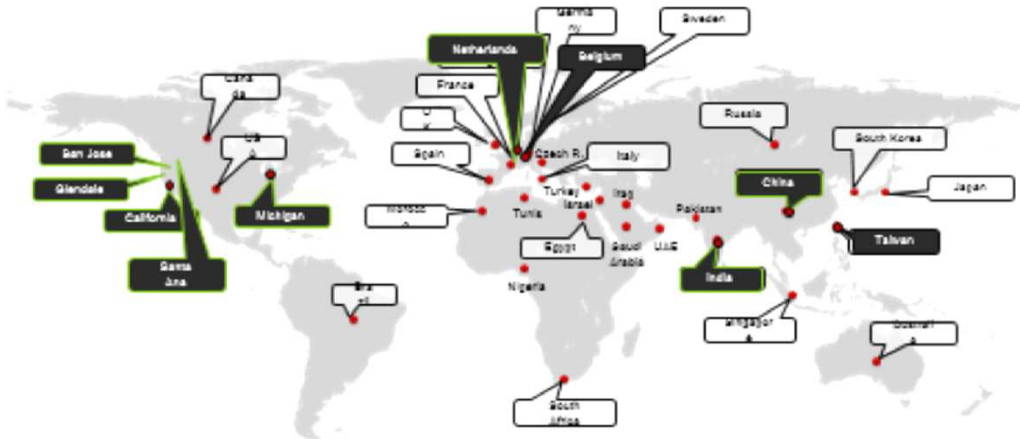
Moldex3D

Moldex3D Micromechanics → Digimat

Tecnologie di simulazione delle plastiche caricate
MSC/Digimat
Luca Sironi

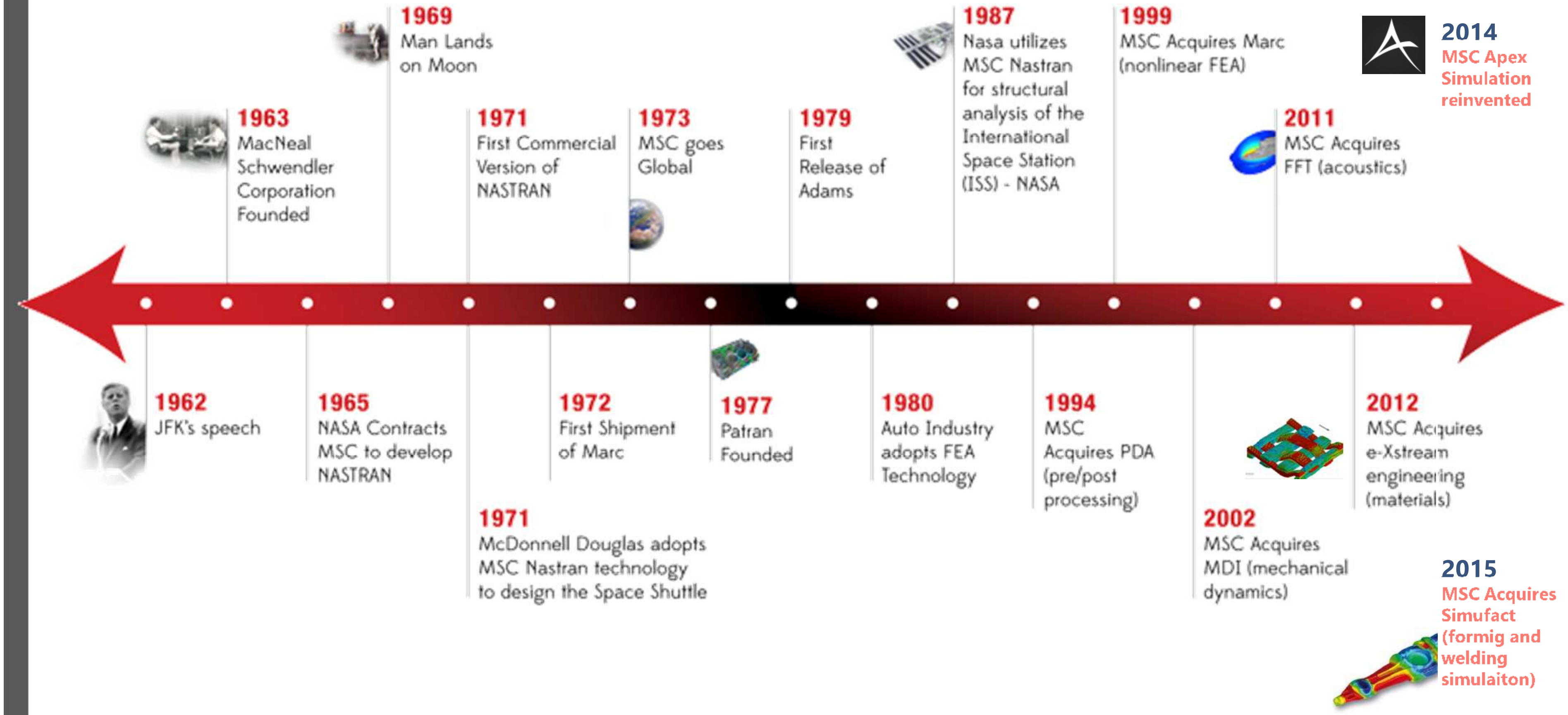
Digimat MSC Software



- **~1,200 Employees**
- **20** Countries
- R&D in **6** countries

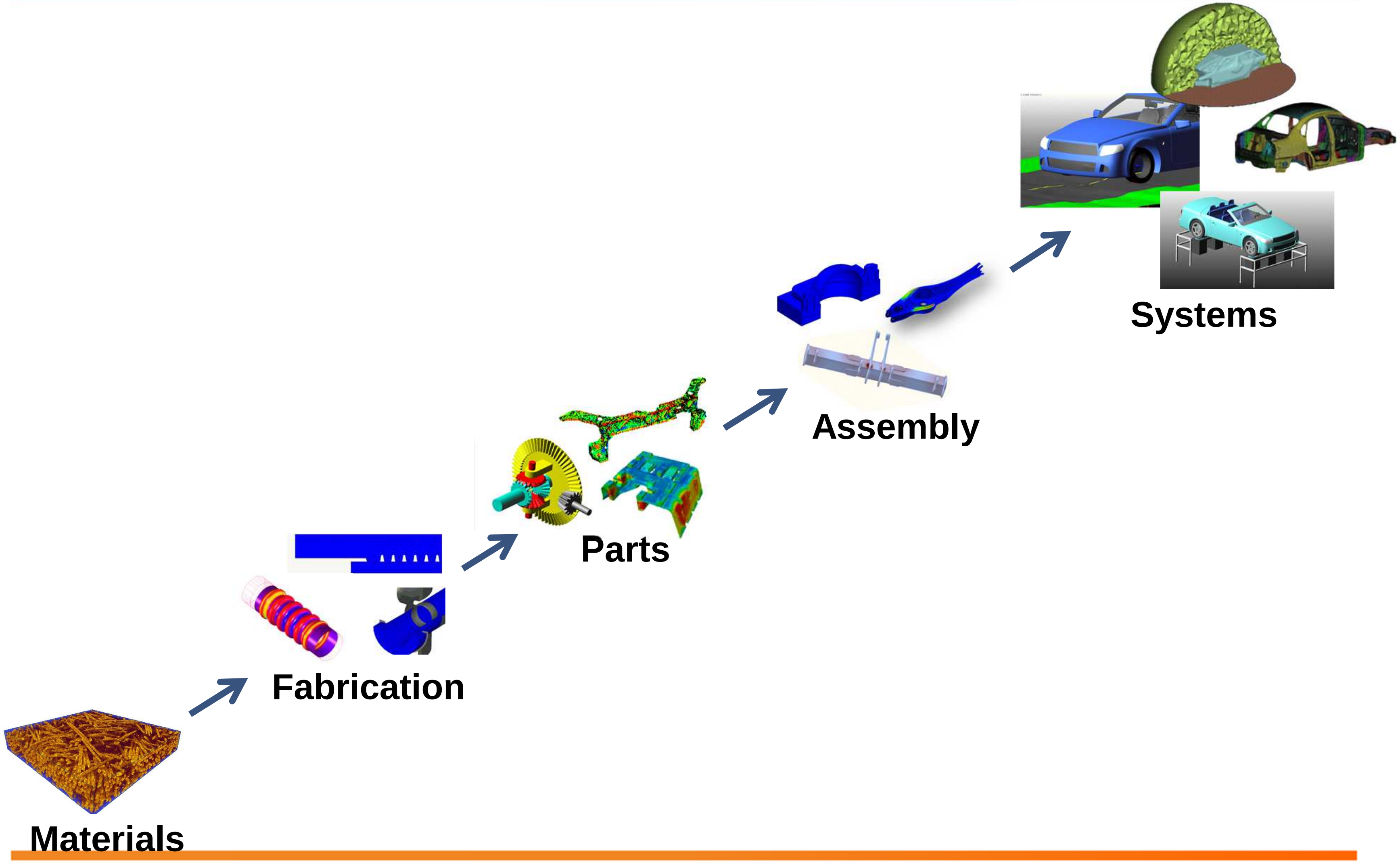
MSC Software

Experience in Simulation for over 50 years



MSC Strategy

Simulating the Complete Product Engineering Process



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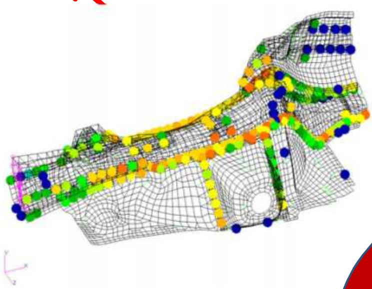
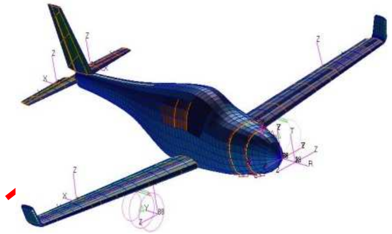
MSC Nastran

