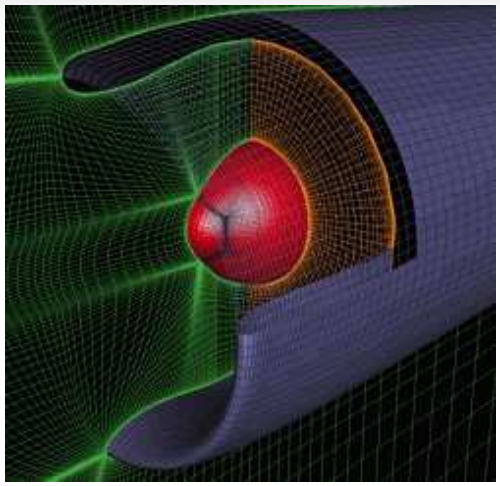
Computer Aided Engineering
Numerical Simulation Process

Fathi El-Yafi
Senior Product Engineer
Product Department of EXA Corporation

Overview

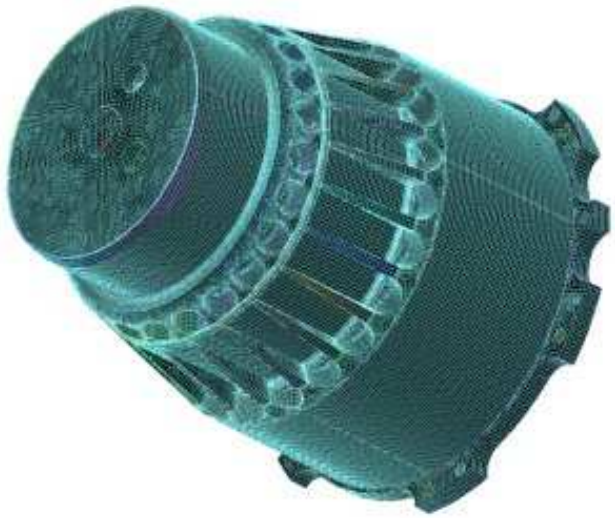
Several branches of computational mechanics can be distinguished according to the *physical scale* of the focus of attention:

Computational Mechanics {
- *Nanomechanics and Micromechanics*
- ***Continuum Mechanics***
- *Systems*



Nanomechanics:
Deals with phenomena at the molecular and atomic levels

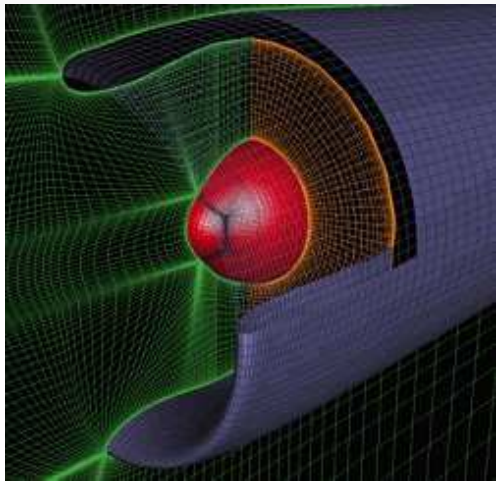
Continuum Mechanics:
Studies bodies at the macroscopic level, using continuum models in which the microstructure is homogenized by phenomenological averages.



System:
Identifies mechanical objects,
whether natural or artificial, that perform a distinguishable function.

Overview

Continuum Mechanics { *Solids and Structures*; *Fluids*; *Multiphysics*

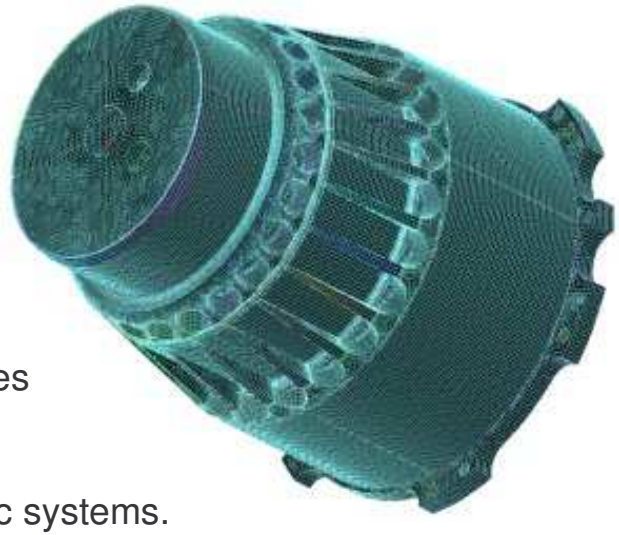


Solids and Structures:

Computational solid mechanics takes an applied sciences approach, whereas computational structural mechanics emphasizes technological applications to the analysis and design of structures.

Fluids:

Deals with problems that involve the equilibrium and motion of liquid and gases. Well developed subsidiaries are hydrodynamics, aerodynamics, acoustics, atmospheric physics, shock, combustion and propulsion.



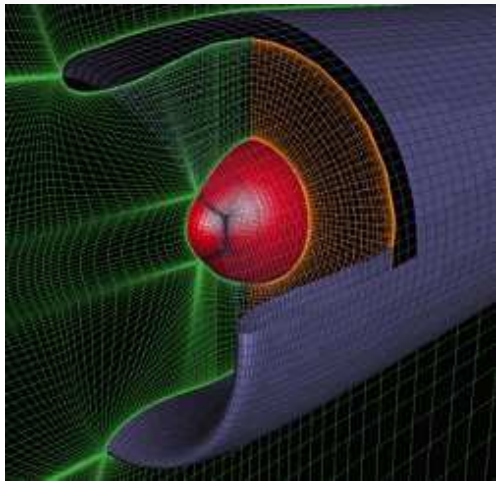
Multiphysics:

Multiphysics is a more recent newcomer.
This area includes mechanical systems that transcend the classical boundaries of solid and fluid mechanics, as in interacting fluids and structures.
Phase change problems such as ice melting and metal solidification fit into this category, as do the interaction of control, mechanical and electromagnetic systems.

Overview

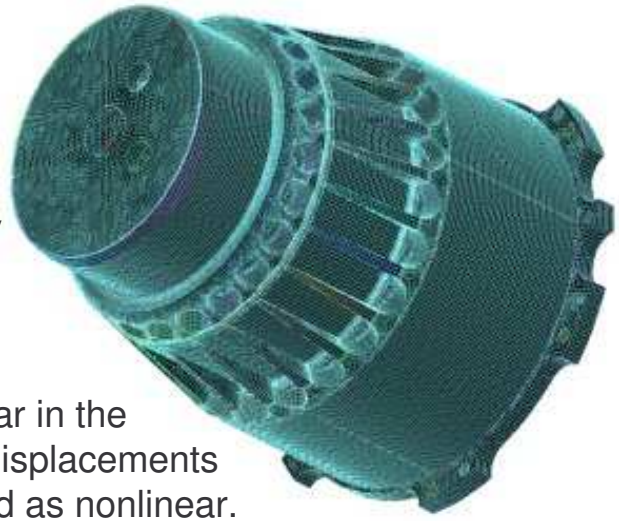
Continuum mechanics problems may be subdivided according to whether inertial effects are taken into account or not:

Continuum Mechanics { *Statics* { *Linear* / *Nonlinear* } / *Dynamics* }



Dynamics:

The actual time dependence must be explicitly considered, because the calculation of inertial (and/or damping) forces requires derivatives respect to actual time to be taken.



Statics:

Problems in statics may also be time dependent but with inertial forces ignored or neglected. Accordingly static problems may be classed into strictly static and quasi-static.

Linear vs. Nonlinear:

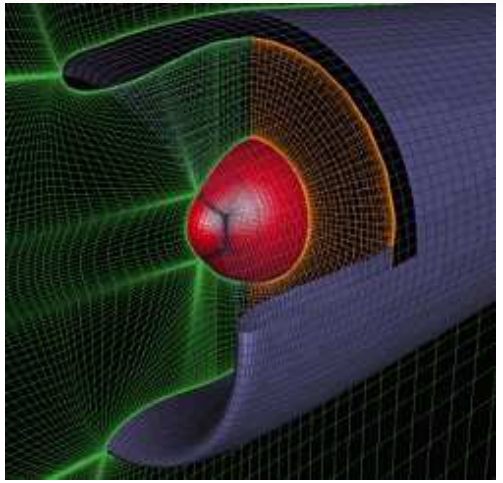
Linear static analysis deals with static problems in which the *response* is linear in the cause-and-effect sense. For example: if the applied forces are doubled, the displacements and internal stresses also double. Problems outside this domain are classified as nonlinear.

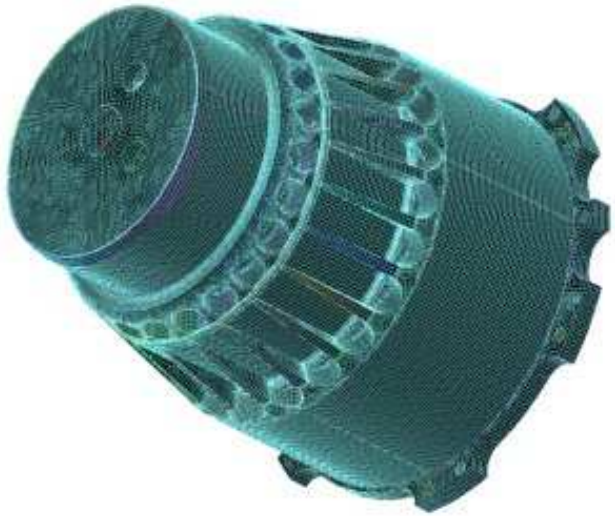
Overview

For the numerical simulation on computer

We must chose a ***spatial discretization method***:

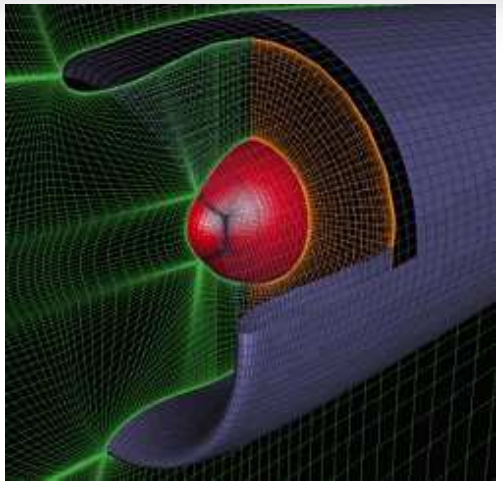
- ✓ ***Finite Element Method (FEM)***
- ✓ ***Finite Difference Method (FDM)***
- ✓ ***Boundary Element Method (BEM)***
- ✓ ***Finite Volume Method (FVM)***
- ✓ ***Spectral Method***
- ✓ ***Mesh-Free Method***

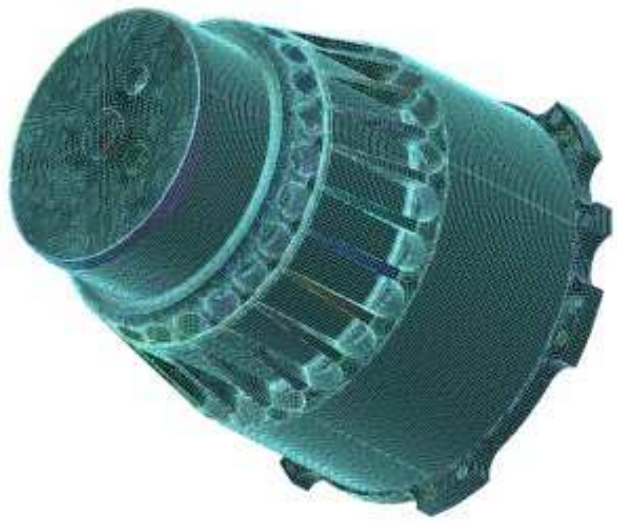




Overview

1. **Some Typical CAE Simulation**
   - ❑ Structure
     - ✓ Stamping
     - ✓ Crash Test
     - ✓ Safety
     - ✓ Rupture
   - ❑ Flow
     - ✓ Aerodynamics
     - ✓ Aeroacoustics
   - ❑ Multi-Physics
     - ✓ Casting
     - ✓ Molding
     - ✓ Injection

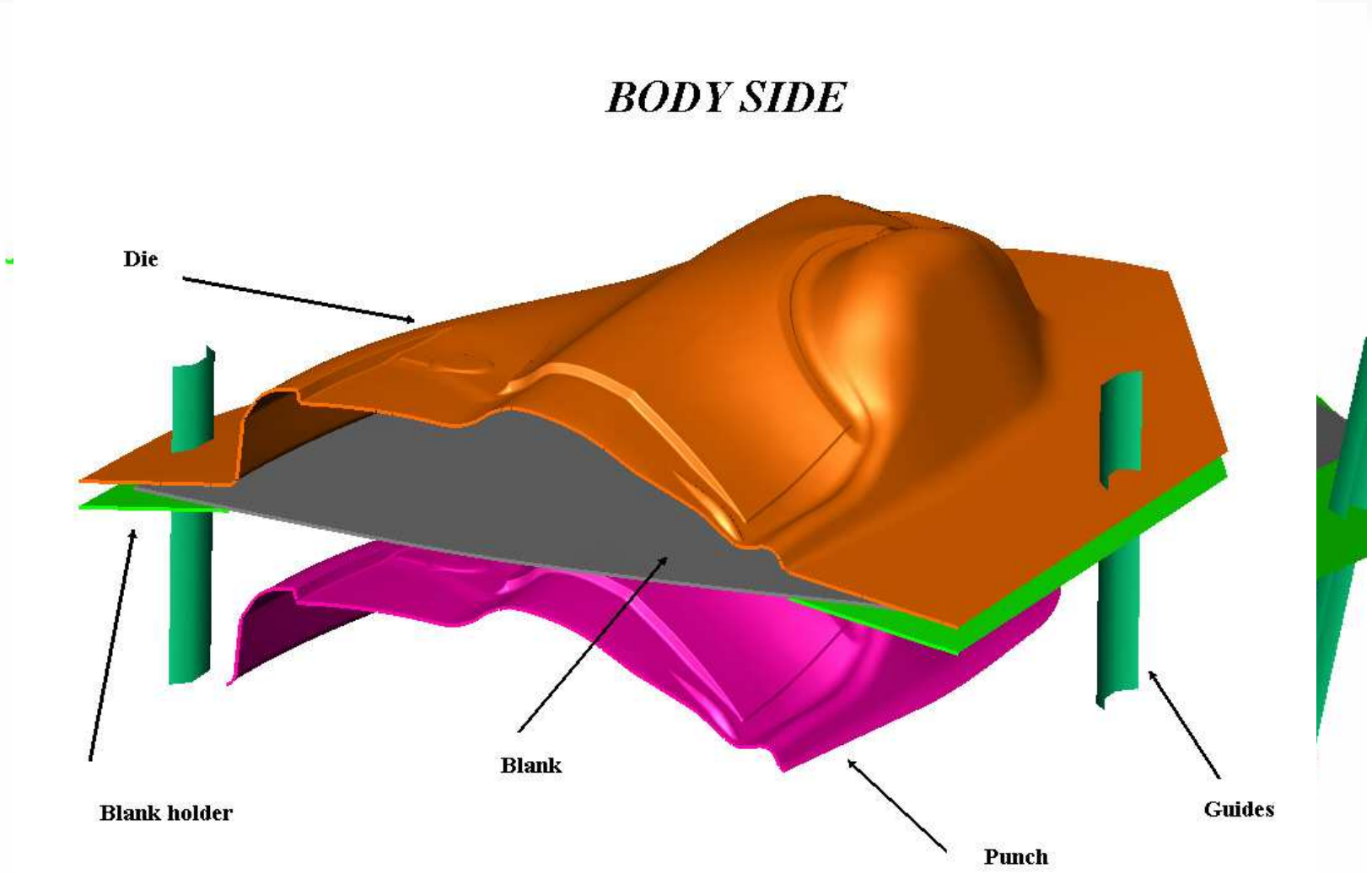




2. **The CAE Simulation Process**

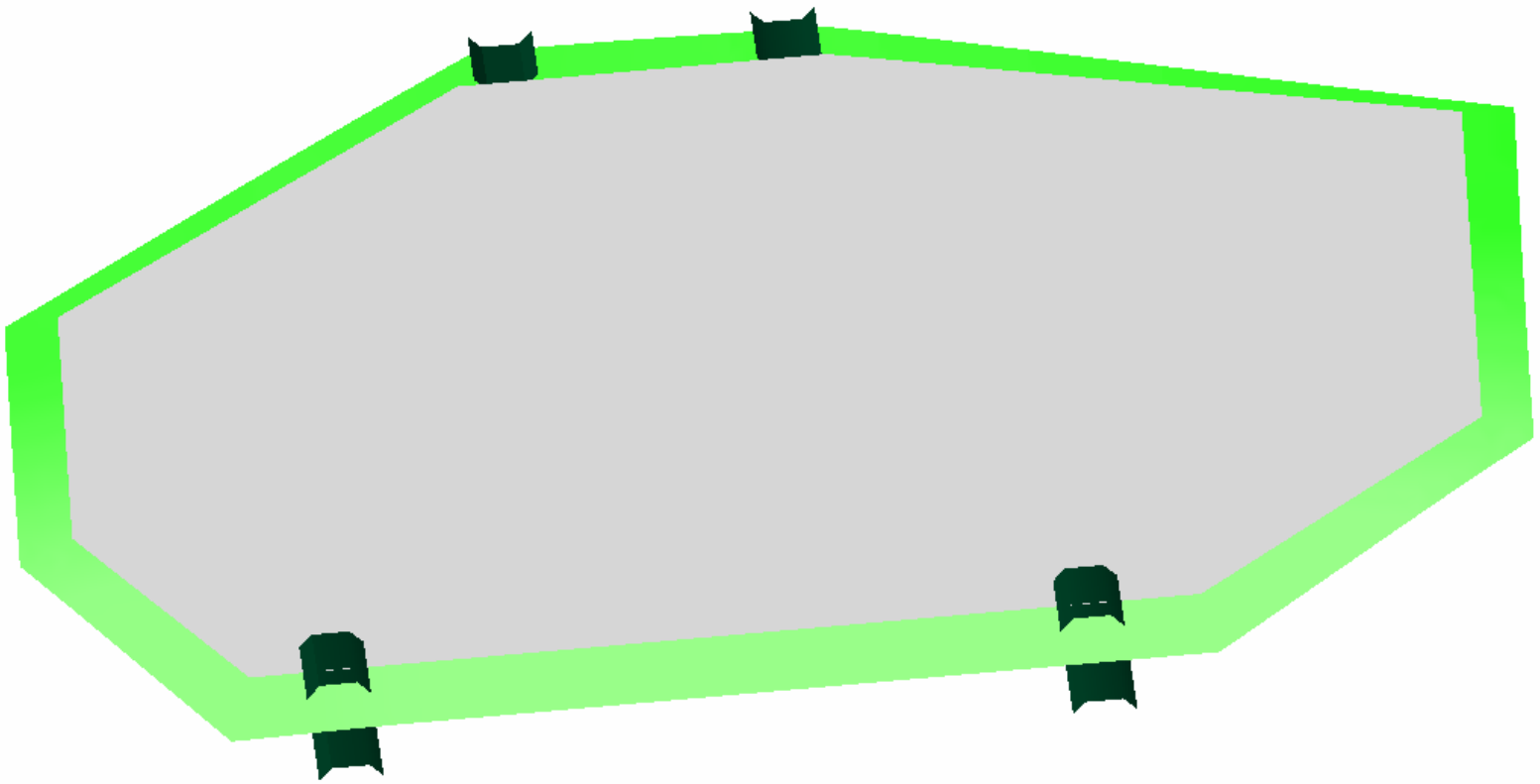
3. **Modeling Complexity**
   - ✓ Multi-Physics (Acoustic, CFD and CEM)

