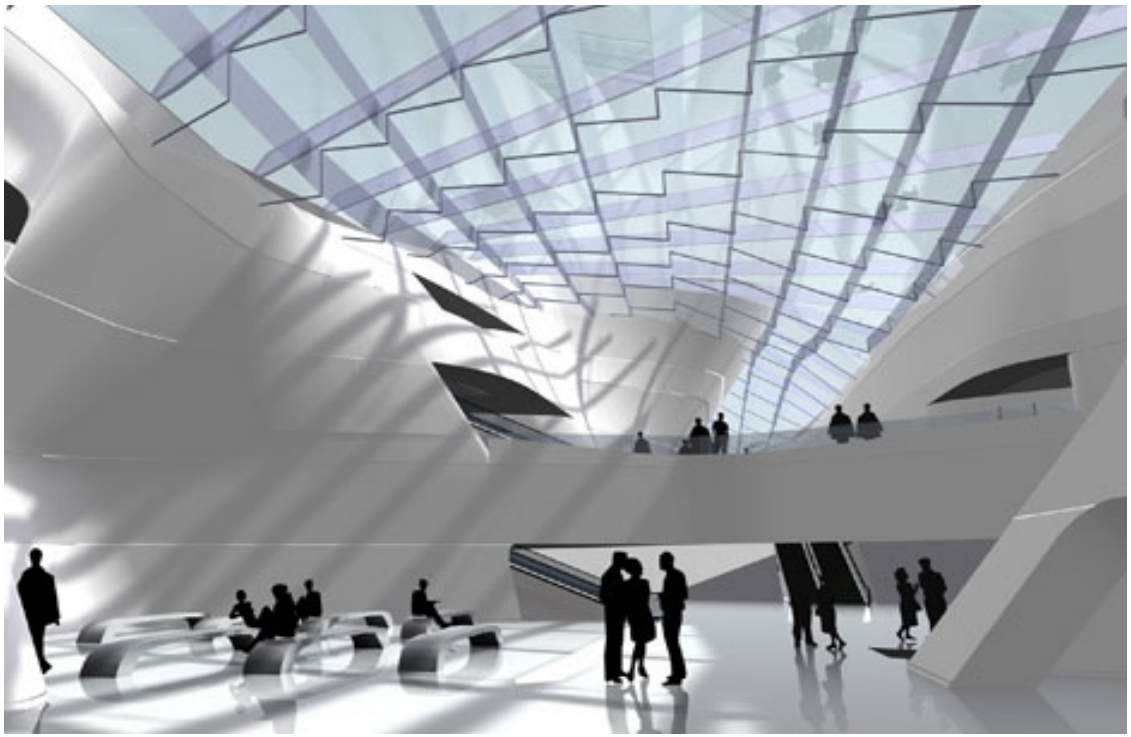
Milan Central station



Current modern stations

Liège

Extended use of glass : more vulnerable to explosions?



Naples, Afragola

Future stations

...

Florence, Belfiore

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

Administrative Arrangement between EC's DG-TREN (Unit: Security of surface transports and transport of dangerous goods) and JRC-Ispra

Objectives

- **make available a simulation tool to investigate the vulnerability of train/metro vehicles and infrastructures, in particular to bomb attacks**
- **assure the European public that security measures are also being taken in the rail transport**

Main problems to be addressed

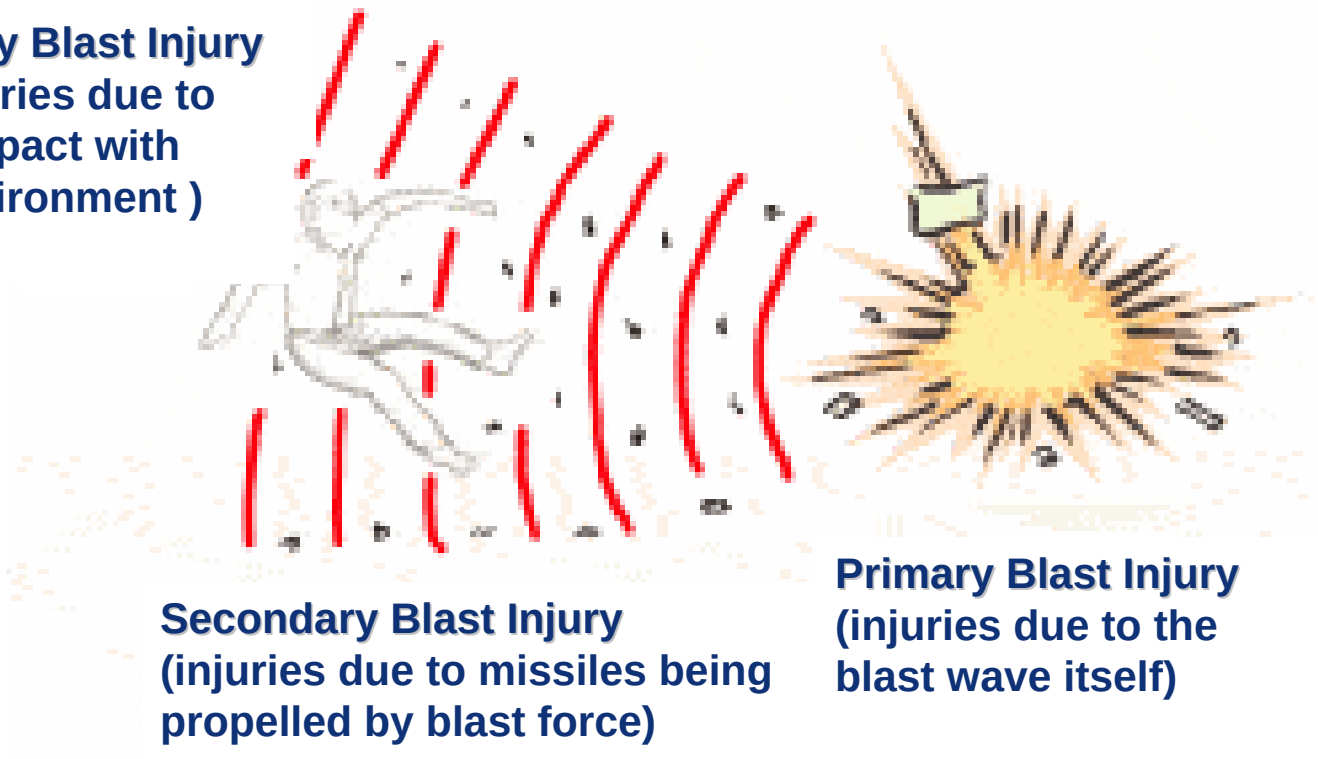
- **Getting the geometry**
- **Adaptation of geometry**
- **Getting the structural properties**
- **Modelling of material fragmentation**
- **Modelling changing environment (presence of trains?)**
- **Post-processing according to relevant criteria (e.g. damage to human body)**
- **Size and computer cost of models**
- **Property rights on specific components, …**