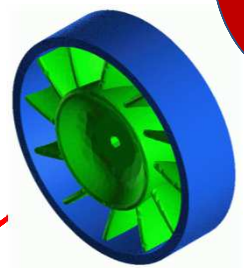
Durability

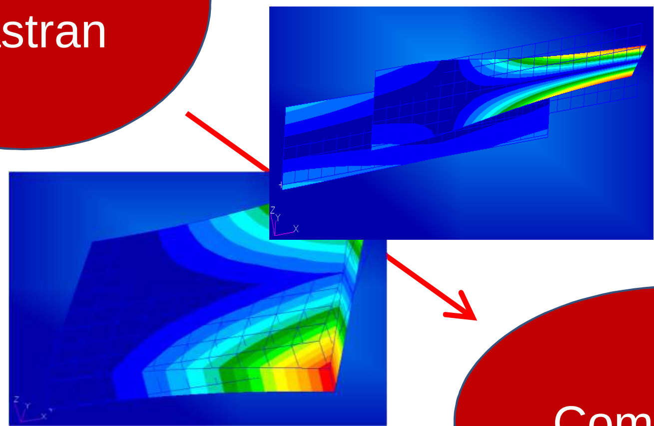
Dynamics





MSC Nastran





Contact

Composites

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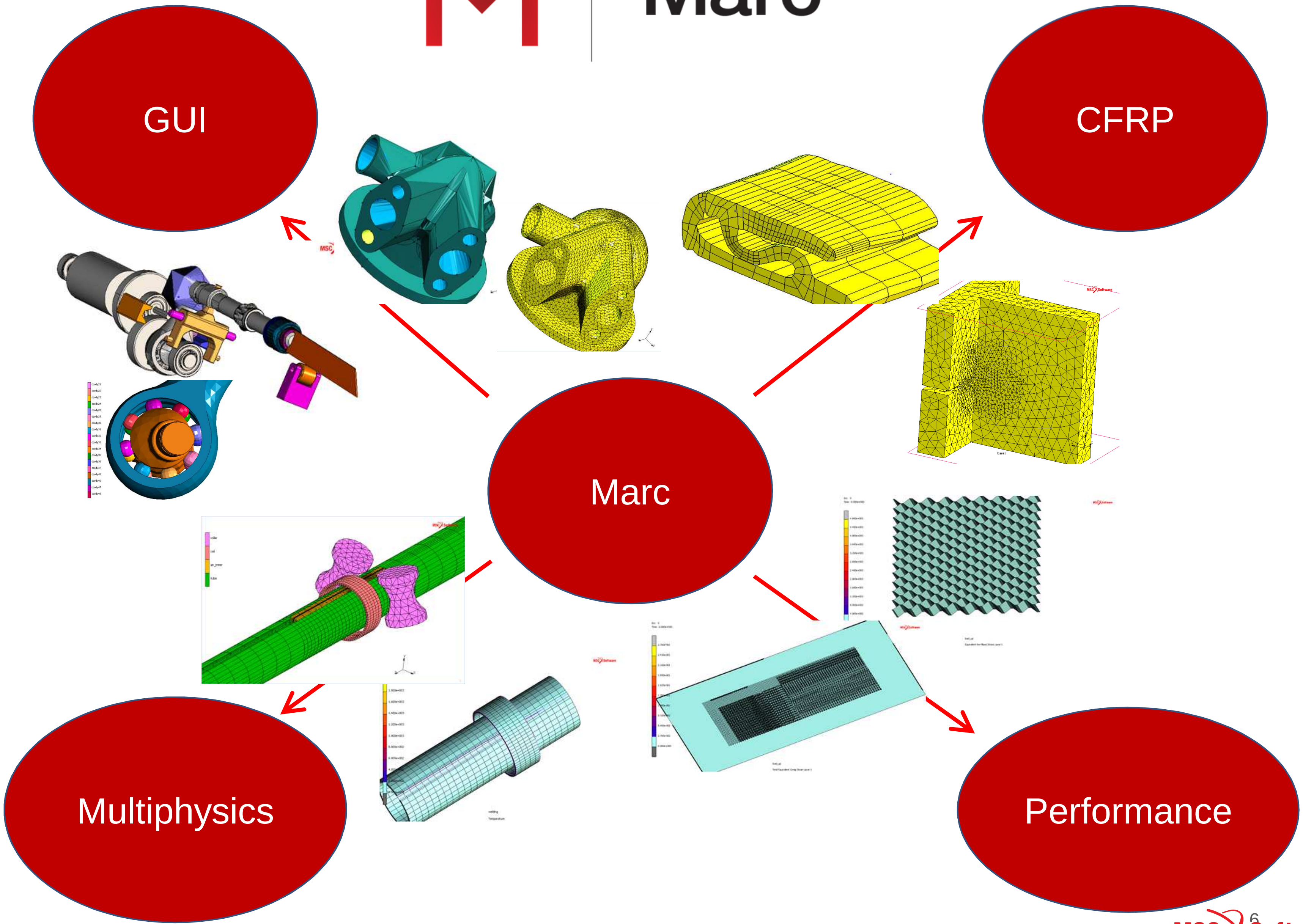
Marc®



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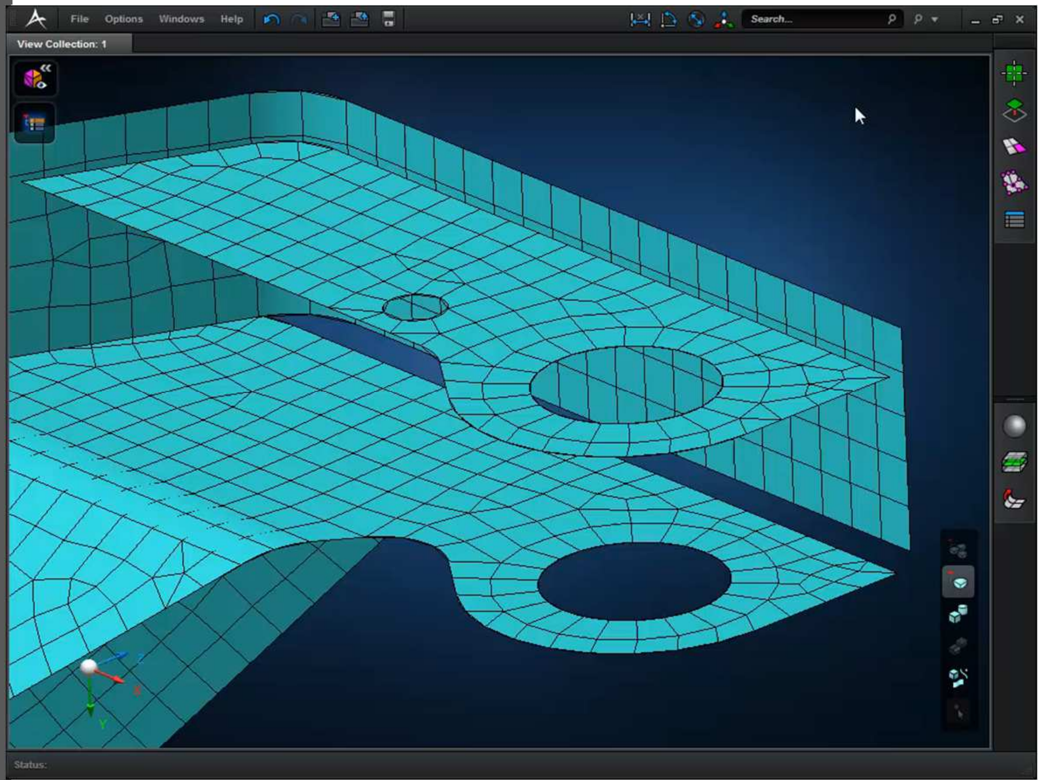
MSC Apex

Moldex3D

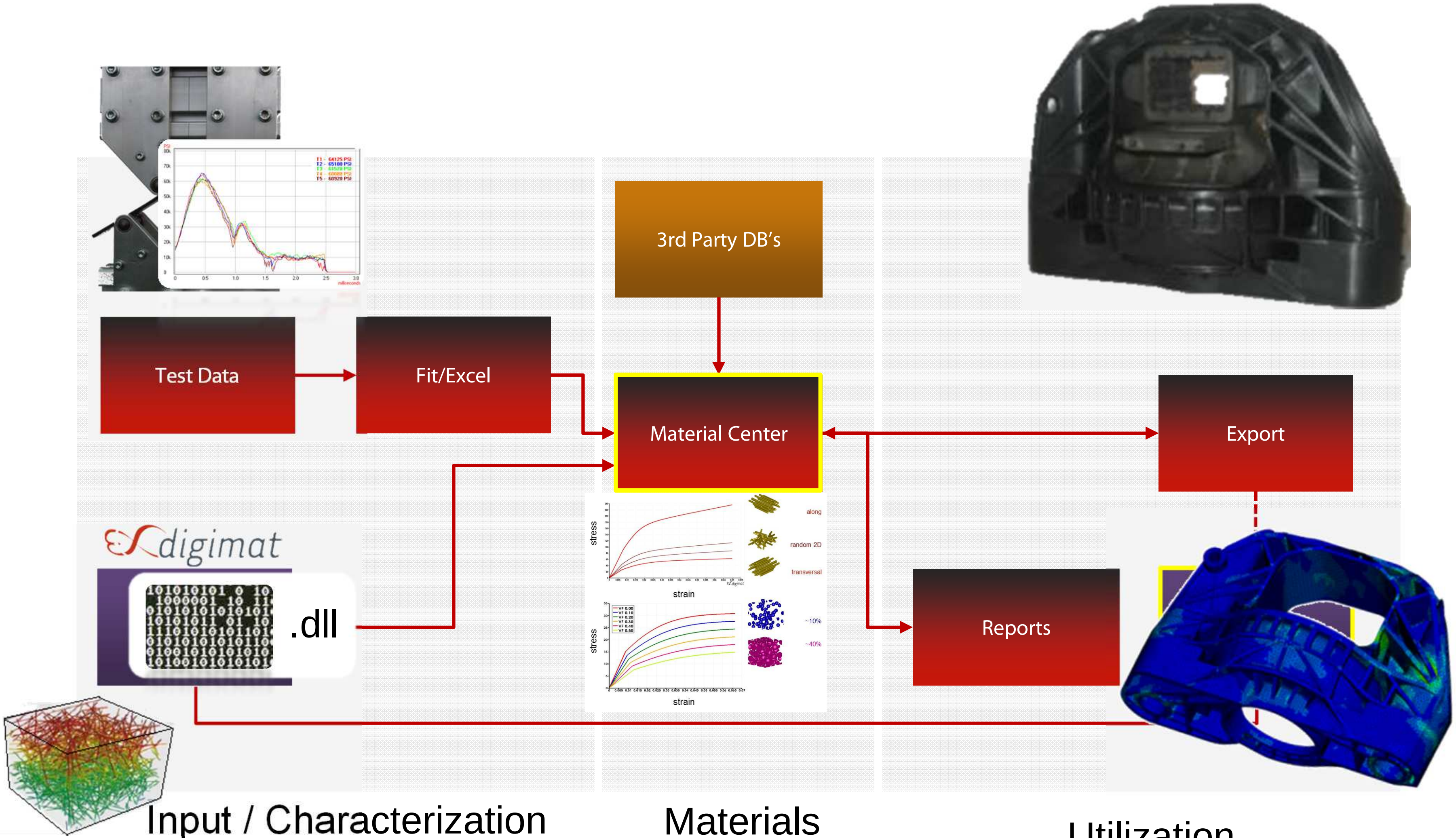
CAE Specific Direct Modeling and Meshing