Structure Simulation: Stamping



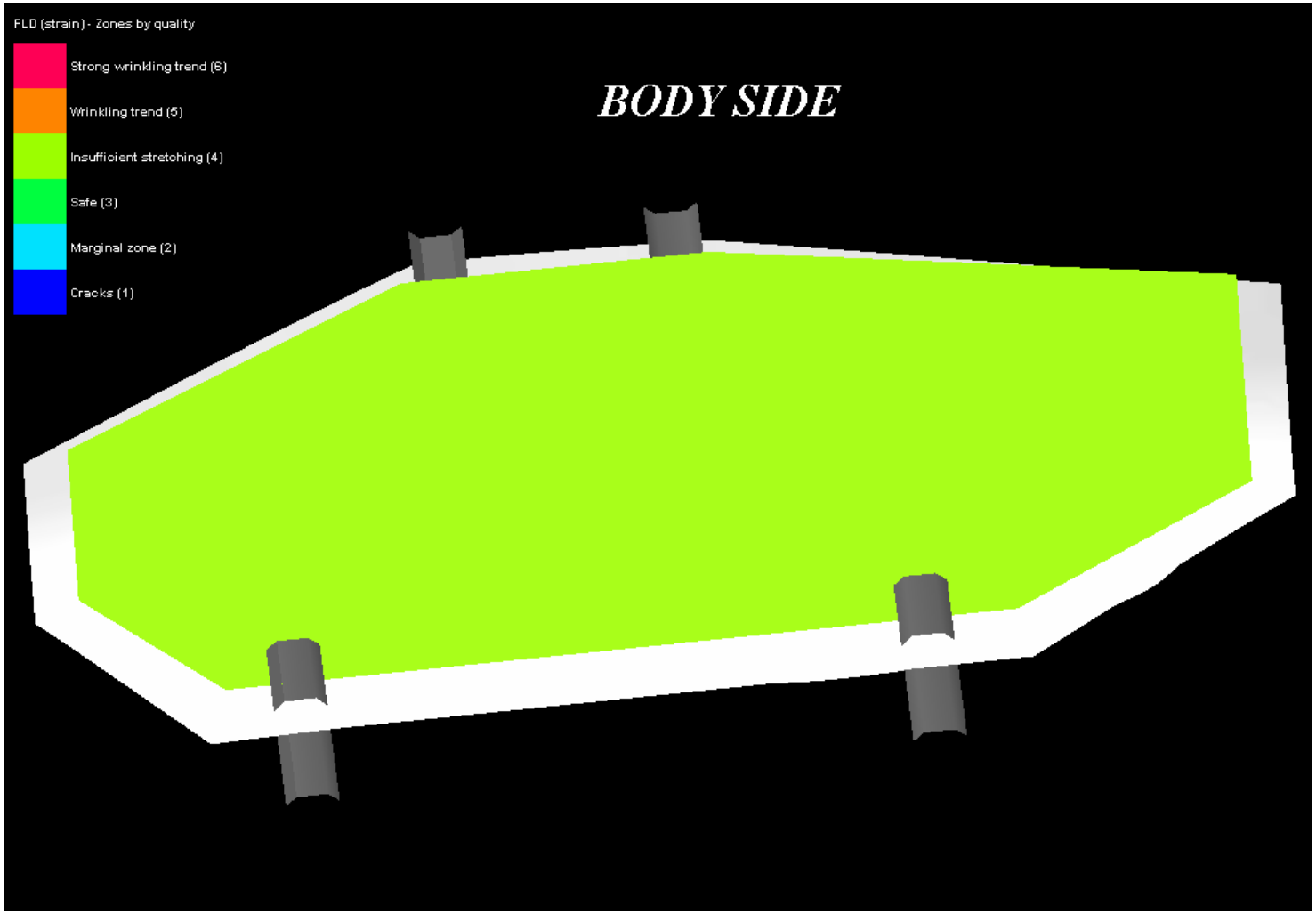
Structure Simulation: Stamping

Strains



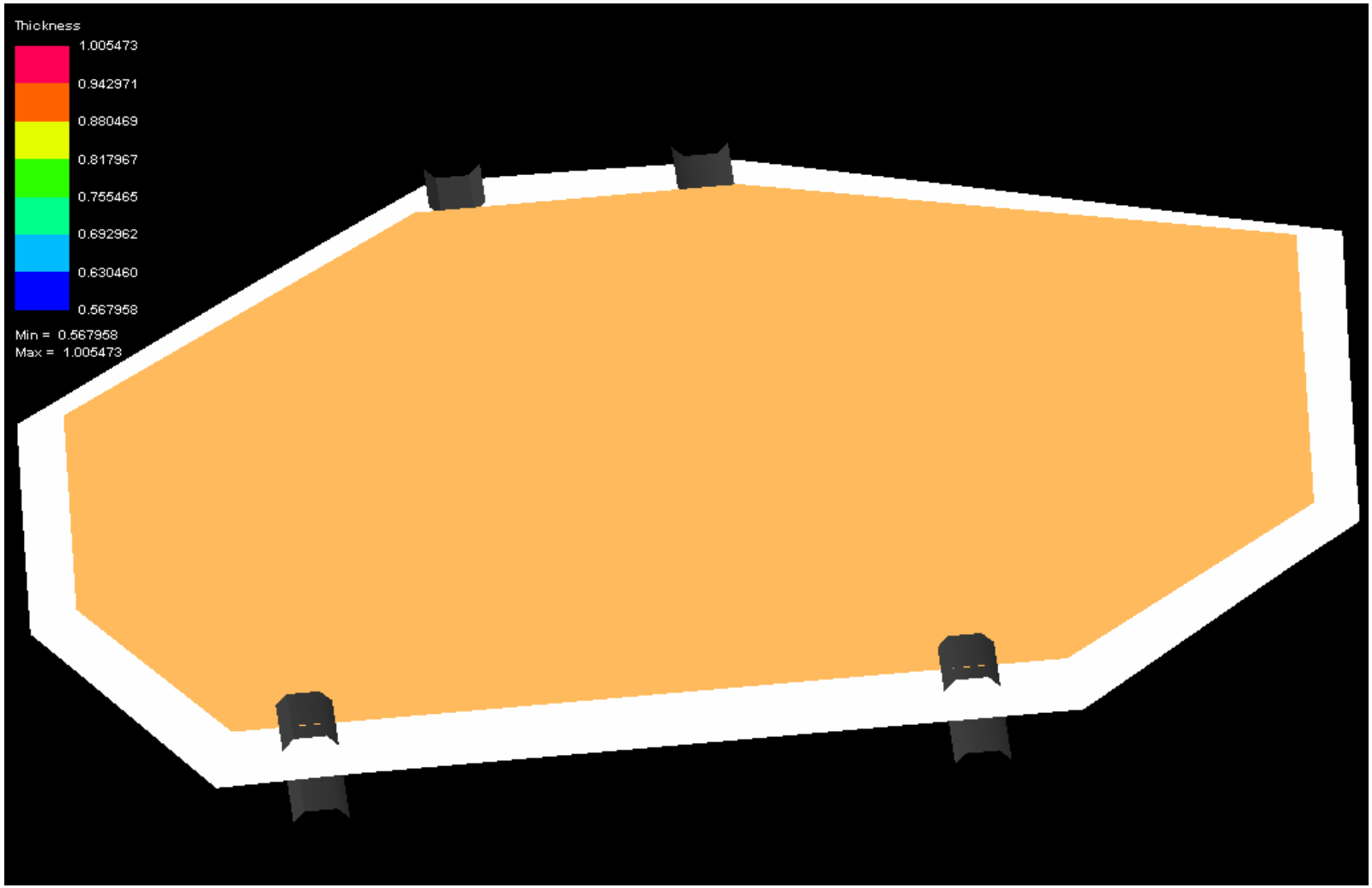
Structure Simulation: Stamping

Total FID



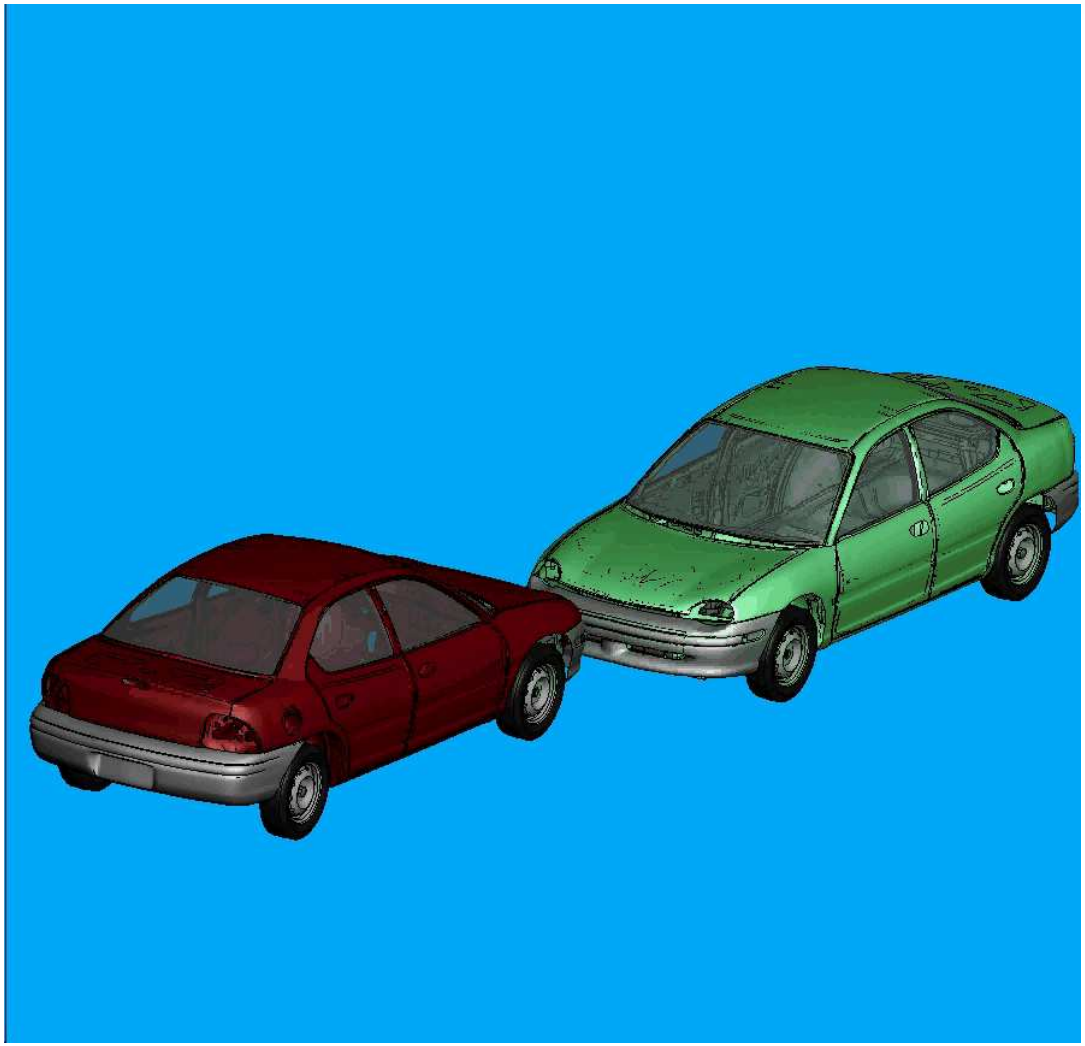
Structure Simulation: Stamping

Thickness



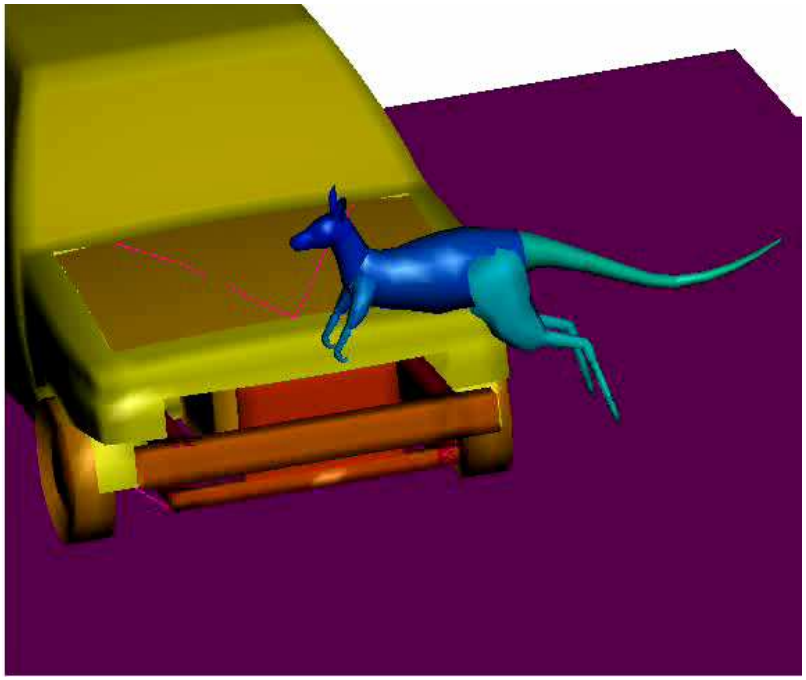
Structure Simulation: Crash Test

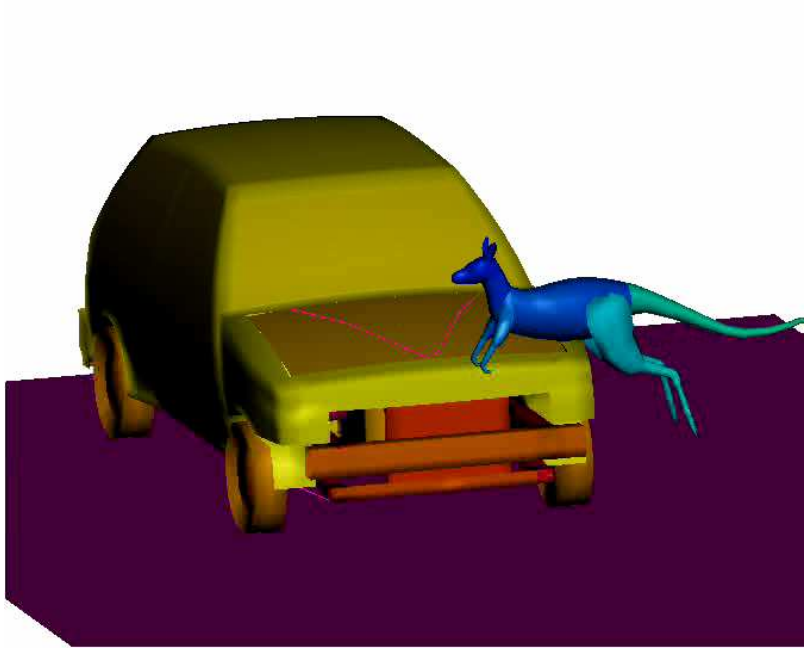
Neon Collision



Structure Simulation: Crash Test

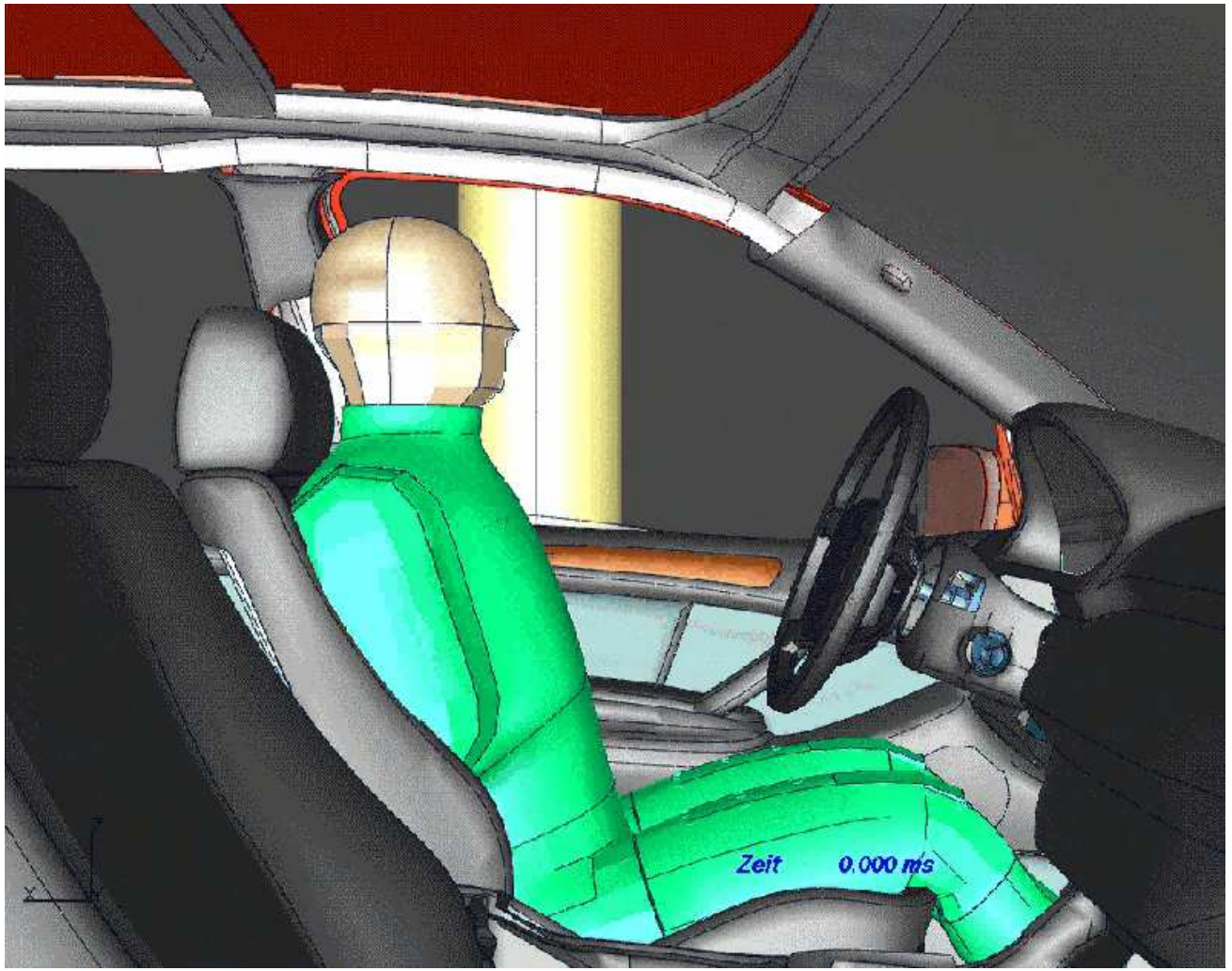
Collision





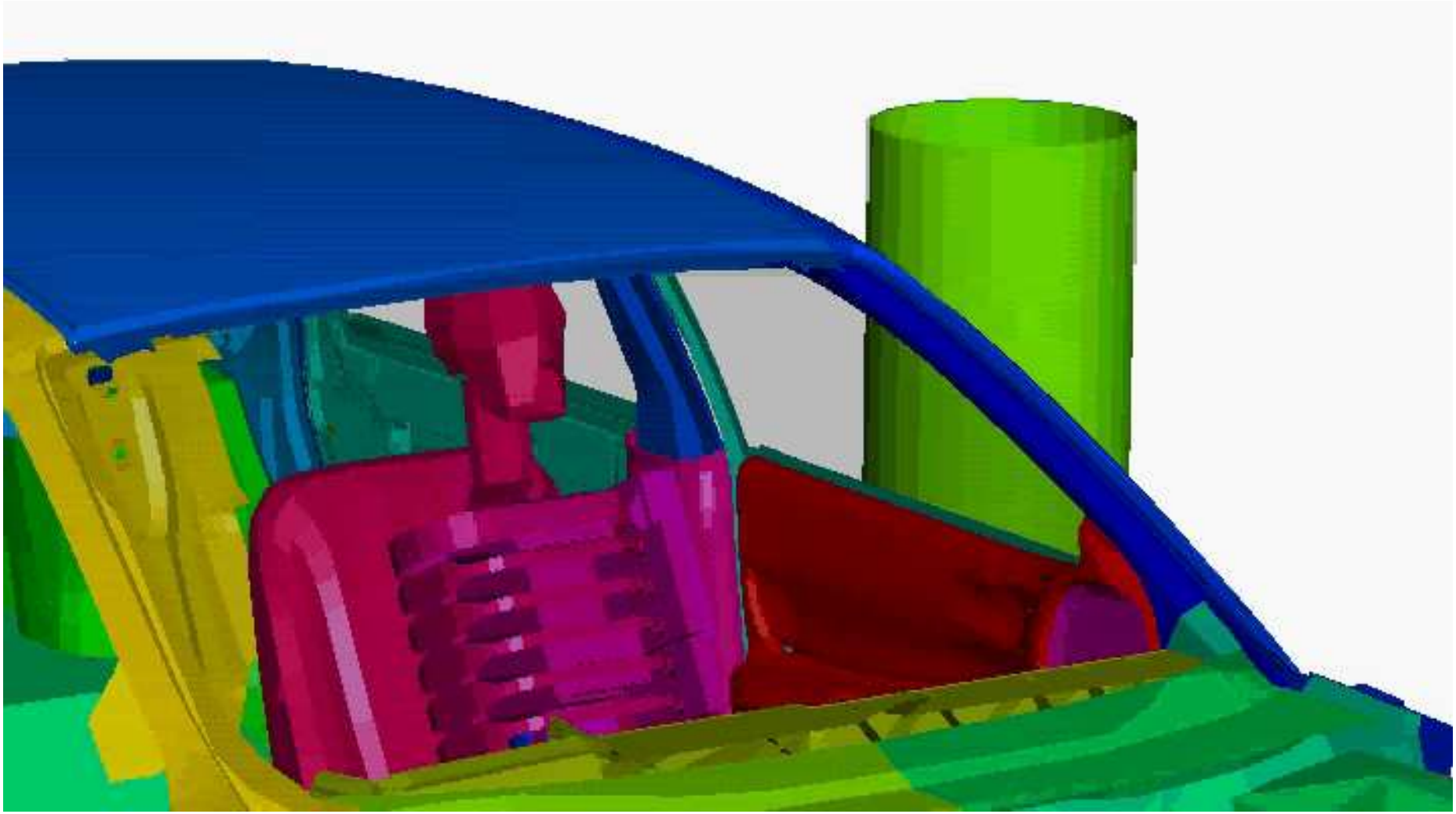
Structure Simulation: Safety

Crash Lateral BMW



Structure Simulation: Safety

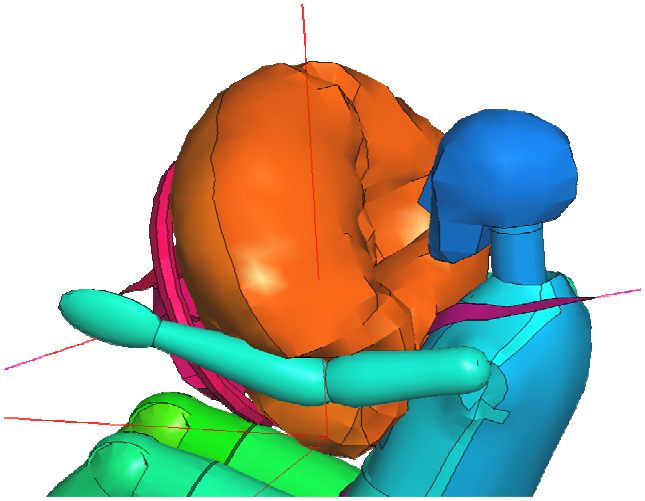
Crash Side

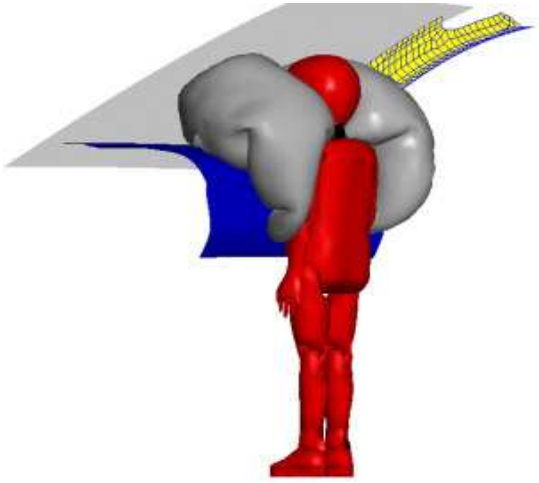


Structure Simulation: Safety

Airbag Simulation

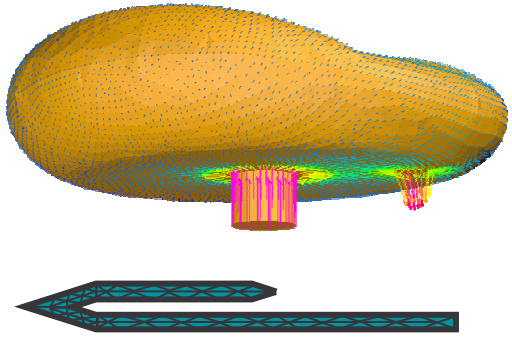
- **Initial needs were covered by simple gas models:**
  - Driver or passenger airbags interact with in-position occupants when deployed
  - Uniform pressure gas models can be sufficient
