INTRODUCTION TO CRASH ANALYSIS

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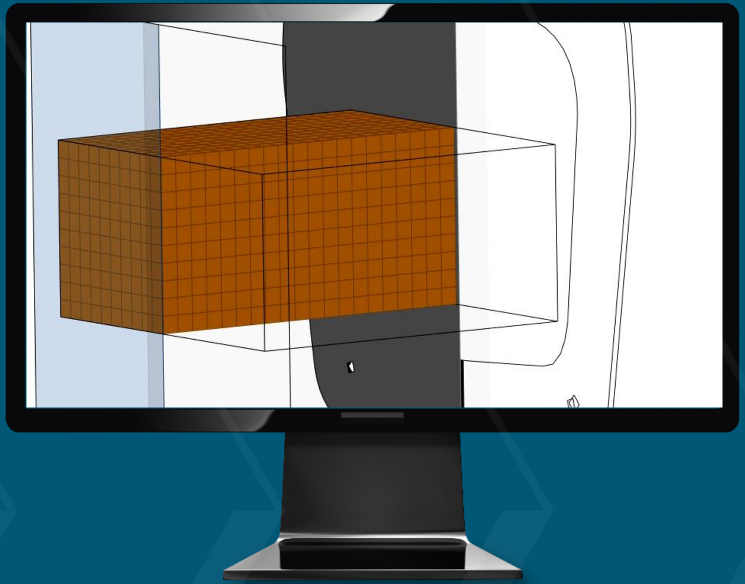
Agenda

Introduction to Crash Analysis

- Introduction to Crash
- Explicit simulations
- What is Altair Radioss™ & What does it solve?
- FEA Workflow
- Application: Simulation of Crashbox



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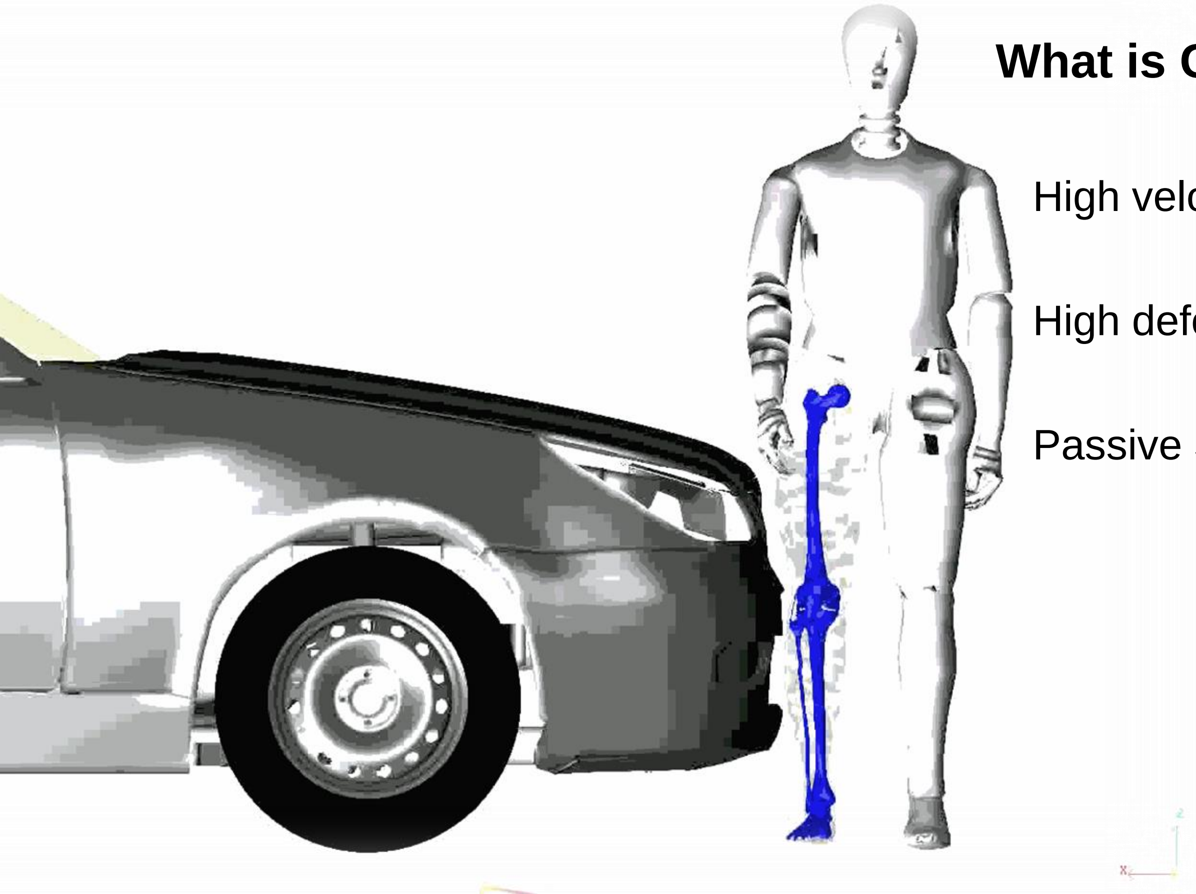
INTRODUCTION TO CRASH

CRASH Analysis



What is Crash analysis?