Apex Approach:

- **Geometry edits done in moments**
  - **Surface Direct Modeling and Meshing, vertex/edge drag, mid-surfacing, surface extend, surface split**
  - **Solid Direct Modeling and Meshing, push/pull, geometry repair**
- **Meshing**
  - **1D, 2D, and 3D, Feature Base Meshing**

The Growing Importance of Materials



Input / Characterization

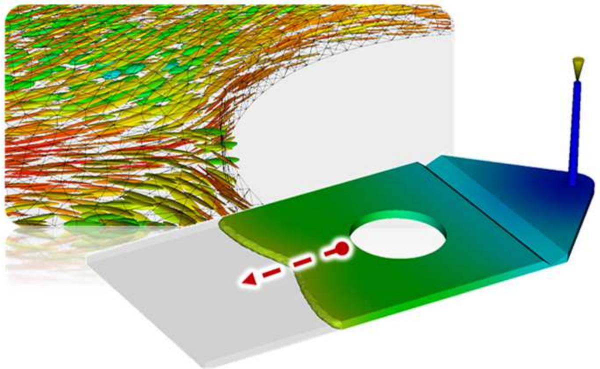
Materials Management

Utilization

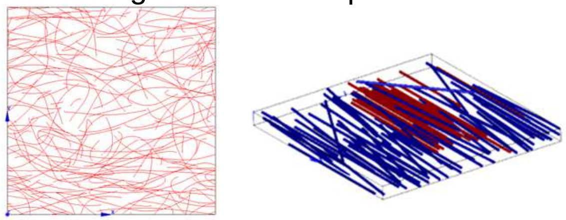
Multiscale Composite Modeling Platform

> A unique solution to simulate multiple types of materials

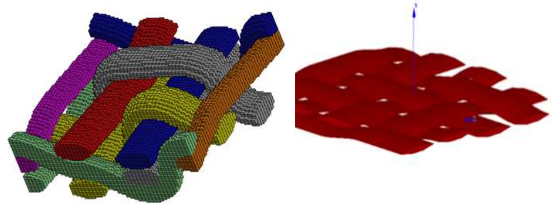
Short Fiber Reinforced Plastics



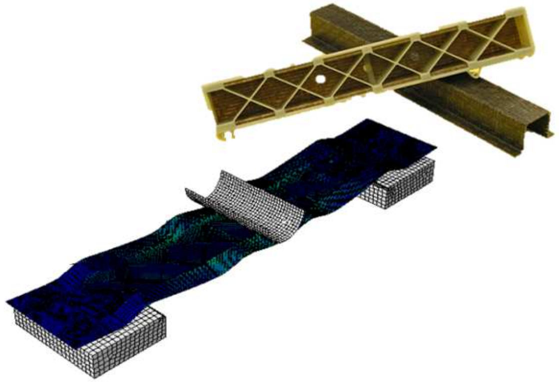
Long Fiber Thermoplastics



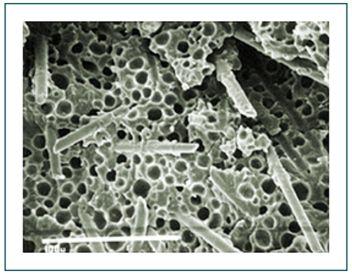
Woven & Braided Composites



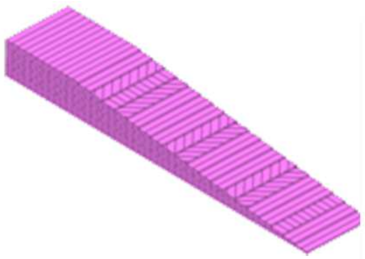
Hybrid Composites



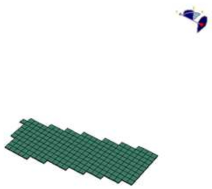
Mucell



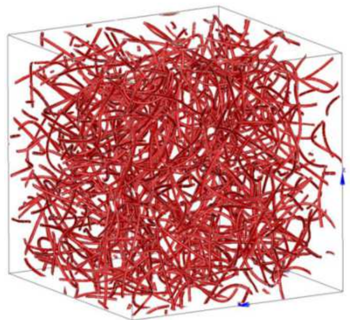
Unidirectional fiber

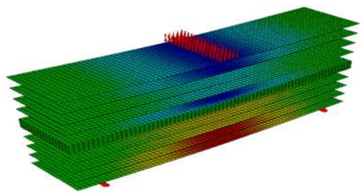


DFC



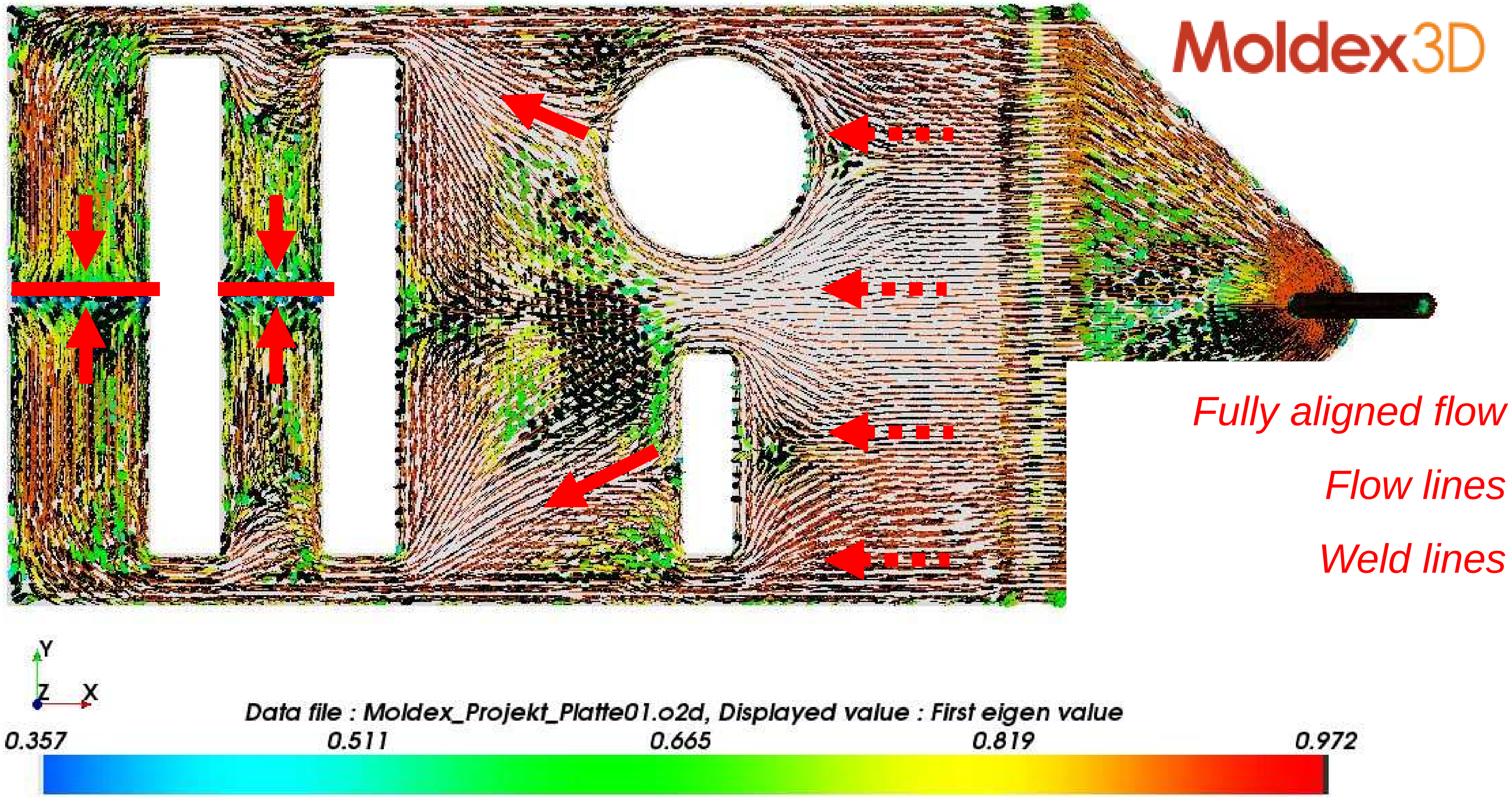
Carbon Nanotubes





sandwich panel

Motivation for Multi-Scale Modeling
Reinforced Plastics: Fiber Orientation



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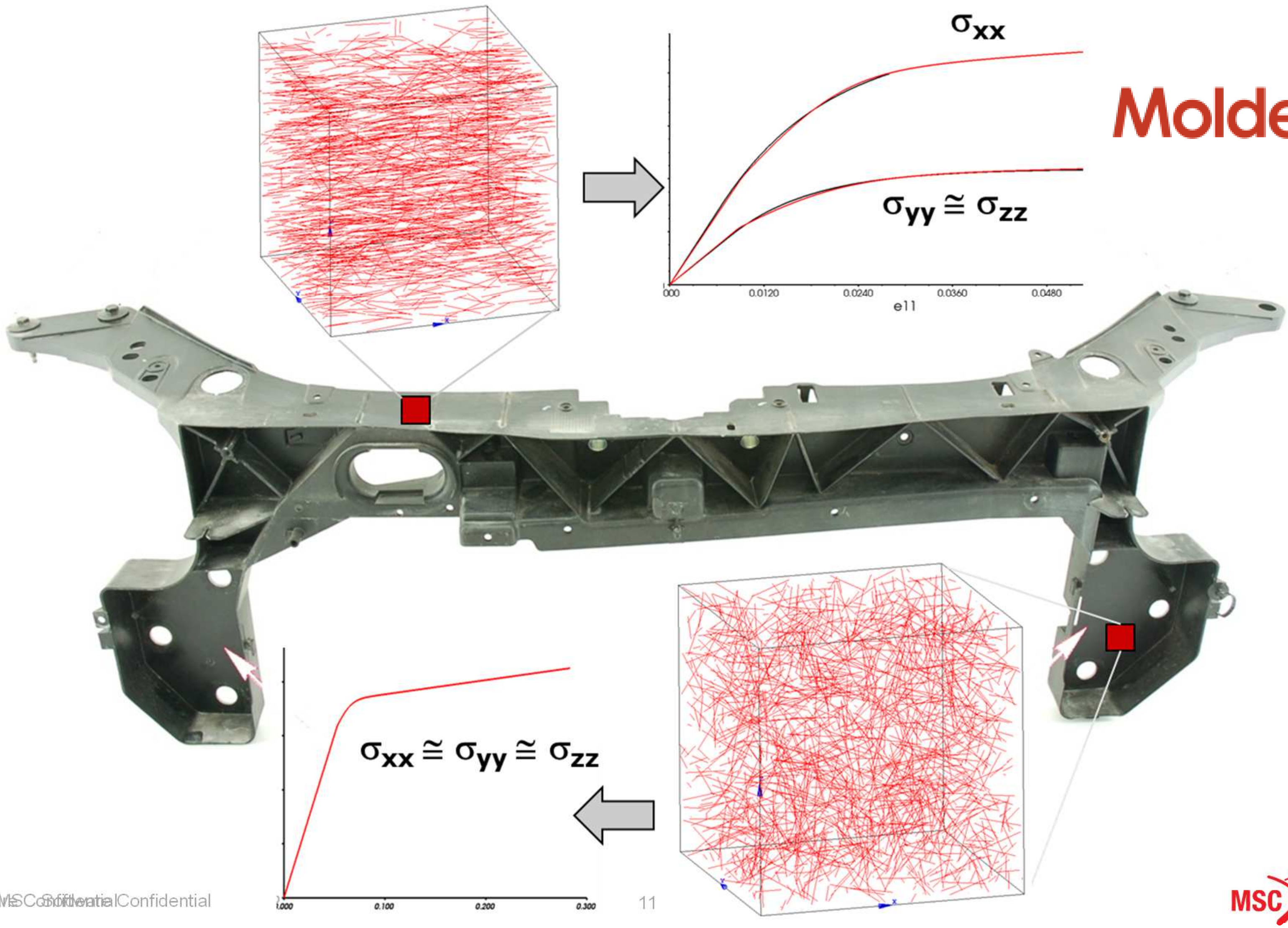