- **New regulations & airbag designs require prediction of airbag deployment dynamics**
  - Out-of position occupants (FMVSS 208)
  - Side airbags, curtains
  - For this purpose, a Fluid Dynamics model of the gas flow is necessary.



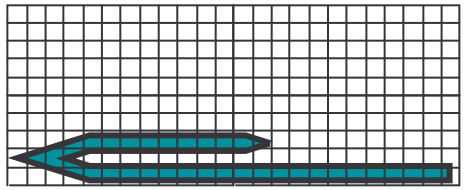


Structure Simulation: Safety

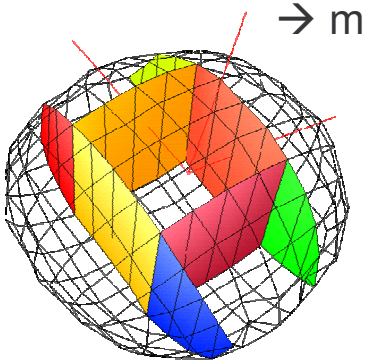
Airbag Modeling



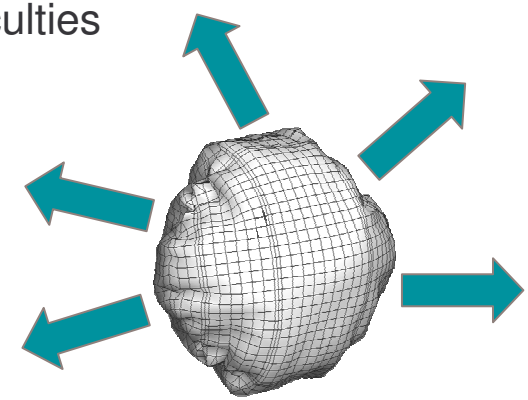
Finite Elements CFD
→ meshing difficulties



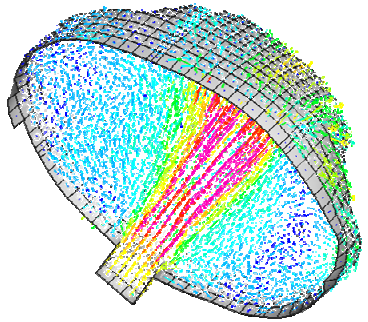
Finite Volumes CFD
→ Model size difficulties



Chambers + Jets:
equivalent model
→ not predictive



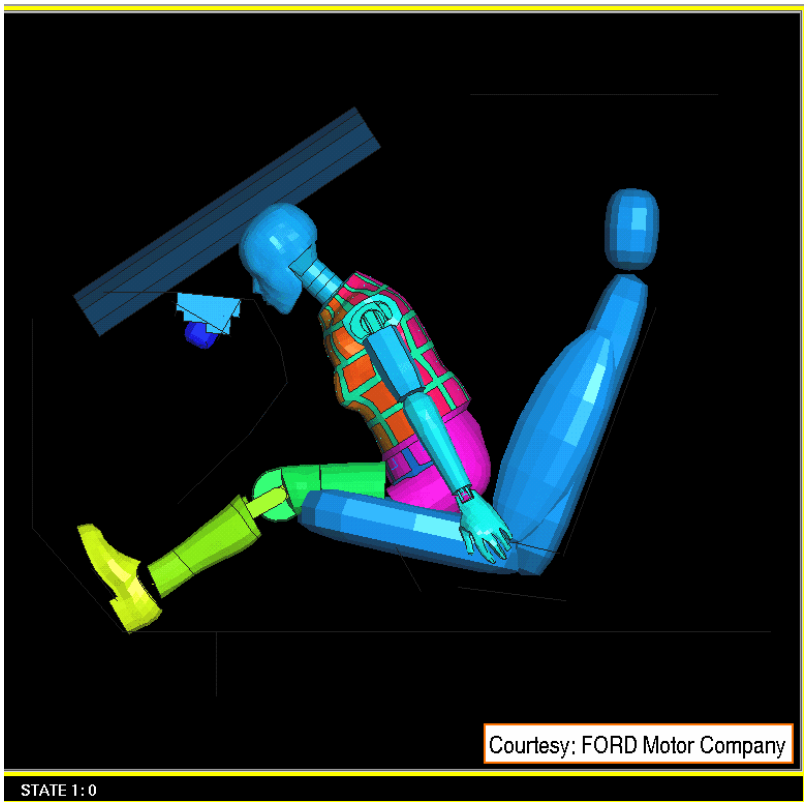
Uniform Pressure
→ Inaccurate



Mesh Free CFD
→ Efficient solution

Structure Simulation: Safety

Airbag FPM Method
A Mesh Free Method

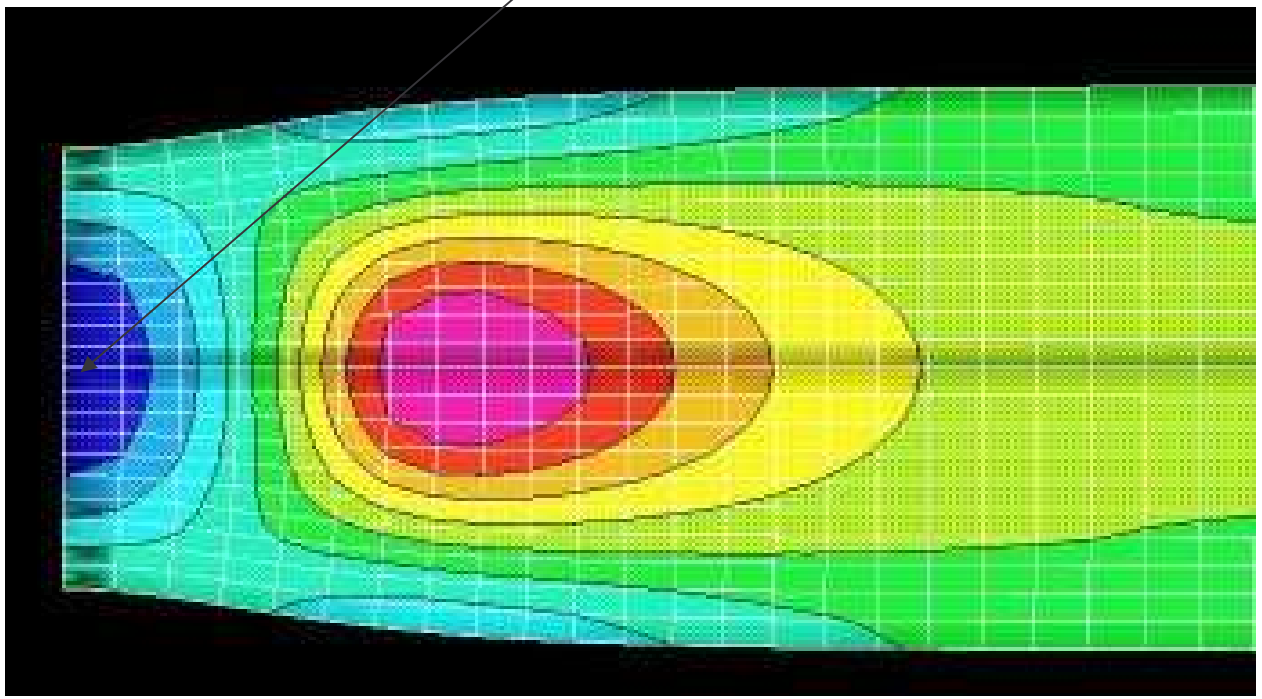




Structure Simulation: Rupture

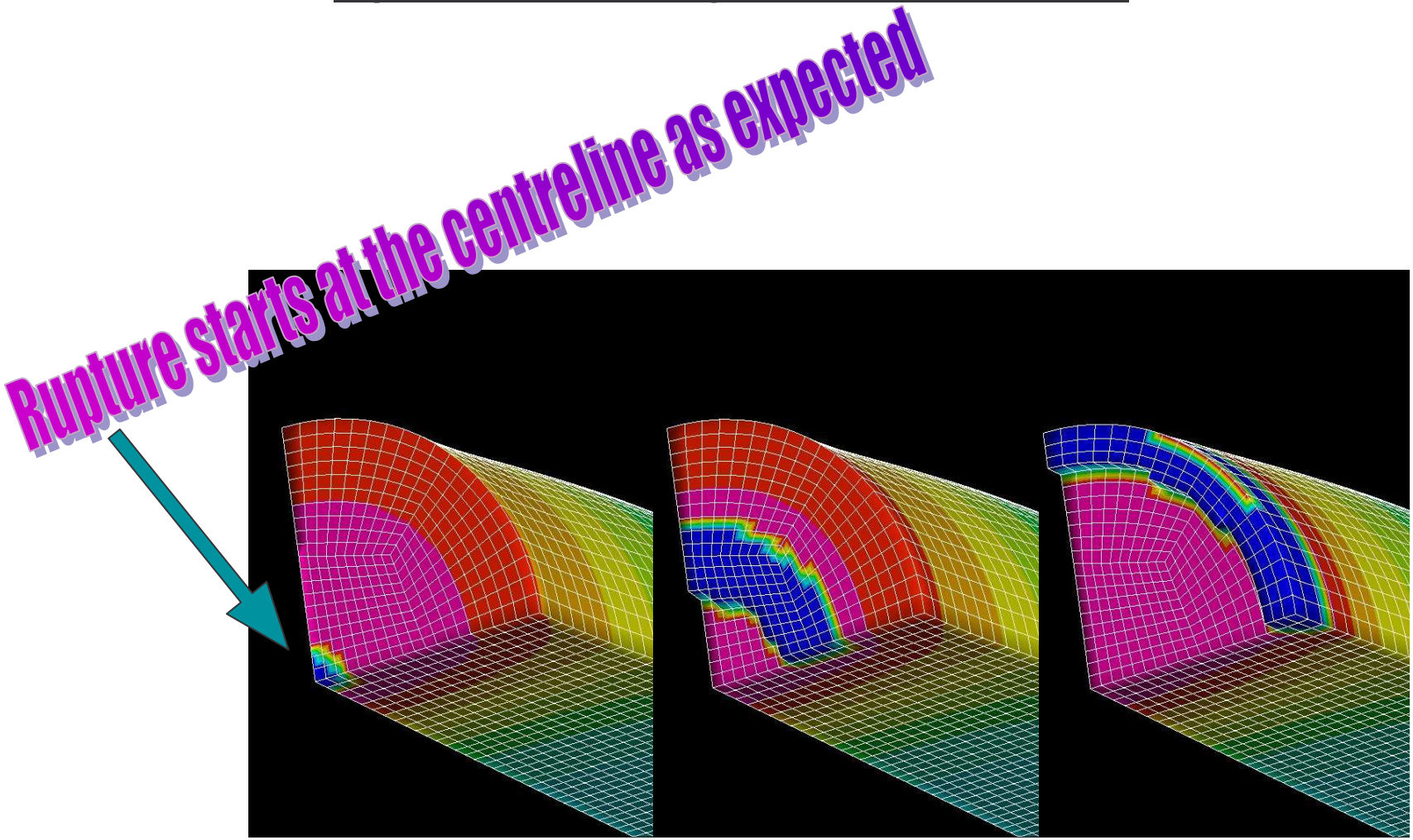
Smooth 'Cylindrical Tension Specimen' (CTS)
- Metal plasticity calibration -