- High velocities (> 1m/s)
- High deformations
- Passive Safety

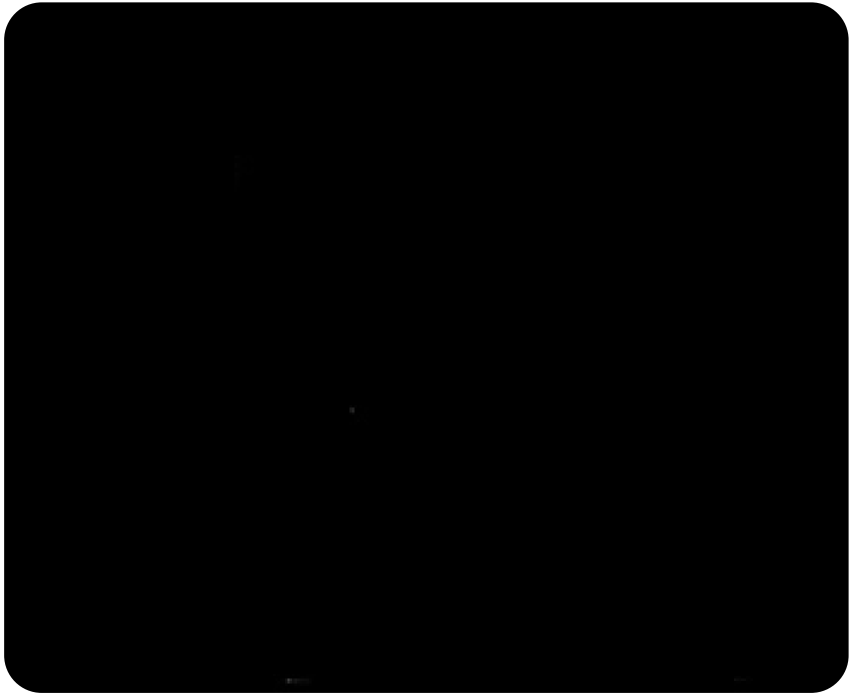
CRASH Analysis

Why doing Crash analysis?

Occupant Safety

Pedestrian Safety

Systems Safety



CRASH Analysis

Why doing Crash analysis?

Regulations (ECE, FMVSS, ADR, etc.)

New Car Assessment Programs (US NCAP, J NCAP, Euro NCAP, IIHS etc.)

Associations (ADAC)

Internal Requirements

CRASH Analysis

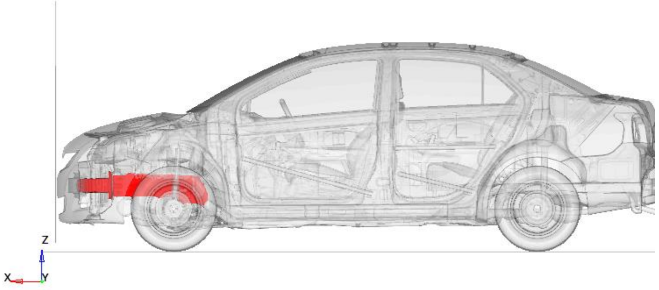
Why doing Crash simulations?

At early stages of project, only CAD are available

Tests are expensive
(especially on prototypes)

