Mehrskalenmodellierung additiver Fertigungsprozesse von Kunststoffen und Verbundwerkstoffen mit Digimat

Presented By: Robert Wesenjak, Application Engineer
September 7, 2018

Who We Are

We are **e-Xstream** engineering, The Advanced Material Modelling Company

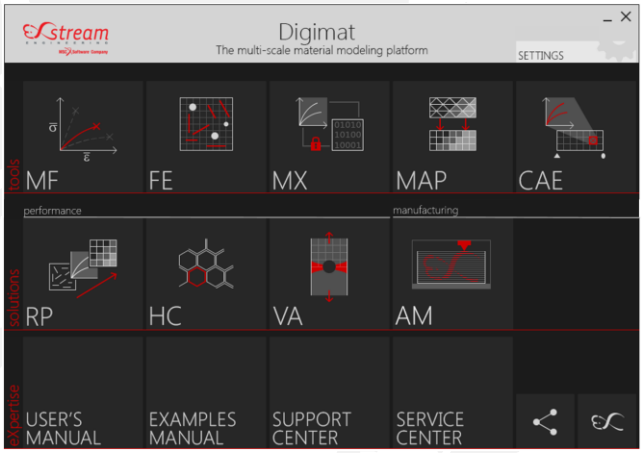
- Founded in 2003
- A team of 65+ members, 100% focused on materials and structural simulation
- HQ in Europe (Belgium/Luxembourg)
- An MSC Software Company since September 2012 / 1,200 engineers in 20 countries
  - 55 years of CAE (Nastran, Adams, …)
- Part of Hexagon MI since April 2017 / 17,000 people (3,400 R&D) in 50 countries
  - Leader of IT solutions to drive productivity & Quality

Our Dedication

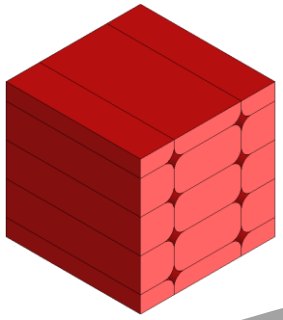
We develop Digimat

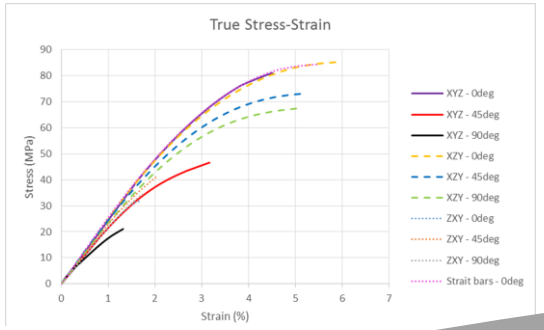
The Upcoming Standard in the Automotive, Aerospace, and E&E Industry for Material Modelling

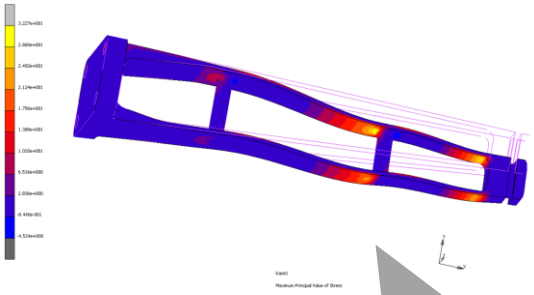
- A unique solution for Composite-Materials
  - Short, long and continuous fiber reinforced composites
- A unique solution for Multi-Performances
  - Crash and Safety, Durability and NVH
- Validated across the Auto/Aero Supply chain
  - Material suppliers ➔ Tier1 ➔ OEM
- Fully developed interfaces to major CAE Solutions
  - FE, Injection, Draping, Compression, …
- Customer and Engineering Services, Support and Training