Max hydrostatic tension at centerline



Structure Simulation: Rupture

Smooth 'Cylindrical Tension Specimen' (CTS)
rapid fracture through section (blue color)



Structure Simulation: Rupture

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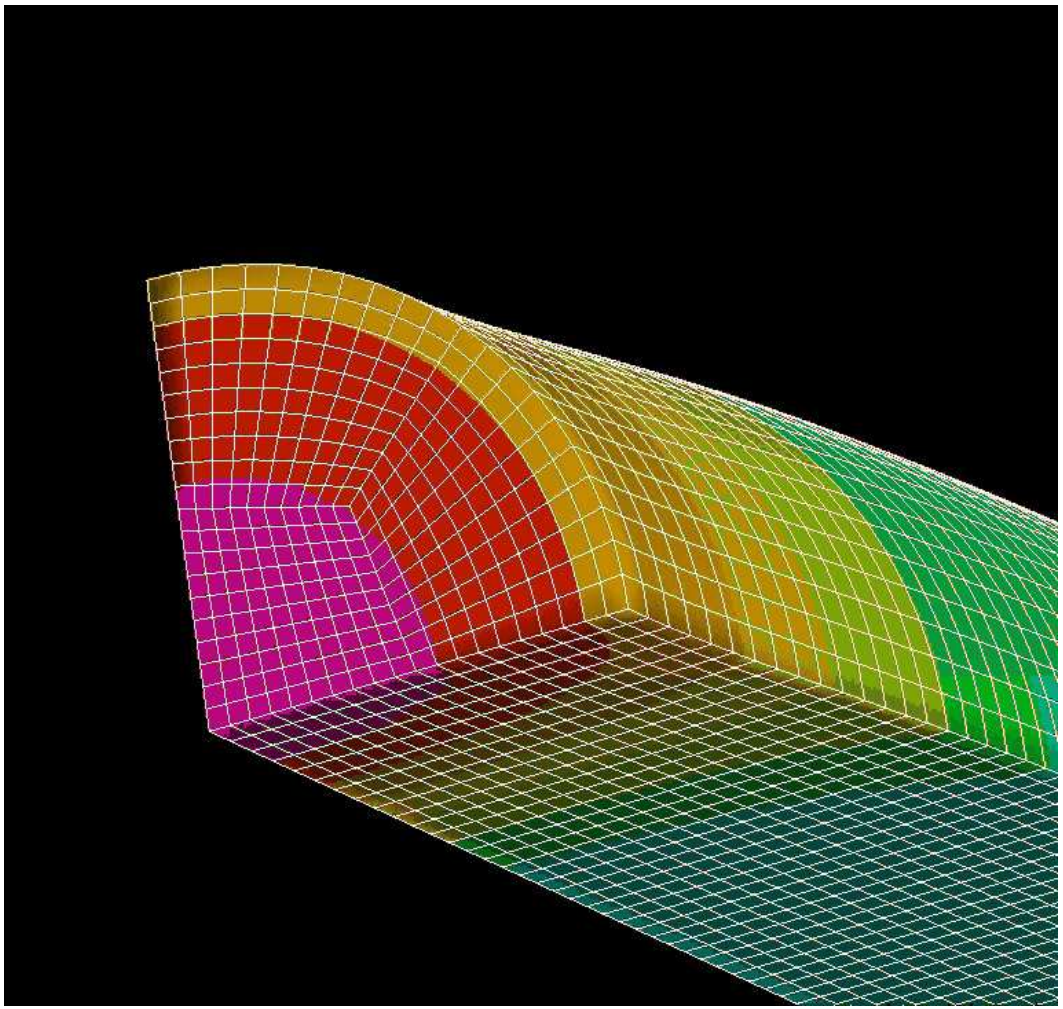
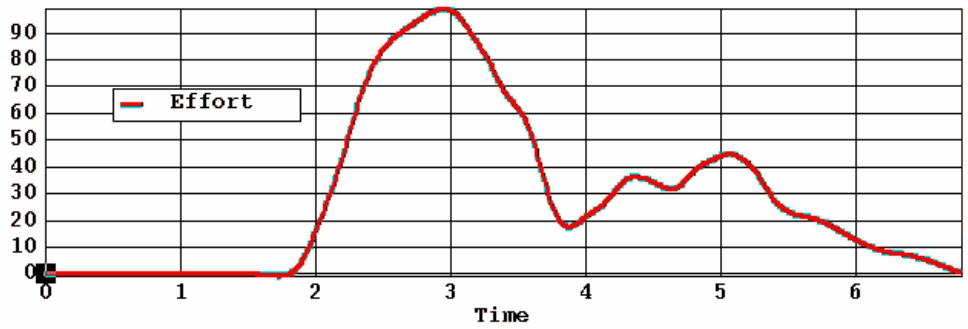
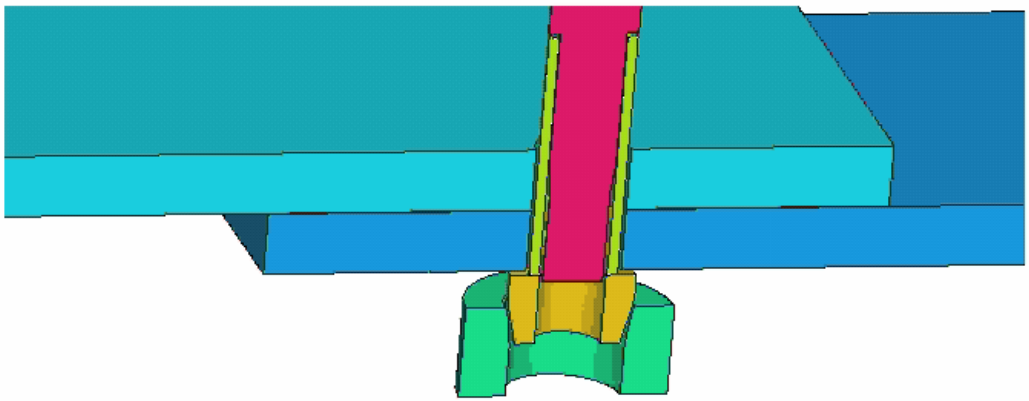