Reduce time development

Robustness & Optimization



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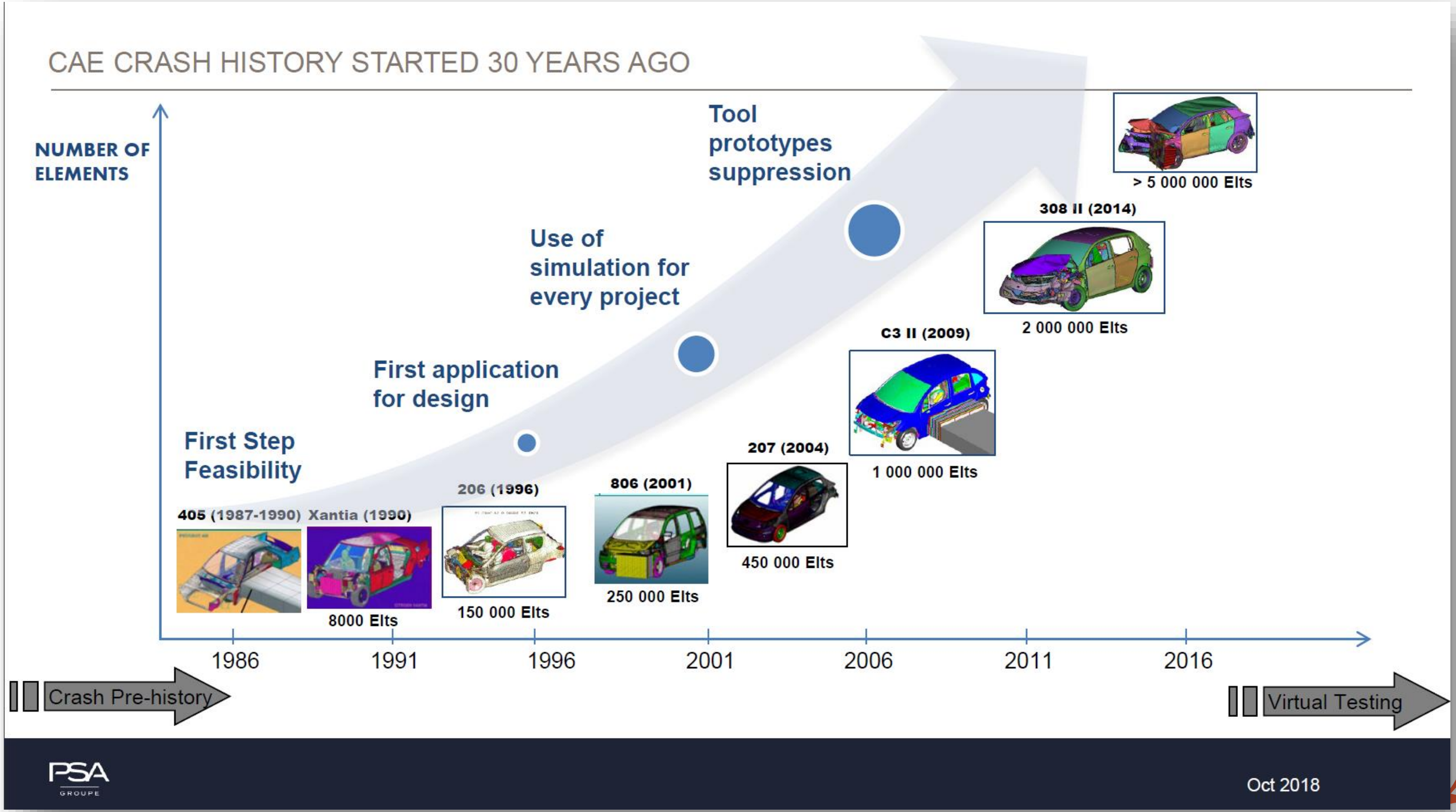
ATC’18 – Crash simulation at Groupe PSA / Main Stakes and Challenges



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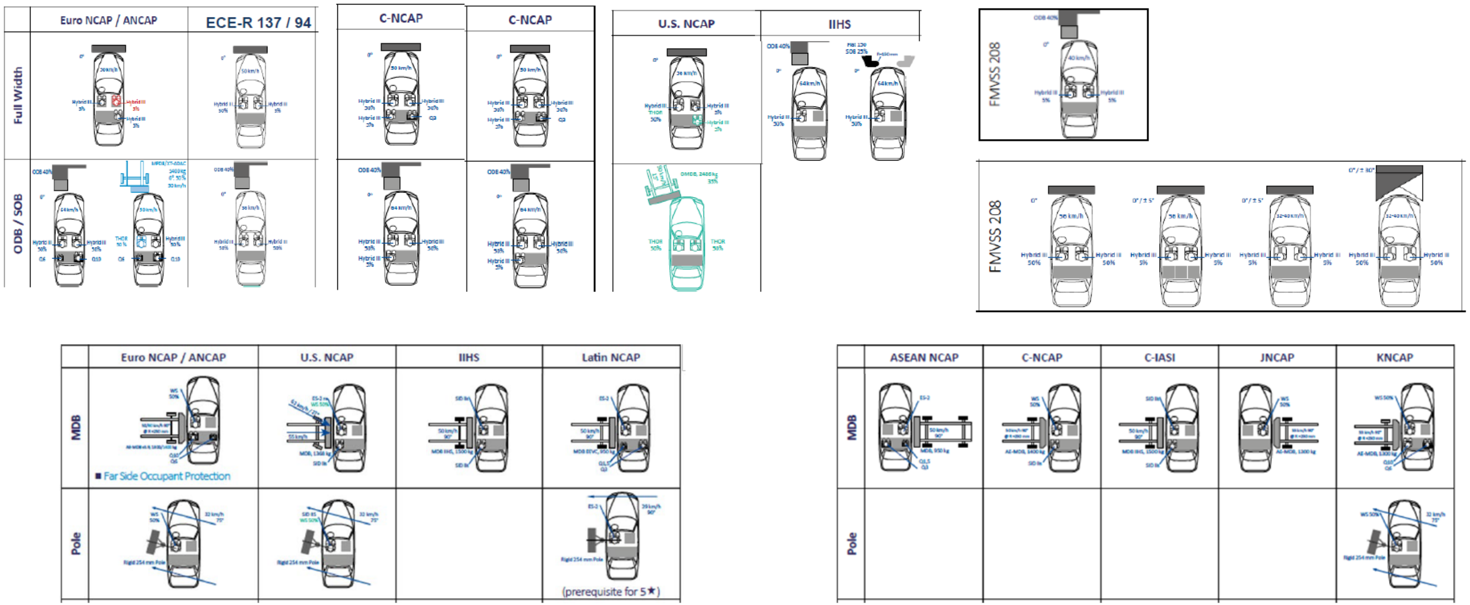
ATC'18 – Crash simulation at Groupe PSA / Main Stakes and Challenges

MORE AND MORE CONFIGURATIONS … LESS AND LESS PHYSICAL TESTS !!!