Numerical Simulation Tools

- Explicit Finite Element code for fast dynamic response of structures (explosions, impacts, crashes, etc) : **EUROPLEXUS Code**, developed in collaboration with French CEA
- Specific capacity for modeling of Fluid-Structure Interaction phenomena
- Long experience in simulation of safety problems
- Interactive web-based development environment
- Collaboration agreements for development and diffusion

Mechanisms of Blast Injury

Tertiary Blast Injury (Injuries due to impact with environment)

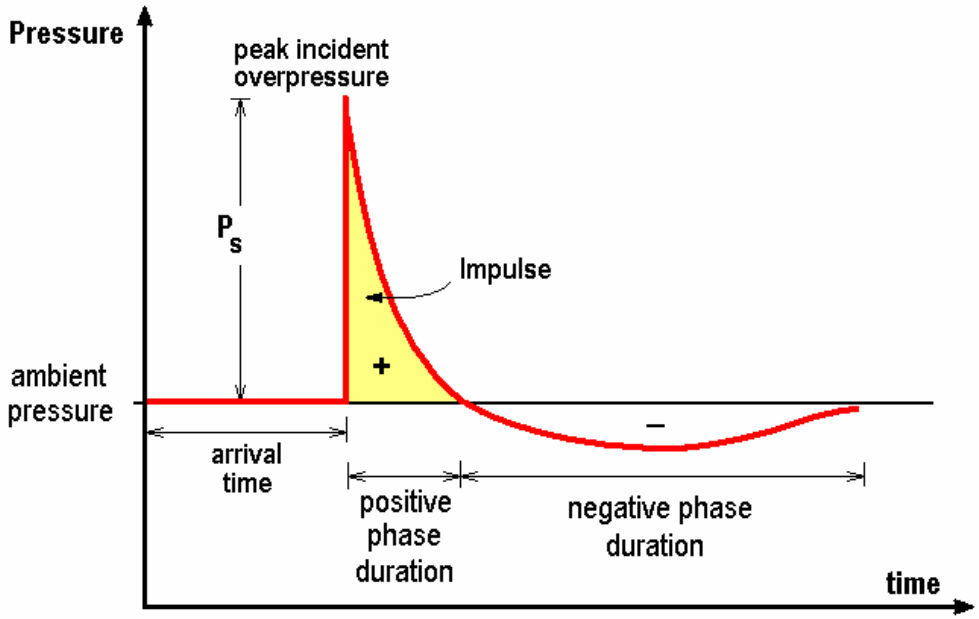


Secondary Blast Injury (injuries due to missiles being propelled by blast force)

Primary Blast Injury (injuries due to the blast wave itself)

Reference: ***Blast Injuries - Physics vs. Physiology***, Jeffrey D. Ferguson, MD, NREMT-P, December 2004

Human Injuries Probit Functions



Eardrum Rupture: $Y_1 = -12.6 + 1.524 \ln P_s$

Lethal Injuries

Head Impact: $Y_2 = 5 - 8.49 \ln(2430/P_s + 4x10^8/P_s\, i)$

Whole body Impact: $Y_3 = 5 - 2.44 \ln(7.38x10^3/P_s + 1.3x10^9/P_s\, i)$

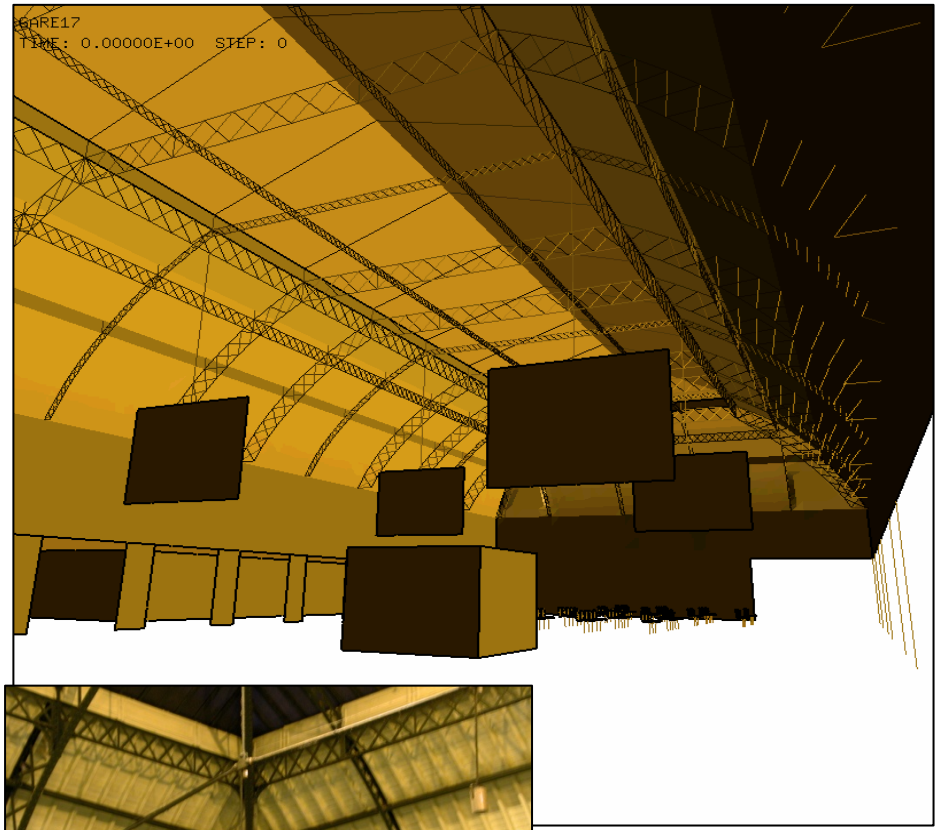
Lung Haemorrhage: $Y_4 = -77.1 + 6.91 \ln P_s$