Structure Simulation: Rupture

Riveting Failure

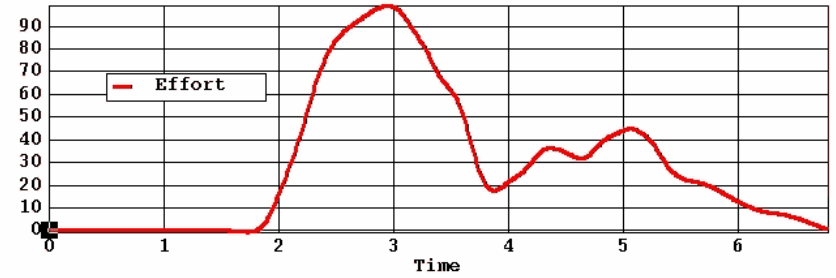


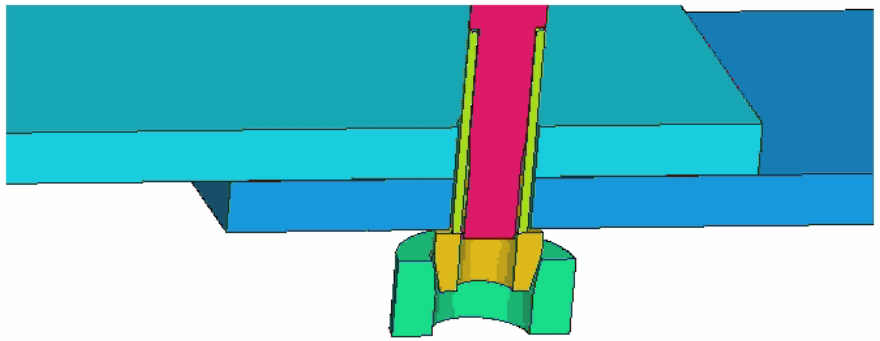


Shear

Structure Simulation: Rupture

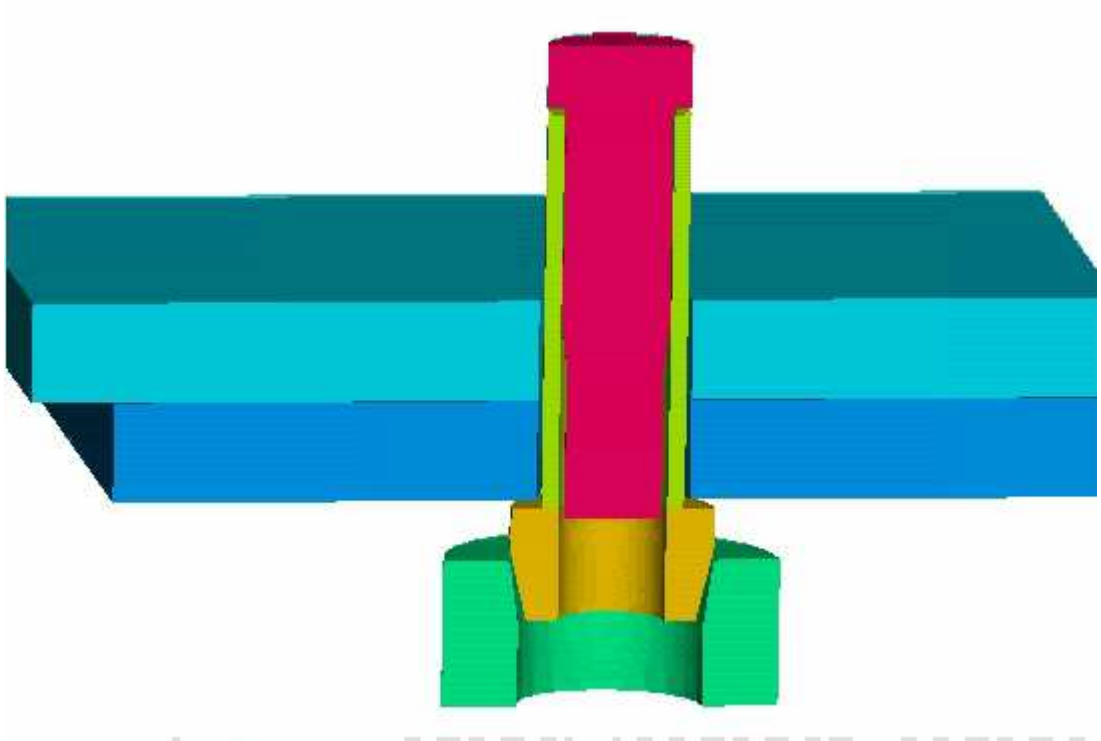
Riveting Failure: Shear





Structure Simulation: Rupture

Riveting Failure: Traction



Structure Simulation: Rupture

Arcelor DP450 Steel

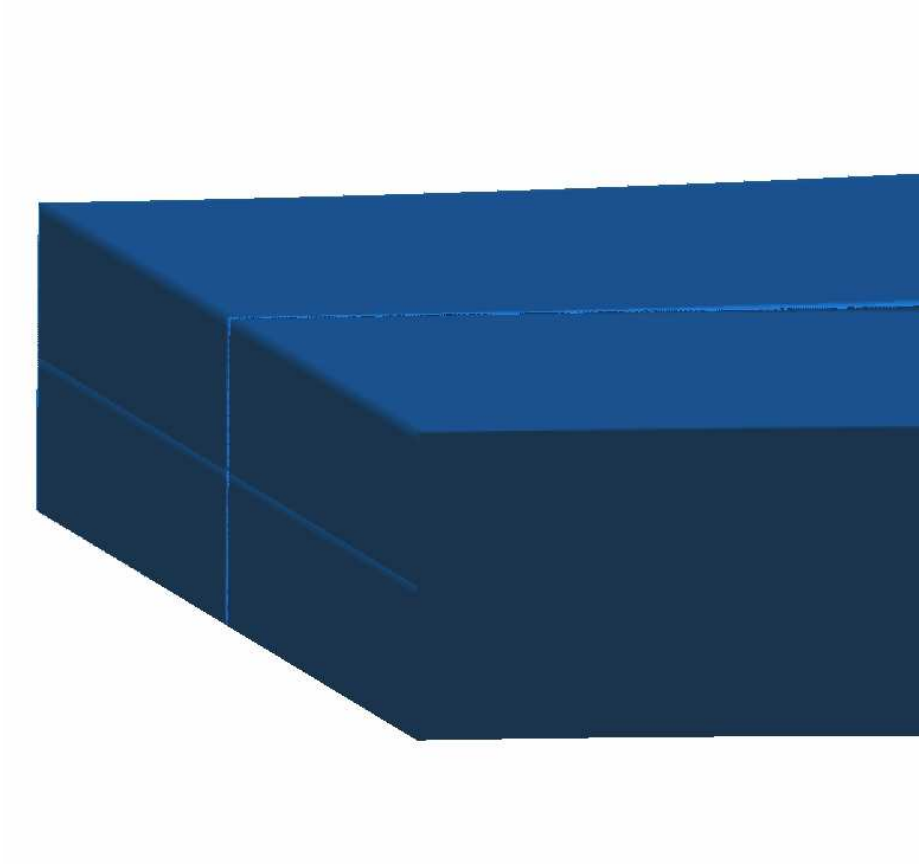
20mm notch



Structure Simulation: Rupture

Arcelor DP450 Steel

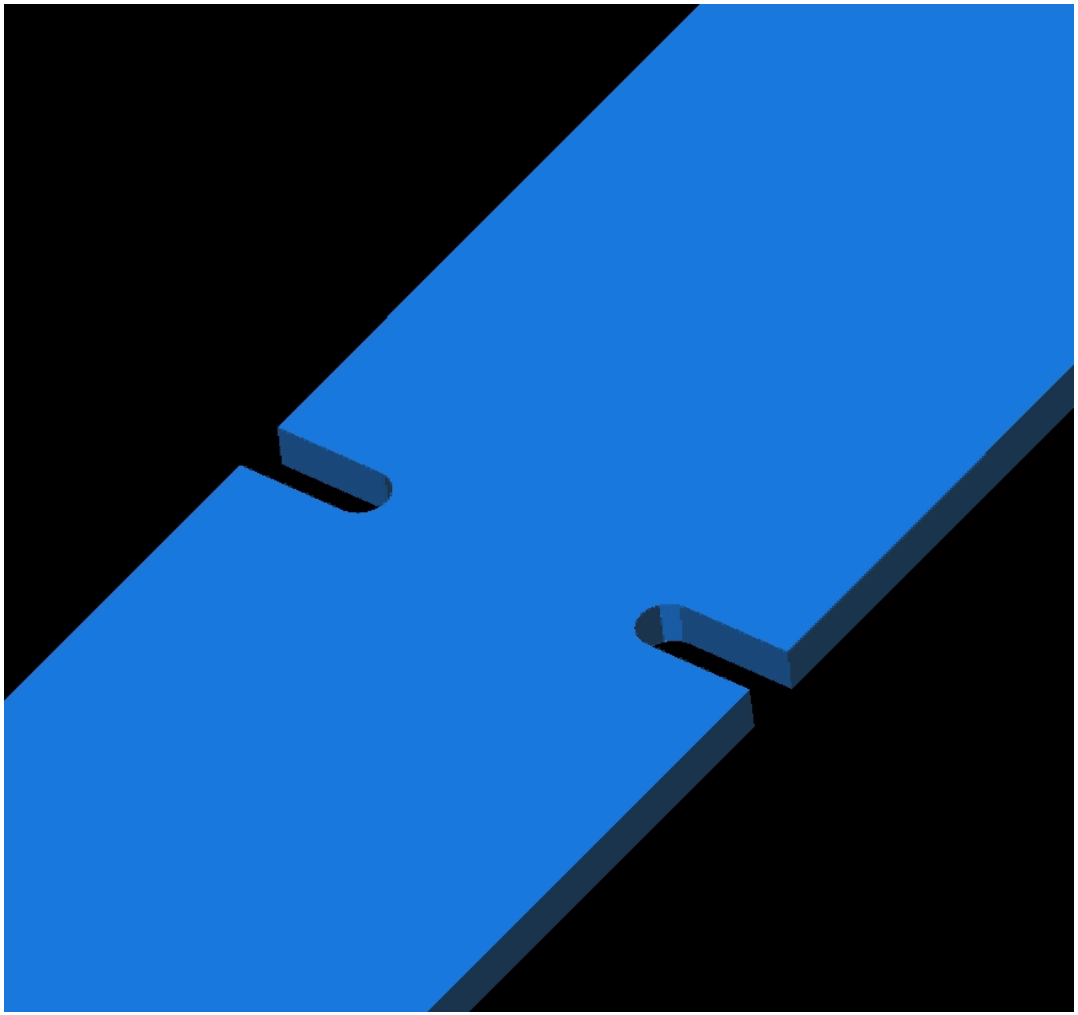
20mm notch



Structure Simulation: Rupture

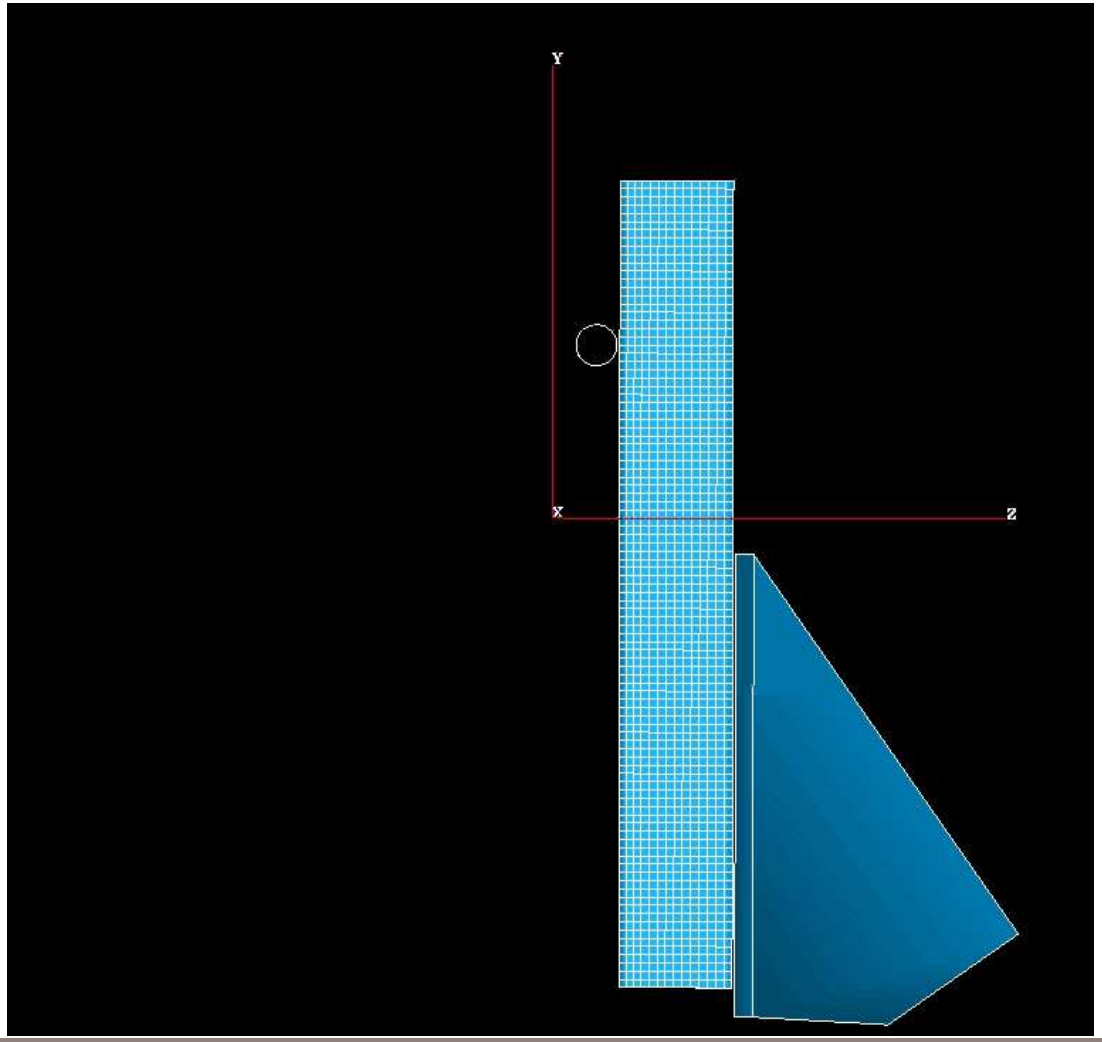
Arcelor DP450 Steel

1mm notch



Structure Simulation: Rupture

Box-Beam Failure (Nissan)

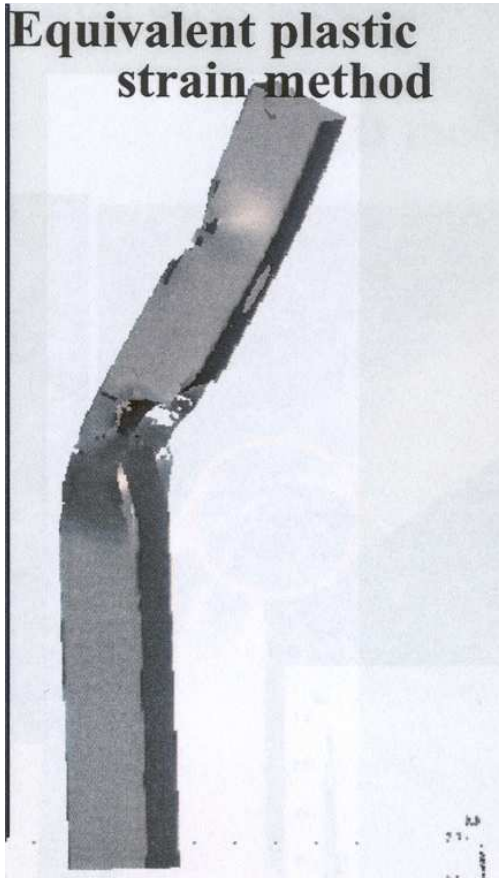


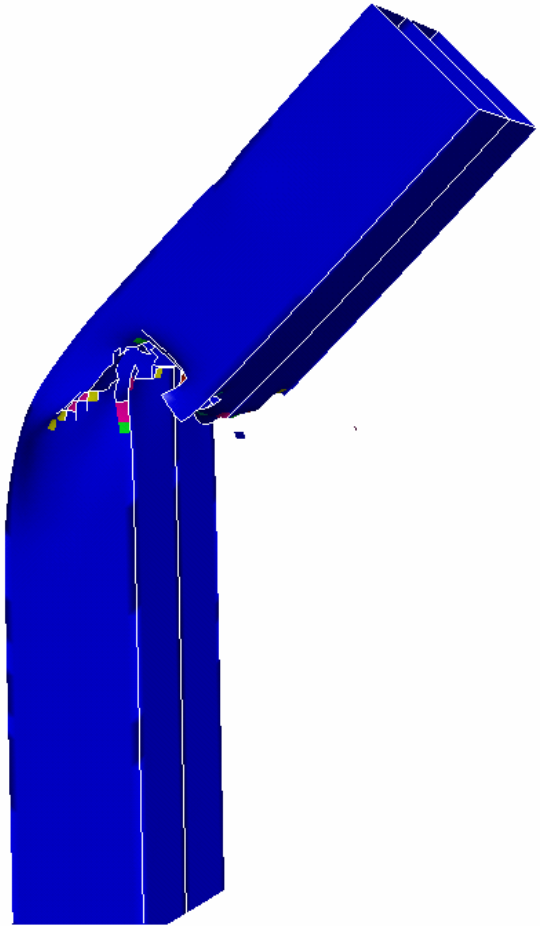
Structure Simulation: Rupture

Box-Beam Failure (Nissan)



Experiment

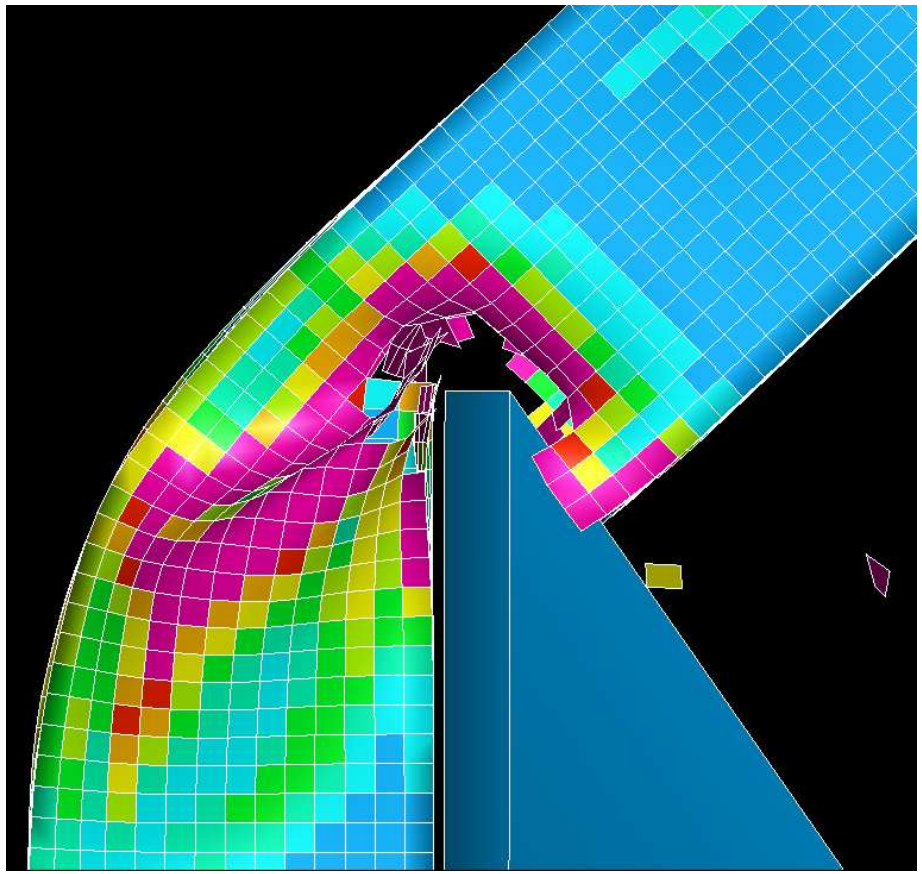




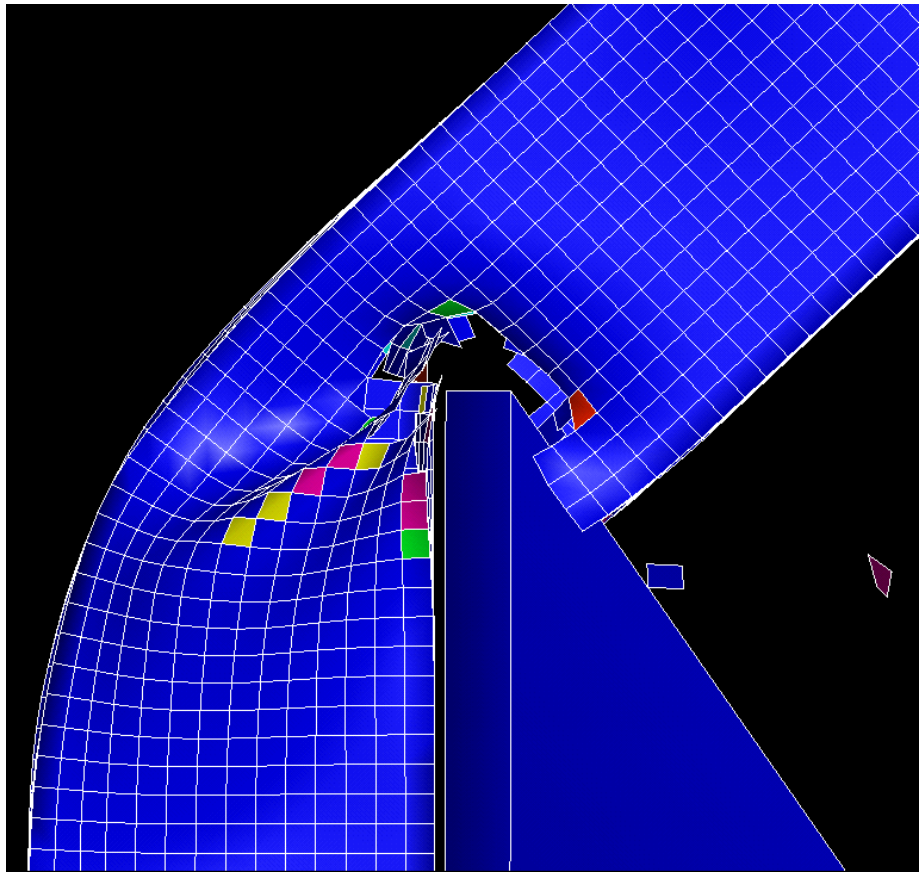
Shell mesh (MAT 171)

Structure Simulation: Rupture

Box-Beam Failure (Nissan)



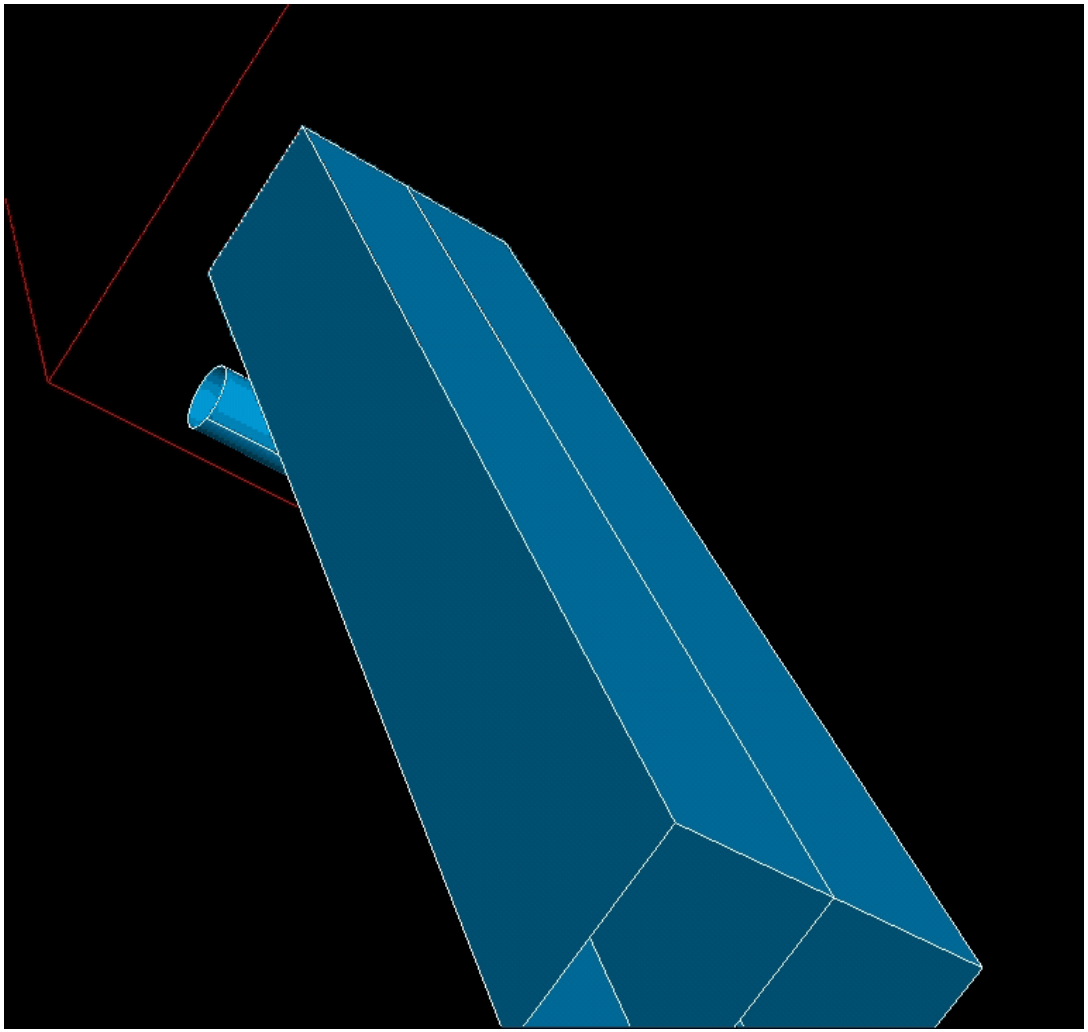
Plasticity



Damage

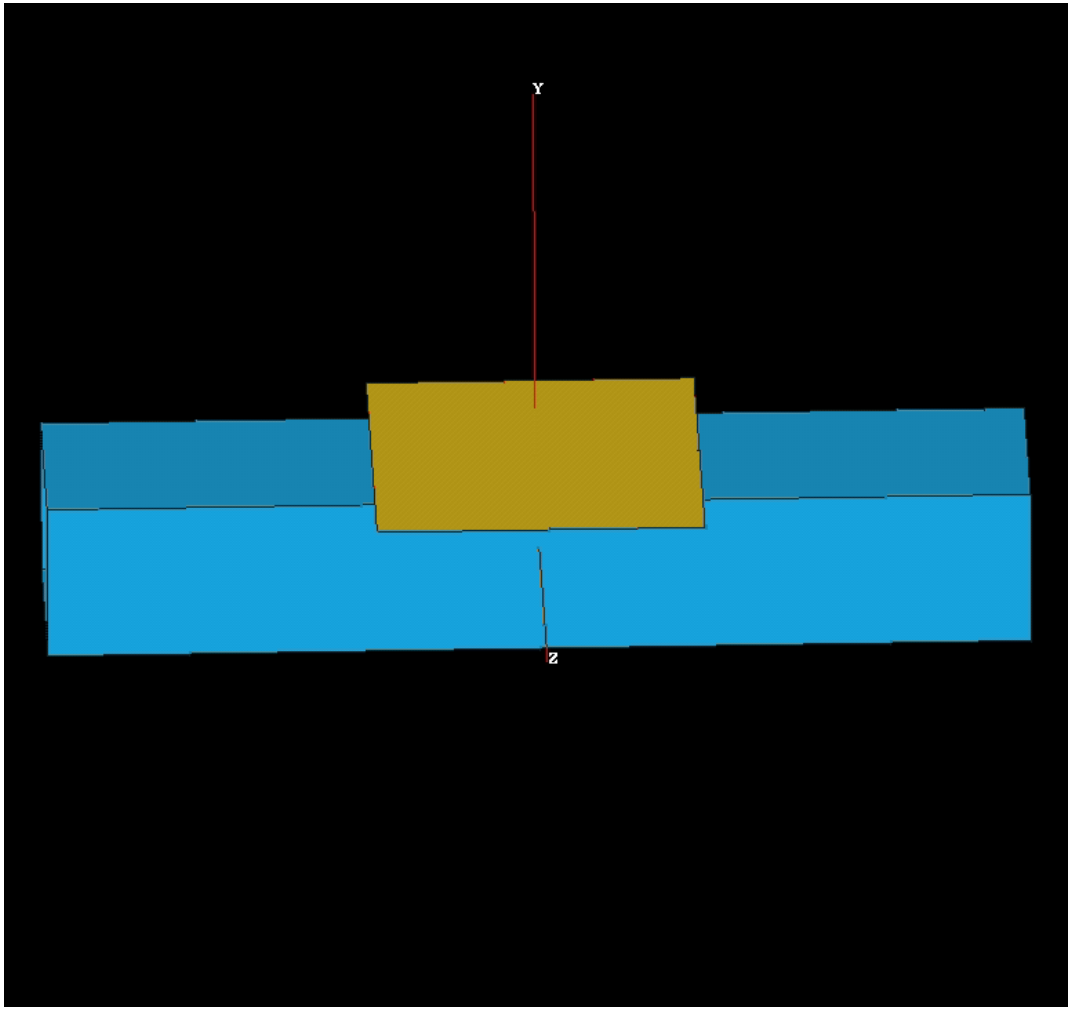
Structure Simulation: Rupture

Box-Beam Failure (Nissan)