EXPLICIT SOLUTIONS

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FE Modeling of a Physical Problem

Space

- The geometry is discretized by Finite Elements

Time

- Discretized by Time Step

Physical Laws

- Mass conservation
- Energy conservation
- Momentum conservation

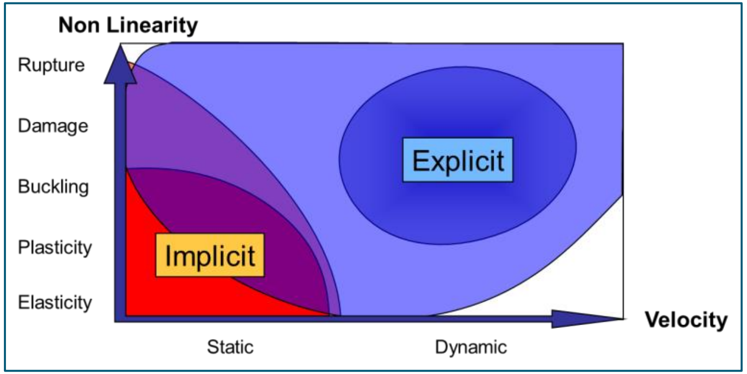
Formulation – Choice of time and space discretization

- Lagrangian
- Eulerian
- Arbitrary Lagrangian Eulerian (ALE)

Explicit Methods *vs.* Implicit Methods

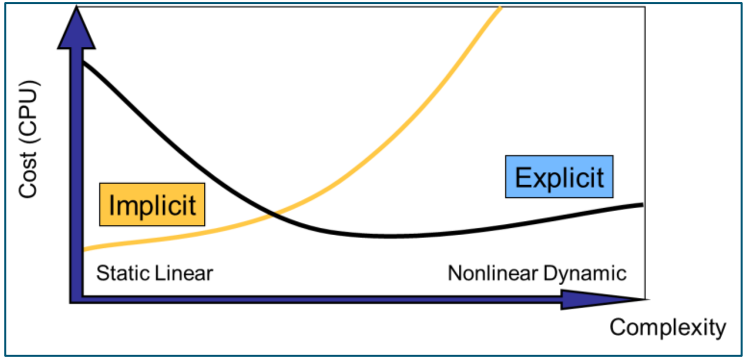
Implicit Methods

The state of a given system is solved for several time steps at once



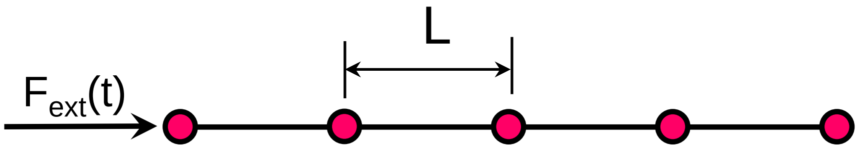
Explicit Methods

The state of a given system at a given time is computed from the state of the system at an earlier time



Definition of Time Step

- The time step Δt is the time required for a shock wave (governed by speed of sound) to propagate across the smallest distance in an element
- An explicit solution is **stable** if $\Delta t < \Delta t_{critical}$
- The solution is **unstable** if information passes across more than one element per time step:



- Stability depends on two factors:
  1. Size of smallest element → **Numerical**
  2. Sound propagation speed → **Physical**

$$\boxed{\Delta t < \frac{l_c}{c}}$$

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Explicit Flow Chart

$$t = t + \Delta t$$

$$\boldsymbol{F}_{\text{external}}$$

$$\boldsymbol{F}_{\text{internal}}$$

$$\{\boldsymbol{F}_{contact}\}$$

$$\dot{v}_i = \sum F_i / m_i$$

Time Integration

1. **Loop over elements**

$$\dot{\varepsilon}_{ij} = \frac{1}{2}\left(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i}\right)$$

$$\dot{\sigma}_{ij} = f(\dot{\varepsilon}_{ij})$$

$$\sigma_{ij}(t + \Delta t) = \sigma_{ij}(t) + \dot{\sigma}_{ij}\Delta t$$

2. **Assemble**

$$\{\boldsymbol{F}_{\text{internal}}\}, \{\boldsymbol{F}_{hourglass}\}$$

$$\dot{x}_{n+\frac{1}{2}} = \dot{x}_{n-\frac{1}{2}} + \ddot{x}_n \Delta t$$

$$x_{n+1} = x_n + \dot{x}_{n+\frac{1}{2}} \Delta t$$

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WHAT IS RADIOSS™? WHAT DOES IT SOLVE?

