Altair

Innovation Intelligence®

Altair Radioss Explicit Solver

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Agenda

1. What is Radioss Explicit Solver
2. Material Laws and Rupture Criteria
3. Fluid Structure interaction
4. Multi-Domain
5. Scalability / Repeatability
6. Advanced Mass Scaling
7. Example: drop test on a composite glass plate

Altair Solvers

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OptiStruct

Implicit

Durability
NVH
Buckling
Thermal

RADIOSS

Explicit

Crash
Safety
Forming
Blast
FSI
Gravity
Springback

MotionSolve

Multi-Body
Dynamics

AcuSolve

CFD
Thermal

FEKO

Electro-
Magnetics

Design and Optimization

RADIOSS is a Complete Finite Element Solution in HW

Linear
Statics, Dynamics, Buckling,
Thermal, Plasticity, Quasi-static, Contact

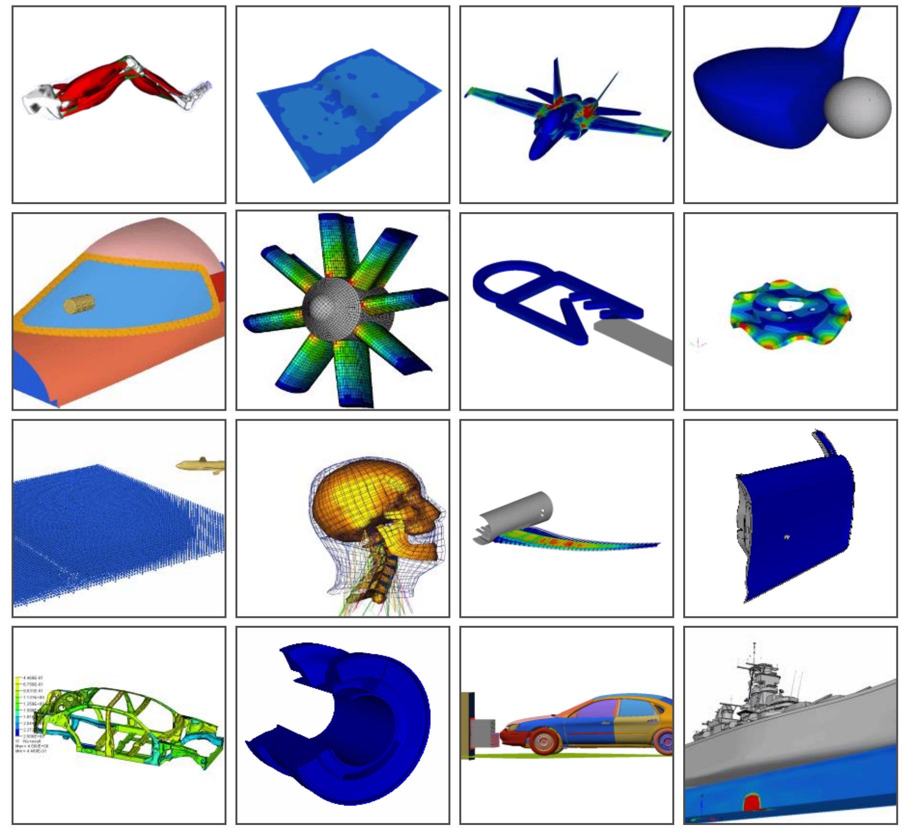
Non-Linear (Implicit)
Quasi-static, Dynamics,
Post-buckling, Materials, Contact

Non-Linear (Explicit)
Impact, Thermal, Materials, Contact

Thermal and CFD
Fluid Structure Interaction (FSI),
Thermal Stress, Multibody

Multi-Body Dynamics
(Rigid & Flexible Bodies)
Kinematics, Static and Dynamic, Quasi-static

RADIOSS



RADIOSS – used in more than 900 companies –

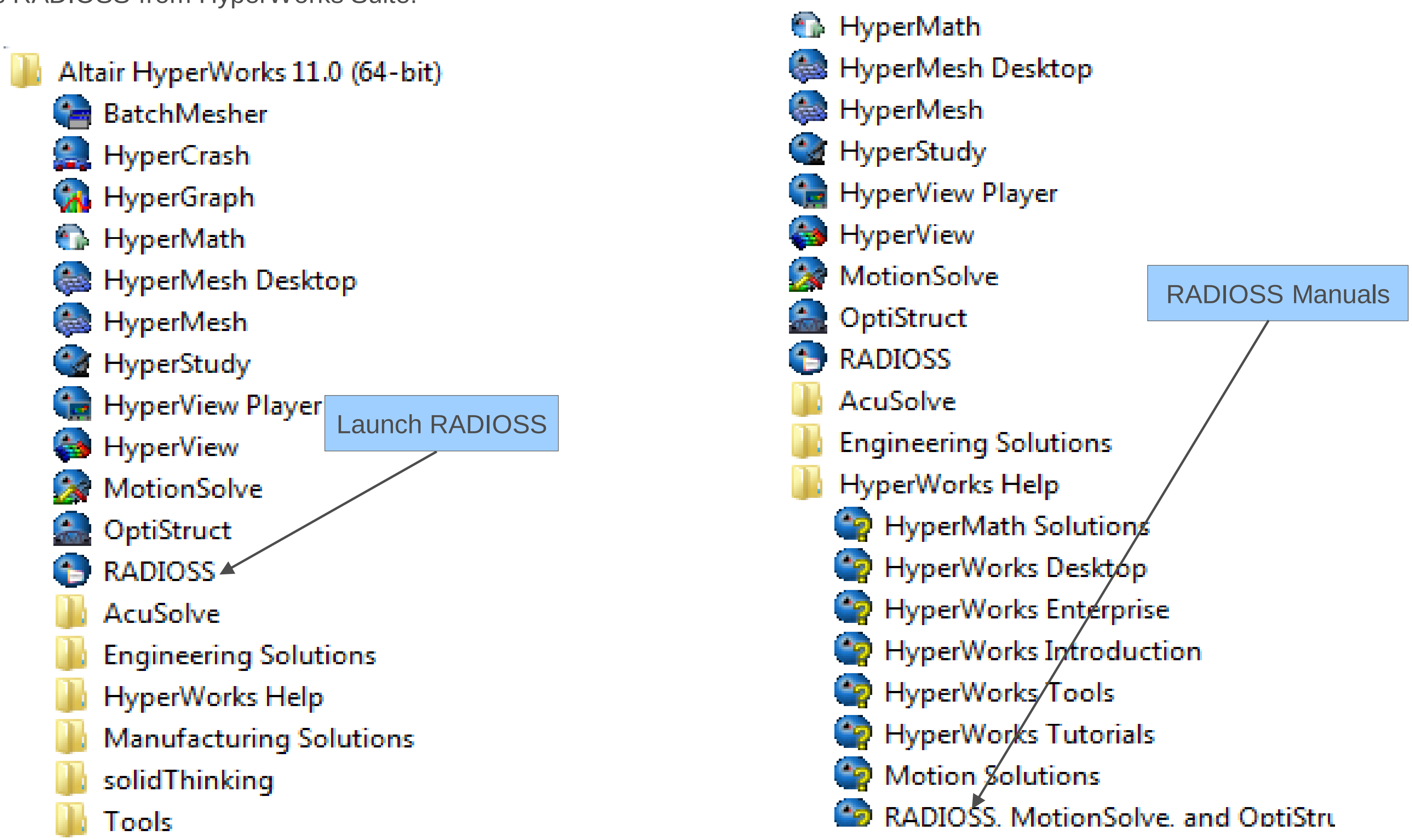
Altair

- **RADIOSS in the automotive industry**

LADA
MODENAS
上汽通用五菱 SGMW
TDK
SHACMAN
SAIC 上汽集团 SAIC MOTOR
HONDA
Ford
RENAULT SPORT F1
BENTELER
Ferrari
SOUEAST 東南汽車
EICHER
DANA
dallara
MAGNA
PLASTIC OMNIUM
維柴动力 WEICHAI POWER
HUTCHINSON PAULSTRA
Volkswagen Motorsport
PSA PEUGEOT CITROËN
PLAXTON
VE COMMERCIAL VEHICLES
A VOLVO GROUP AND EICHER MOTORS JOINT VENTURE
FOTON
GORDON MURRAY
SAHARA Force India formula one team
AP RACING
TAKATA
Autoliv
Nissan Research Center
smr Samvardhana Motherson Reflectec
BMW Motorsport
BUGATTI
FIAT
CRF CENTRO RICERCHE FIAT
Valeo
JMC 江铃汽车
SCUDERIA Toro Rosso
MAXION WHEELS
Automobile Corporation of Goa Ltd.
SML ISUZU
KIRCHHOFF AUTOMOTIVE
Hero
IVECO
TRW
NLM Nippon Light Metal Company, Ltd.
ASHOK LEYLAND
Metalsa Quality as a way of life
brembo
Van-Rob KIRCHHOFF AUTOMOTIVE
FUMAGALLI AUTOMOTIVE WHEELS A division of IOCHPE-MAXION
Mahindra REVA

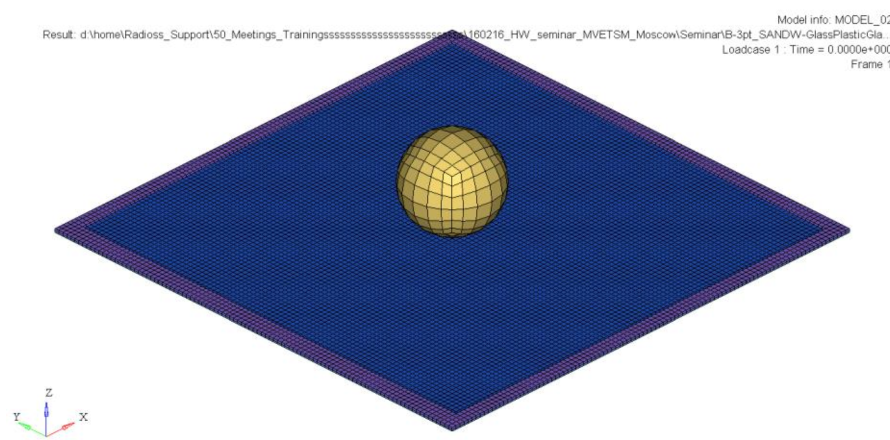
RADIOSS is a Complete Finite Element Solution in HW

Access RADIOSS from HyperWorks Suite:



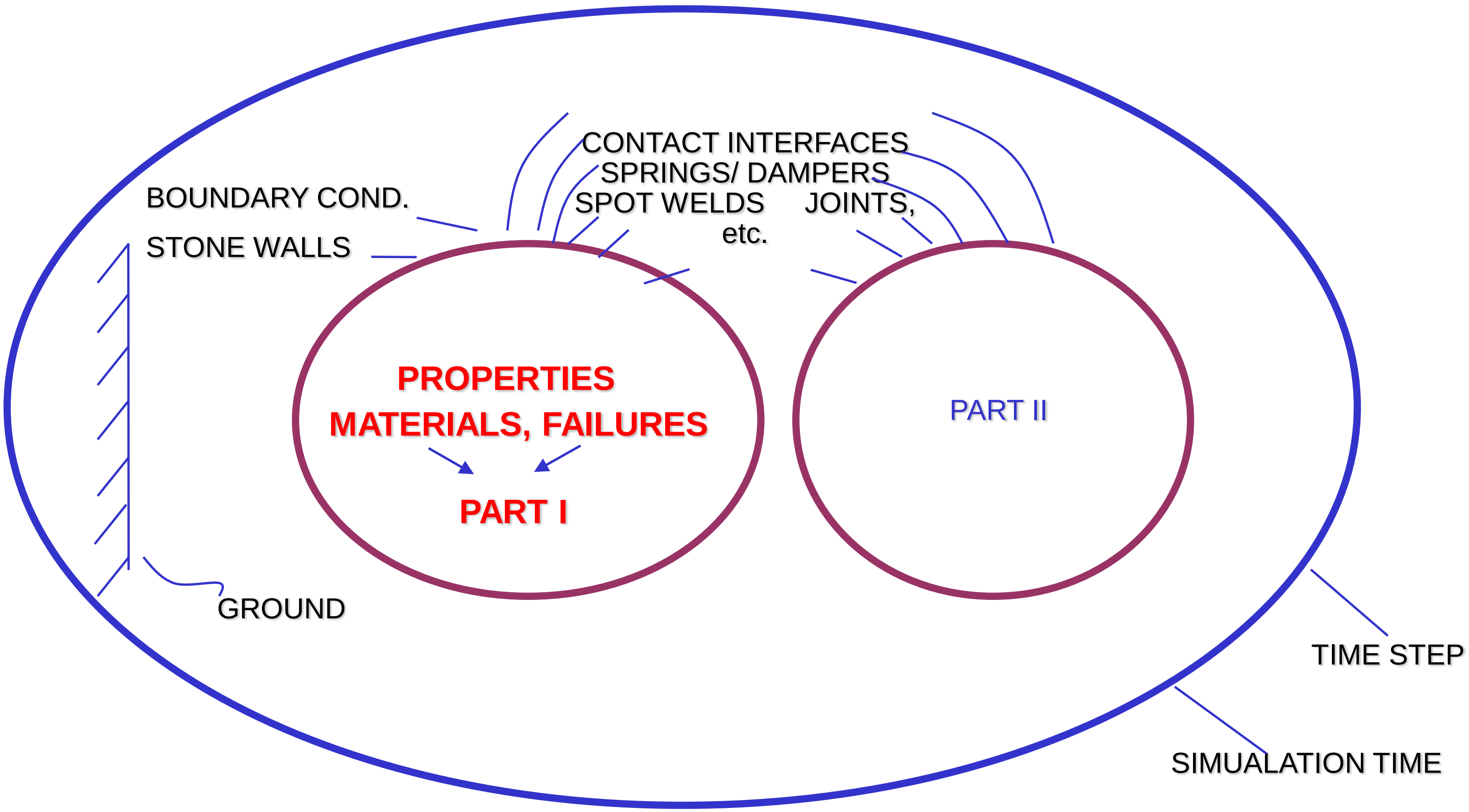
An example of problem that can be solved in Radioss

