# Efficient nonlinear multi-scale modeling of composite structures

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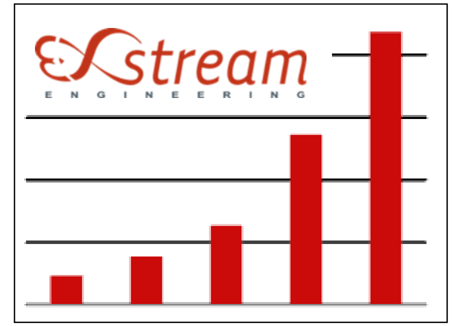
# Efficient nonlinear multi-scale modeling of composite structures

## Agenda

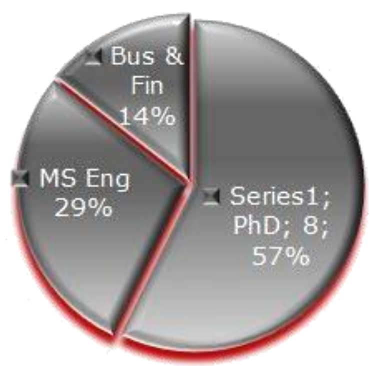
- ✓ e-Xstream engineering
- ✓ DIGIMAT
  - Technology
  - Applications
  - CPU & Robustness
- ✓ DIGIMAT future
  - CPU
  - LS-DYNA Implicit
  - Continuous fibers & drapage

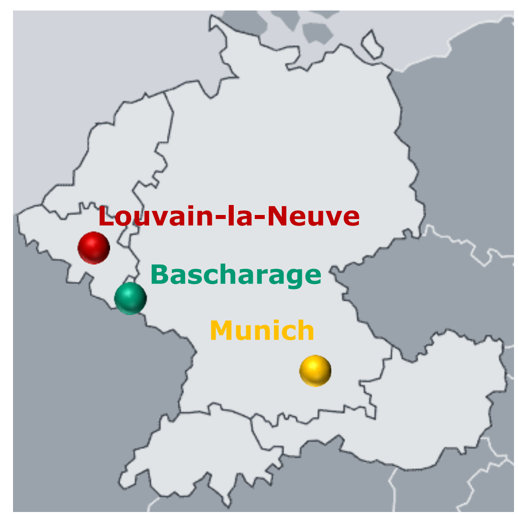
# e-Xstream engineering

- The company
  - ✓ Founded in 2003
- The Business:
  - ✓ Simulation Software & Services
  - ✓ 100% focused on material modeling
- The team
  - ✓ Strong & highly motivated
  - ✓ High level of education
- The product



- **Belgium**
- **Luxembourg**
- **Germany**
- **U.S.**

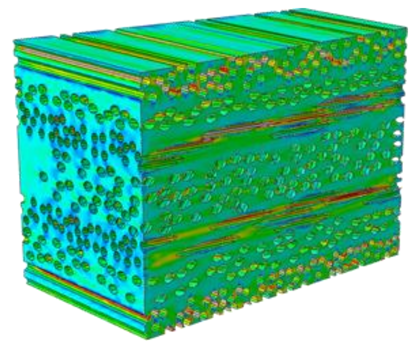


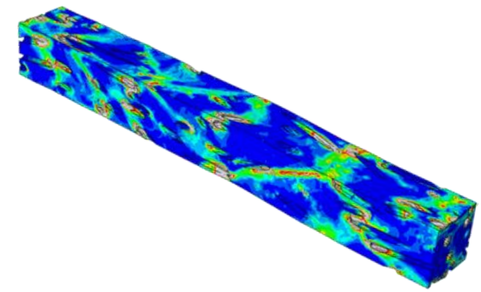



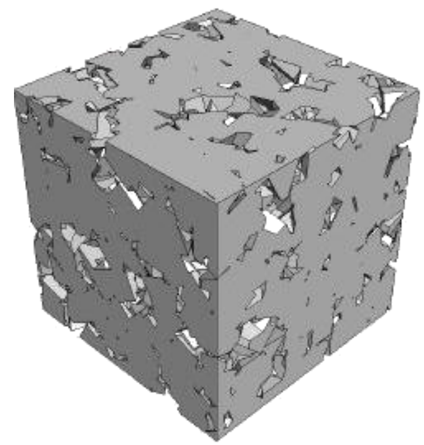
# e-Xstream engineering

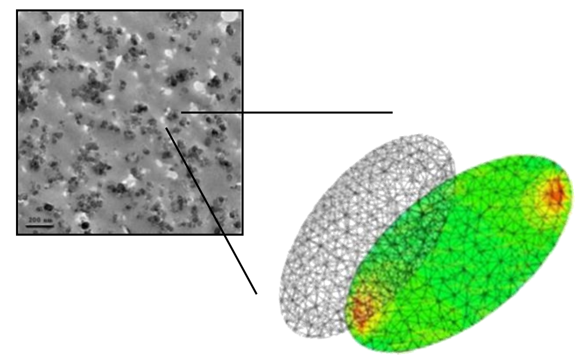
## Composites

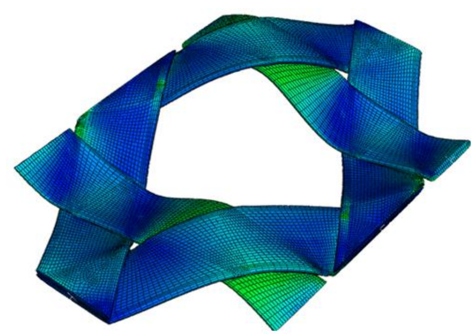
- ✓ Fiber reinforced polymers
  - Short fiber
  - Long fiber
  - Endless fiber
- ✓ Rubber
  - Particle reinforced
- ✓ Hard metals
- ✓ Ceramics
- ✓ Woven composites
- ✓ Nano

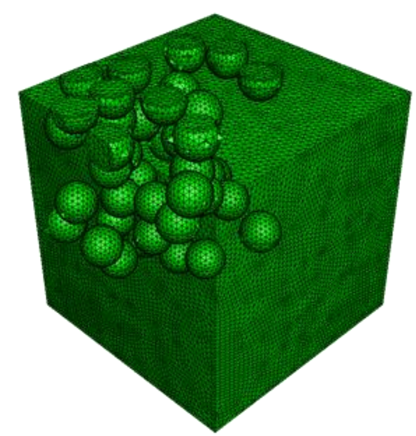








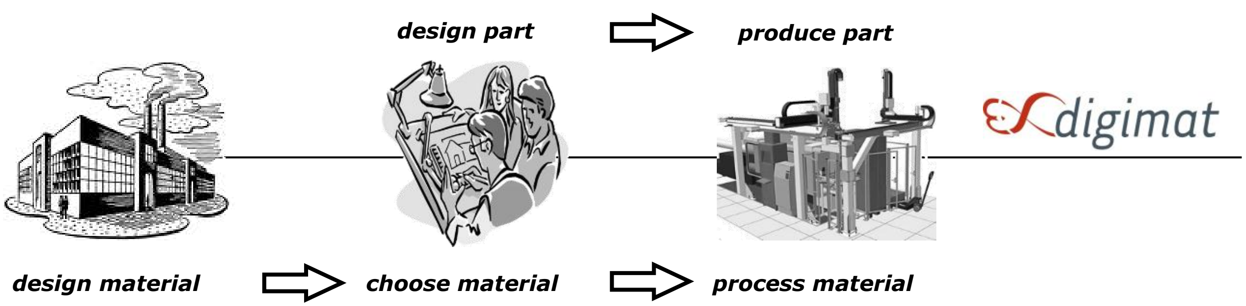


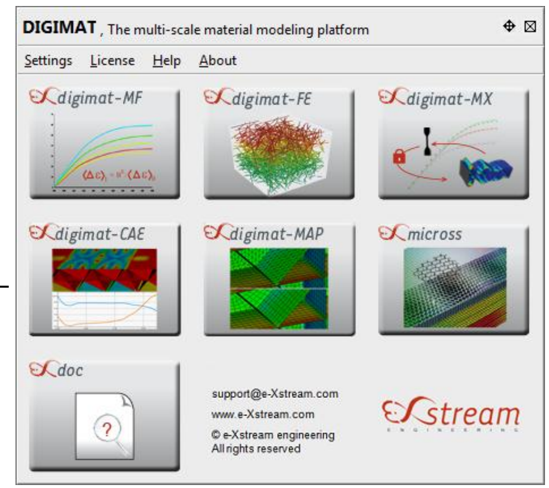


# e-Xstream engineering

- Integration is key to productivity

- Integrate simulation early in the development cycle
  - ✓ Save cost
  - ✓ Drive innovation
  - ✓ Improve time to market
  - ✓ Improve quality of products