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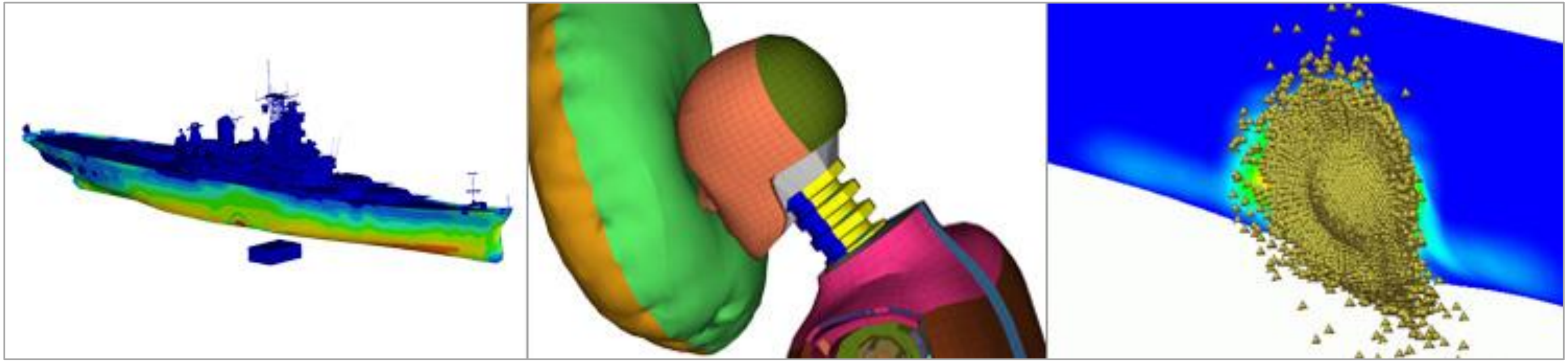
Altair Radioss™: What is it ?

Structural analysis solver for highly non-linear problems under dynamic loadings

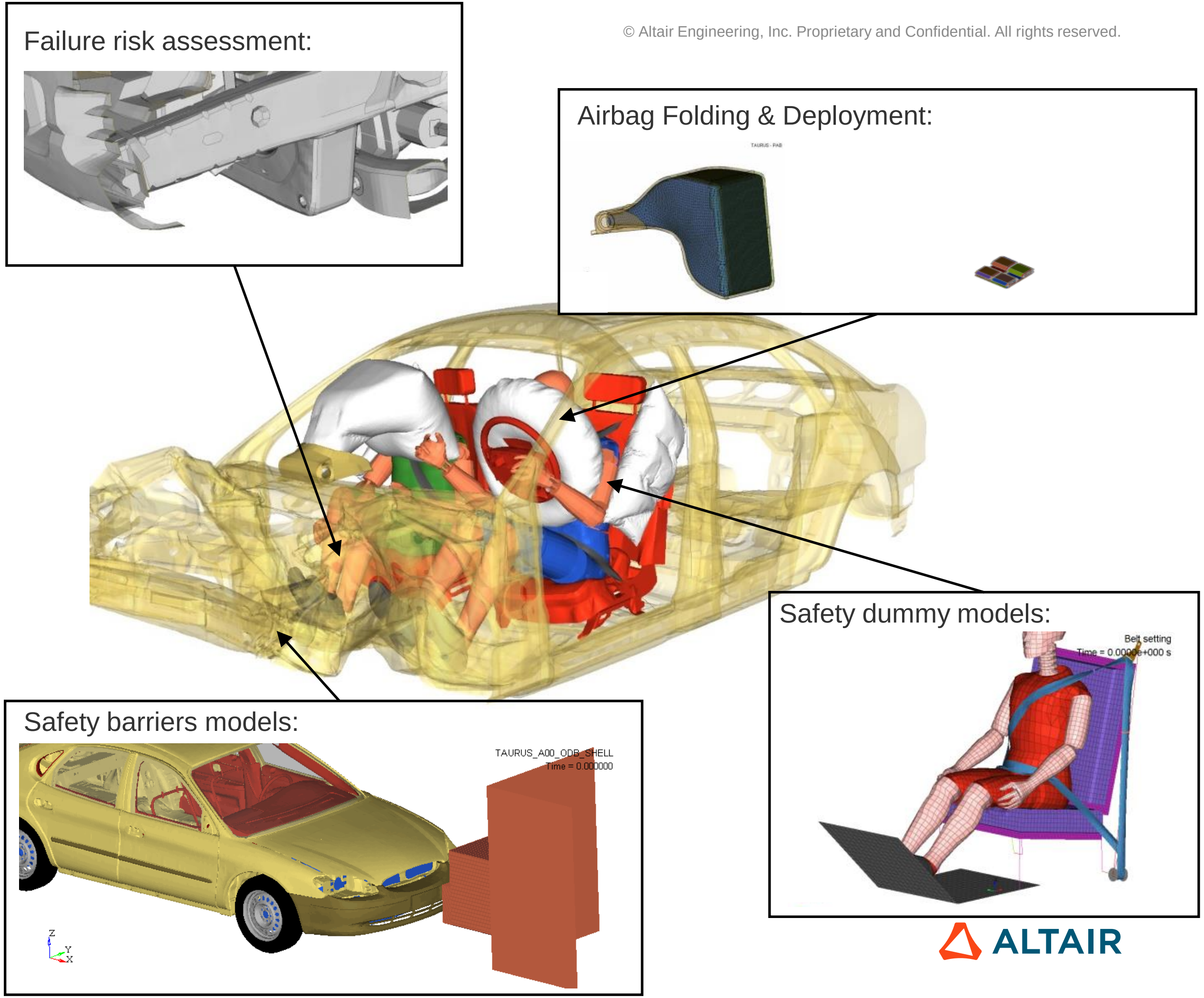
- High Scalability, Quality and Robustness
- Supports Multiphysics simulation and advanced materials
- Used across all industries to improve crash, safety and manufacturability
- For 30+ years an established standard for automotive crash and impact