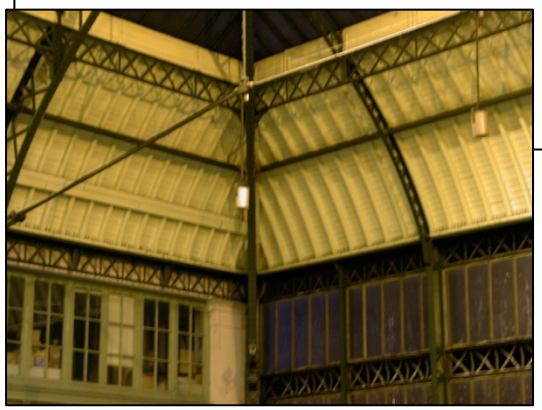
Europlexus FEM → P_s , i → Y → R% → … total probability of injury

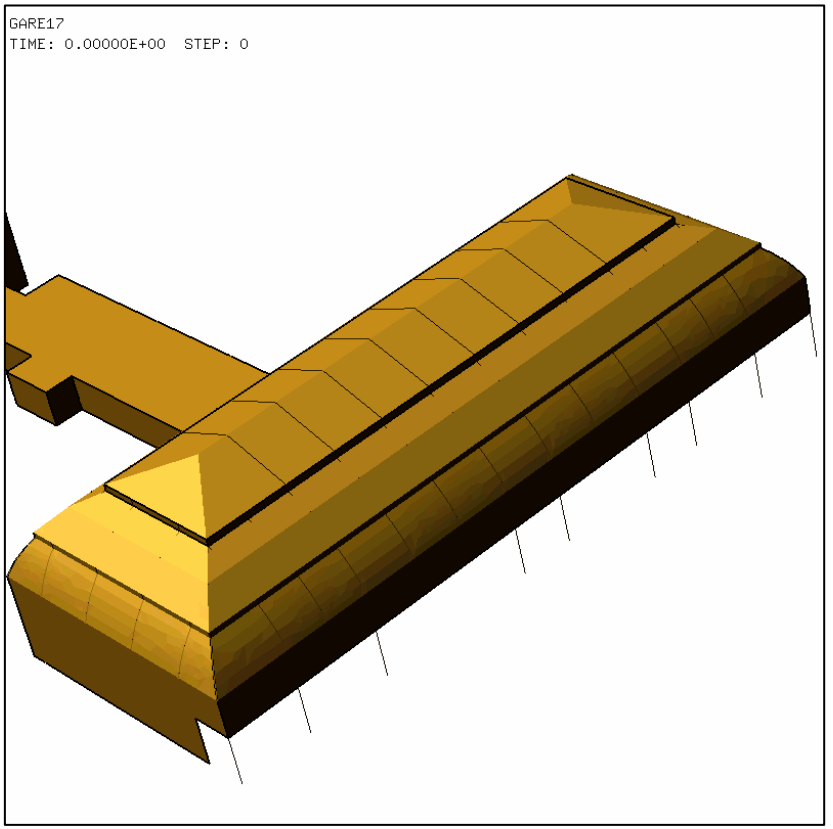
In-Situ Laser Scan + “JRC 3D-Reconstructor”

Historic Railway Station

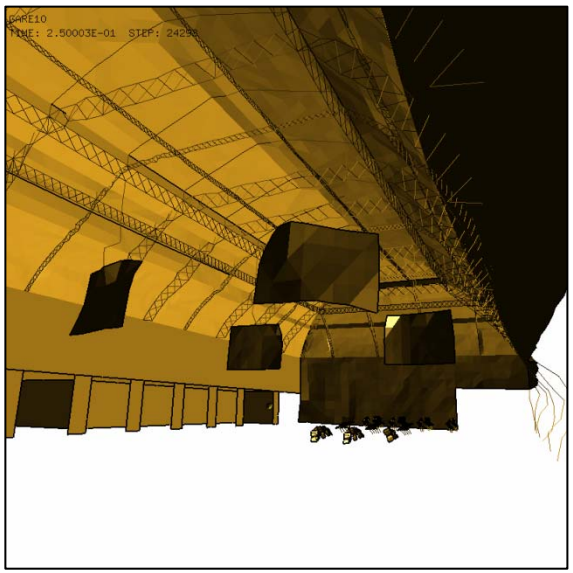
Explosion in Railway Station



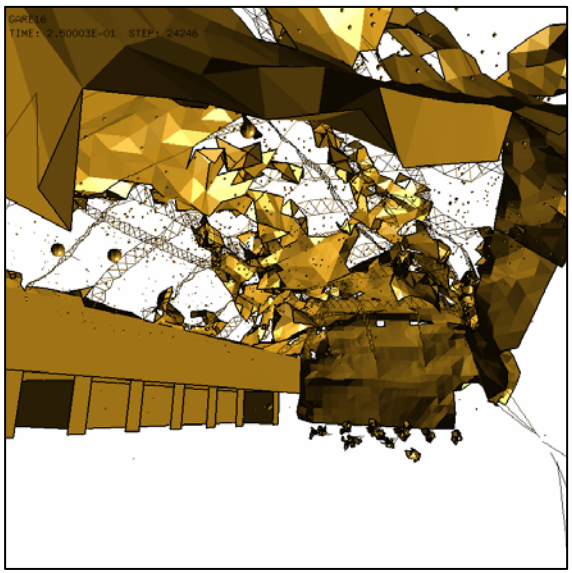




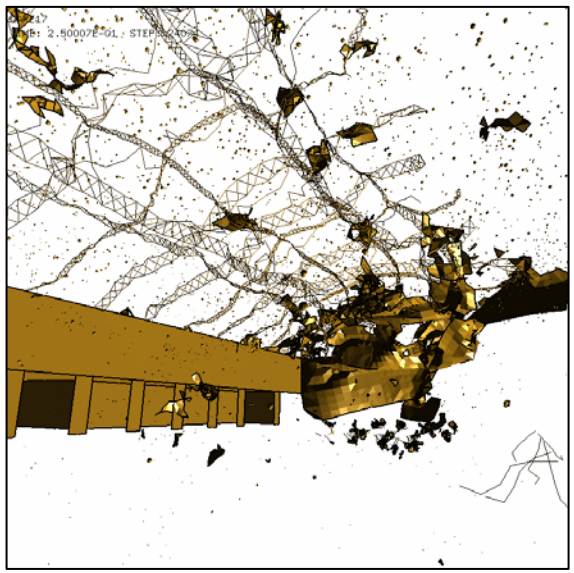
Comparison of final structural damage :