Motivation for Multi-Scale Modeling
Reinforced Plastics: Fiber Orientation



Moldex3D

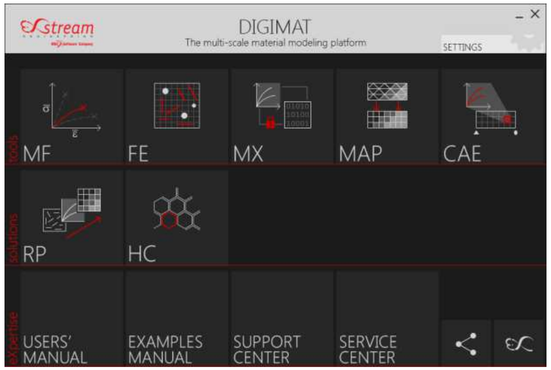
Motivation for Multi-Scale Modeling
Reinforced Plastics: DIGIMAT

> The *mechanical performance of the part* depends on
  - **the orientation of the fibers relative to the loading type and direction.**
  - **the non-linear, strain rate dependent thermo-mechanical behavior of the resin**

> *Fiber orientation* in the part is governed by the manufacturing process.

> **Accurate prediction requires a solution allowing to capture the effect of the fiber orientation on the performance of the resin.**

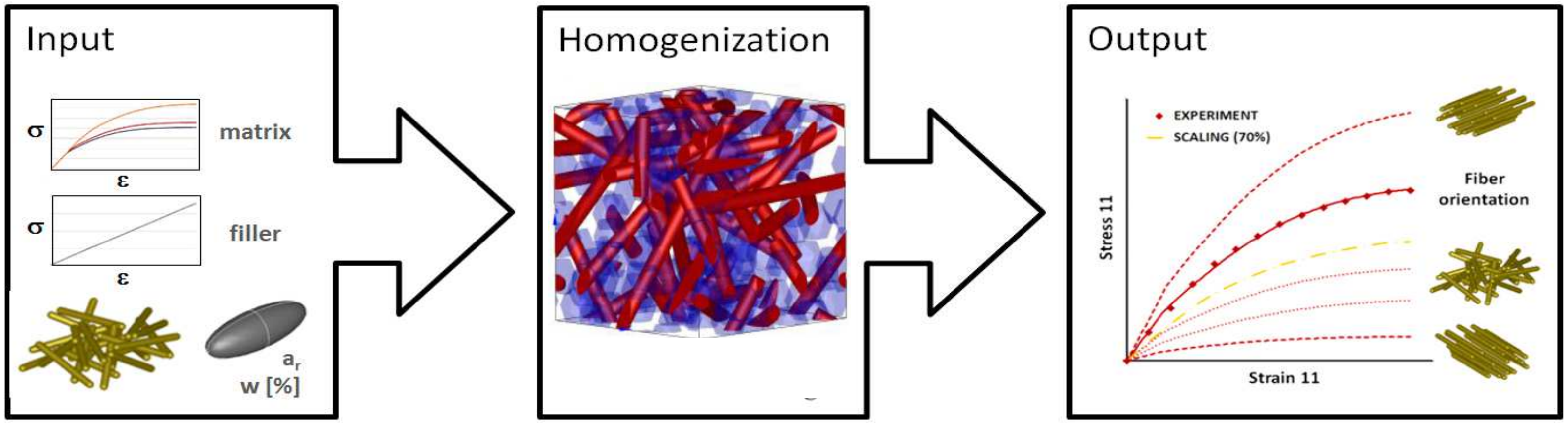
DIGIMAT



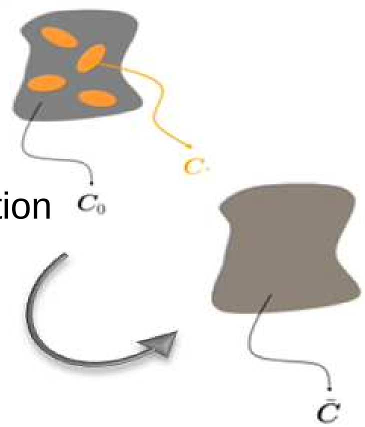
Digimat™

Multi-Scale Modeling Technology

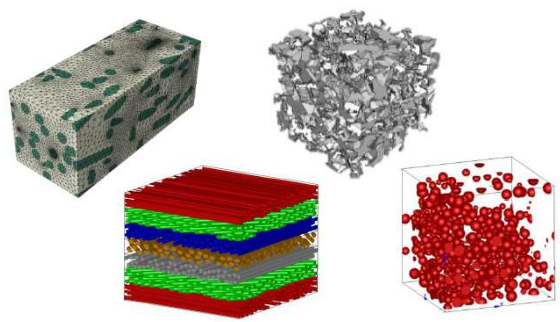
> **Prediction of Non-Linear Anisotropic Macroscopic behavior from constituents properties and microstructure**



- ✓ Semi-Analytical method
  - ✓ Mean-Field homogenization
  - Eshelby based
  - Mori-Tanaka
  - Double inclusion
  - Fast model preparation/solution

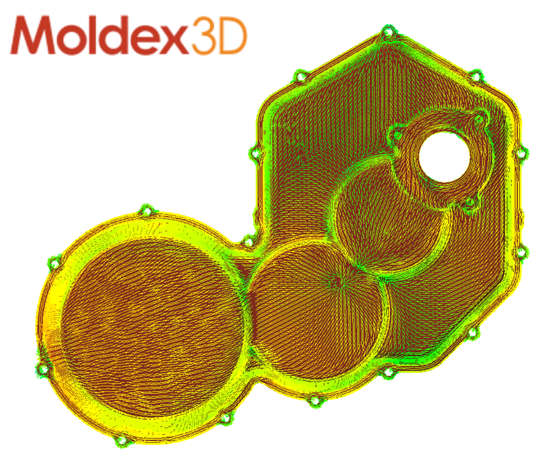


- ✓ RVE Direct Analysis method
  - ✓ Full-Field homogenization
  - Build the accurate RVE geometry
  - Compute it by FEM directly