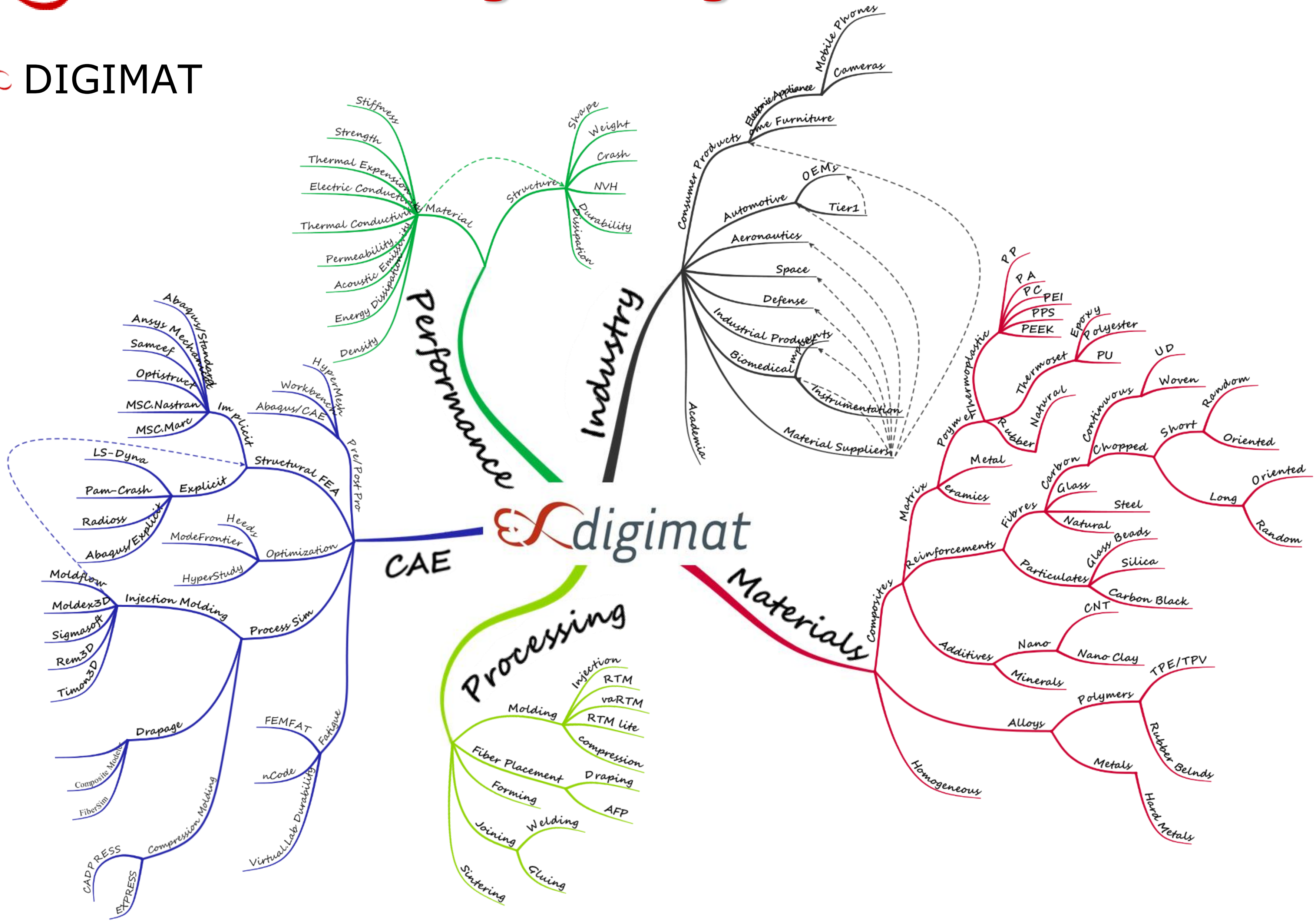



  - ✓ Integrate the solution in one platform
    - DIGIMAT is a fully consistent multi-scale simulation platform
  - ✓ Integrate the solution in the existing environment
    - DIGIMAT offers interfaces to all widely used FEM software

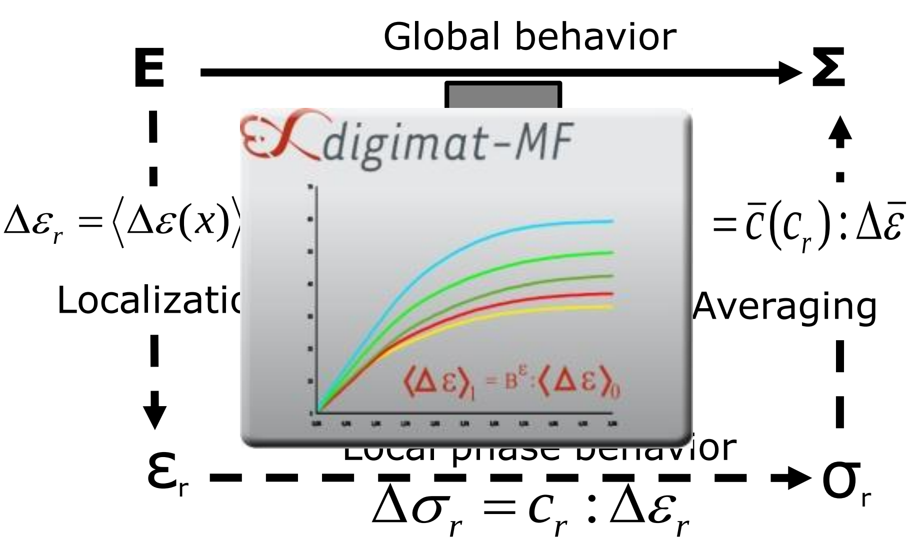
# e-Xstream engineering

## DIGIMAT



# DIGIMAT Technology

## Basic methodology




**Method**

Ellipsoidal inclusions

Uniformly distributed inclusions

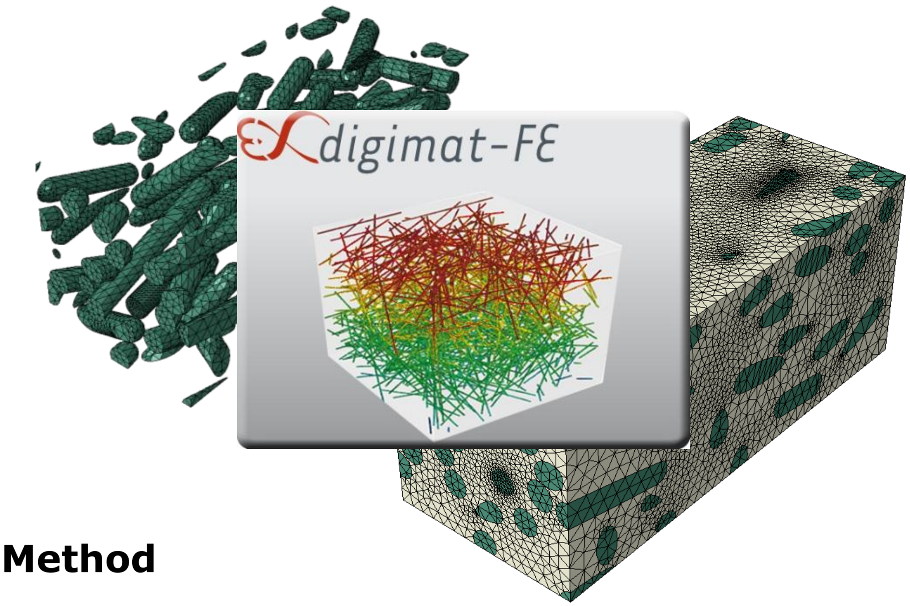
Average per phase (micro) results

**Benefits**

Fast model preparation/solution

Fully coupled multi-scale analyses

Nonlinear material properties




**Method**

RVE generation

FE model (mesh optimization, CPU…)