Structure Simulation: Rupture

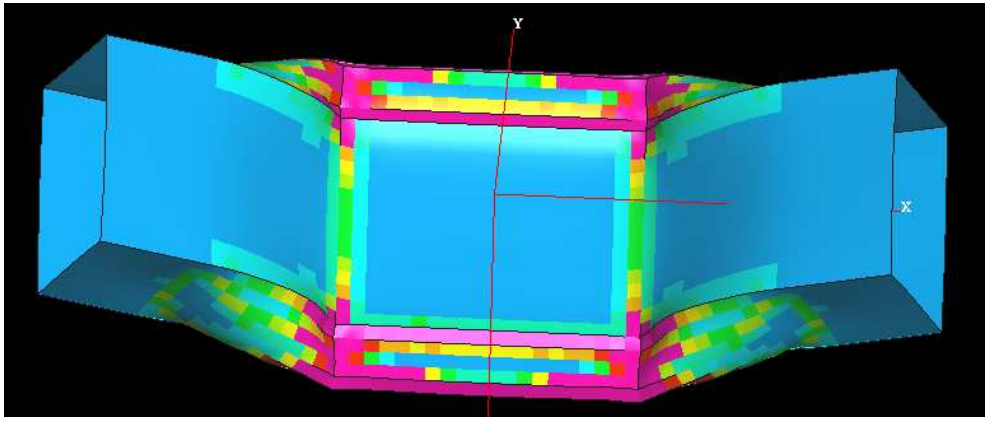
Ductile Failure (Nissan)

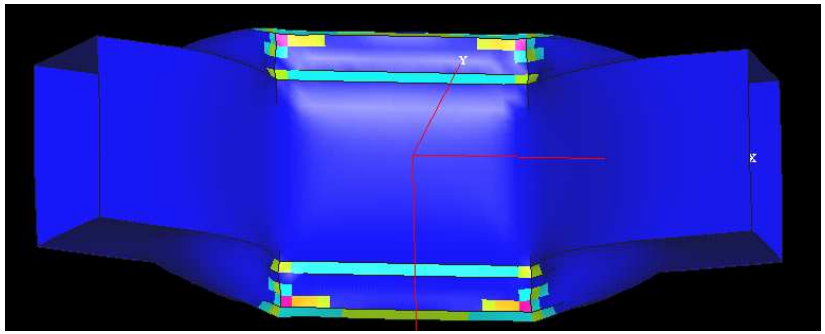


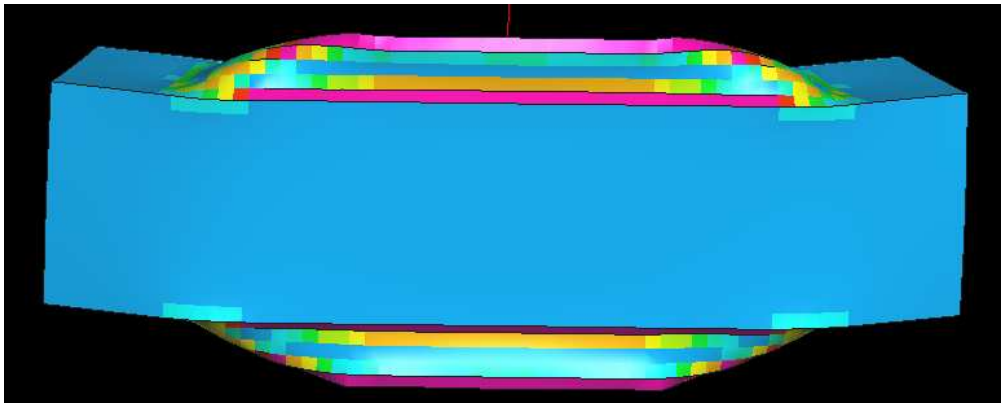
Structure Simulation: Rupture

Ductile Failure (Nissan)







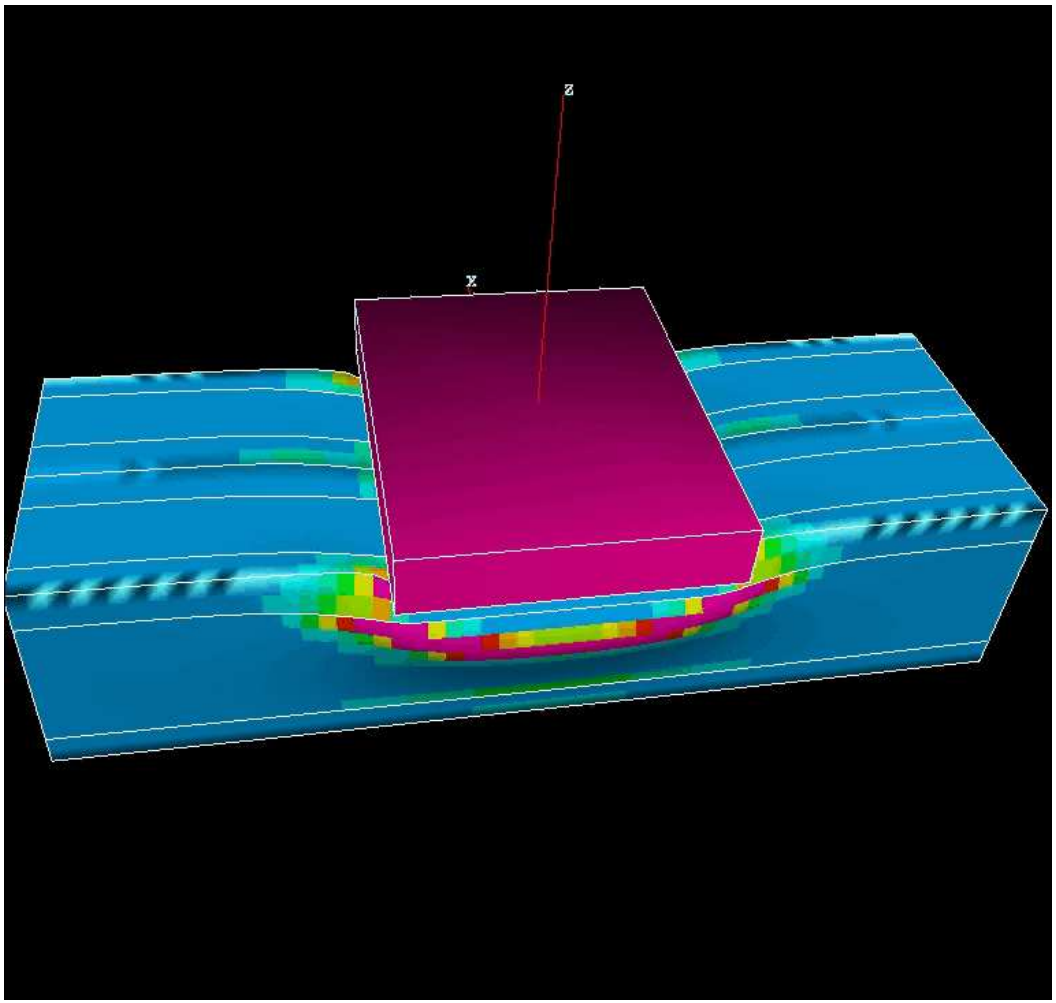


Damage

Plasticity

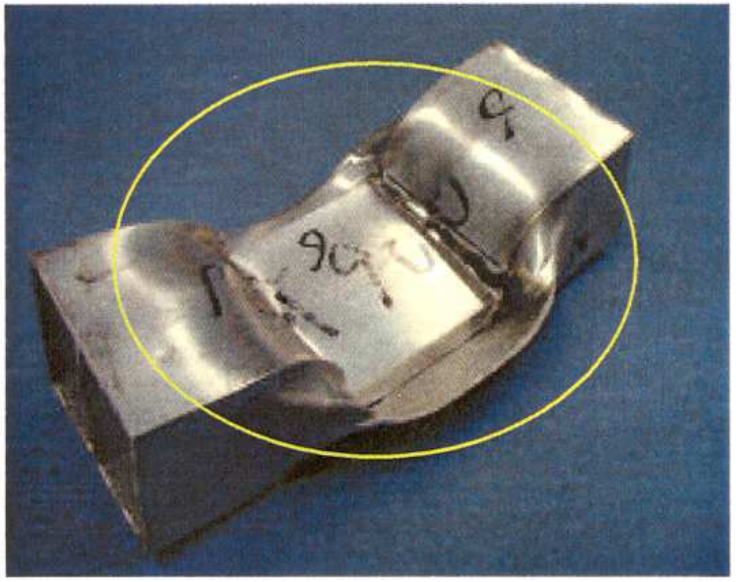
Structure Simulation: Rupture

Brittle Failure (Nissan)

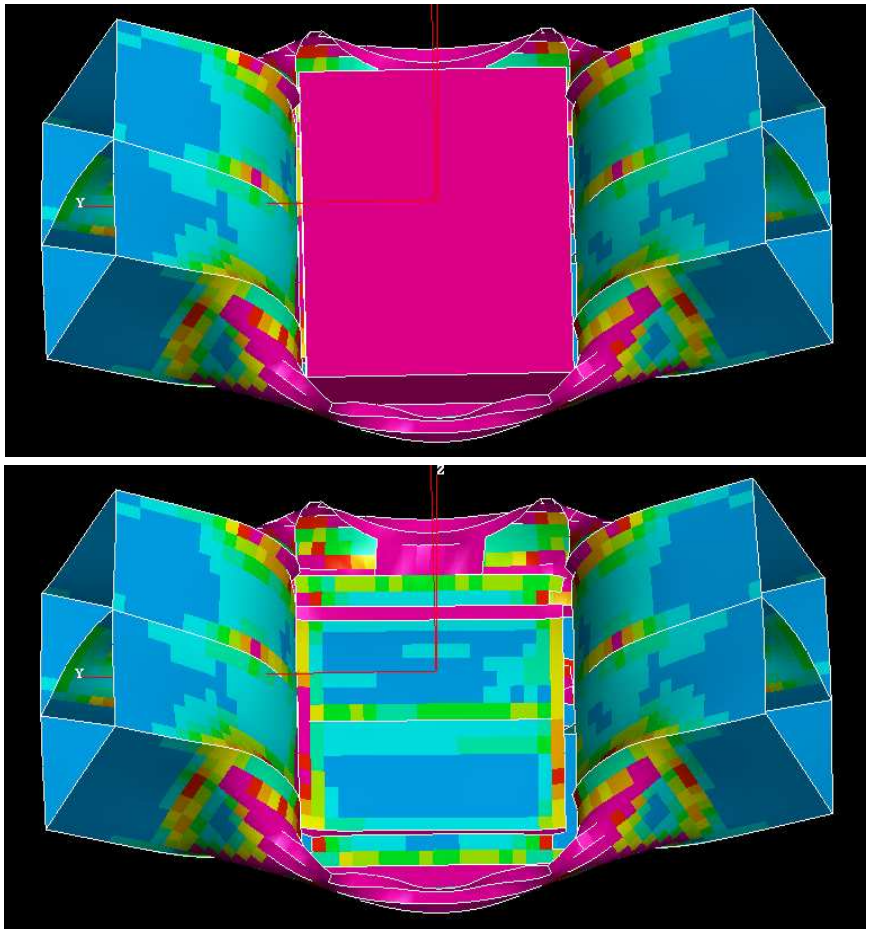


Structure Simulation: Rupture

Brittle Failure (Nissan)



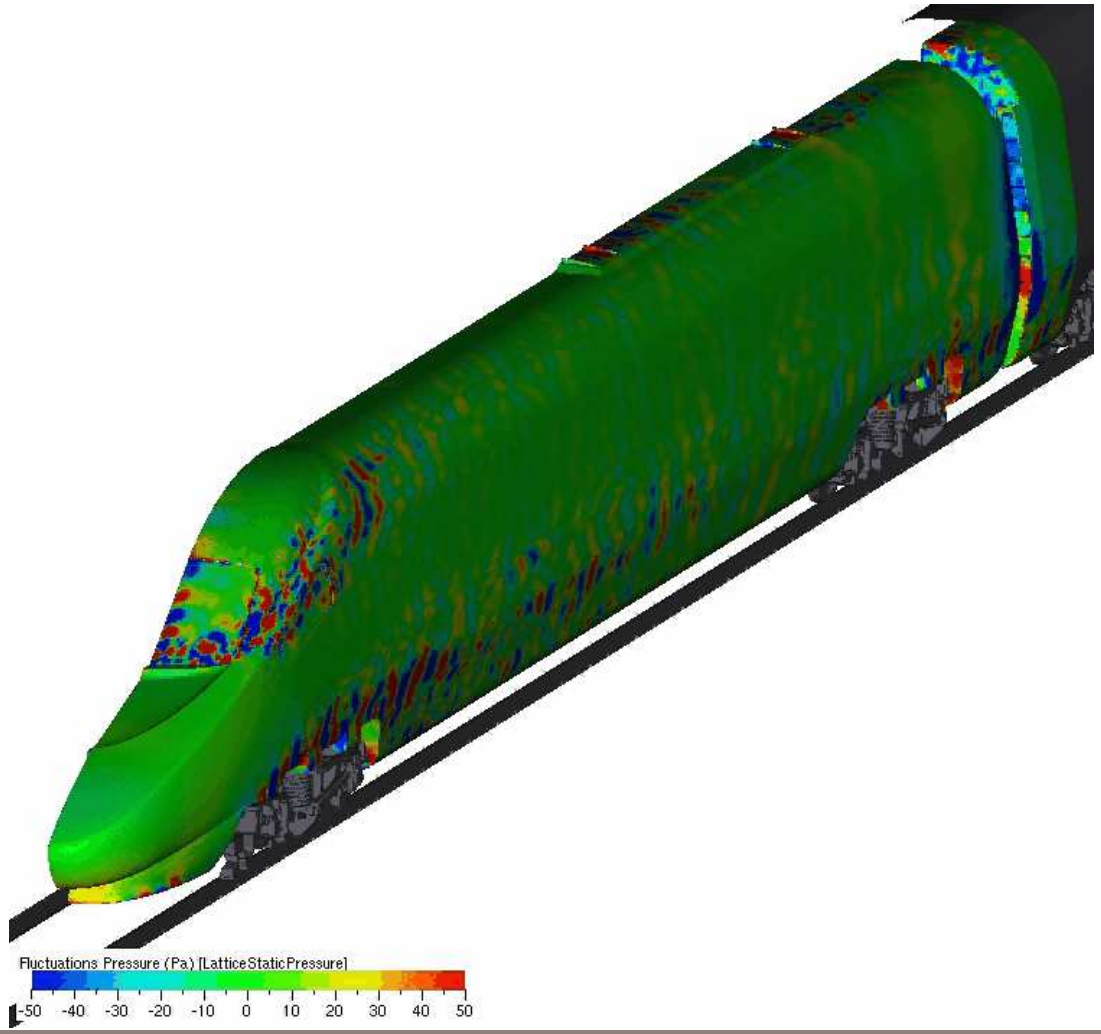
Experiment



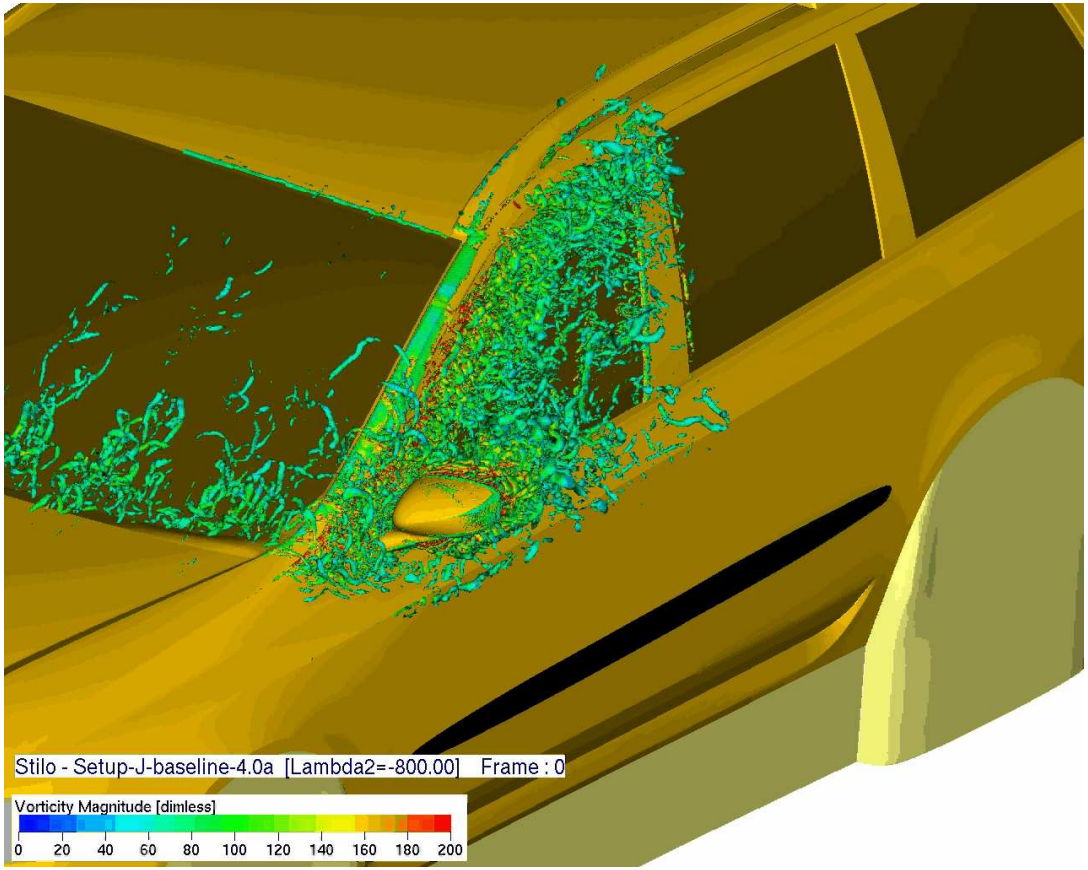
Plasticity (view with and without the punch)