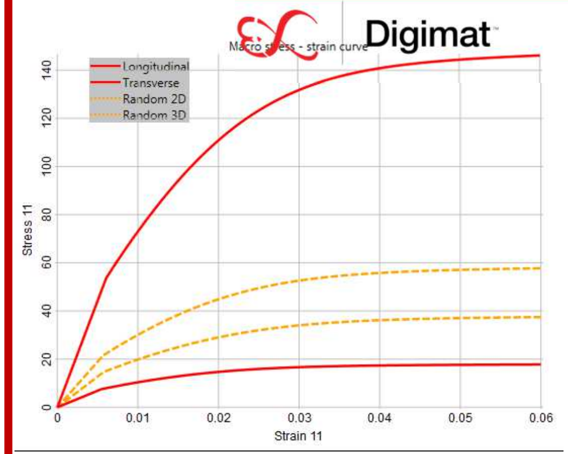


Multi-Scale Modeling Technology

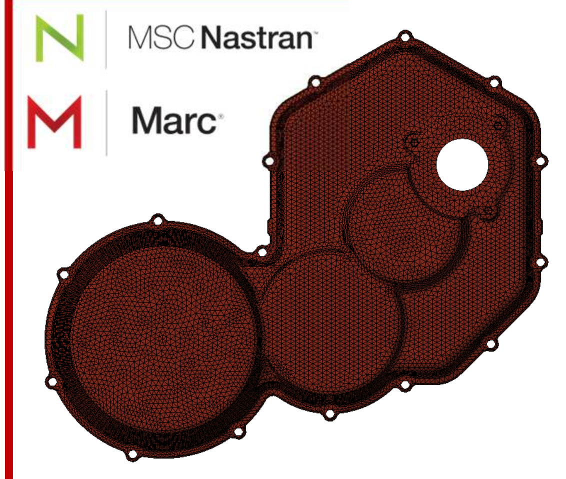
Fiber orientation



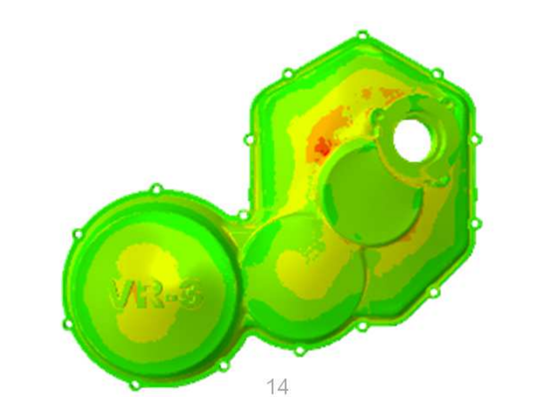
Digimat Material Model



Structural FEM

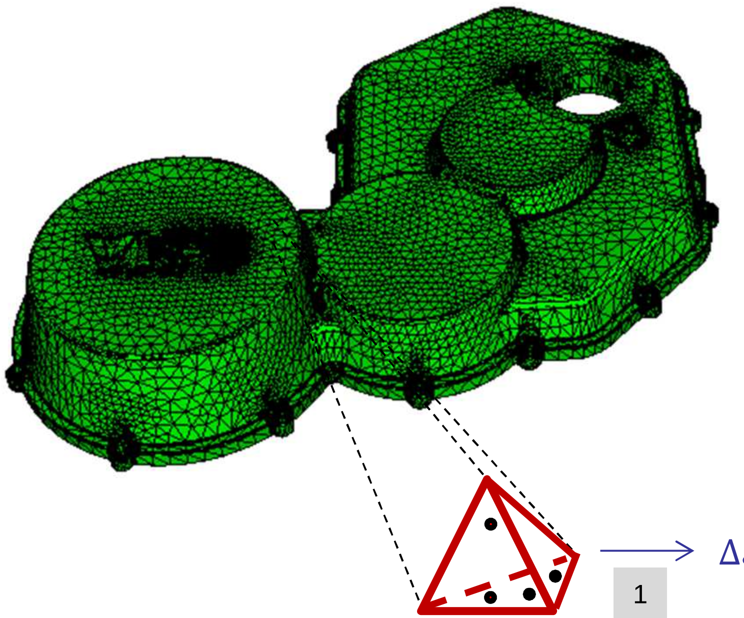


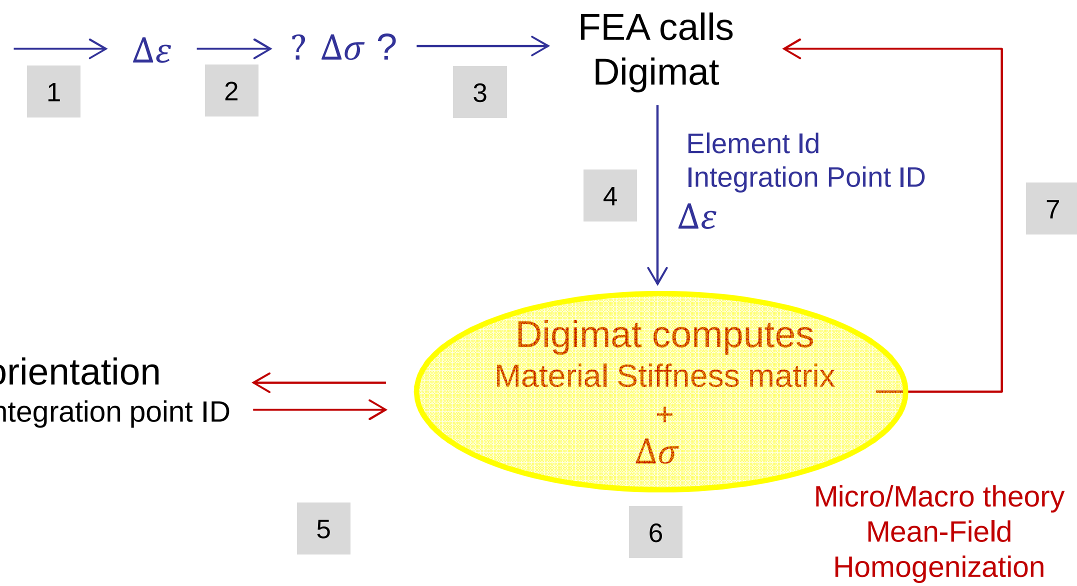
Digimat to FEA (local anisotropic)



Multi-Scale Modeling Technology

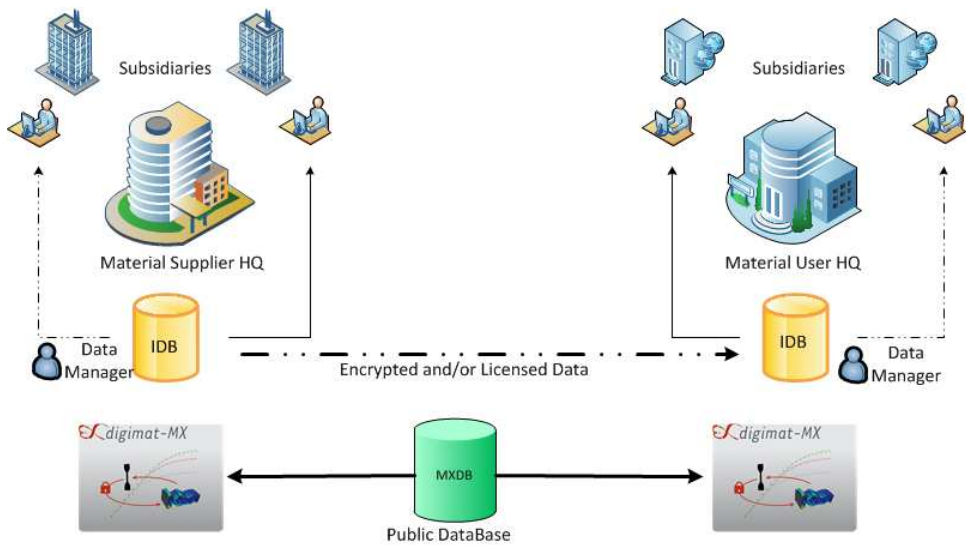
This loop is repeated for every element and increment of the analysis