Uncoupled multi-scale analyses

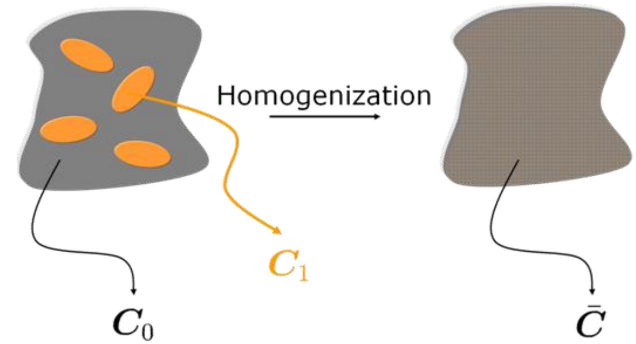
**Benefits**

Accurate predictions at the micro scale

Complex inclusion shapes (non ellipsoidal)

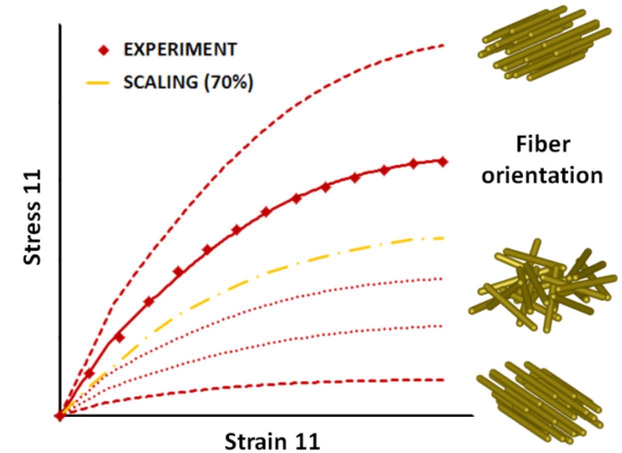
Explicit modelling of clustering & percolation

# DIGIMAT Technology



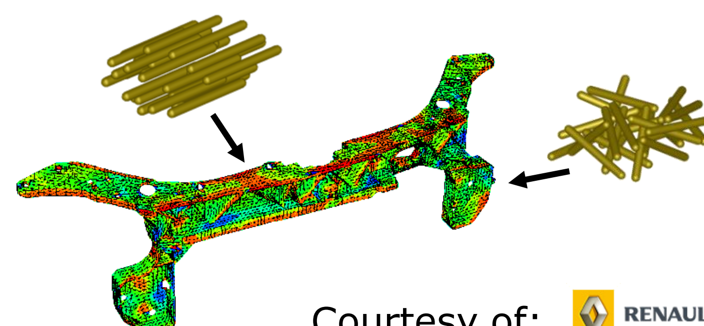

## digimat-MF

- ✓ Central technology for structural engineering
- ✓ Mean-field homogenization
  - The trick
    - Separation of matrix & filler properties
    - Added information about the material microstructure
  - The result
    - Material models sensitive to the microstructure




## digimat-CAE

- ✓ Interfaces to external FEA software
  - To read in microstructure data
  - To connect the Digimat-MF material description to FE solvers