Flow Simulation

F50 – F100 Hz

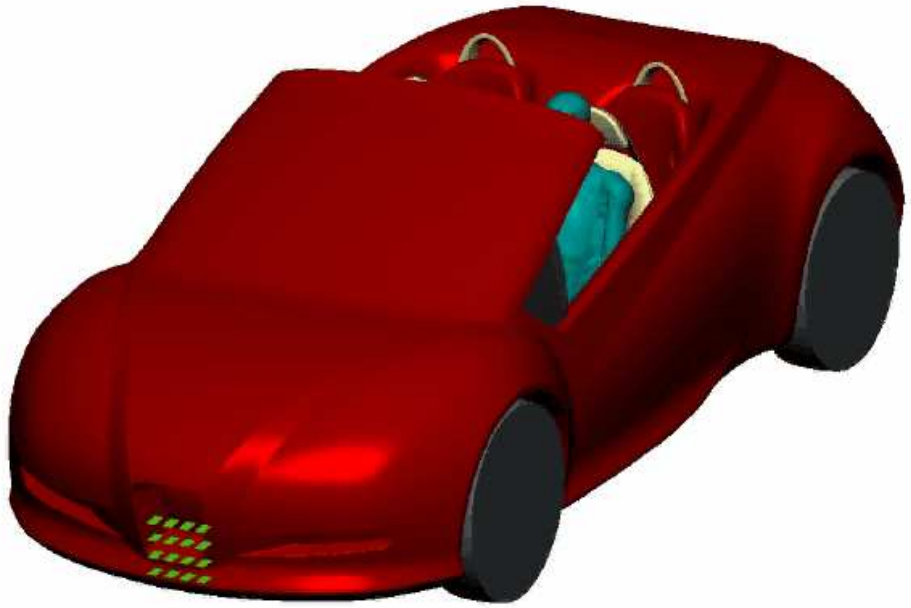


Iso - Surface

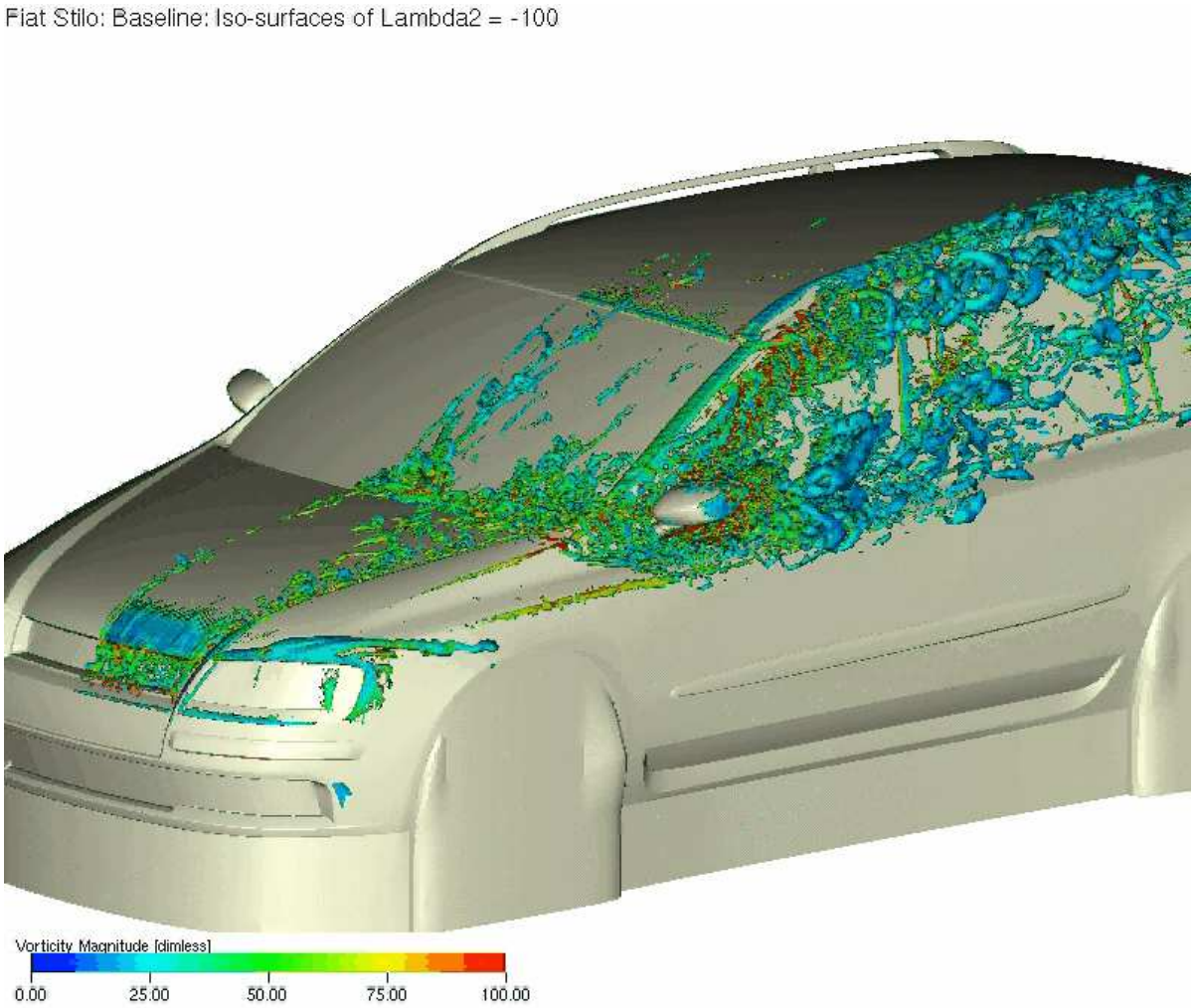

Stilo - Setup-J-baseline-4.0a [Lambda2=-800.00] Frame : 0
Vorticity Magnitude [dimless]
0 20 40 60 80 100 120 140 160 180 200

Flow Simulation

3D Stream

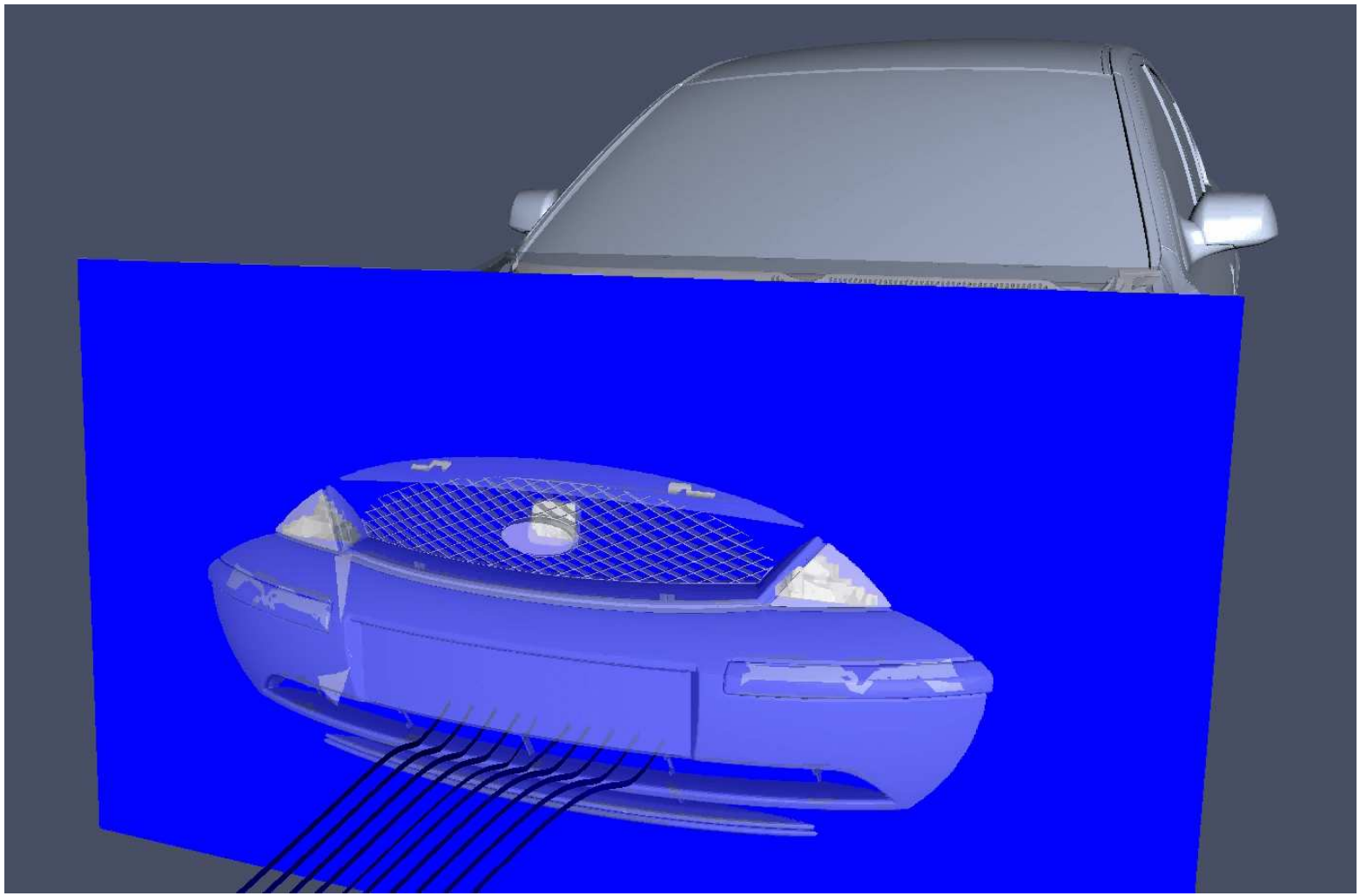


Vorticity


Fiat Stilo: Baseline: Iso-surfaces of Lambda2 = -100
Vorticity Magnitude [dimless]
0.00
25.00
50.00
75.00
100.00

Flow Simulation

Temperature



Flow Simulation

Cooling



volvis_med_xvid.avi

General

PowerVIZ

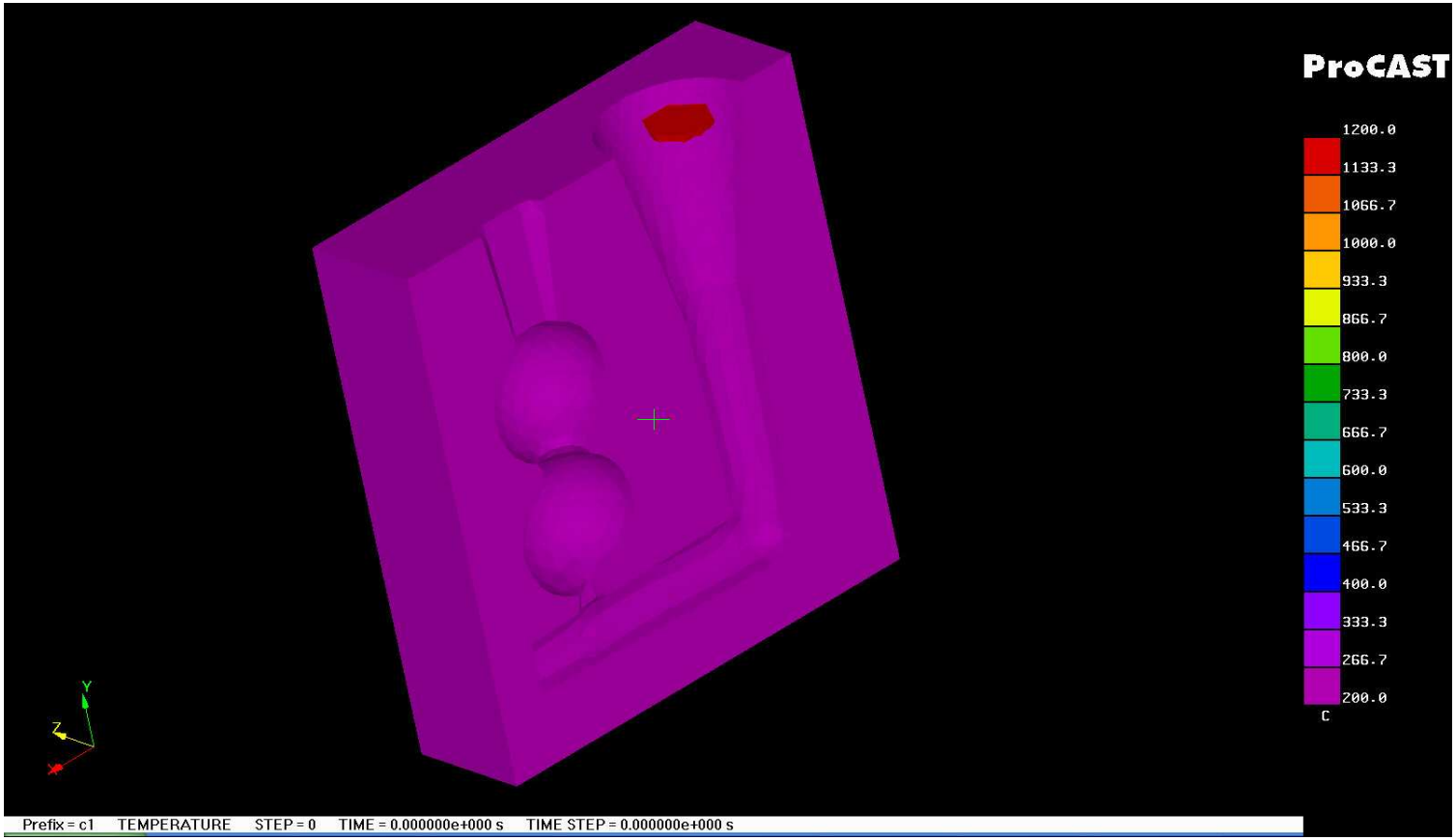
science + computing

Exa CORPORATION

VIS Universität Stuttgart

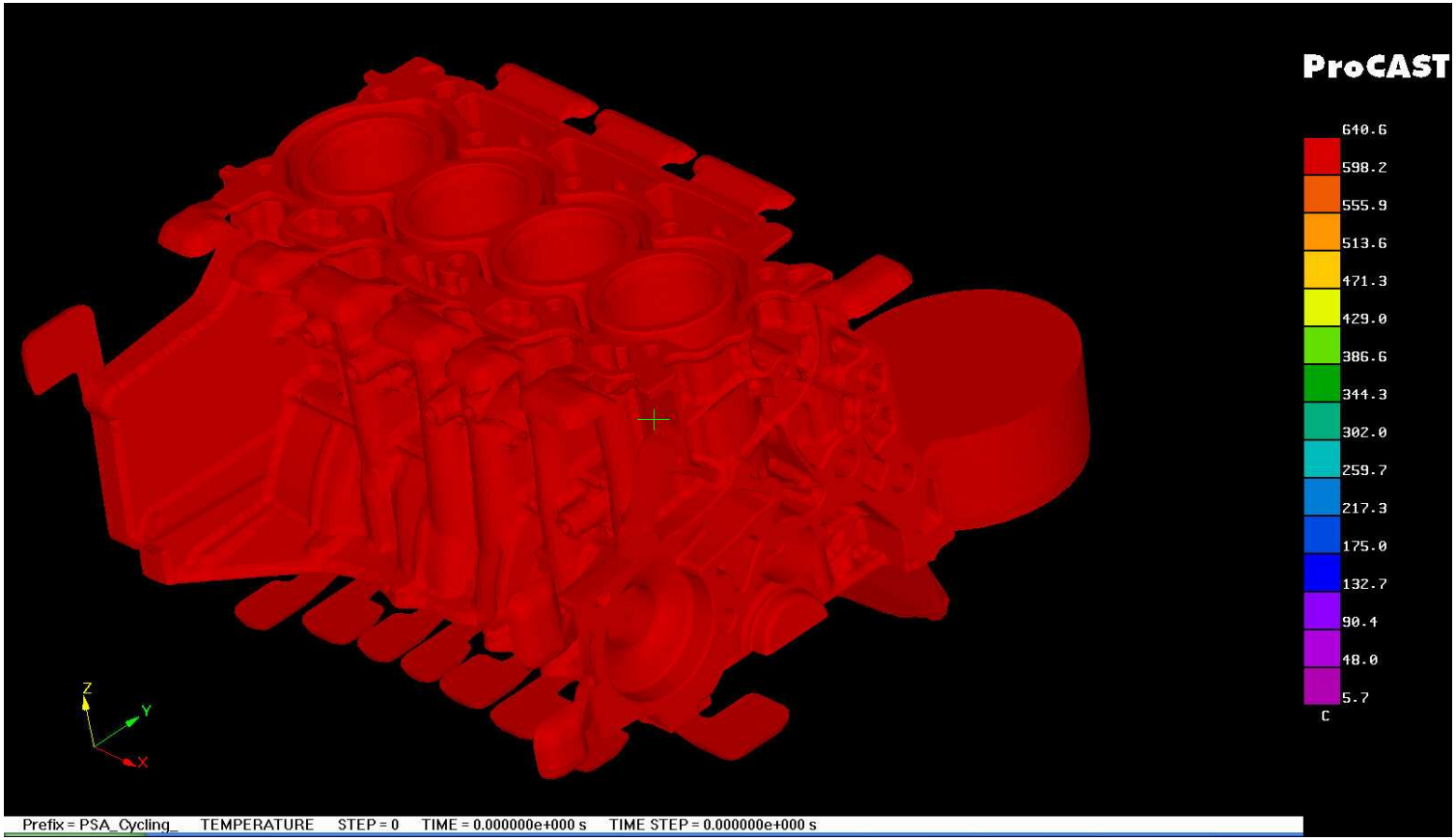
powervizAudi3-xvid.avi

Casting Simulation

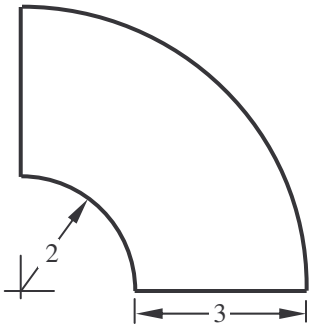


Multi-Physic Simulation

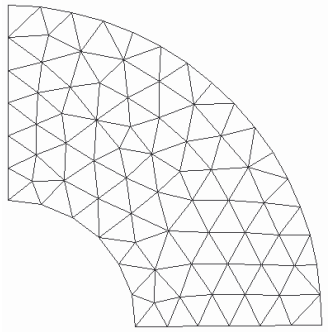
Casting Simulation (cylinder head)