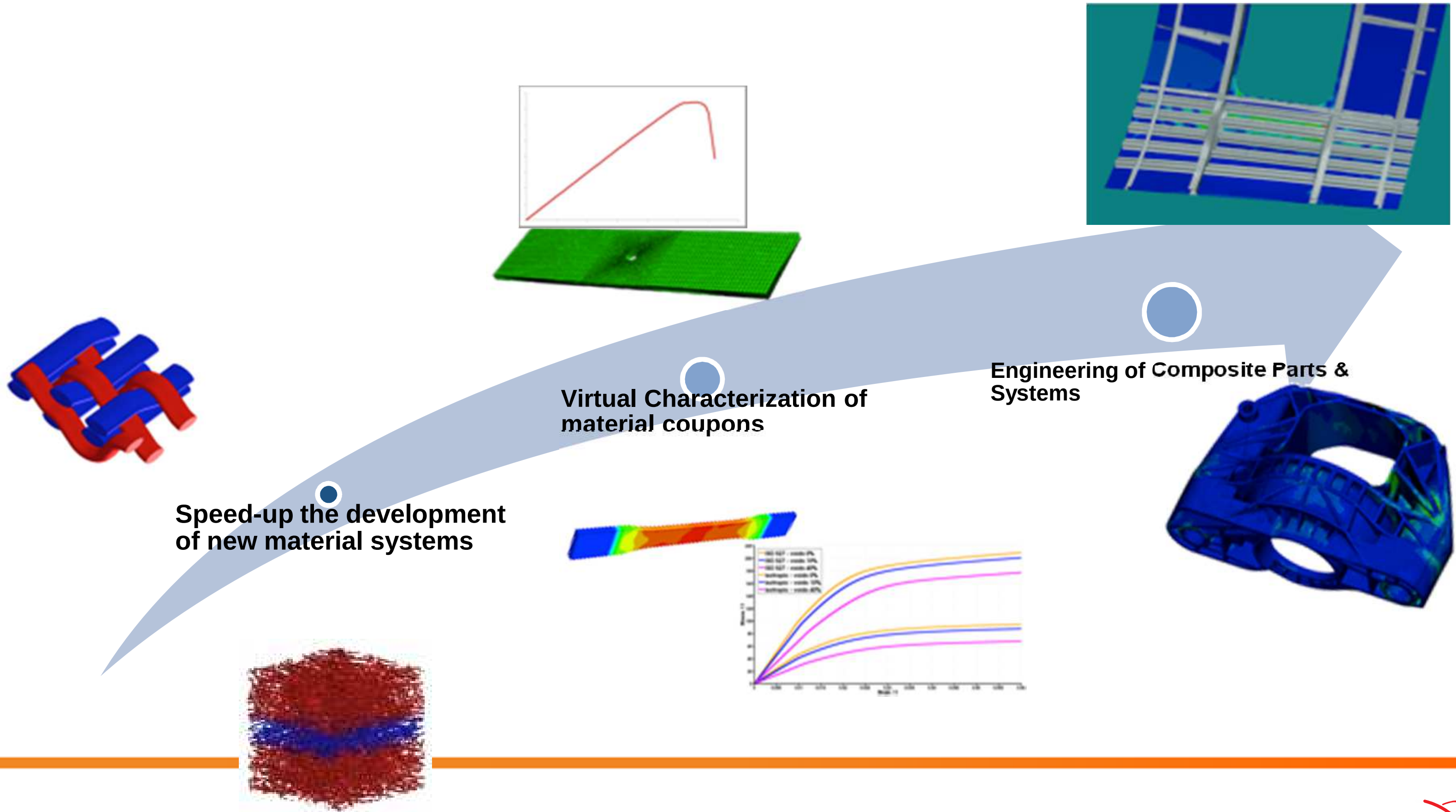


Multi-Scale Modeling Technology
Material eXchange Platform

> Best in market public database directly filled by the most important material suppliers in the plastic industry



From Material Microstructure to End Product Performance



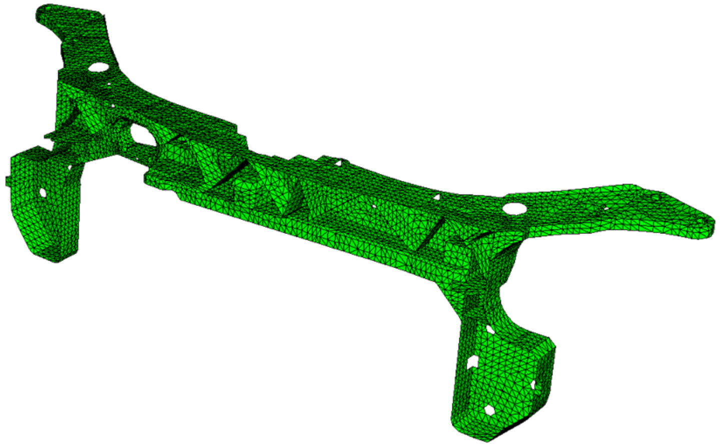
Customer Applications
& Success Stories

RENAULT - Front End Carrier

Impact of method for material models on mass of final design

Material

- PP LGF



Designing for

- NVH

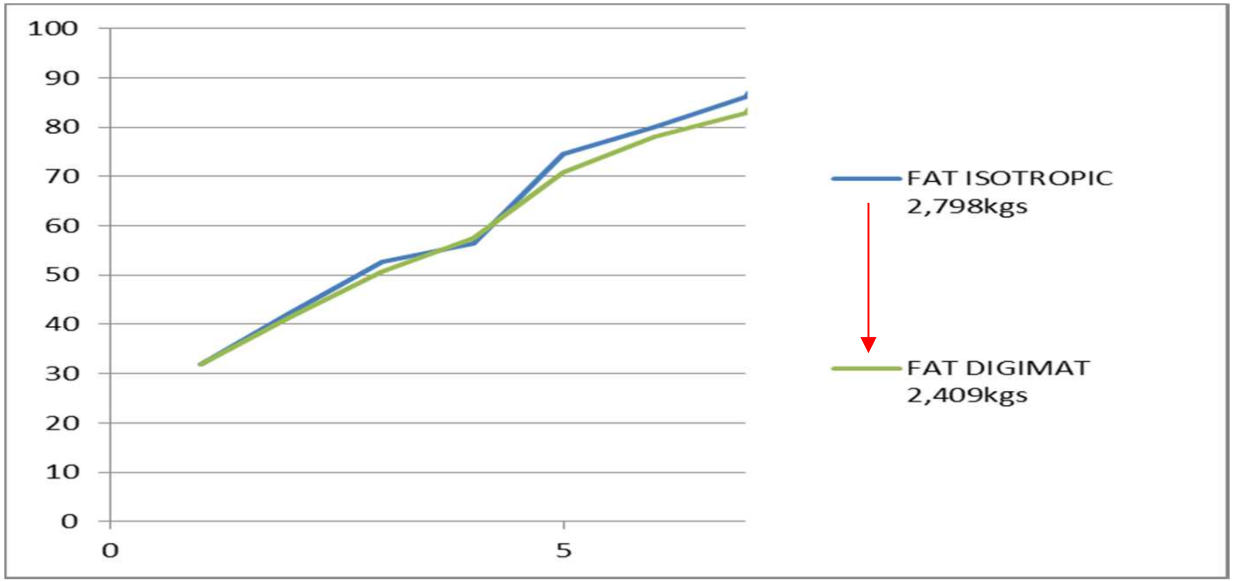
2 methods

ISOTROPIC	DIGIMAT
Homogeneous isotropic E = 5450MPa nu = 0.3	PP-Matrix : E= 1500 Mpa / nu = 0.3 Fibres : E = 72000 Mpa / nu = 0.22 Volume Fraction = 19.46 % (40 % Weight Fraction) Aspect ratio : 100 (Long Fibers)

RENAULT – Front End Carrier

Design results

for equivalent simulated performances



Eigenfrequencies (Hz)