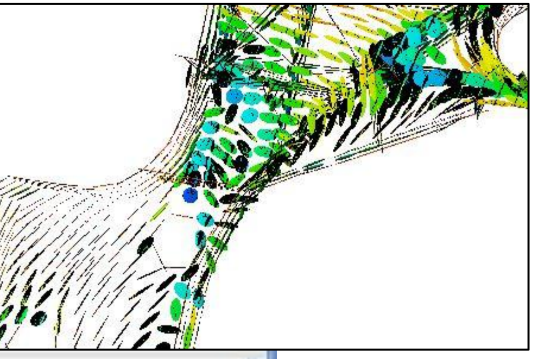
Courtesy of: RENAULT

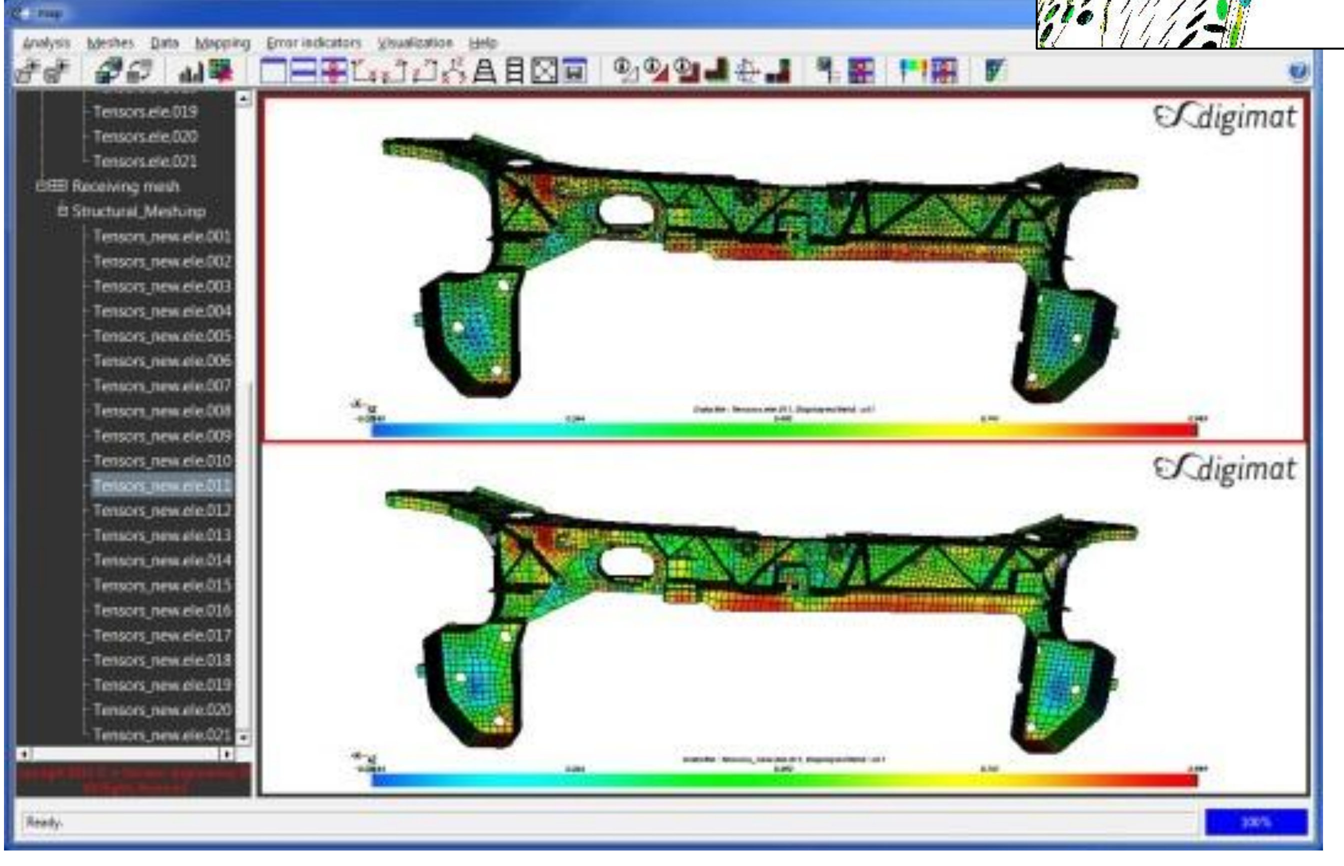
# DIGIMAT Technology

## digimat-MAP

- ✓ Mapping software
  - To transfer data between dissimilar meshes

*Local fiber orientations*



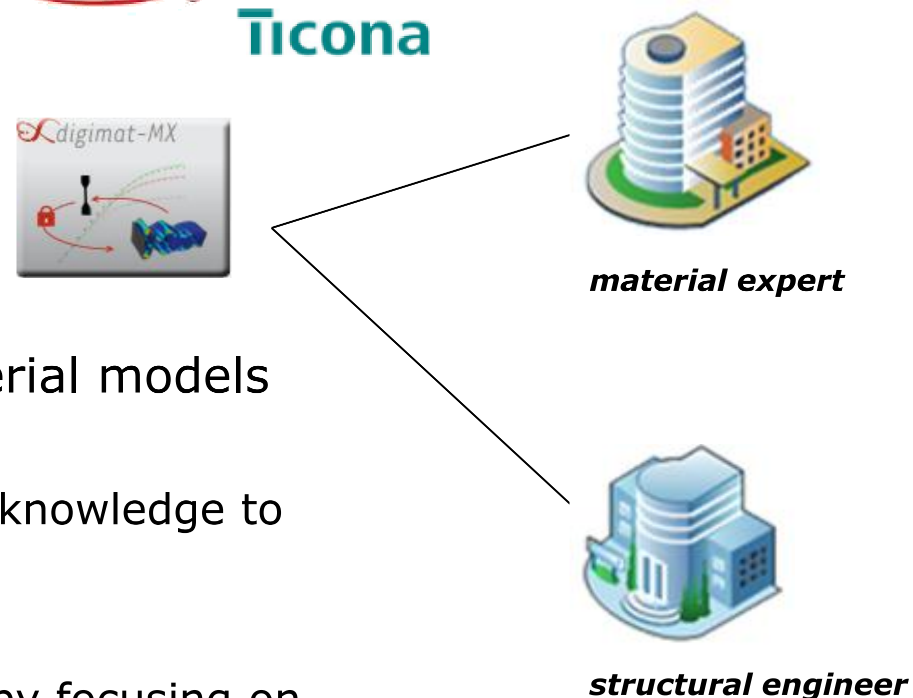


# DIGIMAT Technology

## digimat-MX

✓ Material eXchange platform

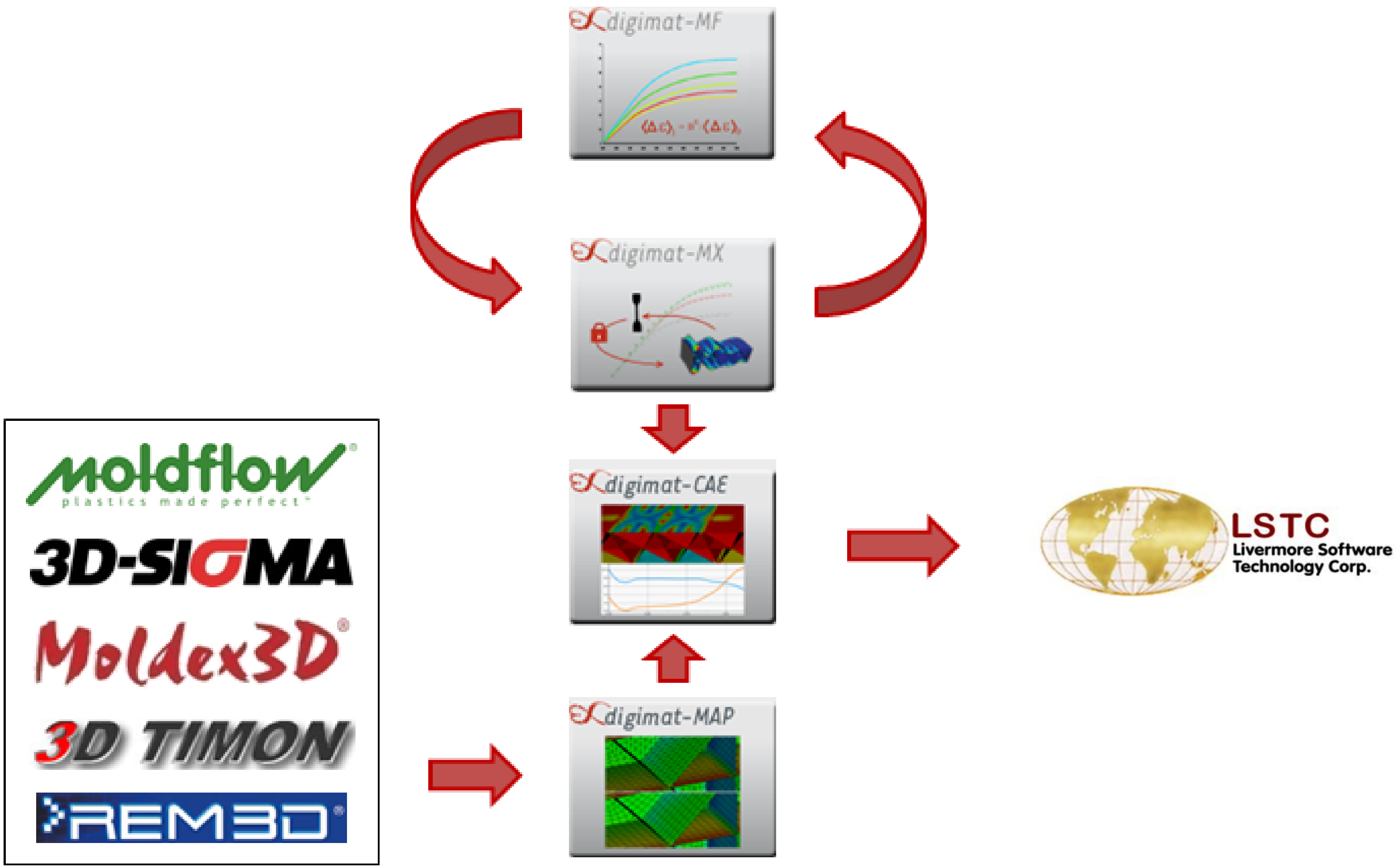



✓ Exchange of DIGIMAT material models

- Material experts offer their knowledge to the structural engineer
- Structural engineers profit by focusing on their core objectives