- **Sphere drop (41kg) on a brittle plate (glass)**
- **Initial velocity of the sphere 5m/s**
- **The plate is composite glass and fixed on the edges**
- **Units: T, mm, s**
- **Elasto- plastic material**
- **Johnson Cook Failure criterion**
- **Crack propagation**
- **<u>This problem is considered in details on seminar (data available if you need)</u>**



Structure of Radioss model

Model set up is similar to other explicit solvers



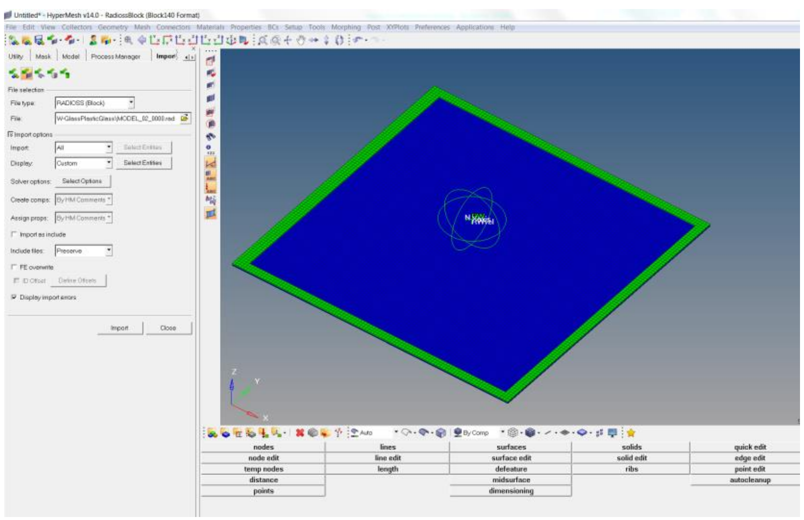
How to create Radioss model

Type ASCII file (for real experts ☺)

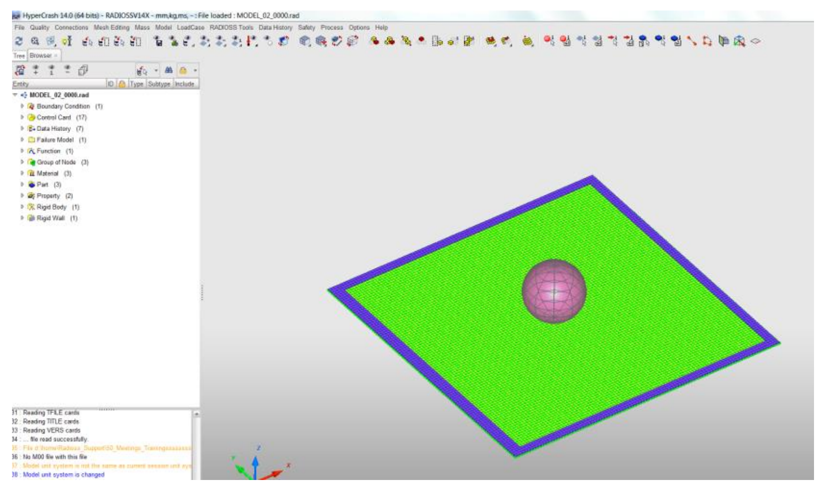
```
#RADIOSS STARTER
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/BEGIN
model2
       140         0
                  kg                  mm                  ms
                  kg                  mm                  ms
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
#-  1. CONTROL CARDS:
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/TITLE
Scaled F furnace with SPH
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|


Etc.
```

Use Hypermesh



Use Hypercrash



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Material library in Radioss

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Metallic alloys

- Law 1 : elastic material
- Law 2 : elasto-plastic material
- Law 27 : elasto-plastic brittle material
- Law 36 : tabulated elasto-plastic material
- Law 60: ~ 36 + quadratic strain rate interpolation
- Law 66: Visco Elastic Plastic Piecewise Linear Material

Austenitic & stainless steels

- Law 63: Hansel material
- Law 64: Ugine & ALZ material

Crushable foams *(Honeycomb)*

- Law 28: Honeycomb
- Law 50: Crushable foam
- Law 68: Cosserat medium

Foams

- Law 33: Closed Cell visco-elasto-plastic
- Law 35: Generalized Kelvin-Voigt open/closed cells
- Law 38: Tabulated visco-elastic material
- Law 70: Tabulated hyper visco elastic material

Rubber

- Law 42: Ogden-Mooney-Rivlin
- Law 62: Hyper Visco Elastic material

Plastic

- Law 36: tabulated elasto-plastic material
- Law 65: Elastomer material
- Law 66: Visco Elastic Plastic Piecewise Linear Material
- Law 76: SAMP

Glass

- Law 27:elasto-plastic brittle material
- Law 36: tabulated elasto-plastic material

Composite

- Law 36: tabulated elasto-plastic material
- Law 15: Tsai-Wu plasticity
  + Chang & Chang failure
- Law 25: Tsai-Wu plasticity model

Fabric

- Law 19: linear elastic orthotropic material
- Law 58: nonlinear elastic material

Special

- Law 5: Jones Wilkins Lee Material
  (Explosives e.g. TNT)

+ User defined material subroutines

Material Law 2: simple elasto- plastic material

- Material LAW2 Johnson-Cook with rupture
  - Example of Radioss card
    - Mild steel material

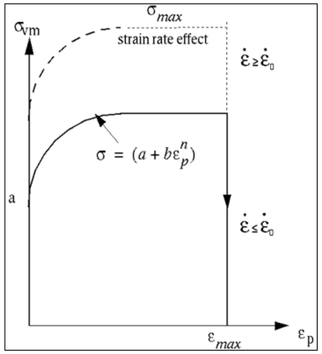
- Material LAW2 (Johnson-Cook)
  - Definition
    - The material law is defined using Johnson – Cook formulation :

$$\sigma = (a + b\varepsilon_p^n)(1 + c\ln\frac{\dot{\varepsilon}}{\dot{\varepsilon}_0})(1 - T^{*m})$$

plastic strain effect — strain rate effect — temperature change

- σ = True stress level
- ε_p = True plastic strain
- a = Yield stress
- b = Hardening modulus
- n = Hardening Exponent

- c = Strain rate coefficient
- $\dot{\varepsilon}$ = Strain rate
- $\dot{\varepsilon}_0$ = Reference strain rate

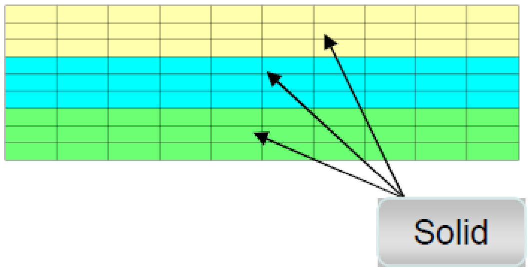



```
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/MAT/PLAS_JOHNS/1
Material_A
#        Init. dens.          Ref. dens.
             7.8E-9                    0
#                 E                   Nu
             210000                   .3
#                 a                    b                    n              Eps_max               sigmax
                400                  550                   .5                   .4                    0
#                 c                 EPS0       Icc    Fsmooth                F_CUT
                  0                    0         0          0                    0
#                 m               T_melt                rhoCp                  T_i
                  0                    0                    0                    0
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
```

Orthotropic non-linear laminated composite material

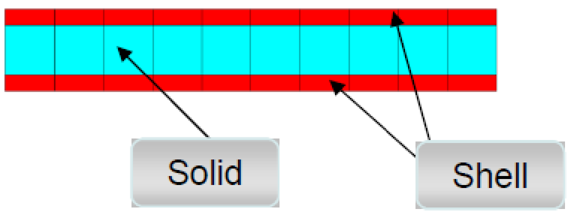
Each ply with at least one solid

- Large model, long CPU time
- Advance Mass Scaling to increase simulation speed
- High accuracy



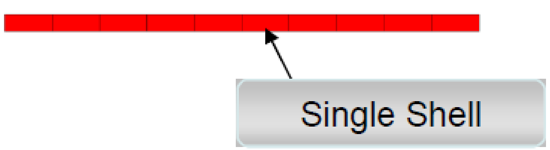
Mixed approach (middle layer thick)

- Shells for top and bottom ply
- Solid, thick shell or cohesive for middle layer
- Several solid layers to provide rotation
- Medium size model, significant CPU time



Shell & Thick shell approaches

- Reduced integration in normal direction
- Sandwich shell approach
- One shell element through the thickness
- Multiple plies, with different materials
- “Standard size “ model

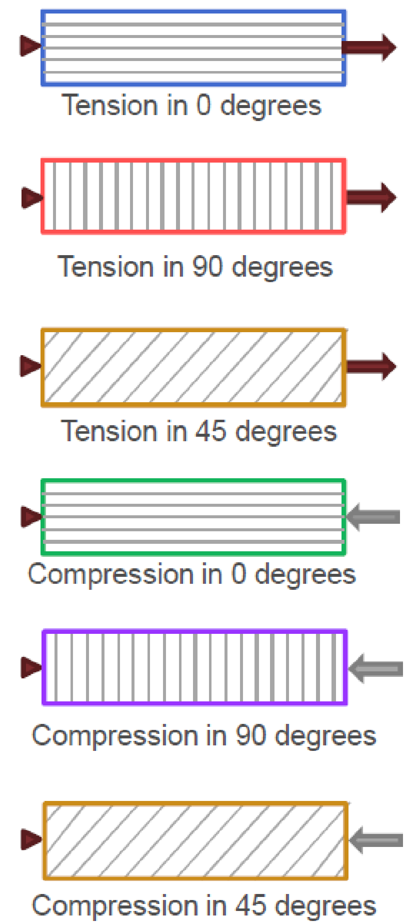


Orthotropic non-linear composite material

Elastic

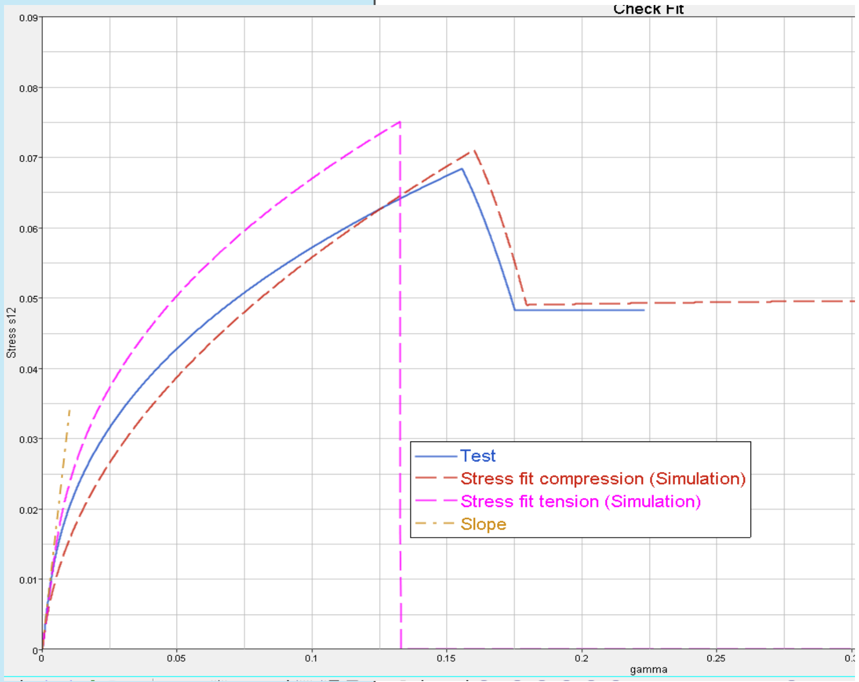
Post-Yield

```
/MAT/COMPSH/10
Altair composite material
#              RHO_I
             1.5E-9                   0
#                E11                E22                NU12      Iform                E33
              127205               7004                 .05          1
#                G12                G23                 G31                 EPS_f1             EPS_f2
               15094              15094               15094                      0                  0
#             EPS_t1             EPS_m1               EPS_t2                 EPS_m2            d_tens
                   0                  0                    0                      0                  0
#              Wpmax              Wpref      Ioff     IFLAWP                  ratio
                   0                  0         6          0                    1.0
#                  c          EPS_rate_0               alpha                                 ICC_global
                   0                  0                    0                                          0
#            sig_1yt               b_1t                 n_1t              sig_1maxt              c_1t
                1350                  0                    0                      0                  0
#            EPS_1t1            EPS_2t1          SIGMA_rst1              Wpmax_t1
                   0                  0                    0                      0
#            sig_2yt               b_2t                 n_2t              sig_2maxt              c_2t
               66.38                  0                    0                      0                  0
#            EPS_1t2            EPS_2t2             sig_rst2               Wpmax_t2
                   0                  0                    0                      0
#            sig_1yc               b_1c                 n_1c              sig_1maxc              c_1c
                 650            .517338              .718969                      0                  0
#            EPS_1c1            EPS_2c1             sig_rsc1               Wpmax_c1
                   0                  0                    0                      0
#            sig_2yc               b_2c                 n_2c              sig_2maxc              c_2c
                 125            .527013              .324912                      0                  0
#            EPS_1c2            EPS_2c2             sig_rsc2               Wpmax_c2
                   0                  0                    0                      0
#           sig_12yt              b_12t                n_12t             sig_12maxt             c_12t
               0.004               67.0                 0.29                      0                  0
#           EPS_1t12           EPS_2t12            sig_rst12              Wpmax_t12
                   0                  0                    0                      0
#          GAMMA_ini          GAMMA_max                d_max
                1E31               1E31                .9999
#   Fsmooth                Fcut
          0                 0.0
```