Automotive
Aeronautics
Consumer goods
Electronics
Defense
Ship building/Navy
Biomechanics
Offshore
….



WHAT IS RADIOSS?

CRASH & SAFETY IN AUTOMOTIVE



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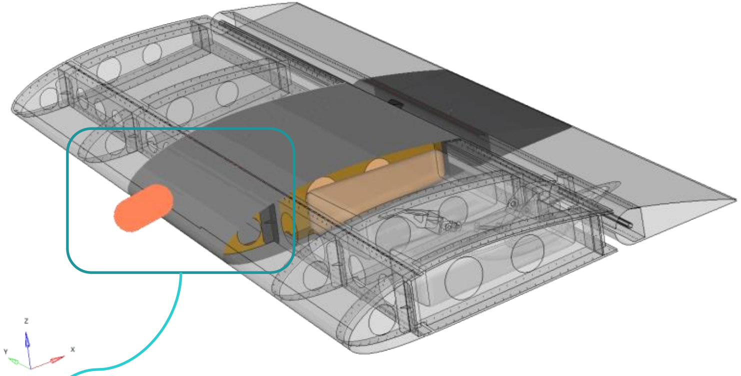
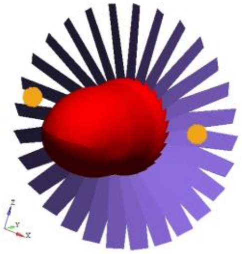
WHAT IS RADIOSS?

CRASH & SAFETY
IN
AERONAUTICS

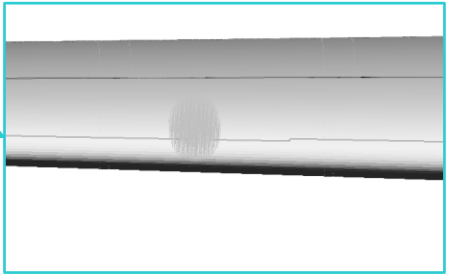
Bird Strike





Debris impact

Composite Modeling



Failure risk assessment

Seat & Safety

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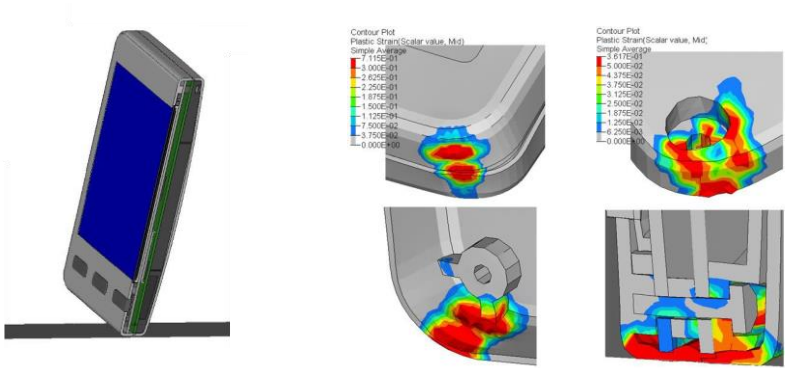
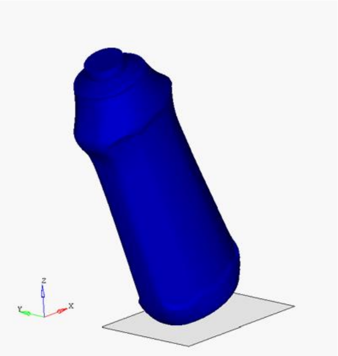
WHAT IS RADIOSS?

DROP



Cellphone



Bottle

Moto helmet

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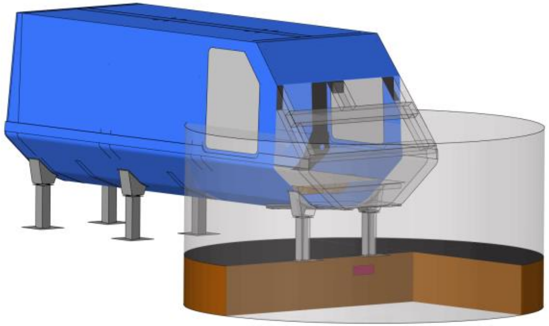
WHAT IS RADIOSS?