# DIGIMAT Applications

- DIGIMAT for injection molded plastic parts

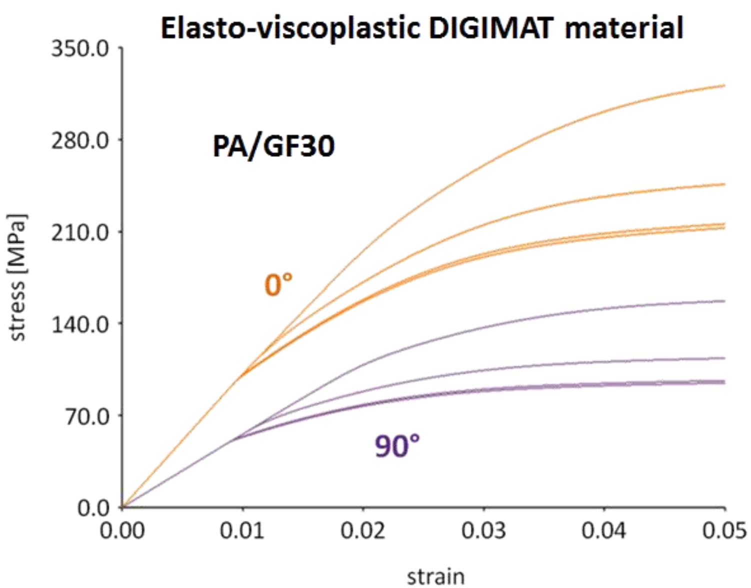


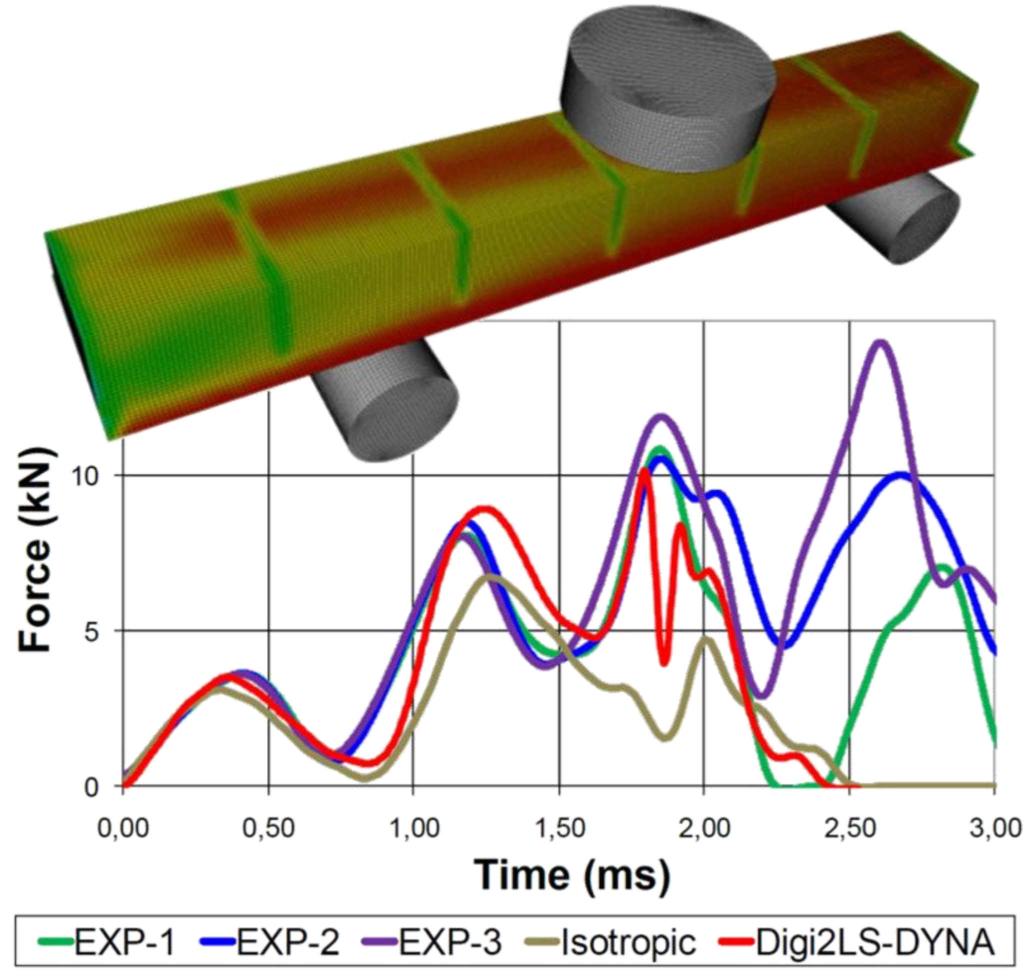

*Injection molding*

# DIGIMAT Applications

- Short fiber reinforced plastics
  - ✓ Impact on a beam

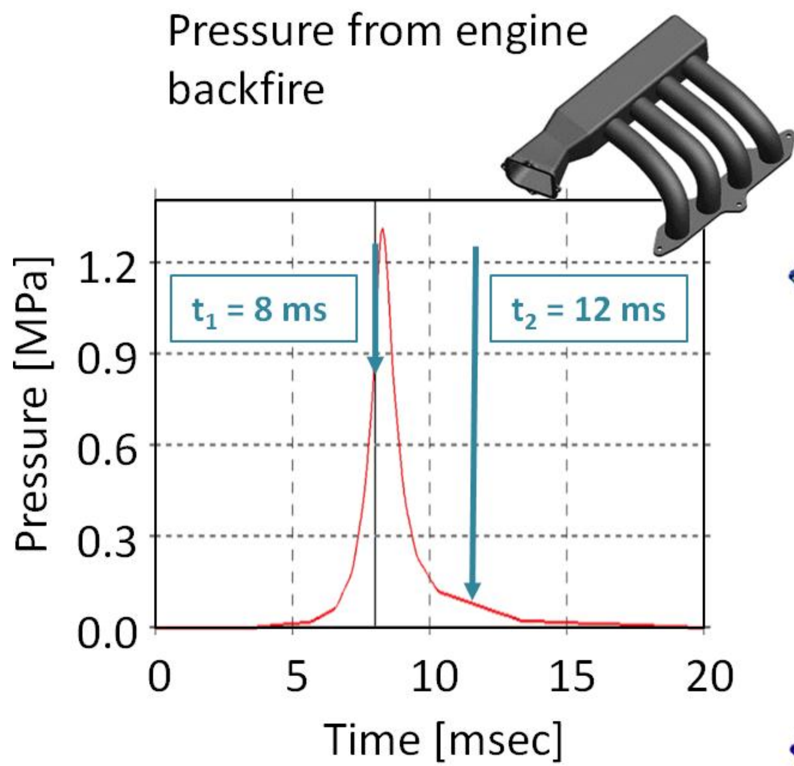
LSTC
Livermore Software Technology Corp.