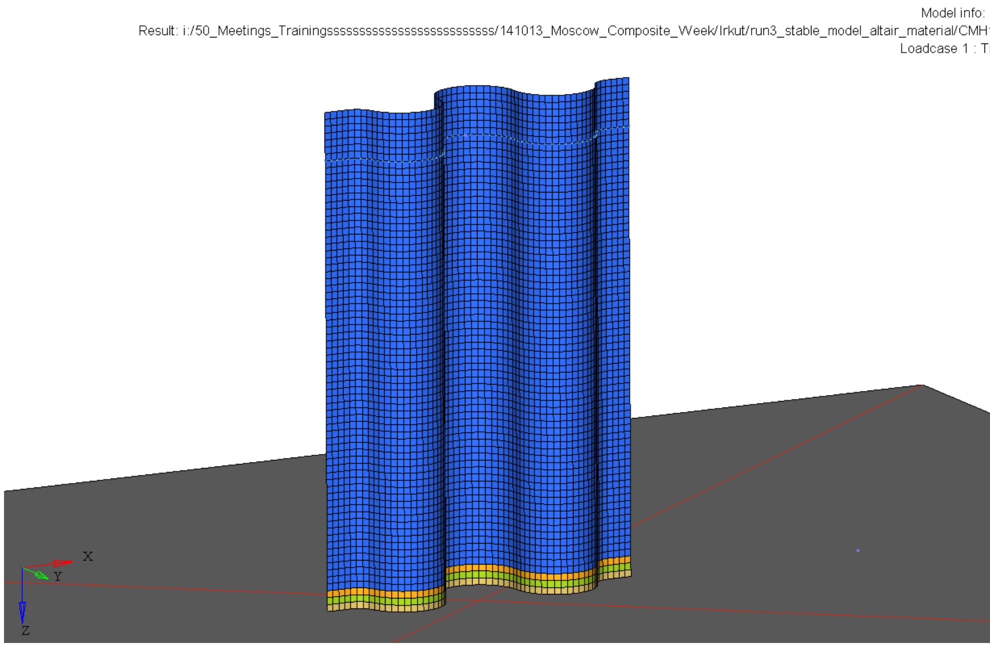
Example of validation for 45 deg compression

```
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/MAT/COMPSH/10
Altair composite material
#        Init. dens.          Ref. dens.
           1.5000E-6                   0
#                E11                 E22                 NU12     IFLAG                 E33
                  42                  40                  .05         1                0.50
#                G12                 G23                  G31                 EPSF1
                 3.4                   3                    3                     0
#              ESPT1               EPSM1                EPST2                 EPSM2
                   0                   0                    0                     0
#              Wpmax               Wpref       Ioff
                   0                   0          5
#                  C                 EPS                ALPHA
                   0                   0                    0
#          sig_trac_1                B_1T                  N_1T          SIGMA_1MAXT
                 0.1                  25                  .10                     0
#            EPS_1T1             EPS_2T1          SIGMA_RST1          Wpmax_trac_1
                   0                   0                    0                     0
#          sig_trac_2                B_2T                  N_2T          SIGMA_2MAXT
                 0.1                  20                  .10                     0
#            EPS_1T2             EPS_2T2          SIGMA_RST2          Wpmax_trac_2
                   0                   0                    0                     0
#          sig_comp_1                B_1C                  N_1C          SIGMA_1MAXC
               .0050                2000                   .5                     0
#            EPS_1C1             EPS_2C1          SIGMA_RSC1          Wpmax_comp_1
                   0                   0                    0                     0
#          sig_comp_2                B_2C                  N_2C          SIGMA_2MAXC
               .0050                2000                   .5                     0
#            EPS_1C2             EPS_2C2          SIGMA_RSC2          Wpmax_comp_2
                   0                   0                    0                     0
#              sig_12               B_12T                N_12T          SIGMA_12MAXT
               .0040                83.0                  .31                     0
#           EPS_1T12            EPS_2T12          SIGMA_RST12        Wpmax_trac_12
               0.075               0.085                 0.05                     0
#          GAMMA_INI           GAMMA_MAX                 Dmax
                1E31                1E31                .9999
#   Fsmooth               Fcut
          0                  0
/FAIL/HASHIN/10
#    IMODEL    ISHELL    ISOLID
          2         2         0
#           SIGMA1_T            SIGMA2_T             SIGMA3_T             SIGMA1_C            SIGMA2_C
                1.20               0.525                 1E30                0.700               0.700
#           SIGMA3_C           SIGMAF_12            SIGMAM_12            SIGMAM_23           SIGMAM_13
                1E30                1E30                0.075                 1E30                1E30
#                PHI            SDELAMIN                 TMAX
                   0                   1                 .010
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
```



- Strains to damage and rest stress in direction 12 are used to reproduce the test behavior
- Note that damage strains are half of the damage gamma values

Sinus beam crash (generic composite material)




```
#- RADIOSS DECK WRITTEN BY HyperCrash
#model4 + interface Julien + loi ductile
#Tue Jul 08 16:48:01 2008
#-
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/BEGIN
CMH17DLR2_001a
       120         0
                  kg                  mm                  ms
                  kg                  mm                  ms
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
#-  1. CONTROL CARDS:
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/TITLE

#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/ANALY
#    N2D3D             IPARITH      ISUB
         0                   0         0
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/DEF_SHELL
#   ISHELL    ISMSTR    ITHICK     IPLAS   ISTRAIN                        I_SH3N     IDRIL
         0         0         0         0         0                             1         0
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/DEF_SOLID
#  I_SOLID    ISMSTR             ISTRAIN                                  IFRAME
         0         0                   0                                       0
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/IOFLAG
#     IPRI               IGTYP     IOUTP    IOUTYY   IROOTYY     IDROT
         0                   0         0         0         0         0
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/RANDOM/1
              1e-03               0.5
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
#-  2. MATERIALS:
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/MAT/COMPSH/1
Altair composite material
#             RHO_I
             1.5E-6                   0
#               E11                 E22                 NU12     Iform                E33
                 42                  40                  .05         1                          .5
#               G12                 G23                  G31               EPS_f1              EPS_f2
                3.4                   3                    3                    0                   0
#            ESP_t1              EPS_m1               EPS_t2               EPS_m2              d_tens
                  0                   0                    0                    0               .9999
#             Wpmax               Wpref      Ioff    IFLAWP
```

- Check model built up
- Definition of materials, properties
- Run settings
- Post processing

RADIOSS – Rupture Criteria

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Failure Model Description

Failure Model Keyword	Type	Description
CHANG	Chang-Chang model	Failure criteria for composites
CONNECT	Failure	Normal and Tangential failure model
ENERGY	Energy isotrop	Specific energy
		using user defined functions
TBUTCHER	Tuler-Butcher model	Failure due to fatigue
TENSSTRAIN	Traction	Strain failure
USERi	User failure model	
WIERZBICKI	Ductile material	Bao-Xue-Wierzbicki model
WILKINS	Ductile failure model	Wilkins model
XFEM_FLD	Forming limit diagram	Fld
XFEM_JOHNS	Ductile failure model	Johnson-Cook
XFEM_TBUTC	Ductile (brittle) failure model	Modified Tuler-Butcher model
EMC	Ductile material	Extended Mohr-Coulomb MIT

MATERIAL MODELS & RUPTURE CRITERIA LIBRARIES

=>

MORE THAN 300 COMBINATIONS

Tabulated failure criterion for elastoplastic materials

- Failure Curve (eps_f vs. triaxiality) test – input is a user function
- Strain Rate Dependency – Different curves for different strain rates
- Element Length Dependency
- Load path is taken into account by damage accumulation
- Bending Behavior: Percentage of Thickness to fail before deleting shells

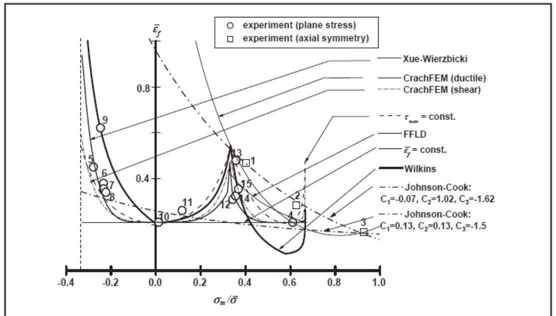
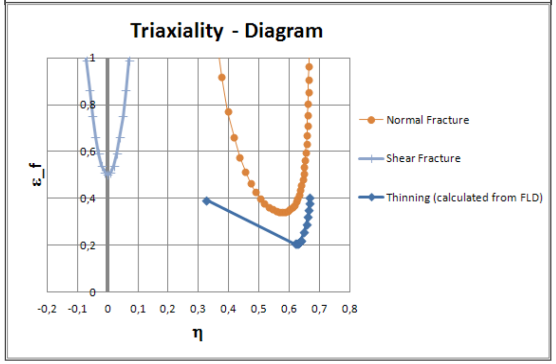
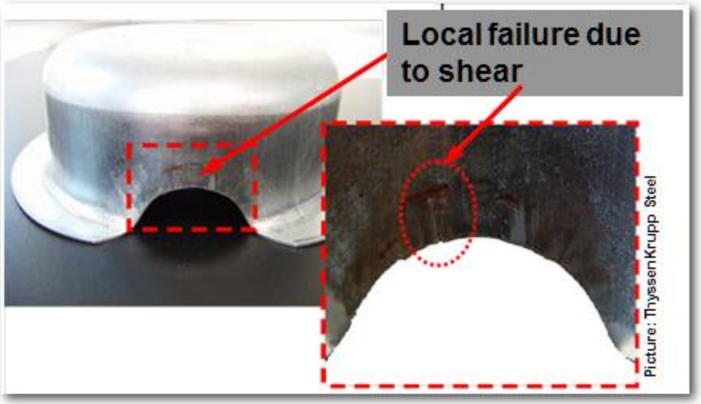


Fig. 19. Comparison of prediction of all seven fracture criteria relatively to the set of 12 test points (plane stress) on 2024-T351 aluminum specimens.





2015 AMERICAS ATC
DEARBORN, MICHIGAN

Tabulated failure criterion for elastoplastic materials

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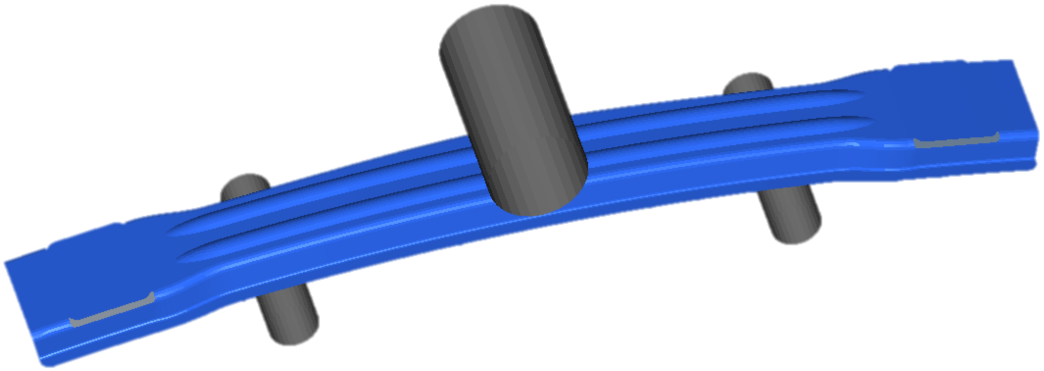
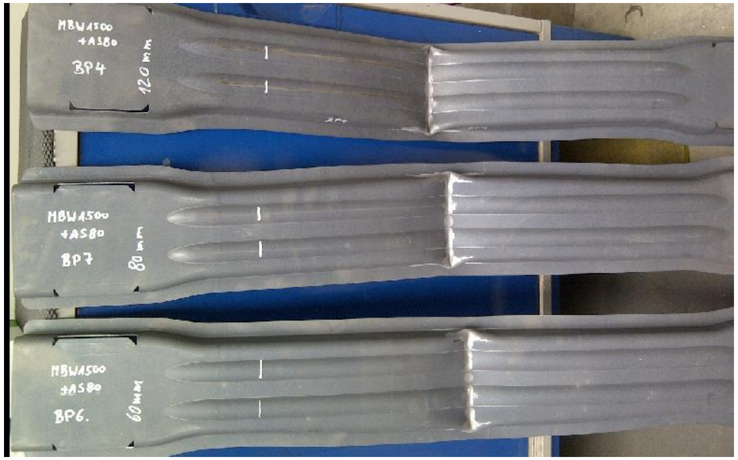
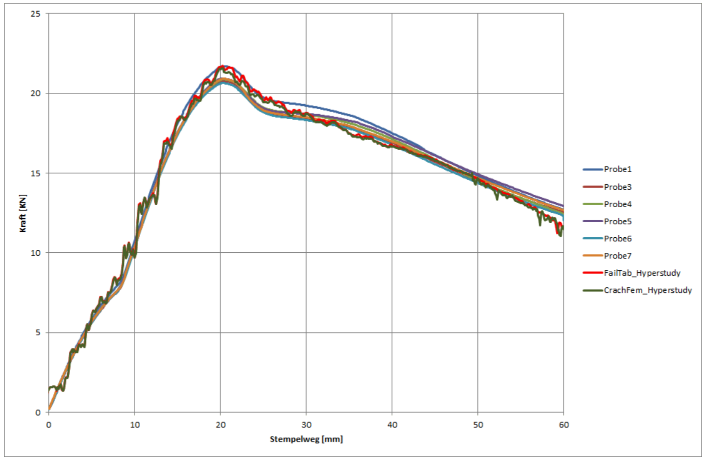
KIRCHHOFF AUTOMOTIVE



RADIOSS simulation





Simple Chang-Chang failure criteria for composites

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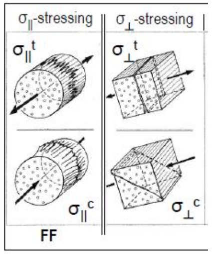


- **With fiber direction 1:**
  - Tensile fiber mode:

$$\left(\frac{\sigma_{11}}{S_1}\right)^2 + \beta\left(\frac{\sigma_{12}}{S_{12}}\right)^2 \geq 1 \qquad \sigma_{11} > 0$$

0 deg Tension
45 deg Tension

  - Compressive fiber mode:

$$\left(\frac{\sigma_{11}}{C_1}\right)^2 > 1 \qquad \sigma_{11} < 0$$

0 deg Compression

- **For matrix cracking:**
  - Tensile matrix mode

$$\left(\frac{\sigma_{22}}{S_2}\right)^2 + \beta\left(\frac{\sigma_{12}}{S_{12}}\right)^2 > 1 \qquad \sigma_{22} > 0$$