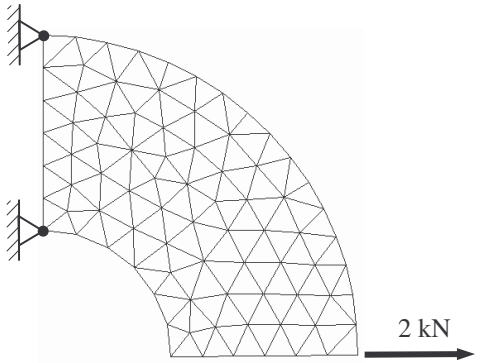
Simulation Process



1. Build CAD Model



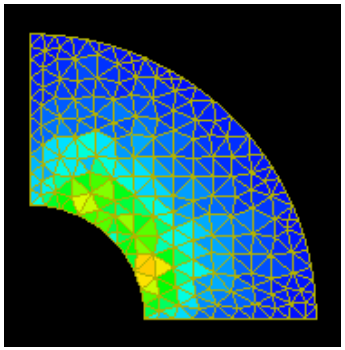
2. Mesh



3. Apply Loads and Boundary Conditions

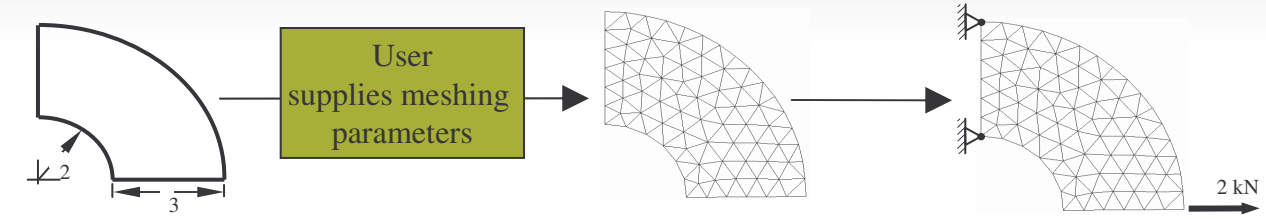


4. Computational Analysis



5. Visualization

Adaptive Simulation Process



1. Build CAD Model

2. Mesh

3. Apply Loads and Boundary Conditions

Adaptivity Loop

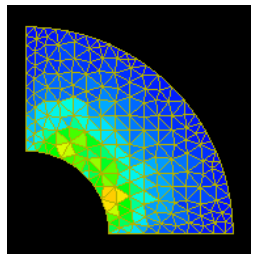


4. Computational Analysis

5. Error Estimation

6. Remesh / Refine / Improve

Error < ε

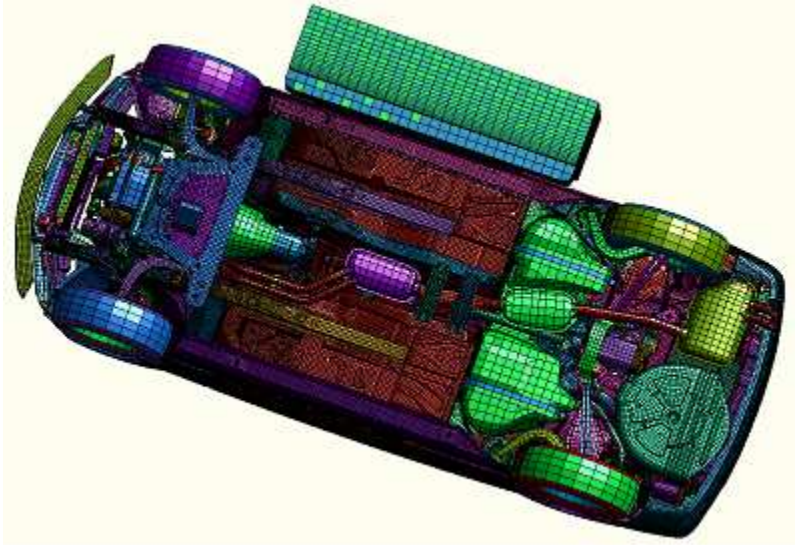


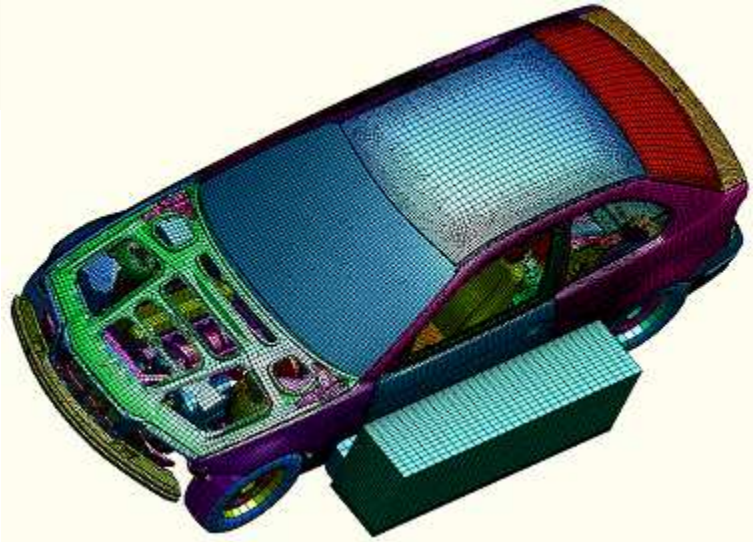
7. Visualization

Modeling Complexity

Crash

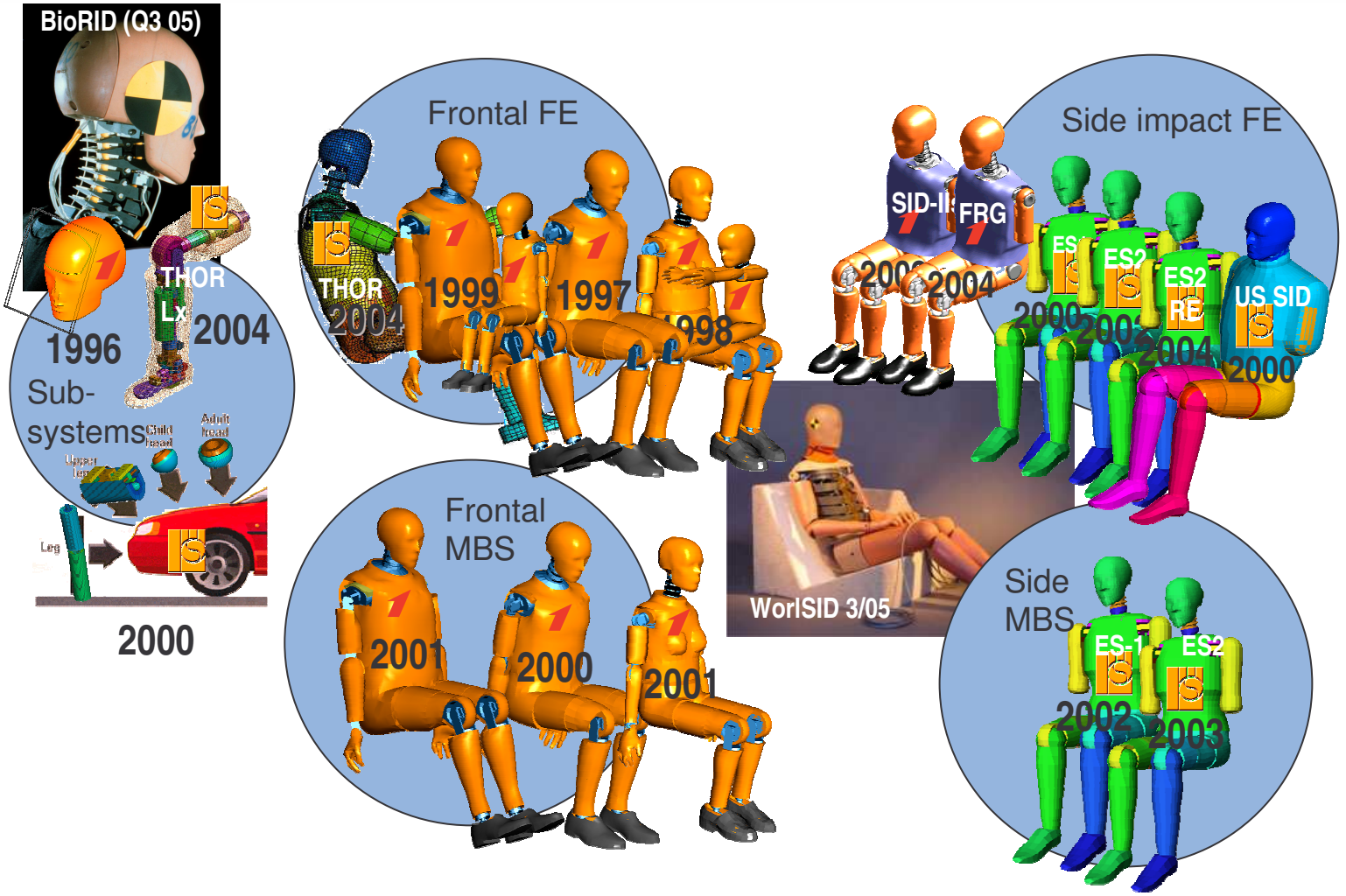






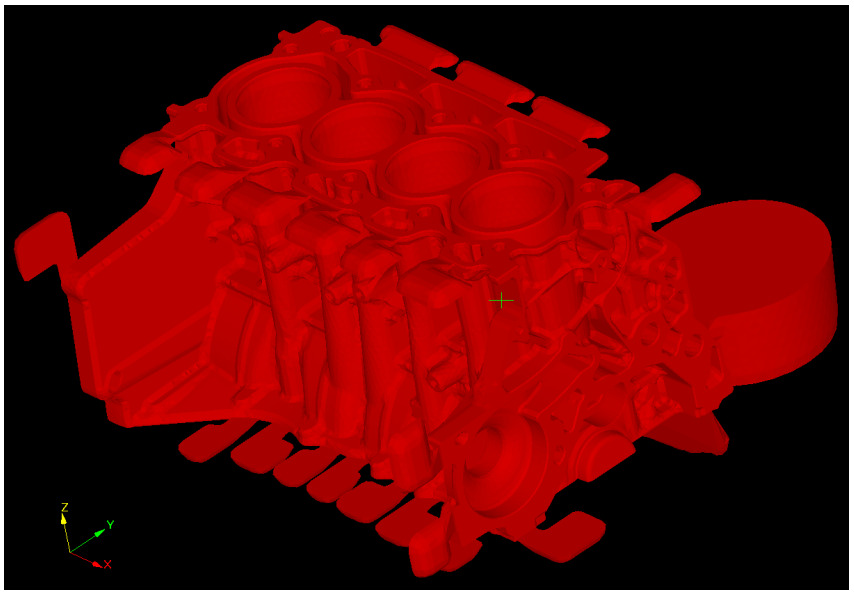
Modeling Complexity

Dummy Model Library



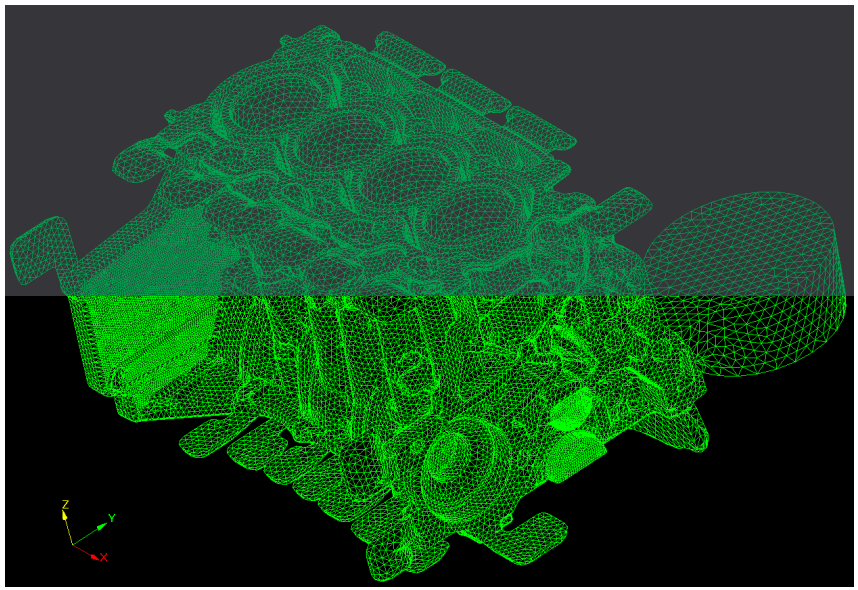
Modeling Complexity

Casting



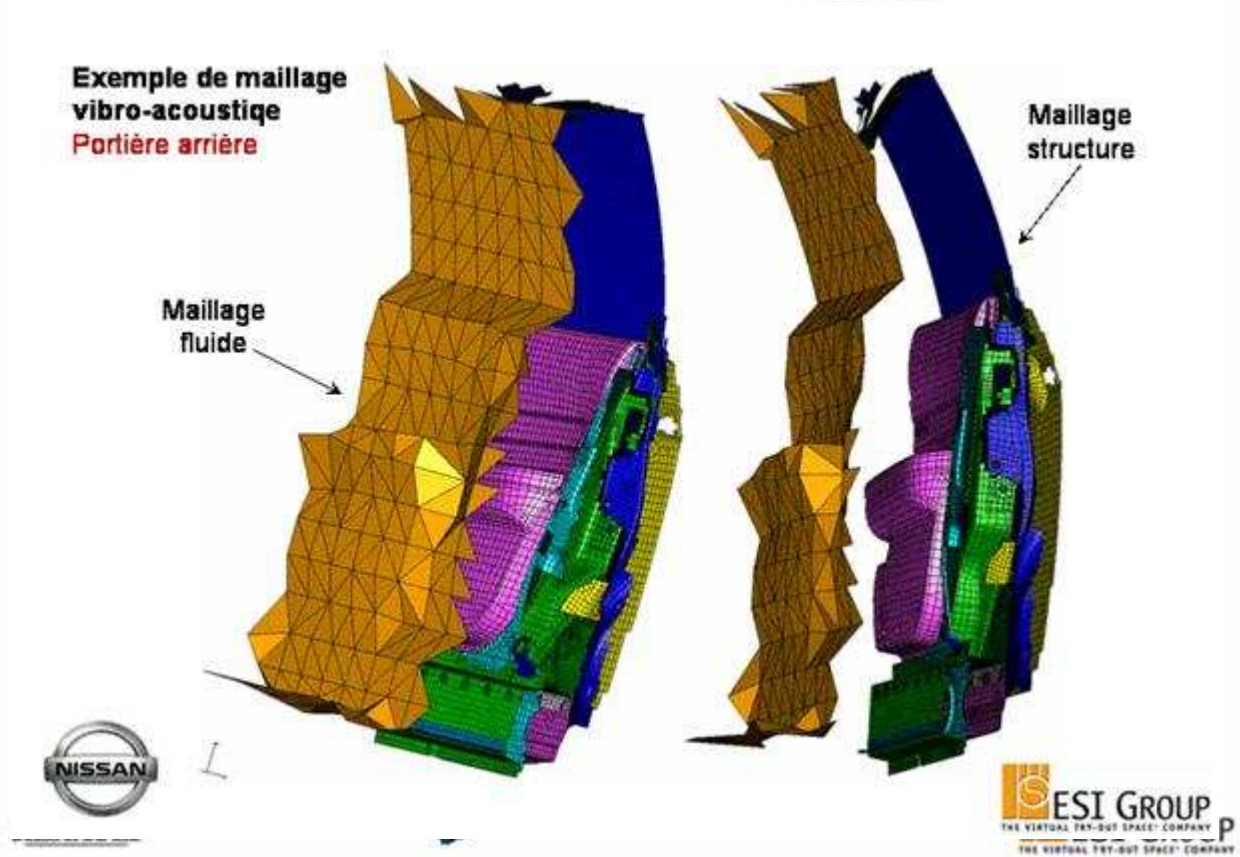
Geometry

Mesh



Modeling Complexity

Vibro - Acoustic Simulation



Thank You