Small Charge

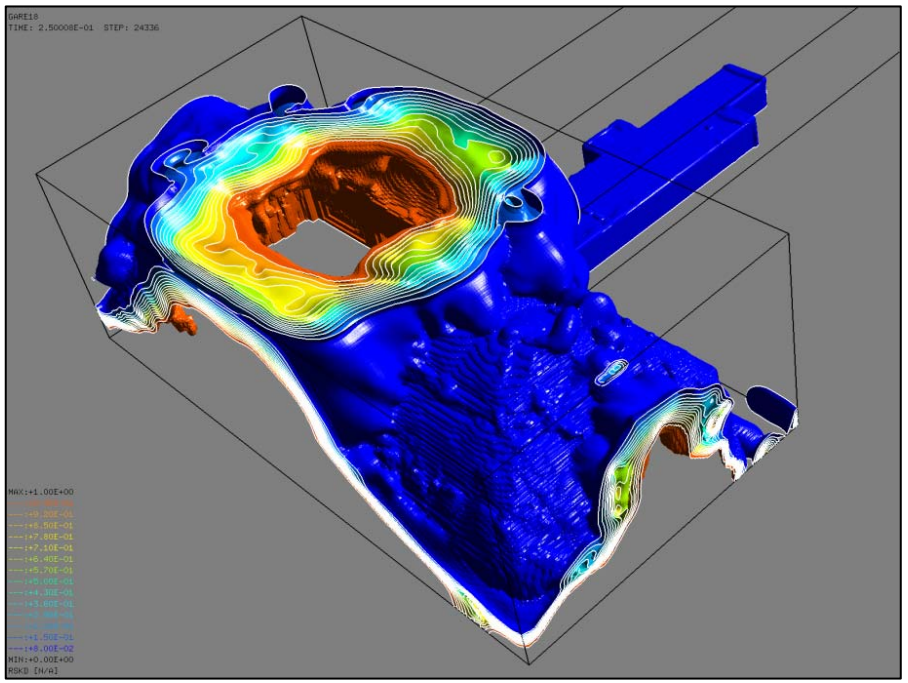


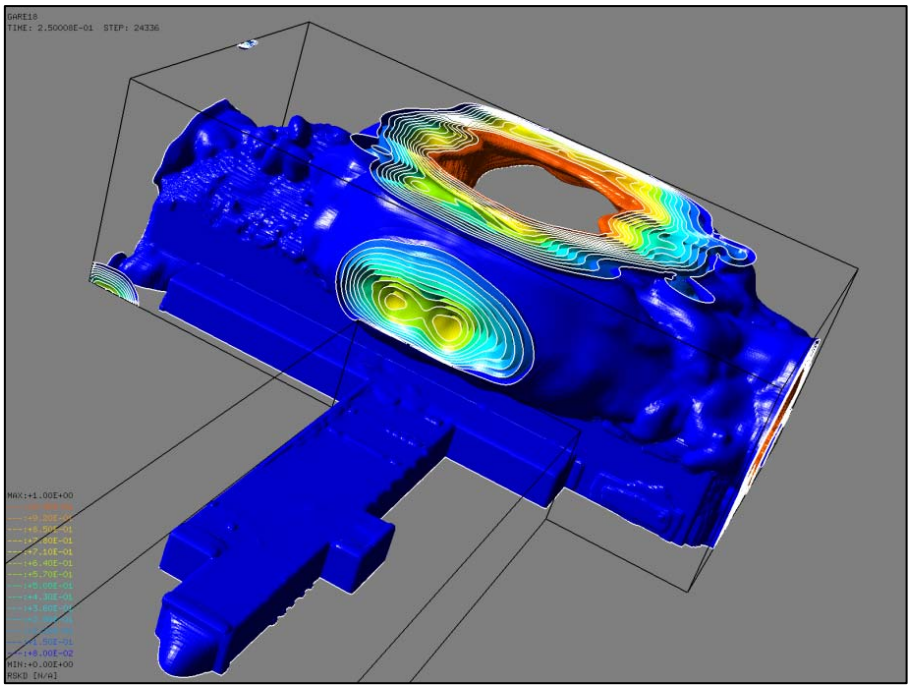
Medium Charge



Large Charge

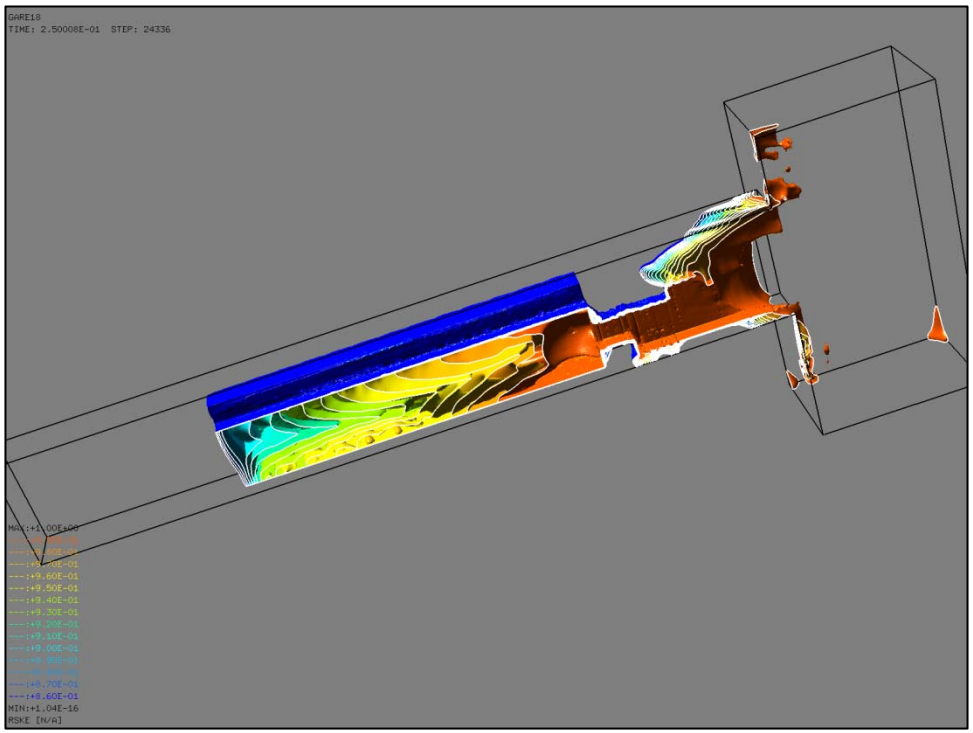
Death percentage iso-surfaces

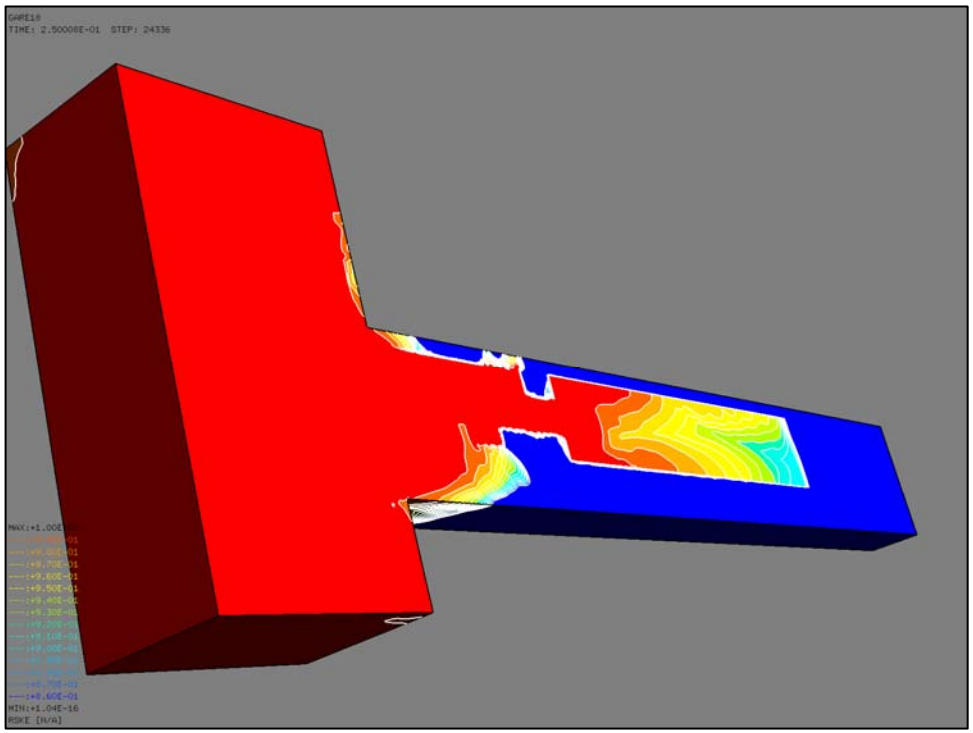




(Large Explosive Charge)