90 deg Tension
45 deg Tension

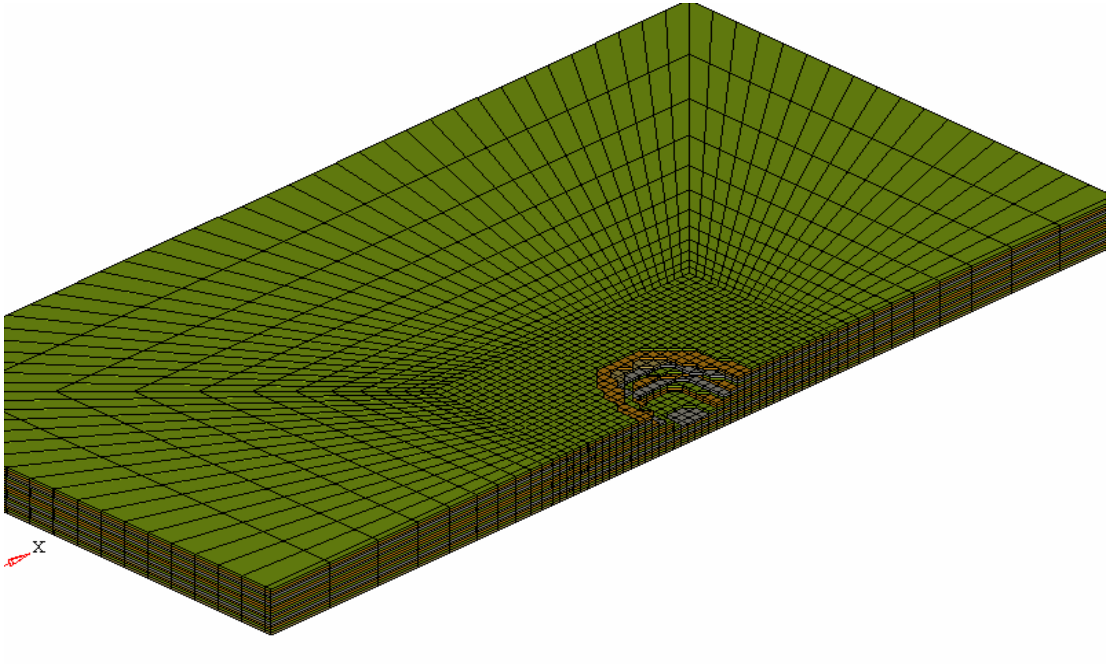
  - Compressive matrix mode

$$\left(\frac{\sigma_{22}}{2S_{12}}\right)^2 + \left[\left(\frac{C_2}{2S_{12}}\right)^2 - 1\right]\frac{\sigma_{22}}{C_2} + \left(\frac{\sigma_{12}}{S_{12}}\right)^2 > 1 \qquad \sigma_{22} < 0$$

90 deg Compression
45 deg Compression

Failure criteria can be combined

- Possibility to apply several failure criteria for one material law :
  - Example :
    - Hashin for fiber
    - Puck for Matrix
    - Ladeveze for delamination



Connect material LAW59 for adhesive layers

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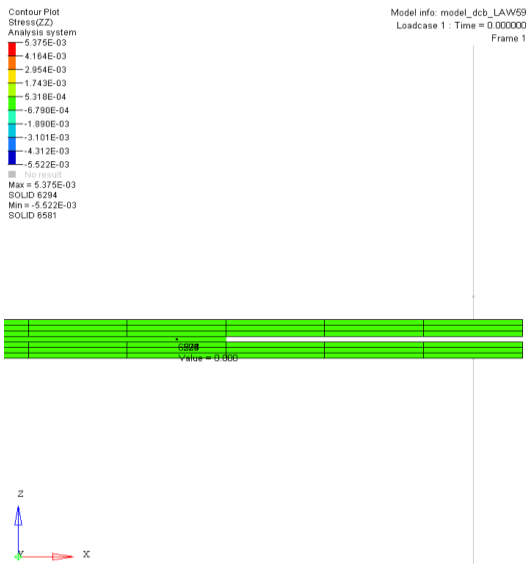
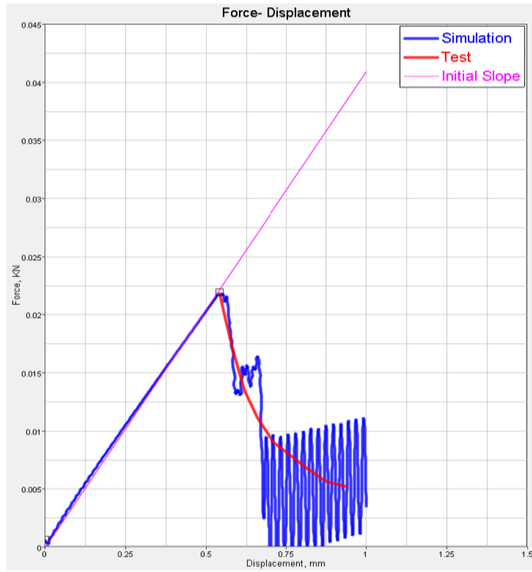
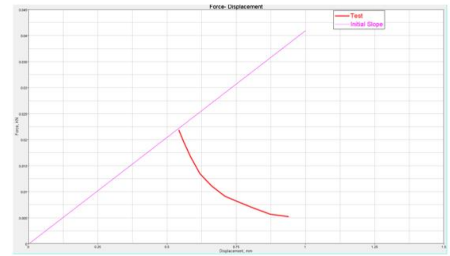




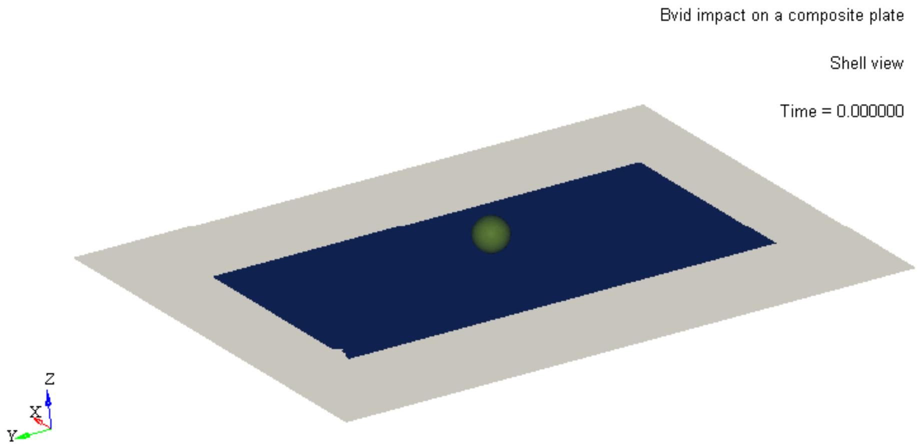


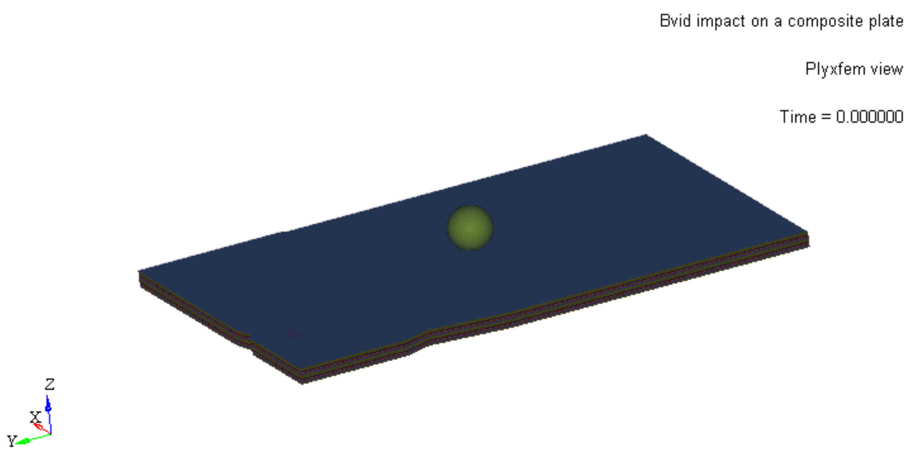
Pre-crack area Crack development

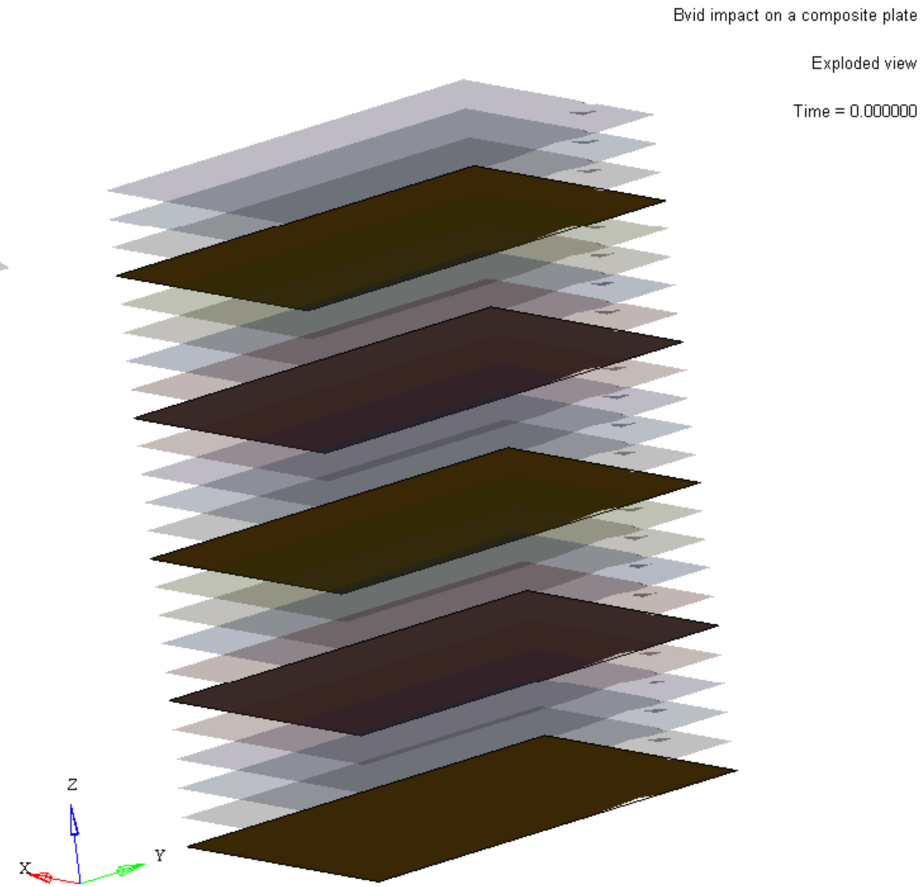
- Typical test curve, which shows force as function of the force transducer displacement . Normally it is shown only in crack area. Before the crack the force displacement curve is assumed to be linear
- In present case crack start at appr 0.5mm half opening (always check in the test whether the displacement is the motion of the force transducer or it is distance between upper and lower transducers)

- For adhesive layers, spotwelds, any other type connections
- Element height does no affect time step. Can be 0!
- Example of DCB test with LAW59