Mode id

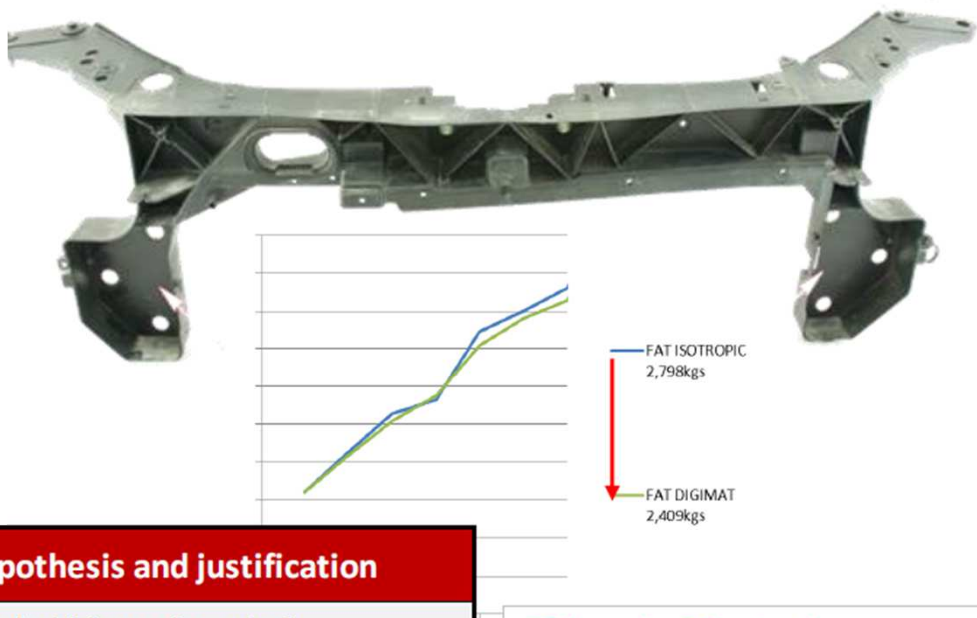
ISOTROPIC method | **DIGIMAT method**

Mass : **2,798** kg

- 0,398 kg
- 14 %

Mass : **2,409** kg

RENAULT – Front End Carrier

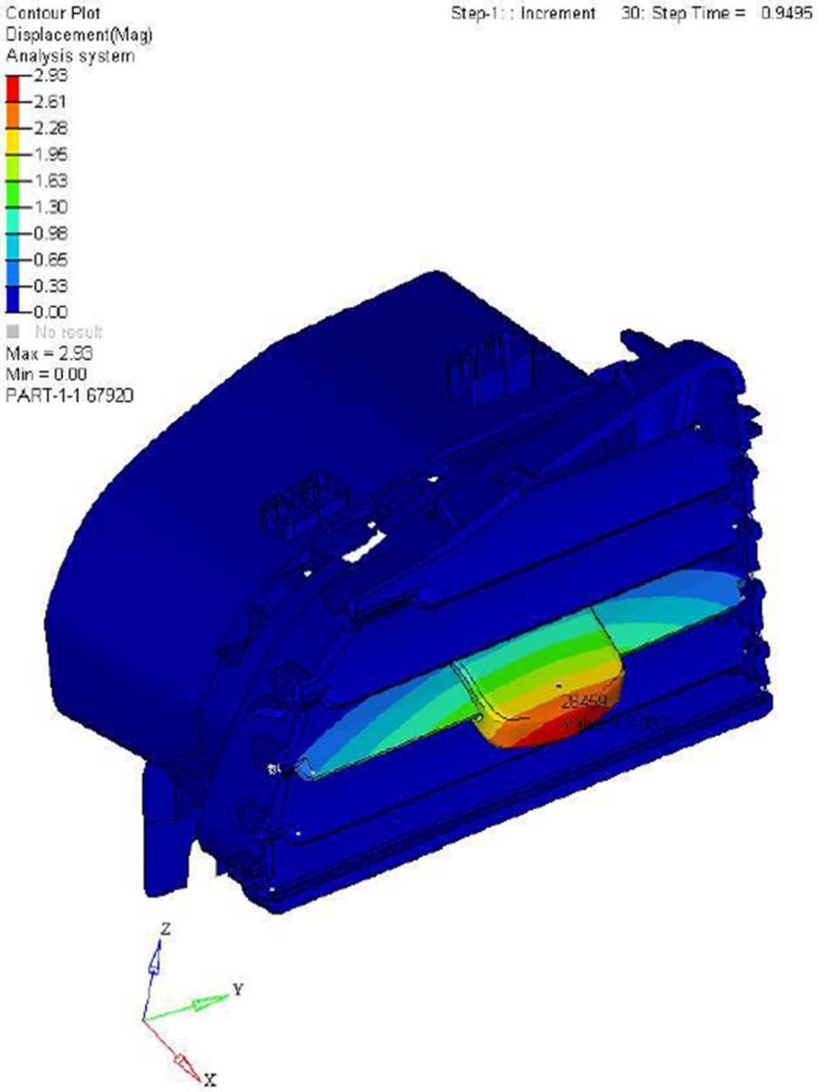


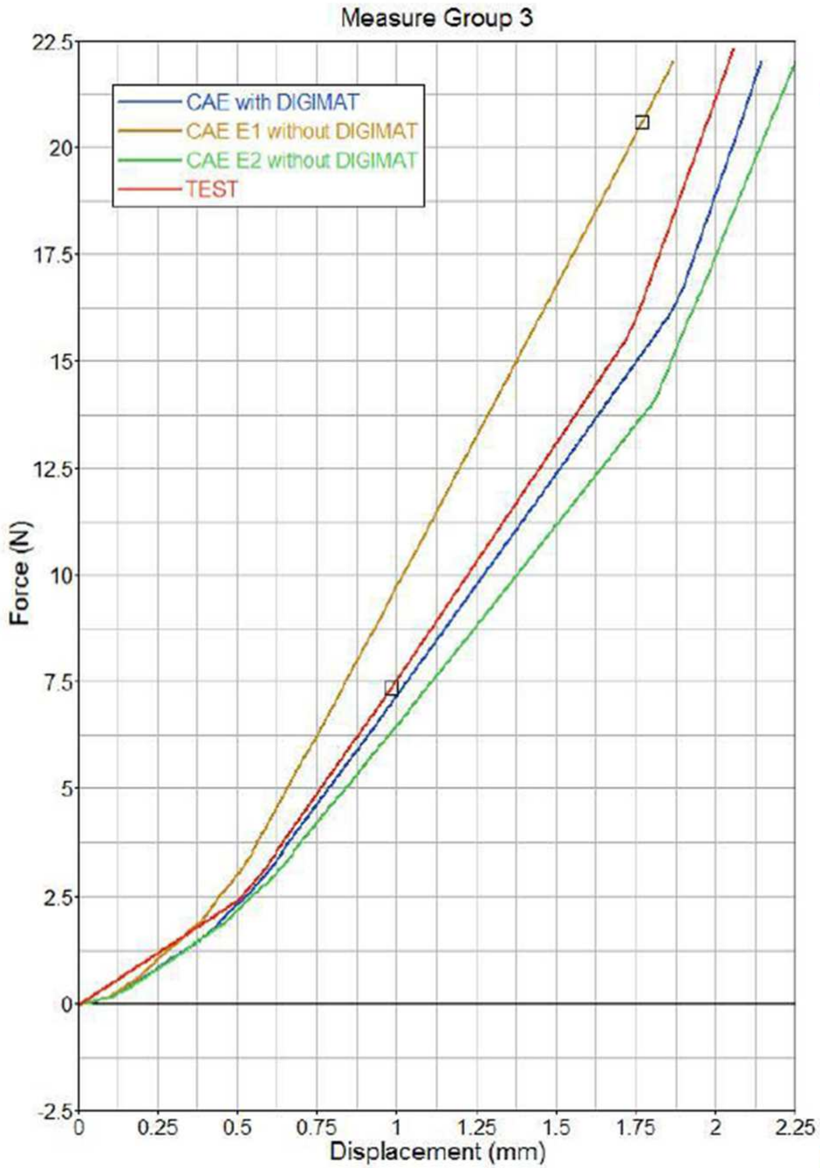
	Value	Hypothesis and justification
Initial mass (kgs)	2.798	part designed with isotropic method
final mass (kgs)	2.409	part designed with DIGIMAT
lightweighting per part (kgs)	0.389	initial mass - optimized mass
lightweight ratio (%)	14%	(optimized mass - initial mass)/initial mass
number of part per car	1	a car contain 1 front end carrier
mass saved per car (kgs)	**0.389**	nb parts per car * lightweighting per part
number of car per year	306006	number of clio III in 2011 (source Renault)
mass saved per year (kgs)	119036	mass saved per car * number of car per year
material cost (€/kg)	3.5	
Material cost saved per year (k€)	416.63	mass saved per year * material cost

Black Metal vs Micro-Mechanics

Mass Saving Factor = 14%

FORD: Air duct - stiffness





FORD: Air duct - stiffness

Ford Motor Co.'s advanced materials characterization process allows design engineers to improve analytical modeling and prove-out of auto interior components molded from neat or reinforced thermoplastics (pictured in the cockpit of the 2011 model year Ford Explorer SUV).

Materials characterization

FASTER, CHEAPER, BETTER

Ford couples commercial codes to analyze auto interior parts more accurately.

One of the more interesting entries last fall in the 41st annual Society of Plastics Engineers Automotive Innovation Awards Competition wasn't a part at all; it was a materials characterization process. Ford Motor Co.'s (Dearborn, Mich.) engineering group developed it for modeling and predictive analysis of automotive interior components. The procedure couples a number of commercial analysis codes with a proprietary materials database, enabling engineers to improve analytical modeling and prove-out of parts molded from neat or fiber-reinforced thermoplastics by injection, blow, microcellular-foam or compression molding. This enables engineers to design interior parts closer to their materials' theoretical limits, achieving a 10 to 20 percent mass reduction. This improves fuel economy, reduces greenhouse-gas emissions, yields a 5 to 15 percent material cost reduction (averaging $10 USD per vehicle) and saves as much as $500,000 in testing costs per program. Ford also anticipates a not-yet-quantified reduction in costly late tooling changes that historically are made close to launch.

"Currently, plastic materials represent only 10 percent of the weight of a typical passenger vehicle," says Jeff Webb, interior technical leader in Ford's North American Engineering – Cockpit and Trim Integration operation. "Attempts to increase that percentage in the past have either failed outright or have been implemented only to revert back to steel, later on, for cost savings."

Because the vast majority of interior components are thermoplastics, designers face some challenges when they model parts molded from these materials and analyze their performance. These include lack of directly useful dynamic data on strain-rate dependence; load-dependent strain-hardening in compression, tension and shear; temperature dependence; creep; load-dependent fracture; and anisotropy for glass-reinforced materials, because the high-pressure injection molding process orients high-aspect-ratio fillers in the direction of melt flow into the tool.

OLD WAY VS. NEW WAY

Formerly, the modeling process for a thermoplastic part began with the supplier's datasheet, which nearly always reported *monotonic* (single-point) properties measured solely in the flow direction. It assumed that properties were isotropic in the cross-flow direction. Unfortunately, studies had long shown that with short-glass-reinforced materials, this was not the case — values measured at 90° to the flow could be as much as *60 percent lower* than values in the flow direction. Using datasheet properties, then, could lead to overly optimistic estimates of mechanical properties across a part, particularly one with great geometric complexity. So an engineer either built in a big safety factor (e.g., thicker wall sections, which added to per-part cost and weight) or opted for the expensive and time-intensive *make-and-break* method to determine material usage. Similarly, everyone knew that despite the monotonic datasheet values, the actual materials were strain-rate, temperature and load dependent. So if an engineer was estimating how a part would behave at a different time, temperature, strain rate or load than was used to measure properties on test specimen via a standard ISO test protocol, there was no *direct* way to get the value needed to plug into analysis software.

During the mid- to late 1980s, GE Plastics (now SABIC Innovative Plastics, Pittsfield, Mass.) measured properties in both flow *and* cross-flow directions over a broad range of temperatures, loads and strain rates. Rather than report properties as a single data point, GE engineers built an extensive database with thousands of data points each for hundreds of the company's materials. They assembled the data in a program called the Engineering Design Database (EDD). Proprietary algorithms enabled an engineer to interpolate or extrapolate from the measured data to estimate engineering properties in different conditions. This provided a much more realistic number that could be plugged directly into structural analysis software.

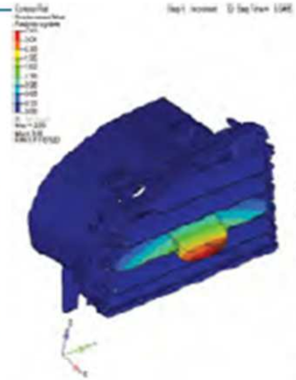
The system worked well and was the best option available at the time, but it was accessible only to someone who used GE materials. For everyone else, the process involved *guestimating* how a thermoplastic material might behave under real-world conditions, which rarely were the same as prescribed under standardized test protocols. This information was fed into a structural analysis code, and parts were molded and subjected to mechanical testing; this likely led to costly and time-intensive design changes, which were implemented in the mesh or solid-model CAD data and then reprocessed.