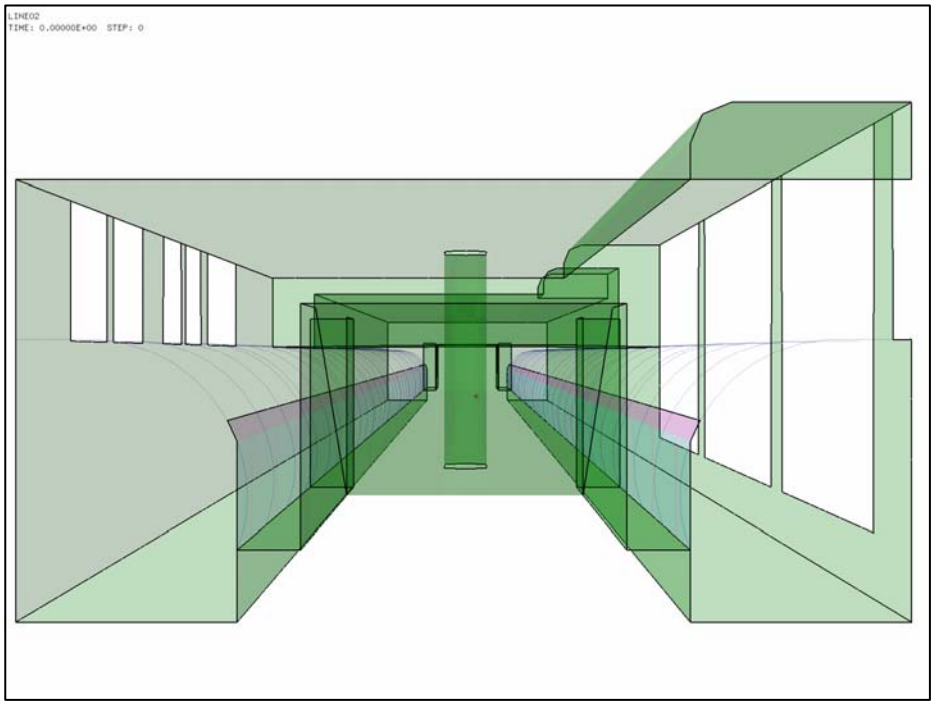
Eardrum Rupture percentage iso-surfaces



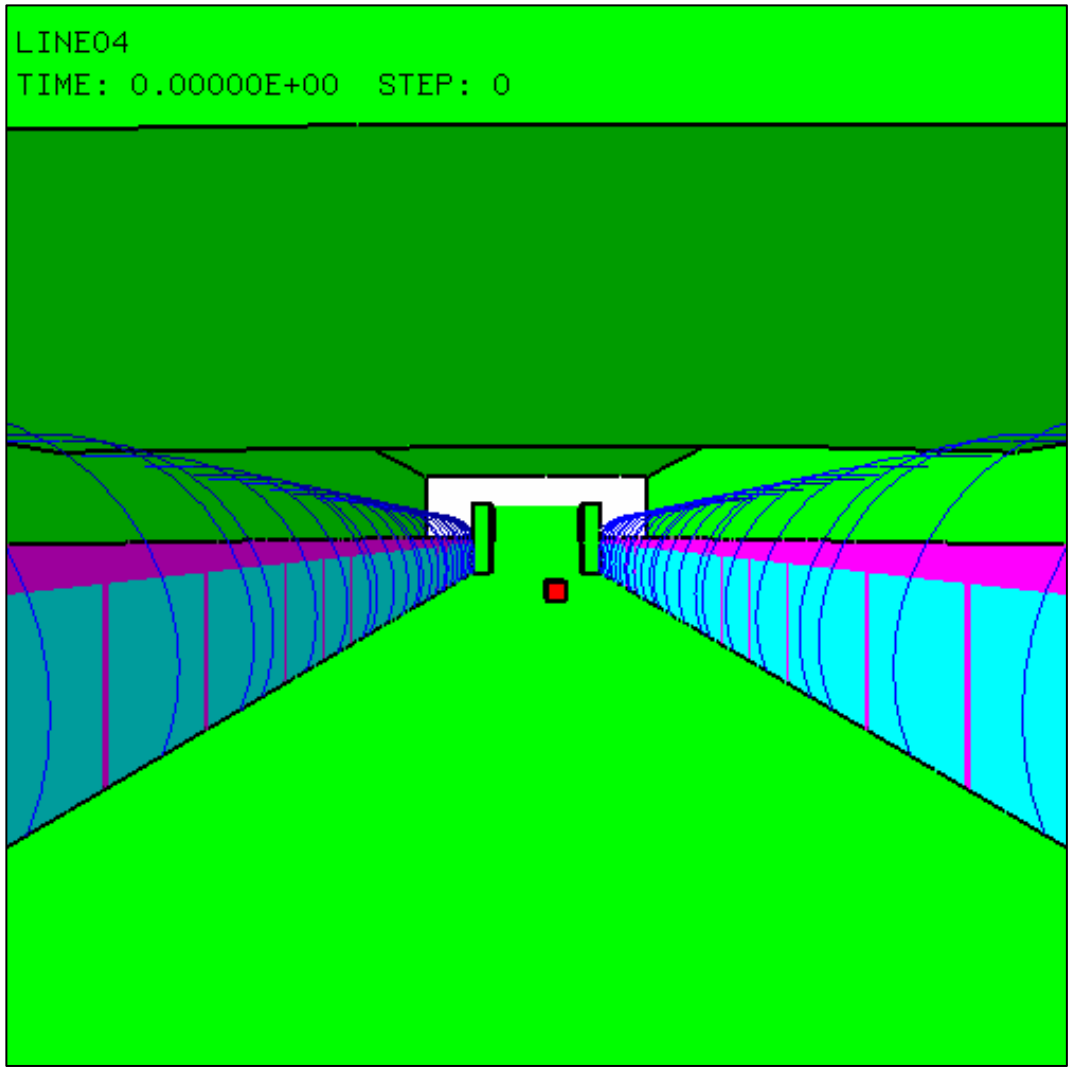


Recent Metro Line Station

platform-edge doors

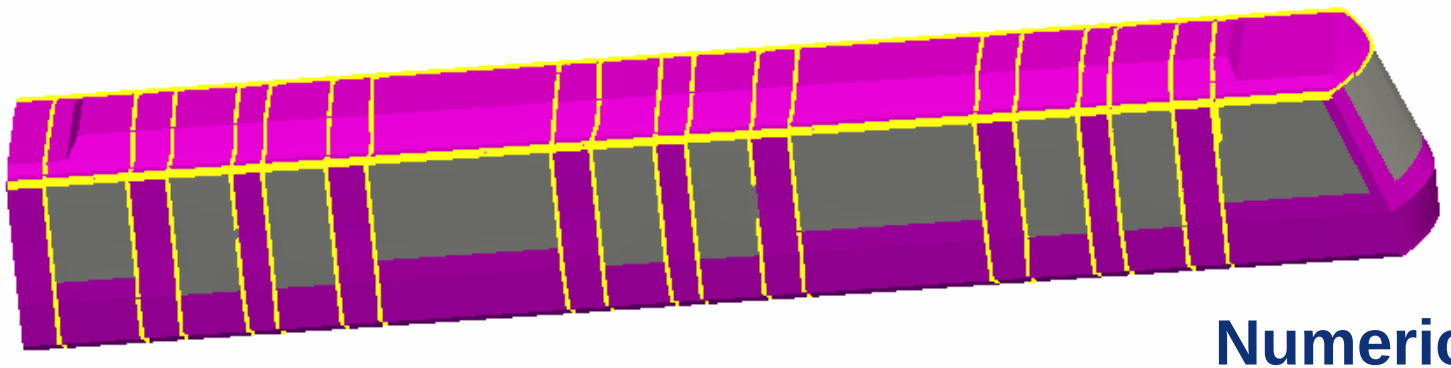


Numerical model



Medium Charge

Metro Line Carriage



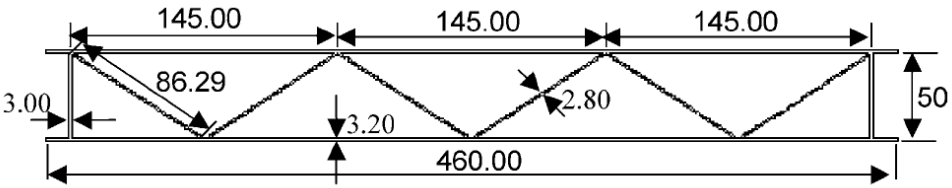
Numerical Model

Bag bomb (8 - 12 kg)

Source: www.spiegel.de

Honeycomb structure

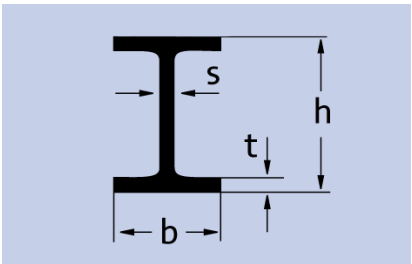
- Detailed model too expensive
- Sandwich element with same thickness, mass and stiffness