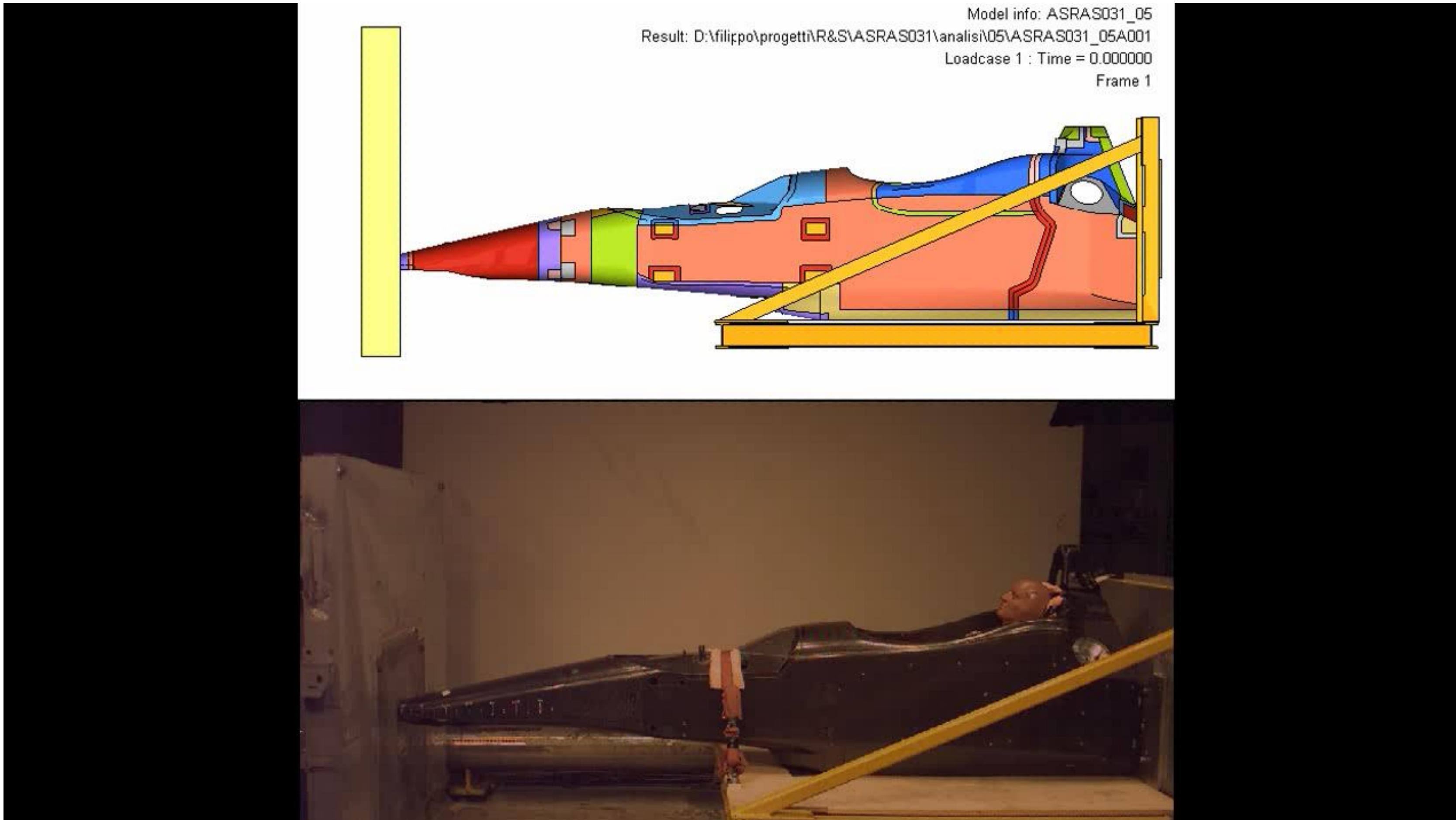
Ply-XFEM Approach for delamination





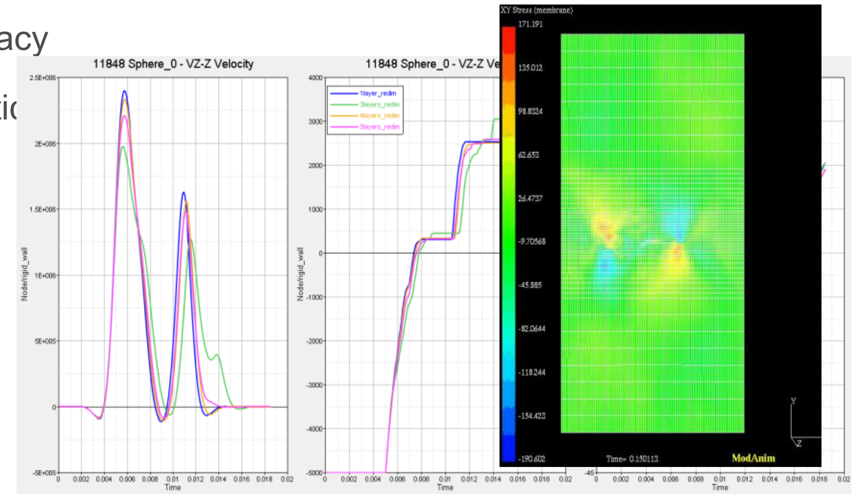


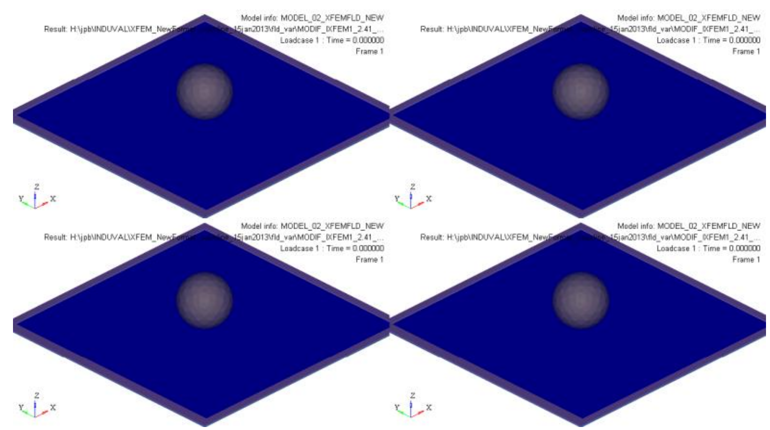
RADIOSS - DALLARA Race cars design Composite structures



RADIOSS - X-FEM

- **Goals**
  - Splitting elements when failure occurs => ↑ accuracy
  - Crack propagation independent of the mesh directio
  - ↑ mesh size independency
  - Allow relatively coarse mesh
- **Capabilities**
  - Compatible properties
    - /PROP/SHELL isotropic mono-layer
    - /PROP/SH_SANDW isotropic/orthotropic multi-layer
  - Compatible failure models
    - /FAIL/JOHNSON
    - /FAIL/TBUTCHER
    - /FAIL/TAB1
    - /FAIL/FLD
    - FAIL/TAB with Lode angle
    - /FAIL/SNCONNECT
    - /FAIL/NXT
  - Crack visualization per layer
  - Simple activation through the flag Ixfem = 1





RADIOSS - X-FEM update

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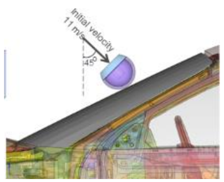
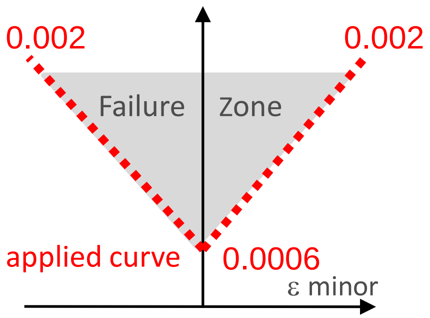
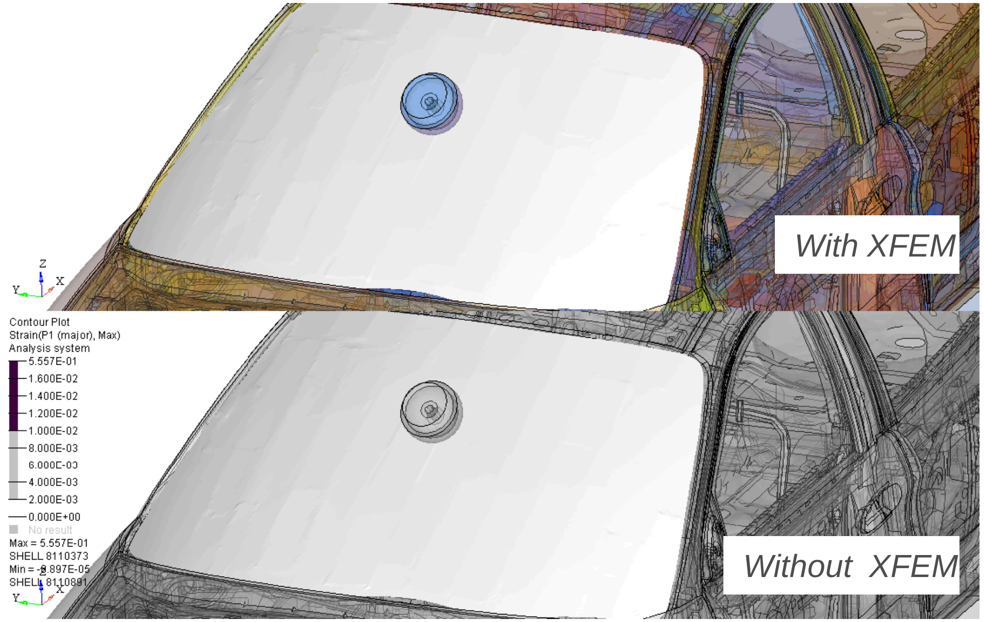
- **Latest enhancements**
  - Addition of an optional "advancement parameter" [0 , 1] in all X-FEM compatible failure models
    - Decoupling of the crack initiation and the crack advancement criteria
    - Enabling the control of cracks number and crack propagation velocity
  - SPMD & H-MPP compatibility and performance optimization
  - Compatibility /MAT/HILL (LAW32) &/MAT/HILL_TAB (LAW43) with /FAIL/JOHNSON criterion



Failure Criteria (FLD)





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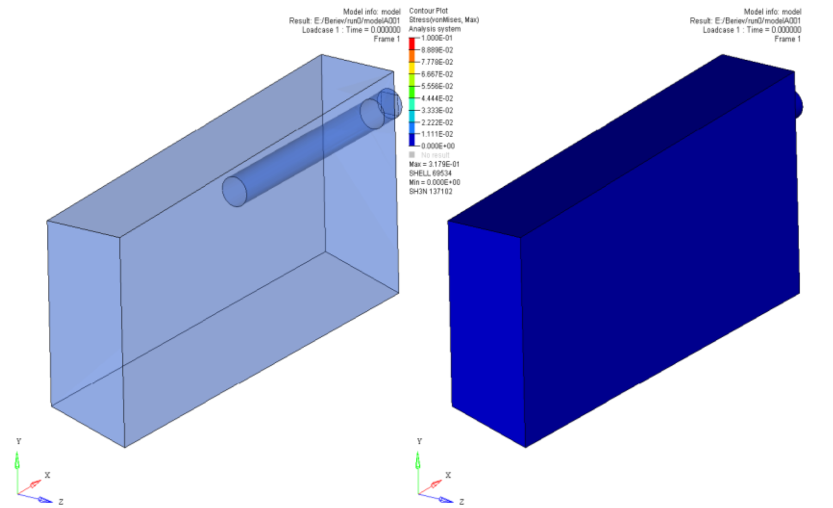
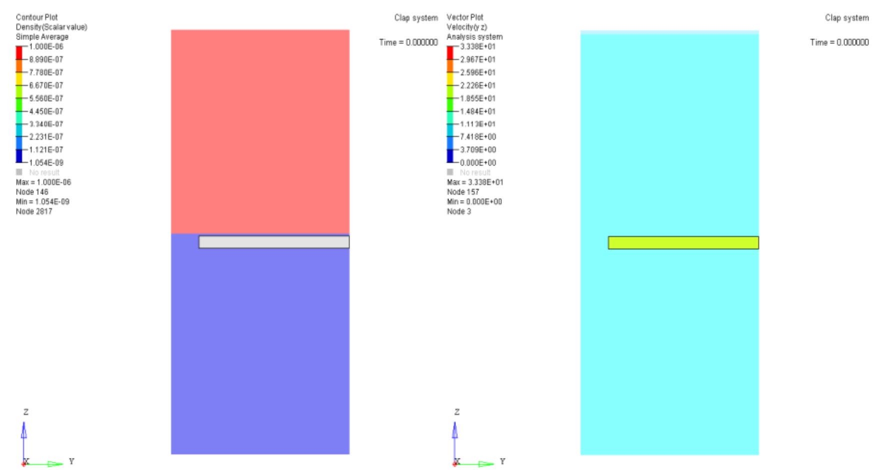
RADIOSS FSI: SPH and ALE

- **Smooth Particle Hydrodynamic is used** :
  1. the fluid fills only a small portion of the domain
  2. Air behavior can be neglected (no cavitation …)



- **Arbitrary Lagranginan Eulerian is recommended:**
  1. the fluid fills most of the domain
  2. Air behavior cannot be neglected (no cavitation …)
  3. Accurate fluid modeling (turbulence …) required



Landing run over a wavy water surface


BERIEV

Numerical Experiment Ltd.

Altair

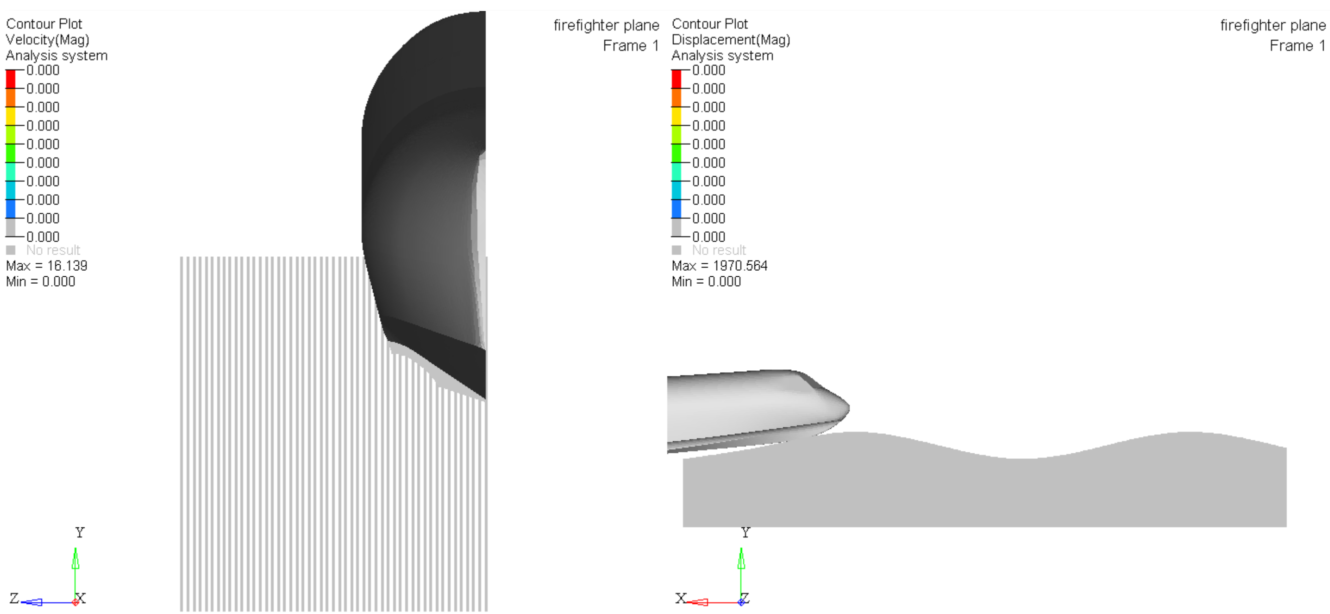
Simulation of a seaplane landing on a rough water surface using the RADIOSS multidomain method

European ATC 2015, Paris
01.10.15

Ivanov K. (Numerical Experiment Ltd., Director, Russia)
Kleptsov V. (Beriev Aircraft Company, Head of Fatigue Department, Russia)
Fokin D. (Altair Inc., Senior Application Specialist, Germany)

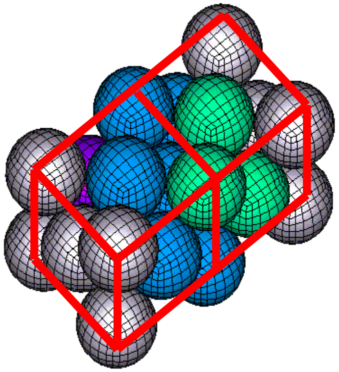
Simulaton:

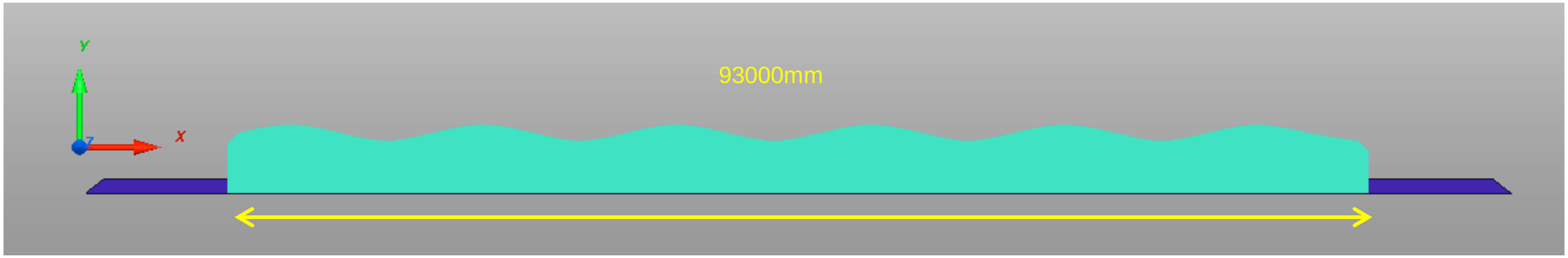
- 180kmh run along 80m water basin



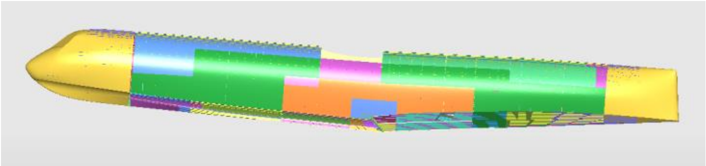
Smooth Particles Hydrodynamics for ditching problems

- Domain divided by a set of particles tied to their neighbors by internal forces
- Incompressible water material is used
- Appr 3.300.000 particles



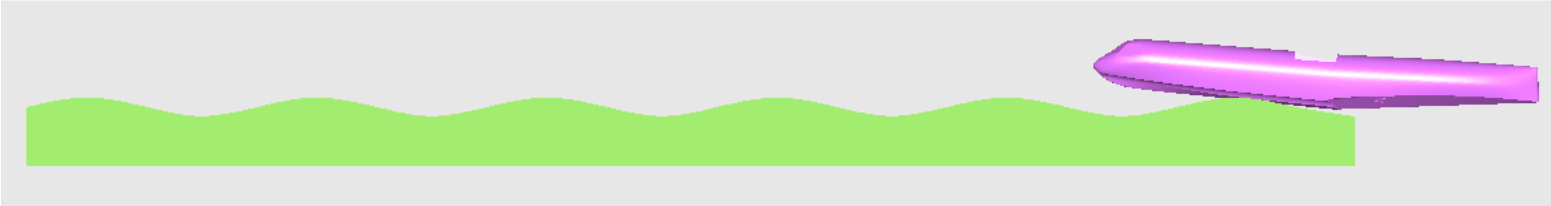


SPH for Multidomain in Radioss



Structural domain:

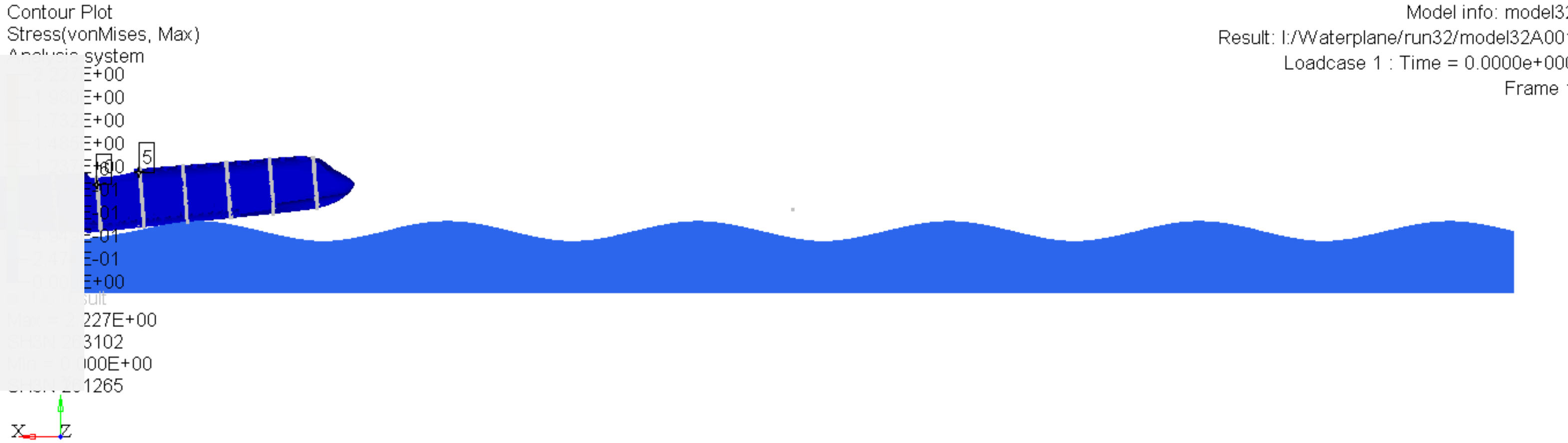
- deformable structure of aircraft
- 300.000 elements
- Maximal possible time step 0.25e-02ms

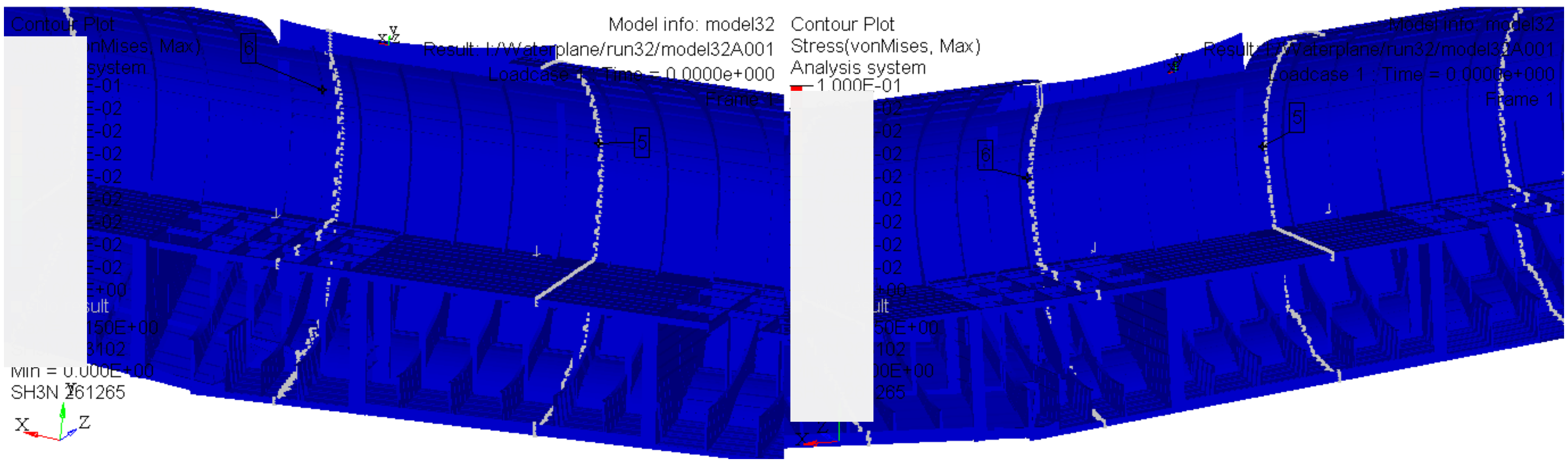


Water domain:

- SPH and void component to replicate fuselage
- type 7 contact between the void and SPH water
- Maximal time step 3.300.000 elements, maximal time step 0.17e-01ms

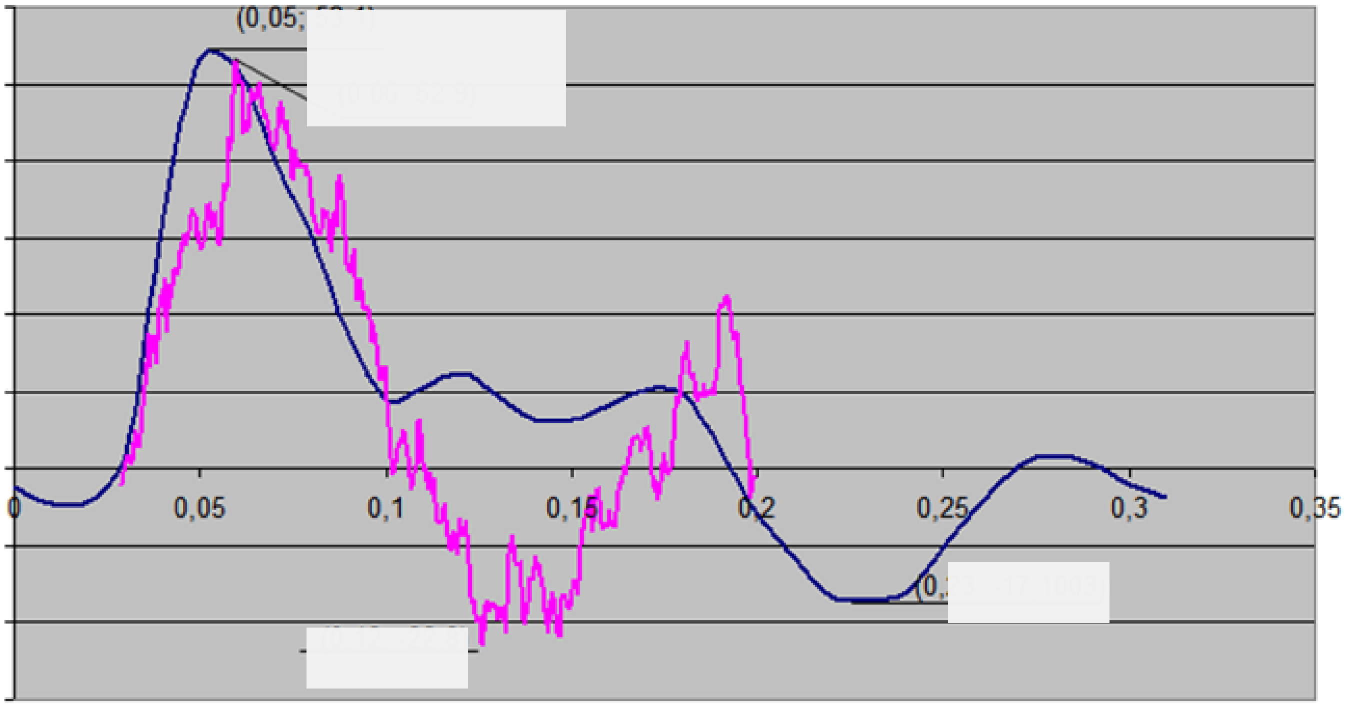
180kmh. Von Mises Stress distribution in structure





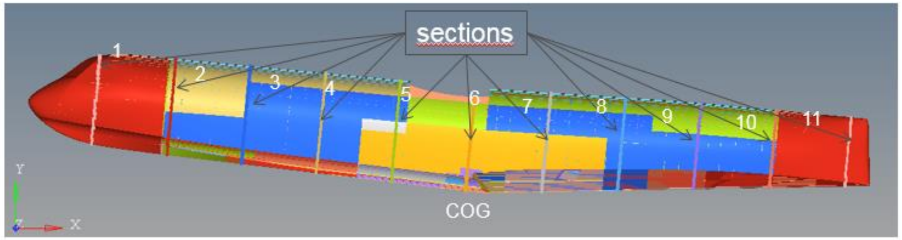
Due to multidomain approach simulation time reduced from 10 to 2 weeks

Comparison to measurements. Moments over one period of wave



Blue: landing test measurements

Lila: Radioss simulations



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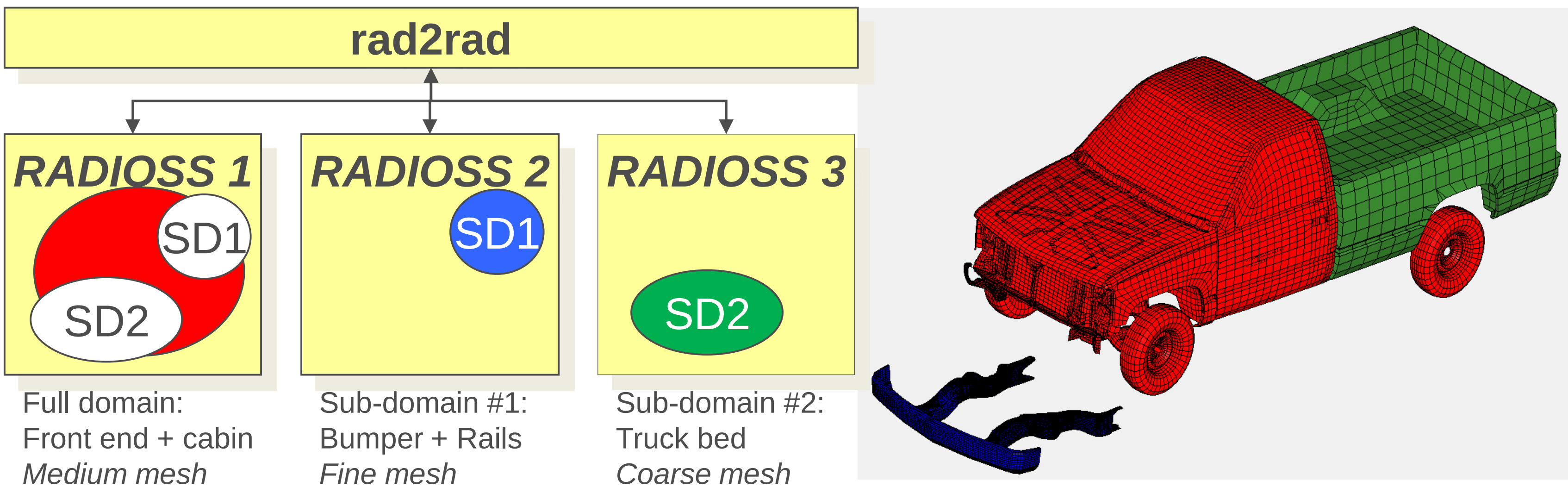
RADIOSS - Multi-Domain

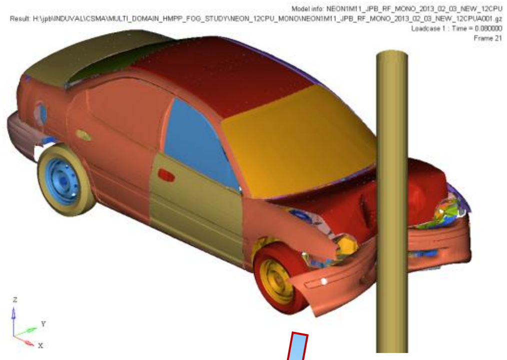
- Each domain is computed as a distinct model using its own time step staying on sync by a master RADIOSS process
- Force and momentum between domains are transferred by the master RADIOSS process insuring equilibrium and stability at sync times
- Only one domain is computed at a time