FLUID-STRUCTURE INTERACTION

Aeronautics: Ditching



Defense: Blast

Defense: Ballistics

Tank Sloshing

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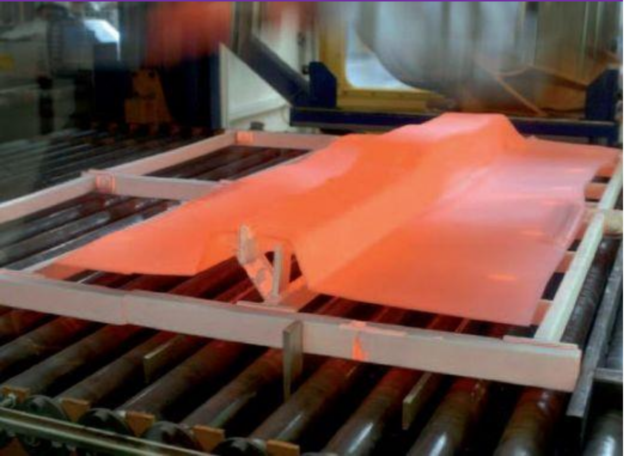
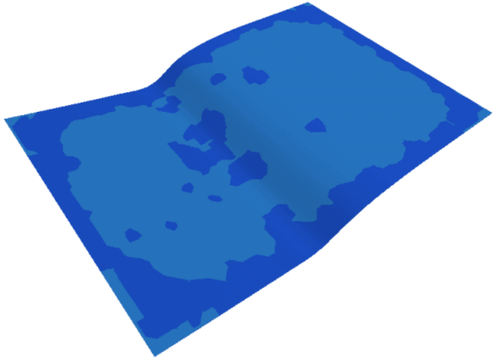
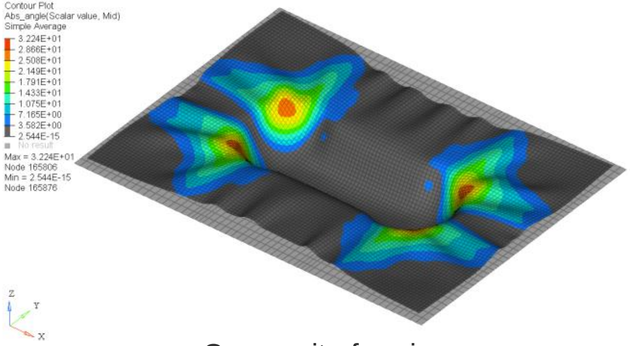
WHAT IS RADIOSS?

MANUFACTURING

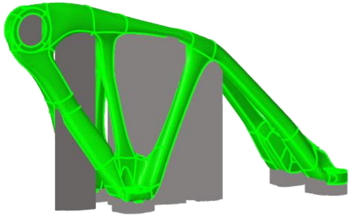


Metal Forming





Composite forming



Additive Manufacturing

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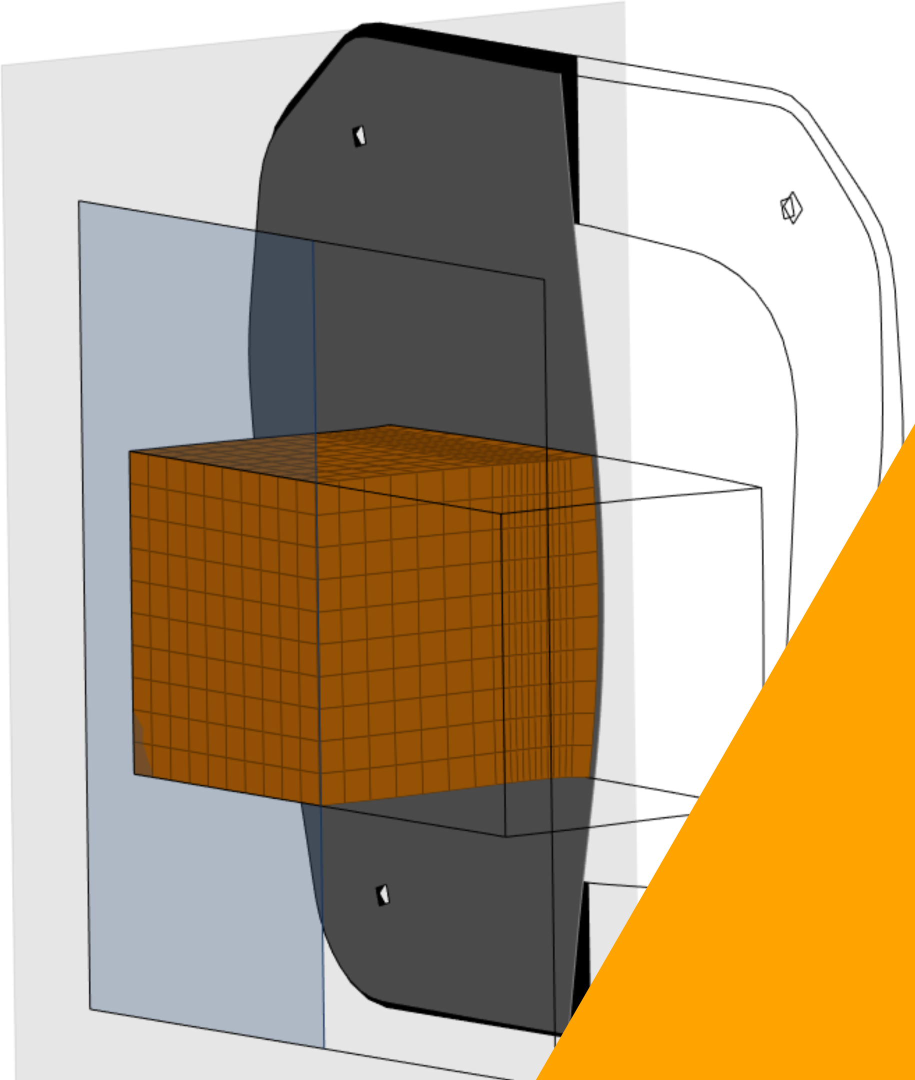