Zheng 2005

OR : Frame structure

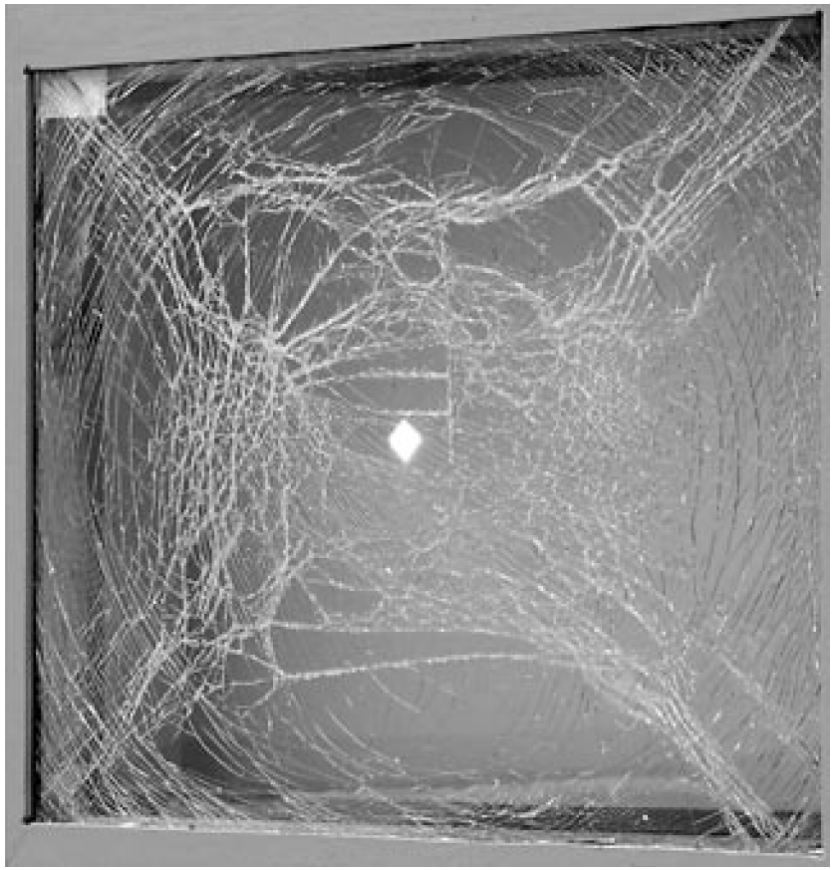
- IPE80
- 3 mm aluminum sheet welded on frame structure



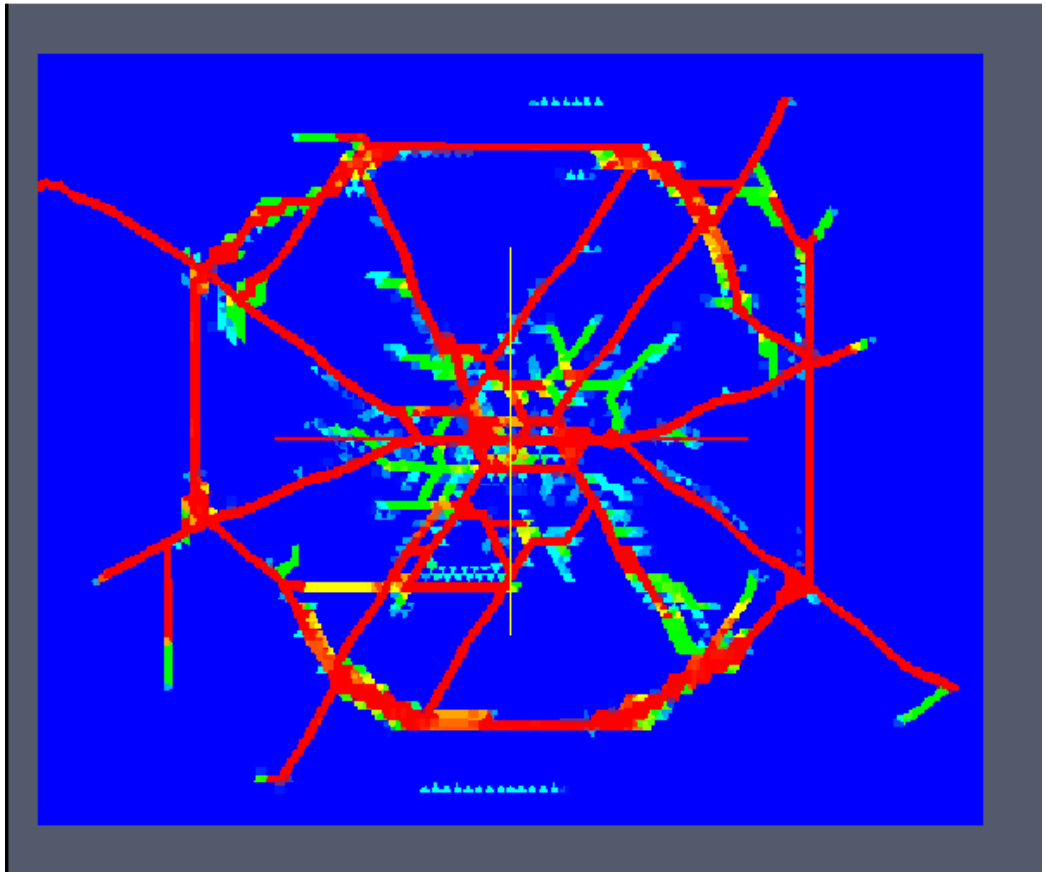
A [m^2]	7.60E-04
max I [m^4]	8.01E-07
h [m]	0.08
c [m/s]	5092