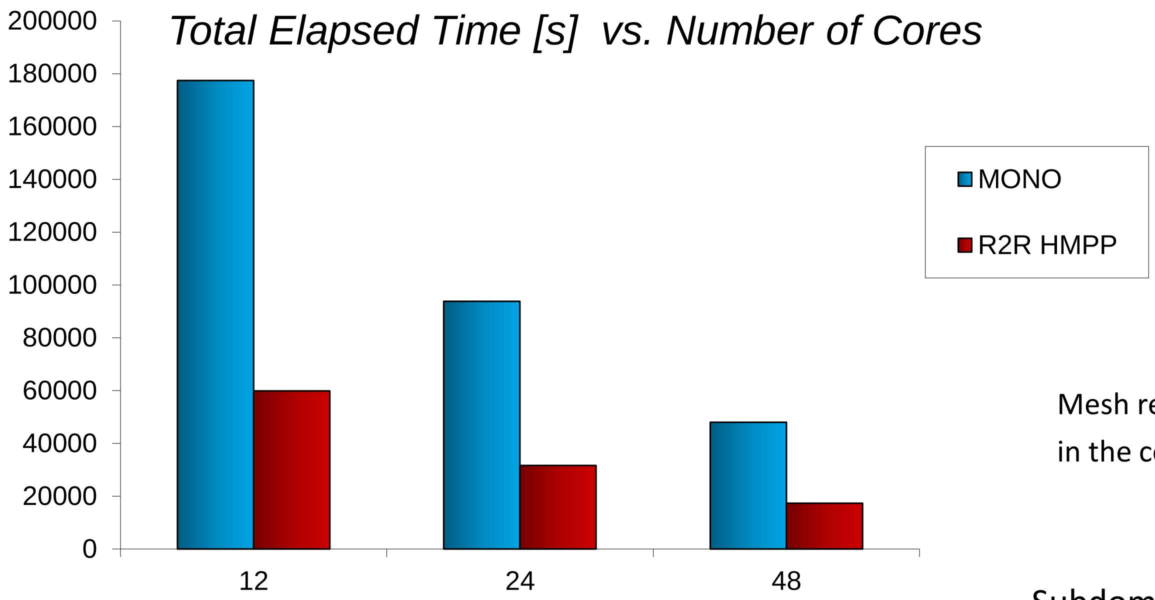


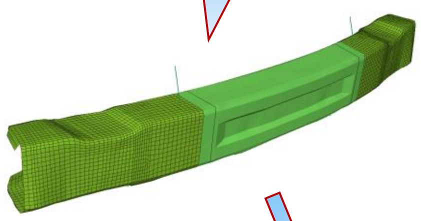
- *No limitation in term on number of domains*
- ***In case of two domains a single input is used and RADIOSS creates automatically the dedicated input decks***

RADIOSS – Multi-Domain

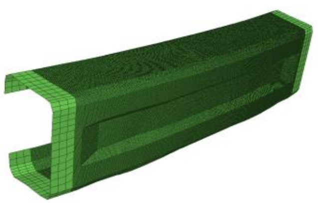
- **NEON** model – pole **1.2M element model**







Mesh refined 10 times (1mm x 1mm) in the central part of the bumper

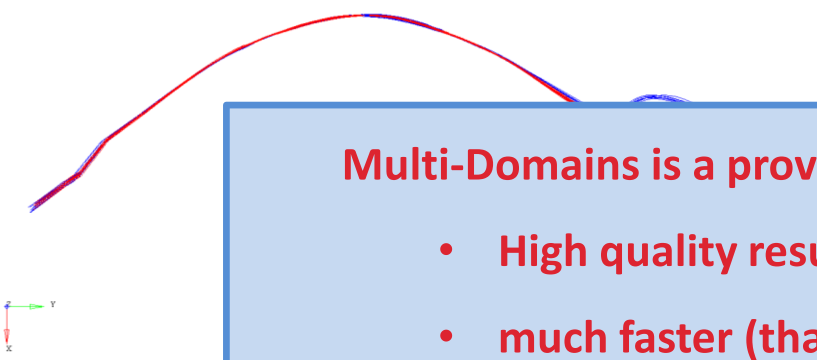


Subdomain : 140k shell elements (12%) – dt = 0.1 μs

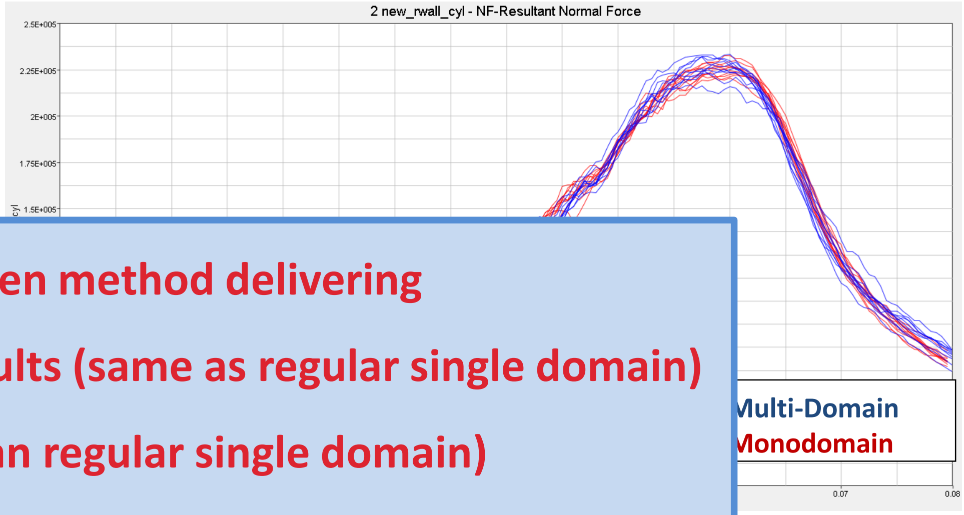
Speed up ratio 2.7

RADIOSS – Multi-Domain

- **Multi-Domain v. Monodomain Robustness Analysis**
  - 1 μm random noise by seed increment of 0.1 from 0.0 to 0.9

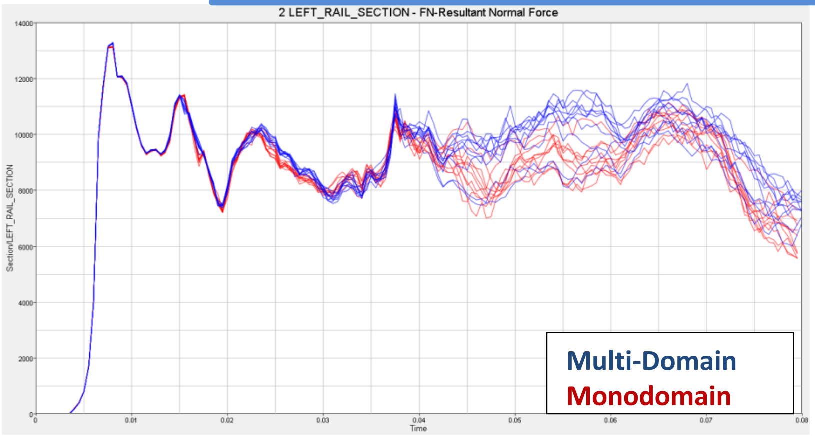


Bumpe

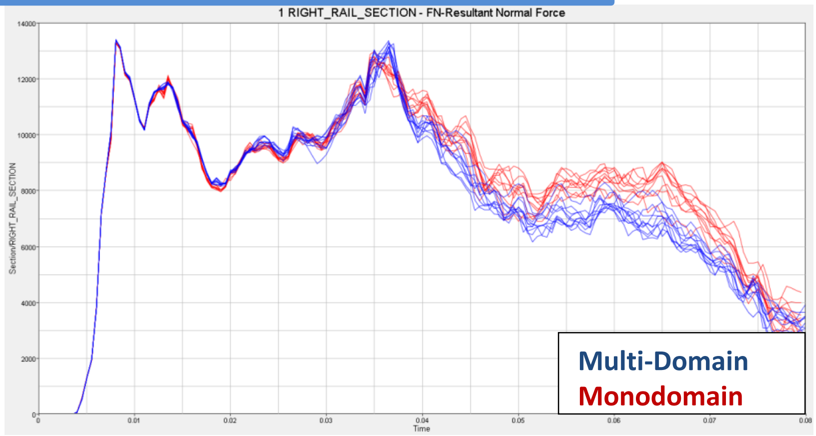


Multi-Domains is a proven method delivering

- **High quality results (same as regular single domain)**
- **much faster (than regular single domain)**



Left Rail Section forces



Right Rail Section forces

Agenda

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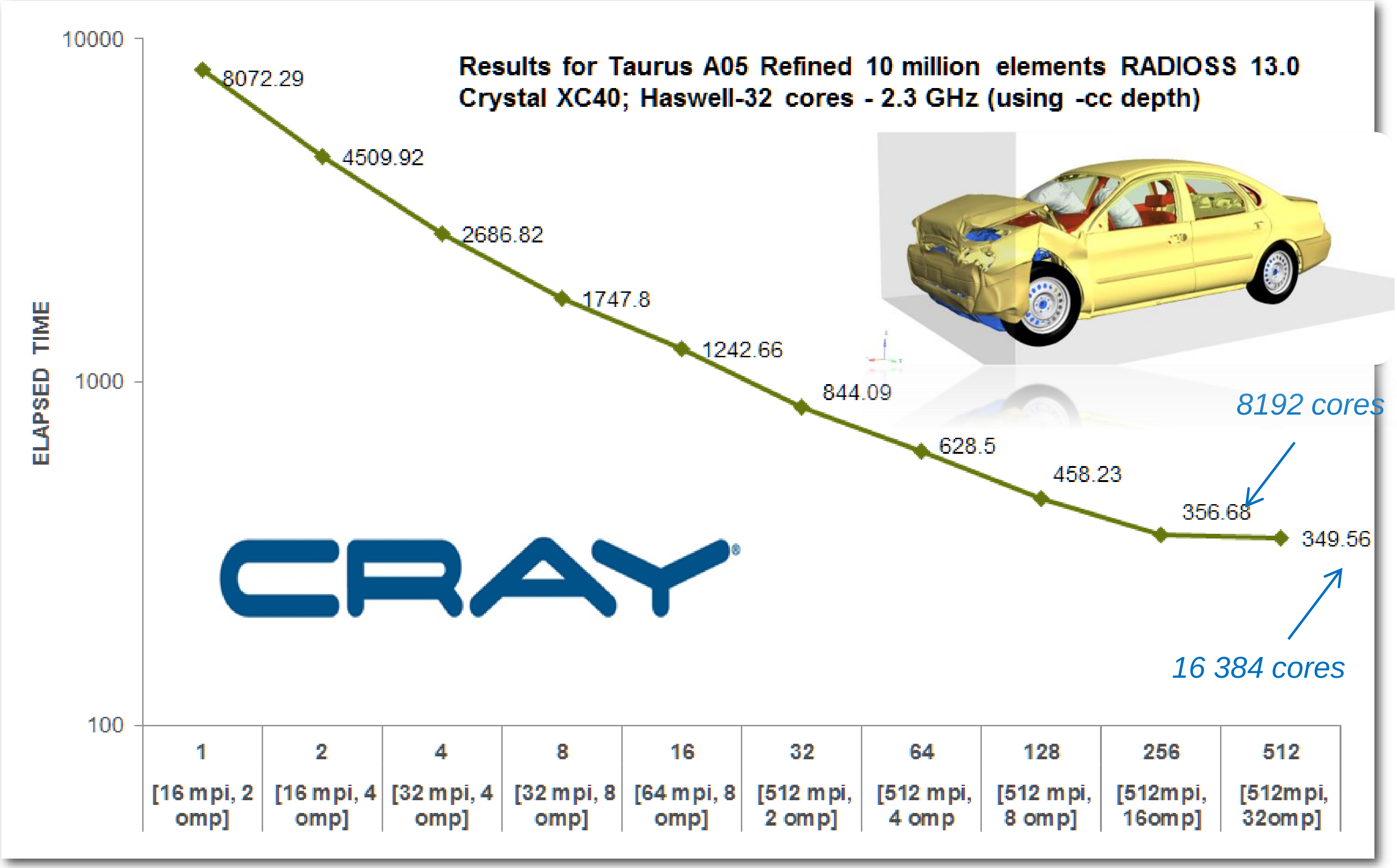
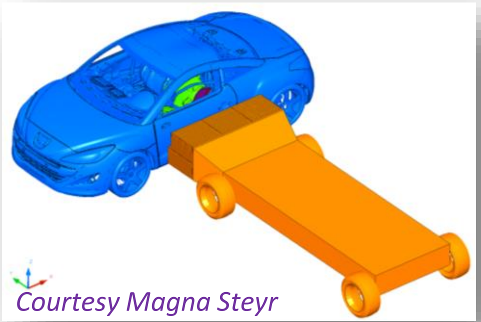
6. **Advanced Mass Scaling**
7. **Example: drop test on a composite glass plate**

RADIOSS: Leading Scalability in crash

- **Scalability** **10 Million Elements** RADIOSS V13.0

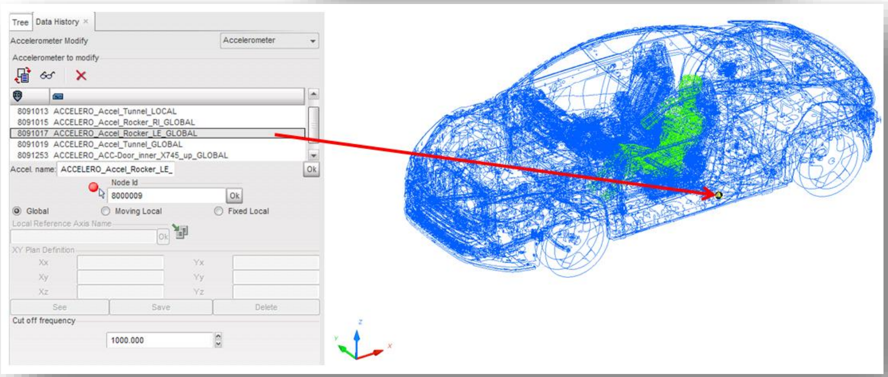


RADIOSS – Unique solution with Full Repeatability



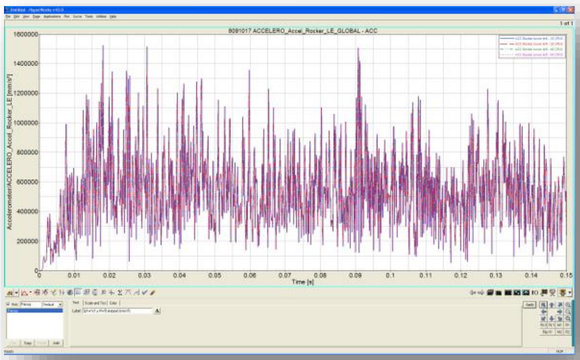
- Full model with dummy and airbag
  1.5 M elts