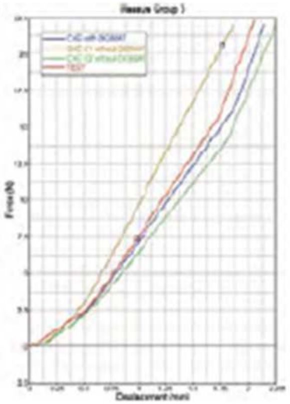
With the new Ford procedure, the initial computer-aided engineering (CAE) analysis is performed using what the company calls its Material Data Cards, which are said to incorporate complete advanced characterization of key materials used in its vehicle interiors. These proprietary data (developed by Ford using internal testing resources and outside contracted testing facilities) are fed into a commercial moldfilling code, such as Moldflow (Autodesk Inc., Framingham, Mass.) or MoldX3D (CoreTech System Co. Ltd., Chupei City, Taiwan). This preliminary analysis gives a design *direction* — that is, it helps set wall thicknesses, indicates where additional structures (e.g., ribbing) might be needed to boost stiffness, etc.

A second step is used for reinforced plastics. It involves what Webb calls an "anisotropy correction" to predict fiber orientation, using the commercial package Digimat, a multiscale modeling package for multiphase composite materials and structures developed by e-Xstream engineering SA (Louvain-la-Neuve, Belgium). This enables engineers to predict anisotropic material properties at any location in the part. Results from this step are coupled with nonlinear structural analysis codes, such as Abaqus (Dassault Systèmes, Vélizy-Villacoublay, France) or LS-Dyna (Livermore Software Technology Corp., Livermore, Calif.), which are used to help optimize part design and process settings. Changes indicated during this step are fed back into the CAD data, and another iteration is completed.

Webb says these analysis tools can predict crack propagation, high strain-rate behavior, anisotropic properties, creep and more with greater accuracy. Further, the new procedure provides more robust tool kickoff and vehicle launches with fewer glitches in previously problematic areas. This means that Ford will use more reinforced plastics on vehicles and do so more successfully. | CT |

Ford engineers used the new process to analyze the stiffness of register vanes on the 2011 *Explorer* SUV (results shown at right). The analysis that made use of an anisotropy correction via Digimat software to predict fiber orientation in the finished part provided the best correlation to actual measured data.





CONTRIBUTING WRITER

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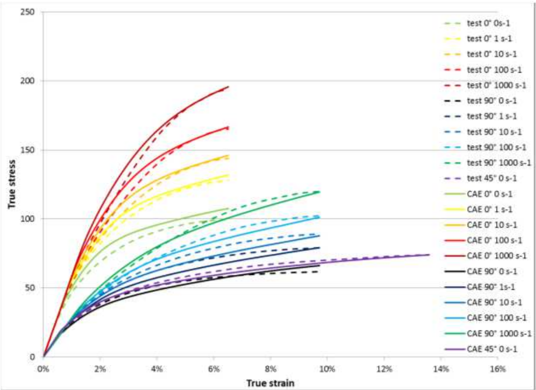
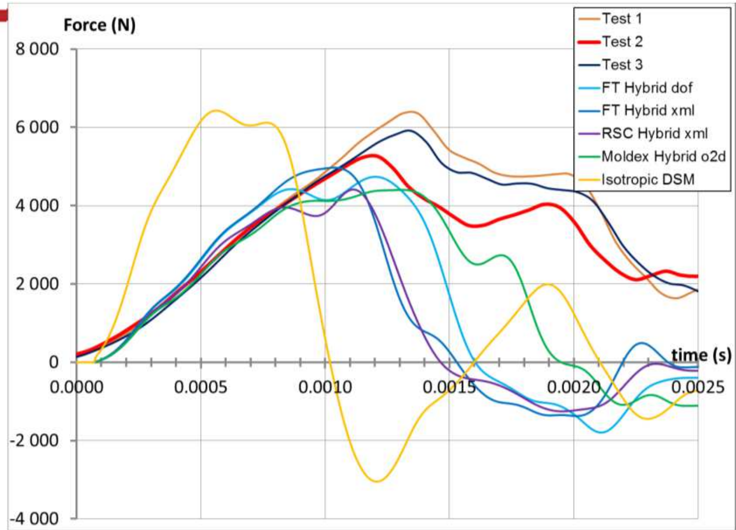
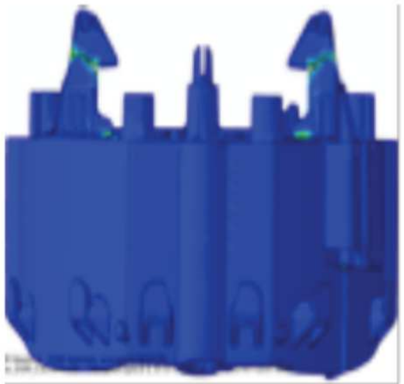
Performance: Airbag Housing Strength in Deployment

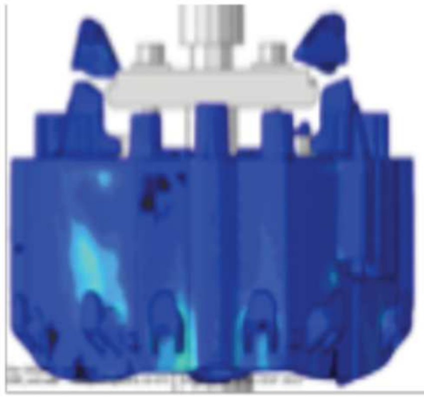






DSM: it occurs in the hooks heads, like in the test

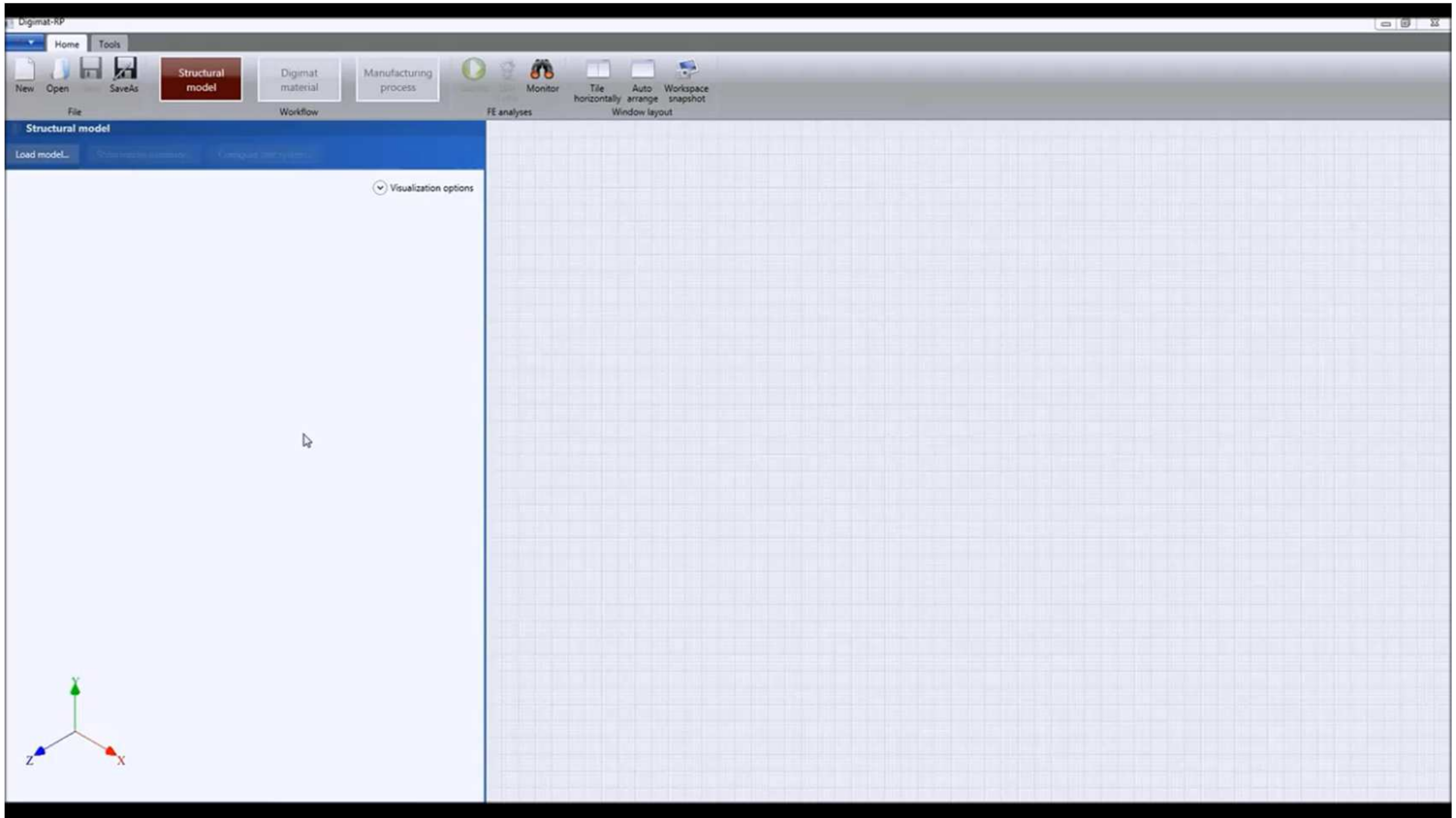
studs, unlike in the test



The failure with Digimat HYBRID 4.4.1 occurs in hooks heads, like in the test

Digimat-RP/Moldex3D: Fiber Estimation

- Fiber orientation estimator powered by Moldex3D
- Limited user input requiring no injection simulation expertise



Conclusions & Discussions

> E-Xstream engineering develops & commercializes **DIGIMAT**

- a complete material modeling solution for fast and accurate FEA on composite and reinforced plastic made parts

  - For most types of microstructures : short fibers, long fibers, continuous fiber (UD, Woven, braided…), discontinuous fiber composites, mucell…
  - For all types of performances (stiffness, NVH, crash, fatigue..)
  - With all the major FE solvers of the market : Nastran, Marc, Abaqus, Ansys, Pamcrash, Radioss…
  - Taking into account the local stiffness behavior related to the local fiber orientation tensor of the material by mapping fiber OT field from a donor mesh (most of time, the injection simulation mesh) onto the structural mesh

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Thank You

MOLDING INNOVATION