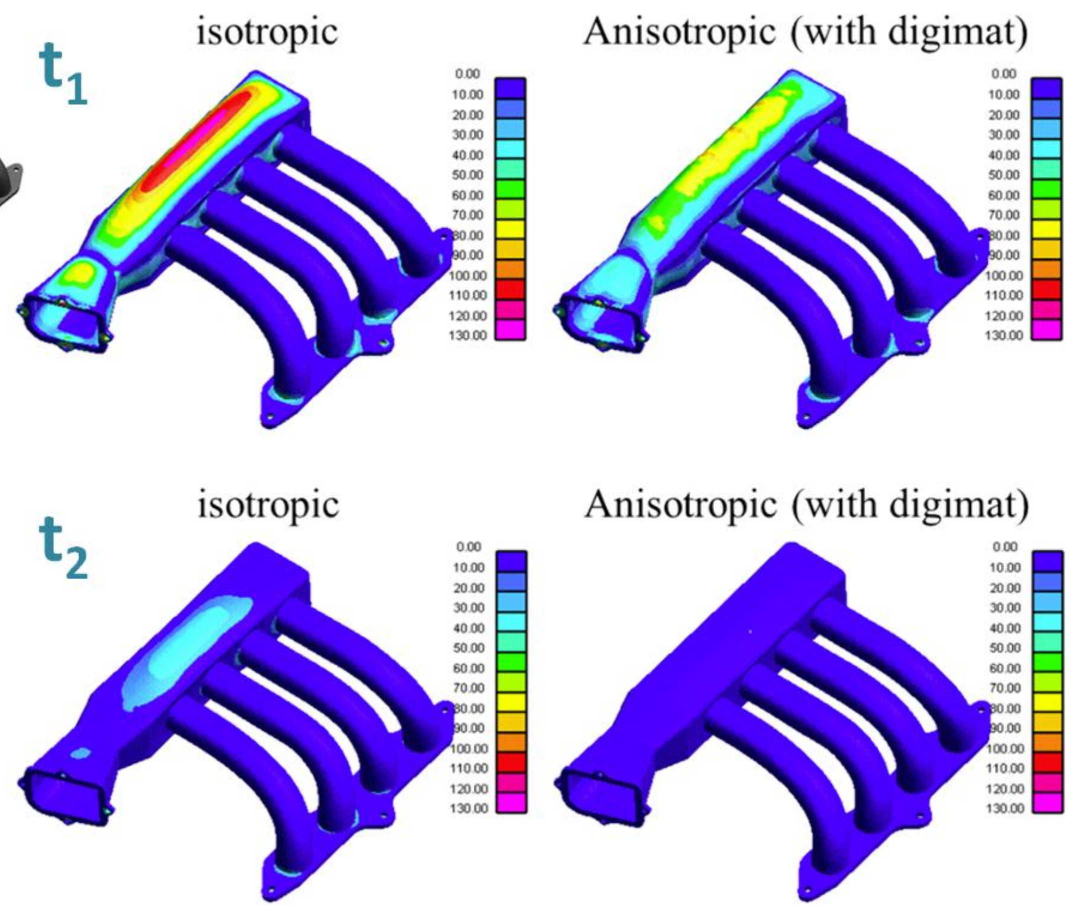


# DIGIMAT Applications

- Short fiber reinforced plastics
  - ✓ Air intake manifold



# Robustness & CPU

- DIGIMAT convergence schemes

  - ✓ Two sources for improved robustness
    - Mori-Tanaka convergence scheme
    - Scheme enforcing plane stress condition for shell elements

  - ✓ Initiative for 4.1.2 based on 7 customer models
    - Small and medium size
    - EP / TEP / EVP
    - Shell & solid

  - ✓ Improvements
    - 5 out of 7 models run up to finalization (small & medium size)
    - 2 out of 7 models show major improvements (medium size)

# Robustness & CPU

- DIGIMAT convergence schemes

  ✓ Comparison of CPU between 4.1.1 and 4.1.2

  - Shell [EP] 4 – 22 % improvement in CPU (explicit)
  - Shell [EVP] 17 – 45 % improvement in CPU (explicit)
  - Solid [EVP] 0 % improvement in CPU (explicit)
  - Solid [TEP] 22 % improvement in CPU (implicit)

  ✓ Major improvements for shell elements & explicit solvers

  ✓ Using SUD is key for CPU time reduction

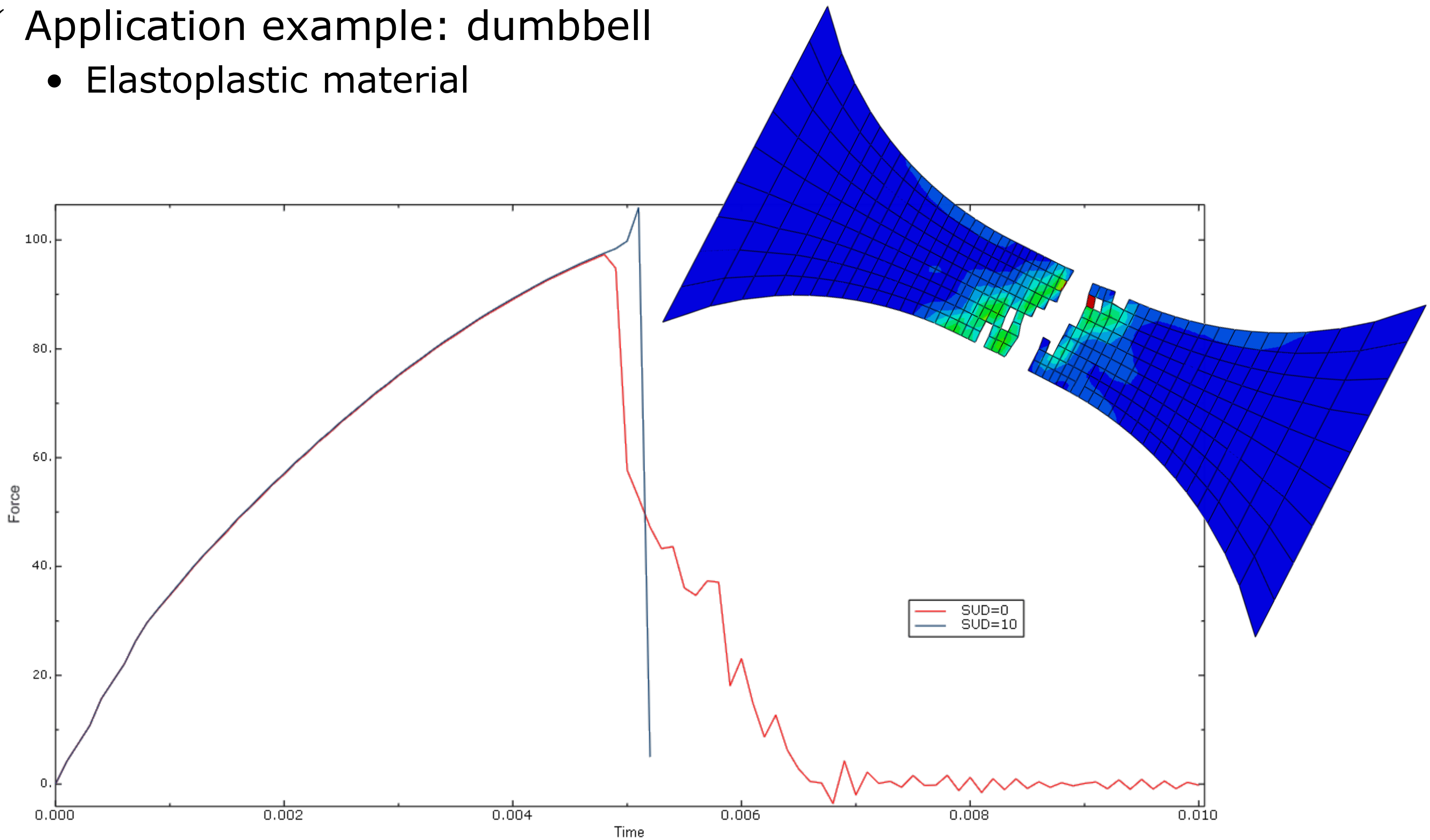
  - With SUD=2-10 about 60 – 90 % of computational time can be saved with respect to SUD = 0
  - Post failure has to be checked carefully

  ✓ Recommended approach using SUD today

  - Determine the *time of failure* in a quick pre-analysis (SUD>0)
  - Quasi-static load scenarios

# Robustness & CPU

- Recommended approach using SUD today
  - ✓ Application example: dumbbell
    - Elastoplastic material