- Runs on 16, 32, 48 & 64 cores



- Accelerometer No.:8091017 (Rocker Lower Left)

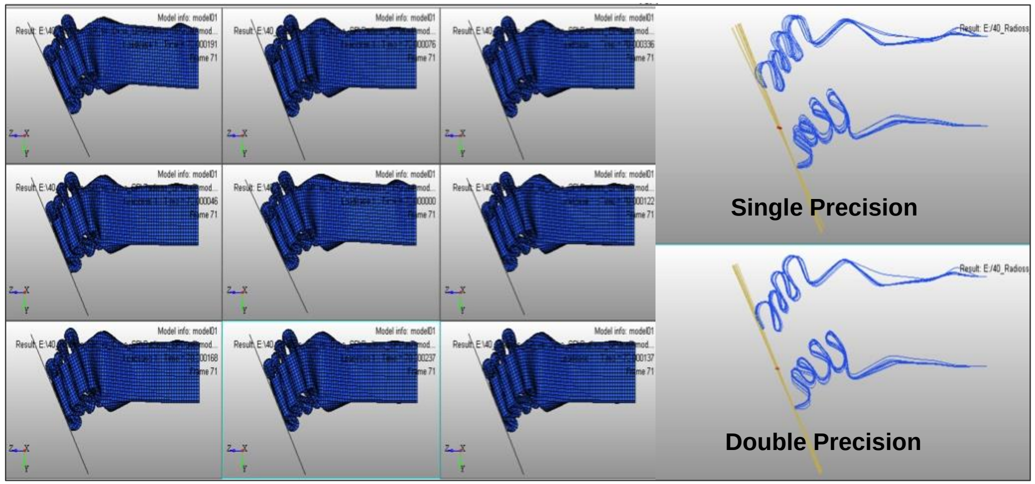
- Perfect Repeatability Independent of amount of cores

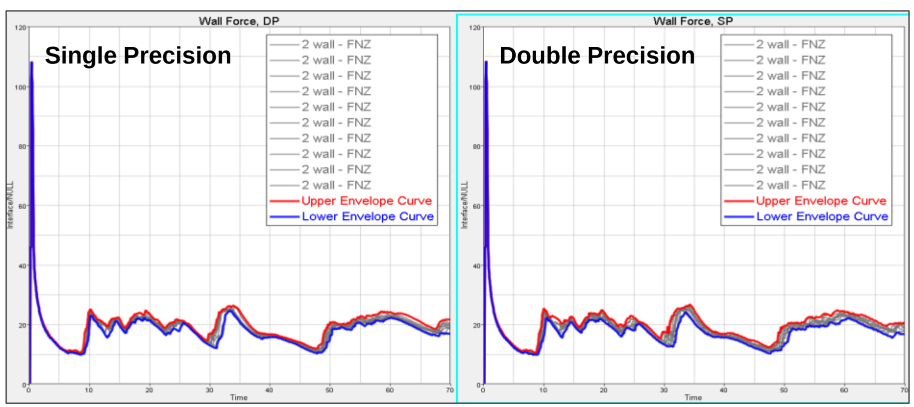


Courtesy Magna Steyr

RADIOSS - Robustness and Repeatability

Numerical scattering in RADIOSS is minimized





Single precision brings 40% speed up

(RADIOSS runs with 1 e-6 random noise applied to all nodes)

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RADIOSS speed up solution Advanced Mass Scaling

- **Classical methods for raising time step**
  - Increase of mass & momentum => change the kinematic energy
  - All frequencies are affected

- **AMS**
  - Non diagonal mass matrix

$$M^* = M + \Lambda$$

$$\lambda = \frac{\delta_e}{12}\begin{bmatrix} 3 & -1 & -1 & -1 \\ -1 & 3 & -1 & -1 \\ -1 & -1 & 3 & -1 \\ -1 & -1 & -1 & 3 \end{bmatrix}$$

  - Assembling elementary matrices
    - δ_e large enough to obtain the target time step
  - Added mass = zero / No change in total mass, energy & momentum
  - Low frequencies are almost not affected

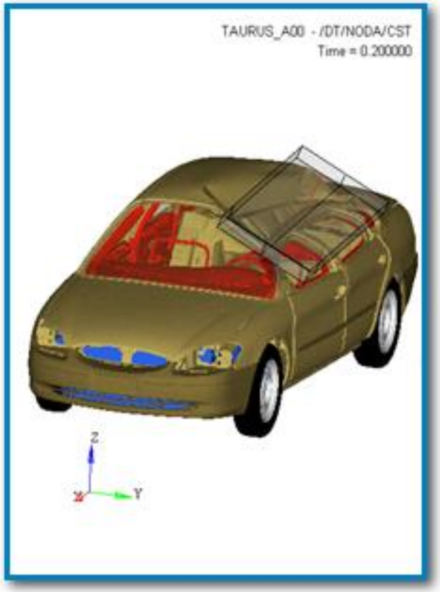
RADIOSS – Advanced Mass Scaling

Altair

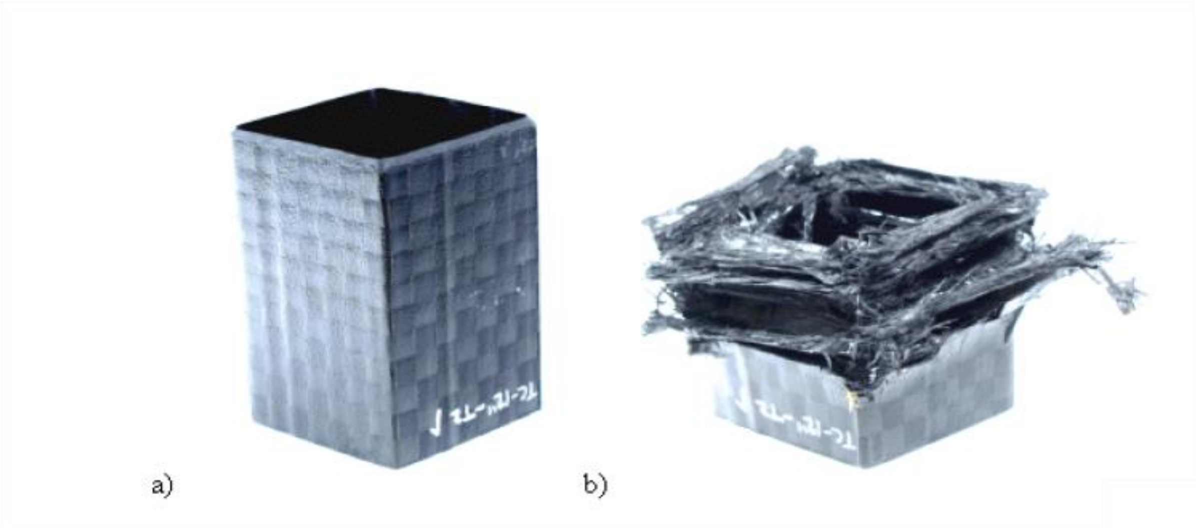
AMS

1. Competitive for quasi static simulation versus implicit
2. Efficient for manufacturing (stamping, …)
3. Allows to stay with a “standard” time step with a fine meshed model

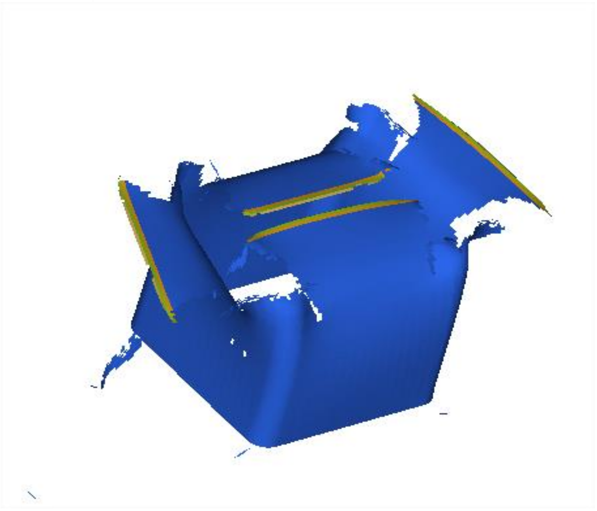
	Mass Scaling	Advanced Mass Scaling
Target time step	0,5 µs	10 µs
Mean time step	0,5 µs	9,9 µs
Nb of cycles	403187	20146
Elapsed Time (16 cores)	19.6h	4.2h
Speed-up		4.64 x



AMS example : quasi-static tube crush

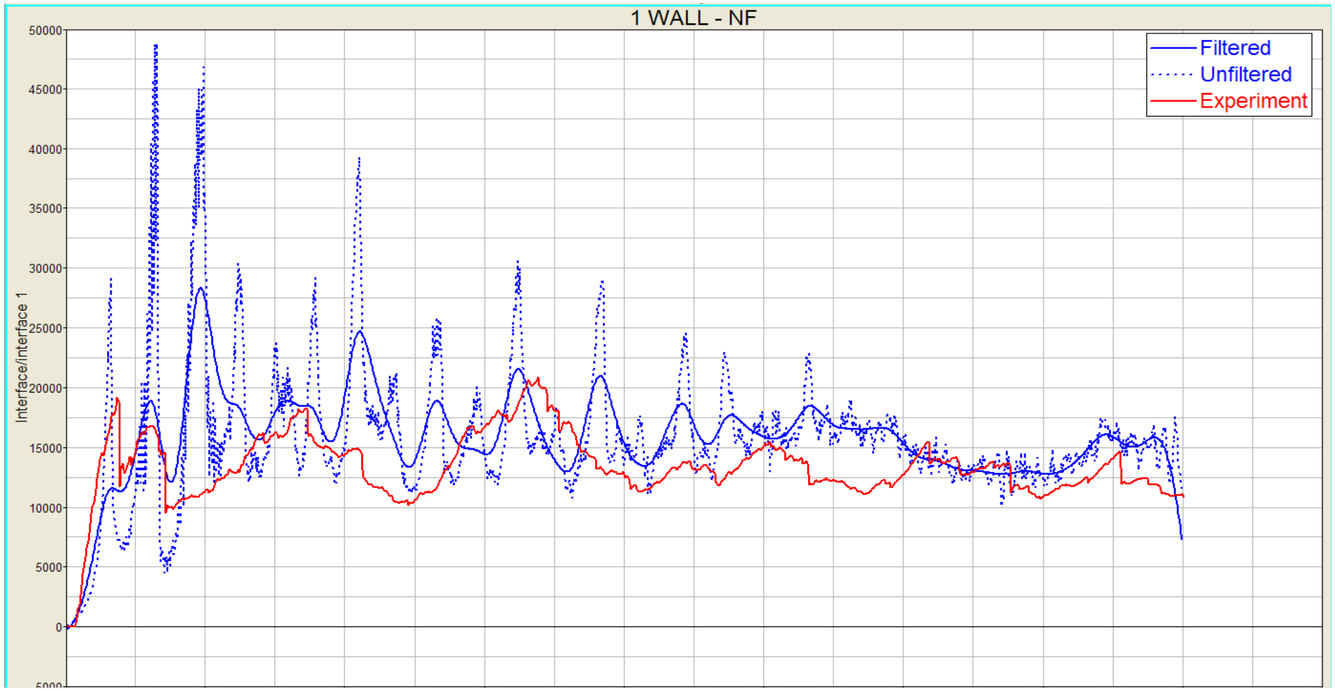


- **Tube : 8 plies carbon epoxy**
- Height : 76 mm
- Side length : 63 mm
- 18545 elements (element size = 1mm)



AMS : example

No AMS (mass is added for cste dt):   : 10 hours
AMS, time step multiplied by 5   :   2 hours 40 minutes
AMS, time step multiplied by 10   :   2 hours 25 minutes



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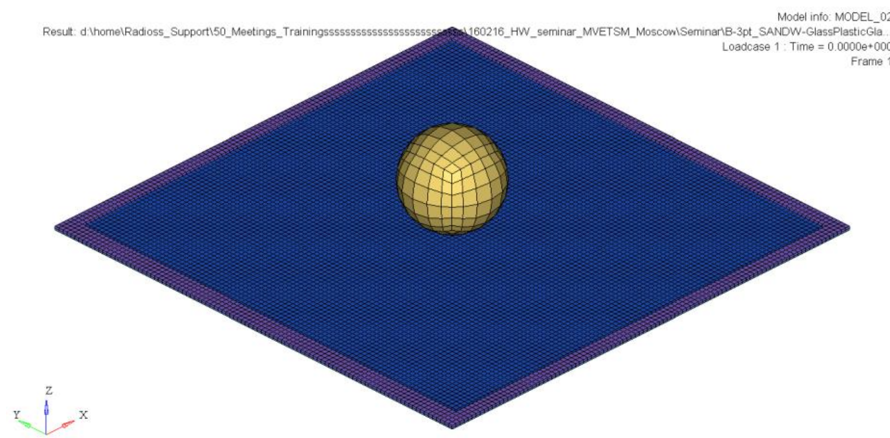
Welcome to Radioss Seminar

The aim of this example is to simulate failure and crack propagation into glass composite structure

Discussed:

- **Definition of elasto-plastic material for the plate**
- **Finite element properties of shell**
- **Rigid wall definition**
- **Boundary conditions**
- **Simulation set up**
- **Post processing of results**



HW programs used:

- **Hypercrash for model set up**
- **Radioss for simulation**
- **Hyperview for postprocessing of results**

Innovation Intelligence®

Thank you for your attention