- Floor fixed
- Explosive in the centre of the carriage

Modeling of Laminated Glass



Experiment

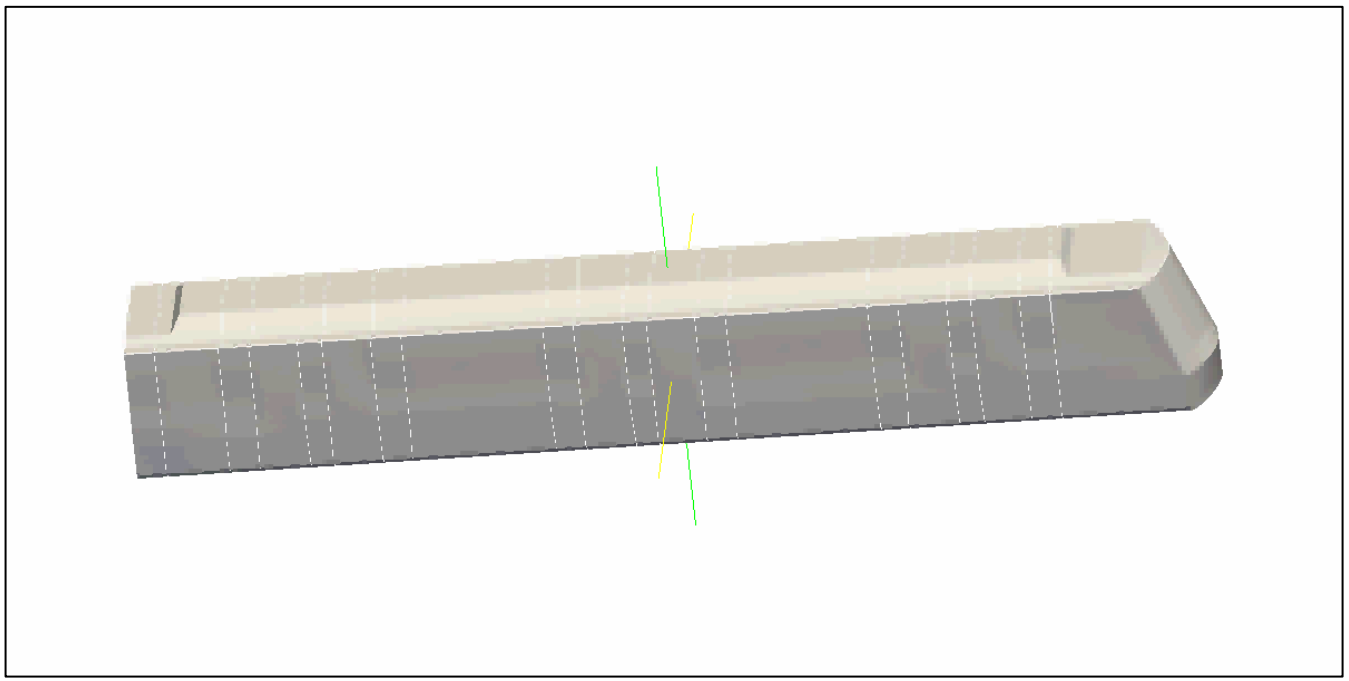


Calculation

10 kg TNT,

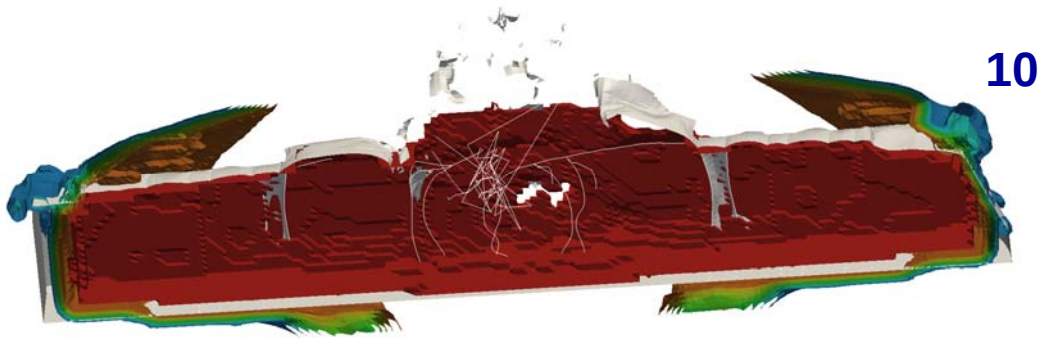
frame structure,

laminated glass



Death Risk Maps

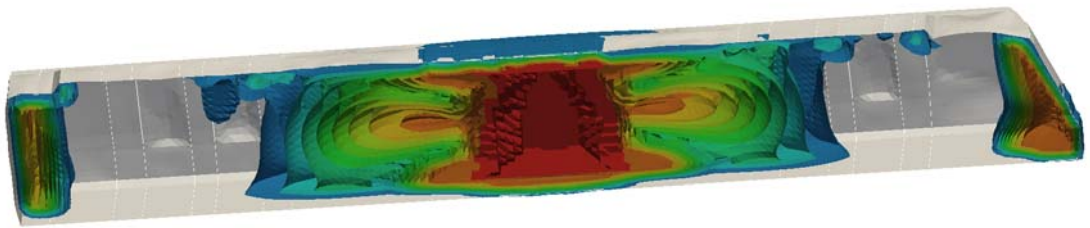
Without Internal Walls



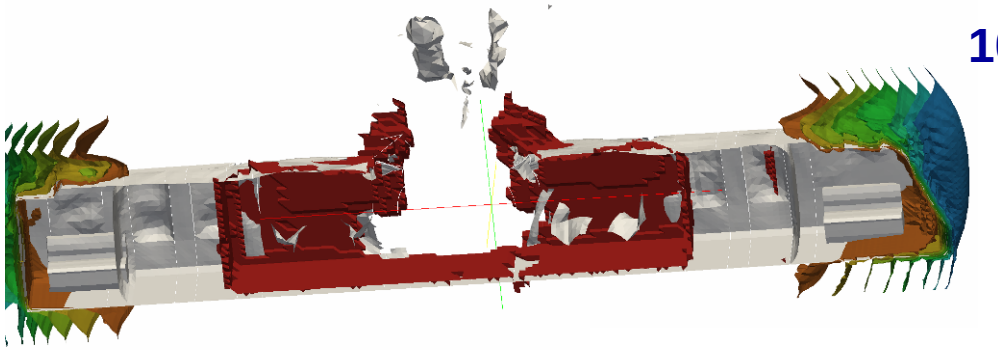
10 kg TNT

0.5 kg TNT

Reflection!

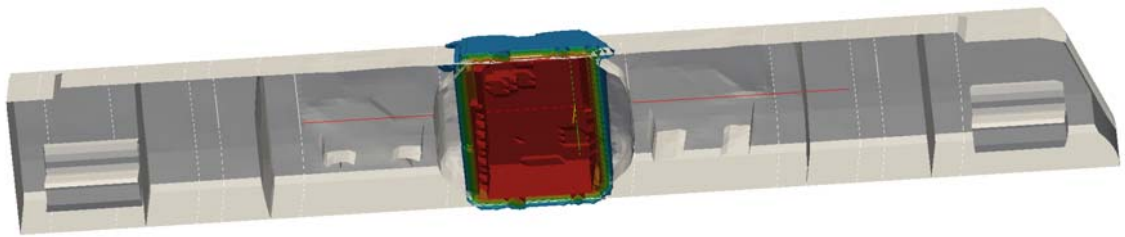


With Internal Walls



10 kg TNT

0.5 kg TNT



Some Conclusions

- By combining *in-situ* Laser Scanning techniques with Finite Element analysis, an efficient and reliable simulation tool (EUROPLEXUS) is developed

- This adds to ELSA's long experience in Vulnerability assessment of buildings and civil infrastructures for risk mitigation (e.g. earthquakes) and in European construction standardization (Eurocodes)

- Specialized modelling of fast transient Fluid-Structure Interaction is essential to accurately represent wave reflection / channelling effects and to allow risk evaluation