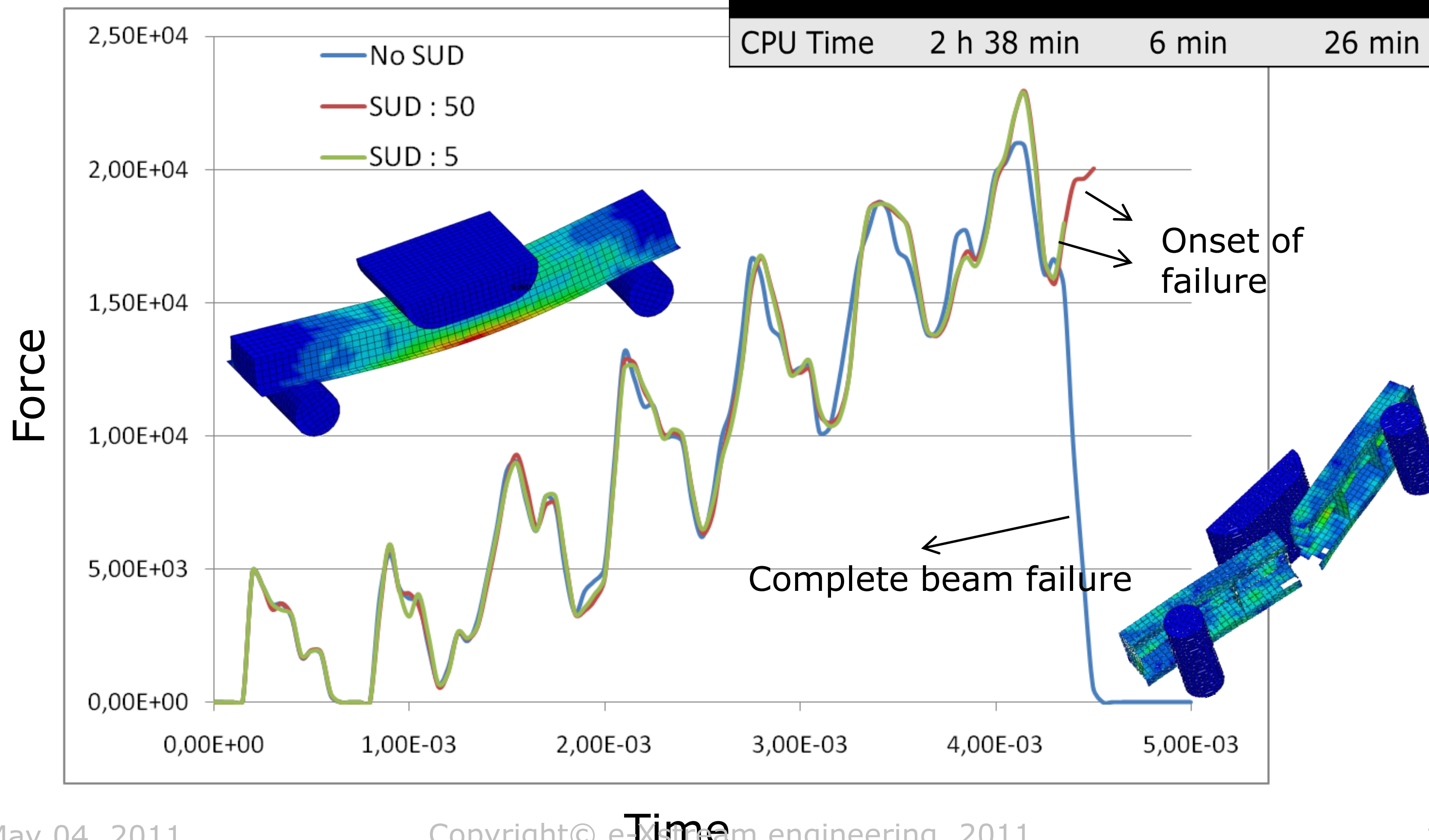
# Robustness & CPU

- Recommended approach using SUD today

  ✓ Application example: impact on a beam

  - Elasto-viscoplastic material

| | No SUD | SUD : 50 | SUD : 5 |
|---|---|---|---|
| CPU Time | 2 h 38 min | 6 min | 26 min |

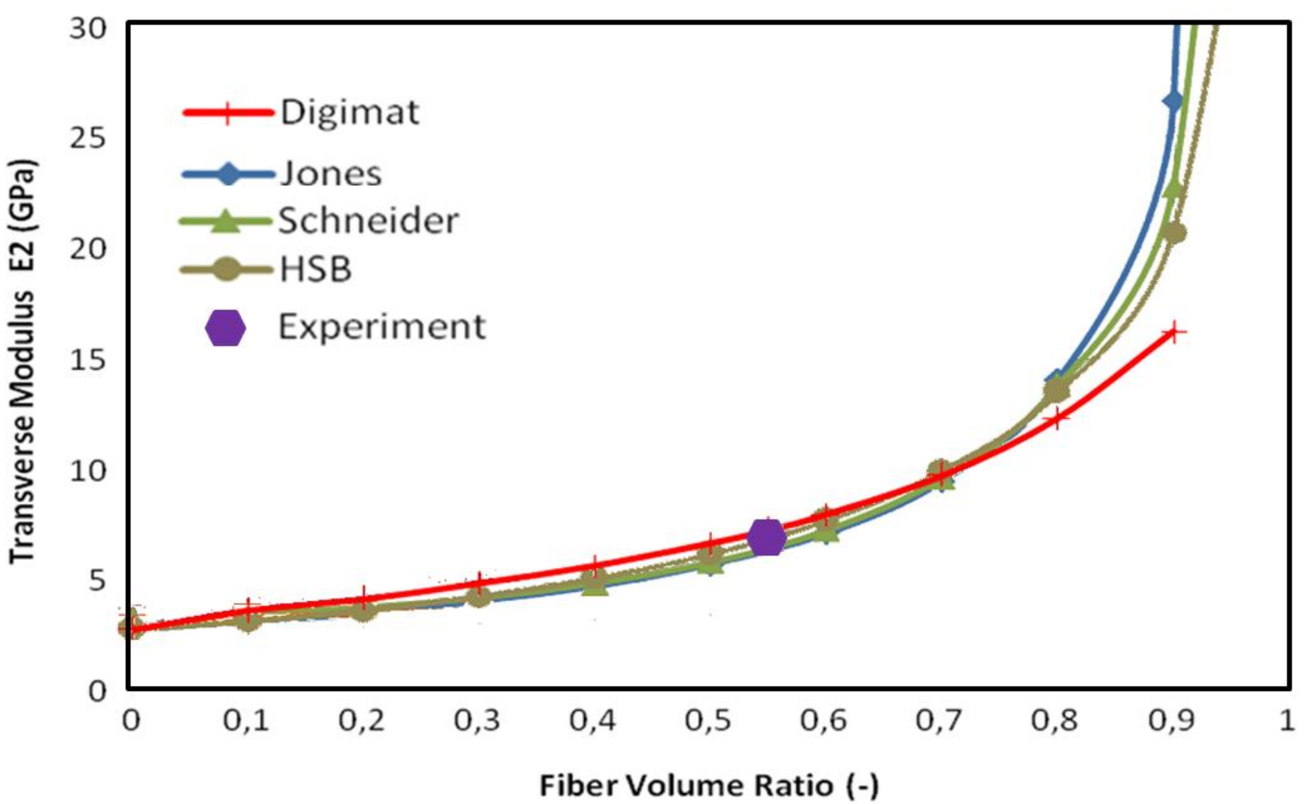


# Future Developments

- Significant CPU reduction also for SUD = 0
  - ✓ Available with DIGMAT 4.2.1
    - As first implementation the method allowing for the maximum speedup is under current work
  - ✓ Change in material description
    - Coarsening of details
    - SpeedUp of Calculation
  - ✓ The user will be able to decide between speed of the analysis and accuracy of the results
- Digimat-CAE/LS-DYNA(Implicit)
  - ✓ Available with DIGMAT 4.2.1
    - A first implementation exists and is under current testing