APPLICATION: CRASHBOX

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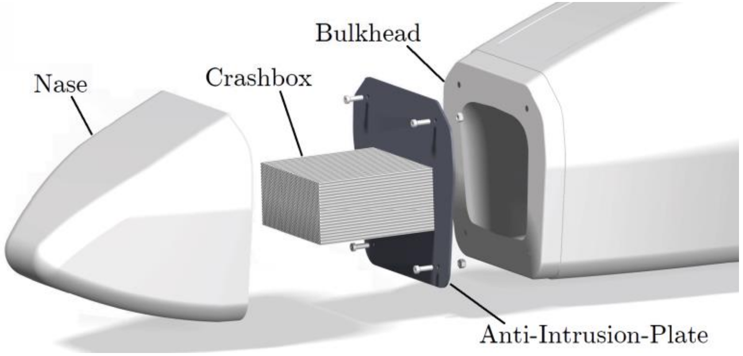
Simulation of a Crashbox for Formula Student

- Unit System: kg, mm, ms → GPa, kN, J

- Impactor
  - Mass: 300kg
  - Initial Velocity: 7 m.s^{-1} (25kph)
  - Kinematic Energy: 7.35kJ

- Input Data:
  - geometries (crashbox, anti-intrusion plate, bulkhead and impactor)
  - Metal reference for the plate and Honeycomb data for the crashbox



Pictures & Data by Institut für Technische und Numerische Mechanik, Universität Stuttgart

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Standard FE Modelling Workflow

CAD → Geometries, Connections (bolts, welding, etc.) & Materials (BoM)

↓ Geometries +…

Main challenge: get geometries as clean a possible

Mesh → Discretize the geometry

Use FE entities that allows to reproduce mechanical behaviour of the part (solid, thin shell, beam, …)

↓ Finite Elements

Pre-processing → Set properties, materials, contacts, loads, boundary conditions

Check the solver input file with dedicated tools

↓ Solver input file(s)

Main challenges:

Computation → Possibly initiated with a solver check of the model

Run the computation

↓ Solver output files

Check the convergence/quality of the simulation

Post-processing → Analysis and interpretation of the results

↓ Results → **Reporting**

Extract all significant information from results

Software: HyperView/HyperGraph, …

(Crash) FE Model Setup Standard Workflow

CAD ←	Get the proper geometries, material & connections info (BoM, Welding database, etc.)
Mesh →	Define Meshing (1D/2D/3D, Elt types) + Meshing Class (size & quality criteria)
Prop & Mat →	Assign Properties (thickness) & Materials
Connections →	Define Welding, Bolts, Glues & Links, Rigids, etc.
Contacts →	Create interfaces: check & remove intersections, penetrations
Load Cases →	BCs, Initial/Imposed Disp./Vel./Acc, Loads, Added Mass, Impactors
Outputs →	Define Measurements

Outputs → **Checks** → **RUN** → **Checks**

Aluminium

Aluminium	Physical & Mechanical proprties	
Density	$2.8 g.cm^{-3}$	$2.8E-6\ kg.mm^{-3}$
Module of Elasticity	70 GPa	70 GPa
Poisson’s ratio	0.33	0.33
Yield Strength	300 MPa	0.300 GPa
Tensile Strength	390 MPa	0.390 GPa
Failure Elongation	28%	28%

Honeycomb

Honeycomb	Physical & Mechanical proprties	
Density	0.0913 $g.cm^{-3}$	9.13E-8 $kg.mm^{-3}$
E11	225.6 MPa	0.2256 GPa
E22 = E33	20 MPa	0.02 GPa
G12	200 MPa	0.20 GPa
G23 = G31	200 MPa	0.20 GPa

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THANK YOU

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