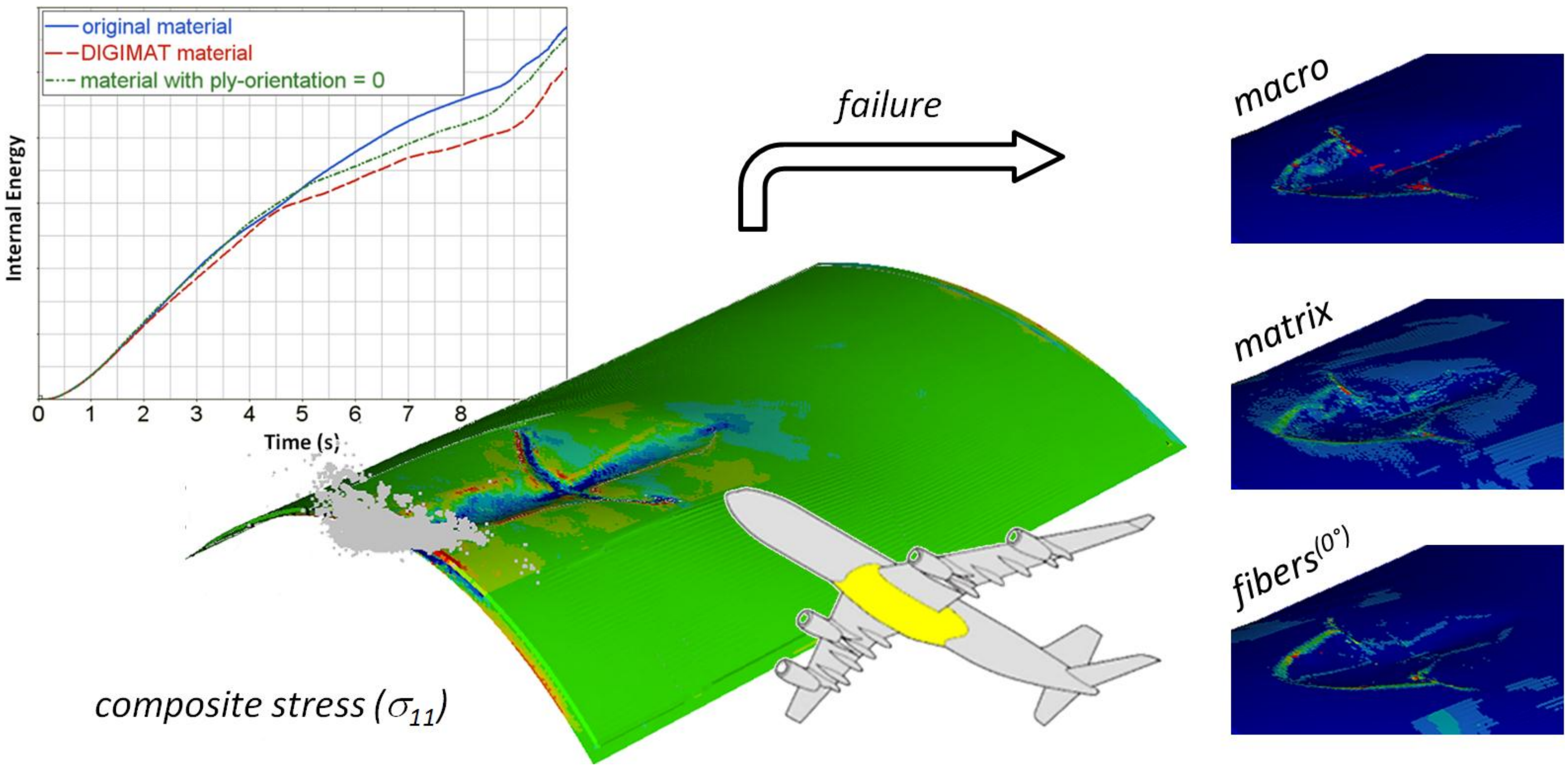
# Future Developments

- Drapage & Continuous fiber reinforcement
  - ✓ M-T Homogenization well suited for prediction of material behavior
  - ✓ Glass fibers, Carbon fibers
  - ✓ Nonlinear matrix properties (+strain rate dependency, temperature...)



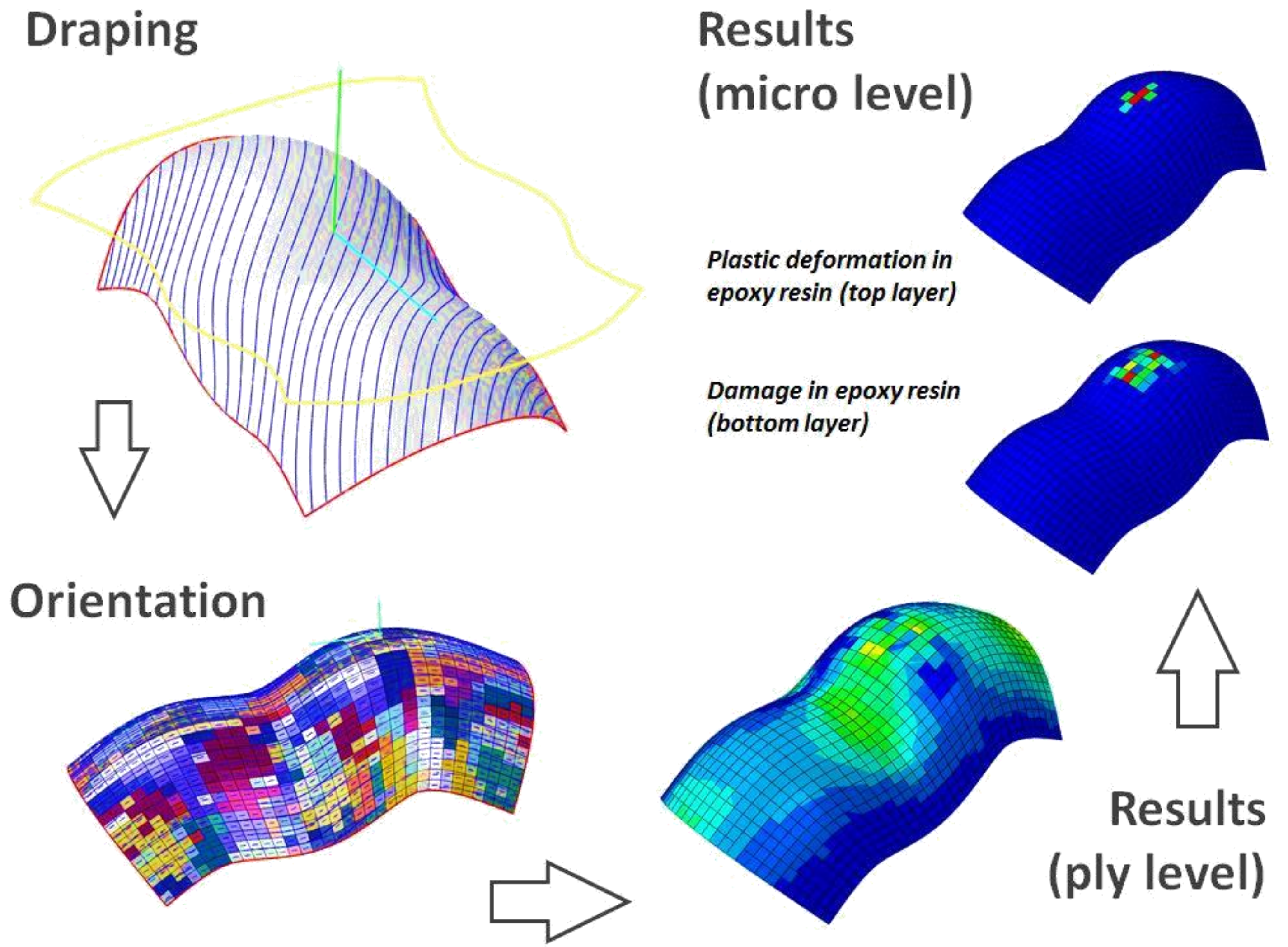
# Future Developments

- Continuous fiber reinforced plastics
  - ✓ Bird strike on an airplane underbelly fairing



# Future Developments

- Interfaces to drapage analysis



# Summary

- e-Xstream engineering: 100% focused on material modeling

- DIGIMAT
  - ✓ Unique nonlinear multi-scale material and structure modeling platform

- Injection molded plastic parts
  - ✓ Well established application basis
  - ✓ Further improvements in CPU & robustness

- DIGIMAT Future (2011/2012)
  - ✓ LS-DYNA Implicit
  - ✓ CPU Improvements
  - ✓ UD composite parts with interfaces to draping