From Manufacturing Process to Product Performance





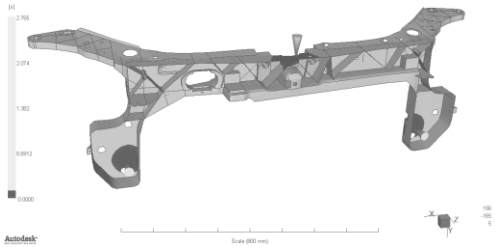


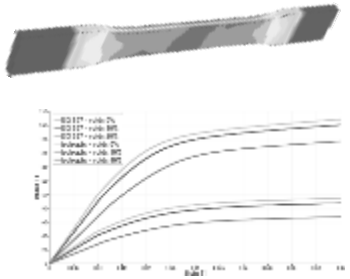
Engineering of AM Parts & Systems

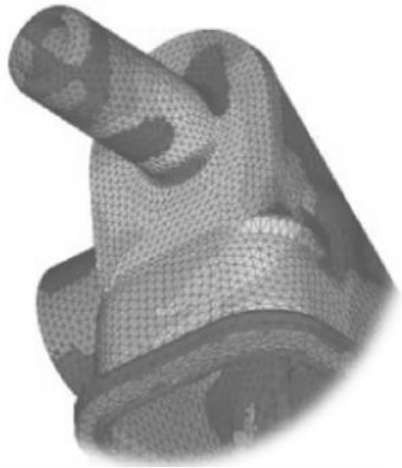
Material characterization (mechanical, thermal, electrical)

Material microstructure

Manufacturing Process Simulation



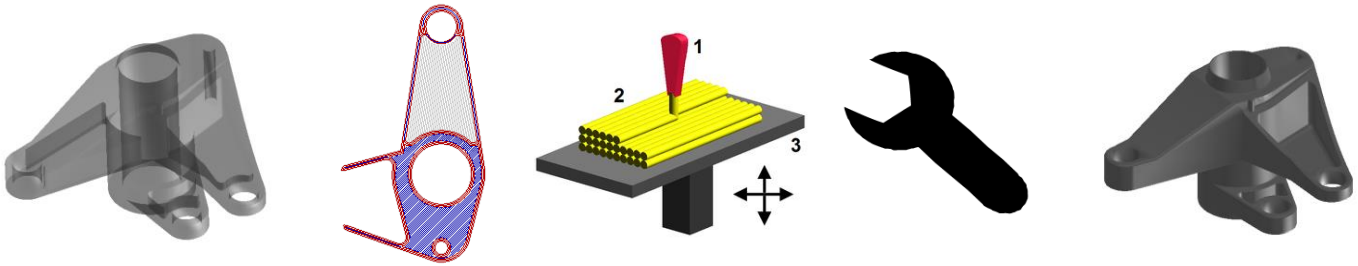




Additive Manufacturing

Additive Manufacturing: Current Workflow

- Test based: trial and error methodology

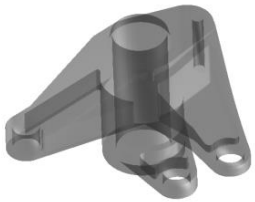


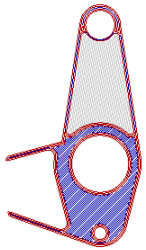
Design	Printer pre-processing	Printing	Post-processing	Final part	Test
• Initial CAD	• *.stl • Material • Toolpath • Process parameters	• Material deposition • **Printing issues**	• Heat treatment • Surface finish	• Warpage • Residual stresses • Porosity	

$$

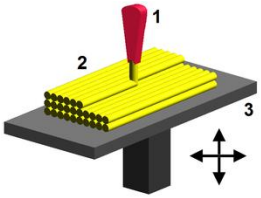
Additive Manufacturing: Digimat Workflow

- Simulation based

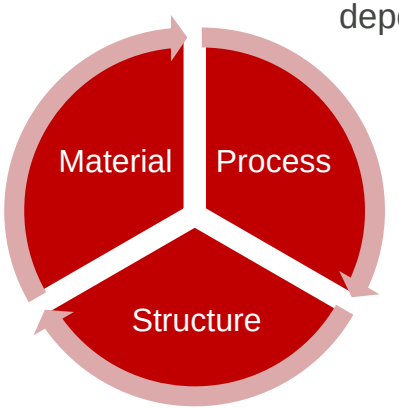




Digimat



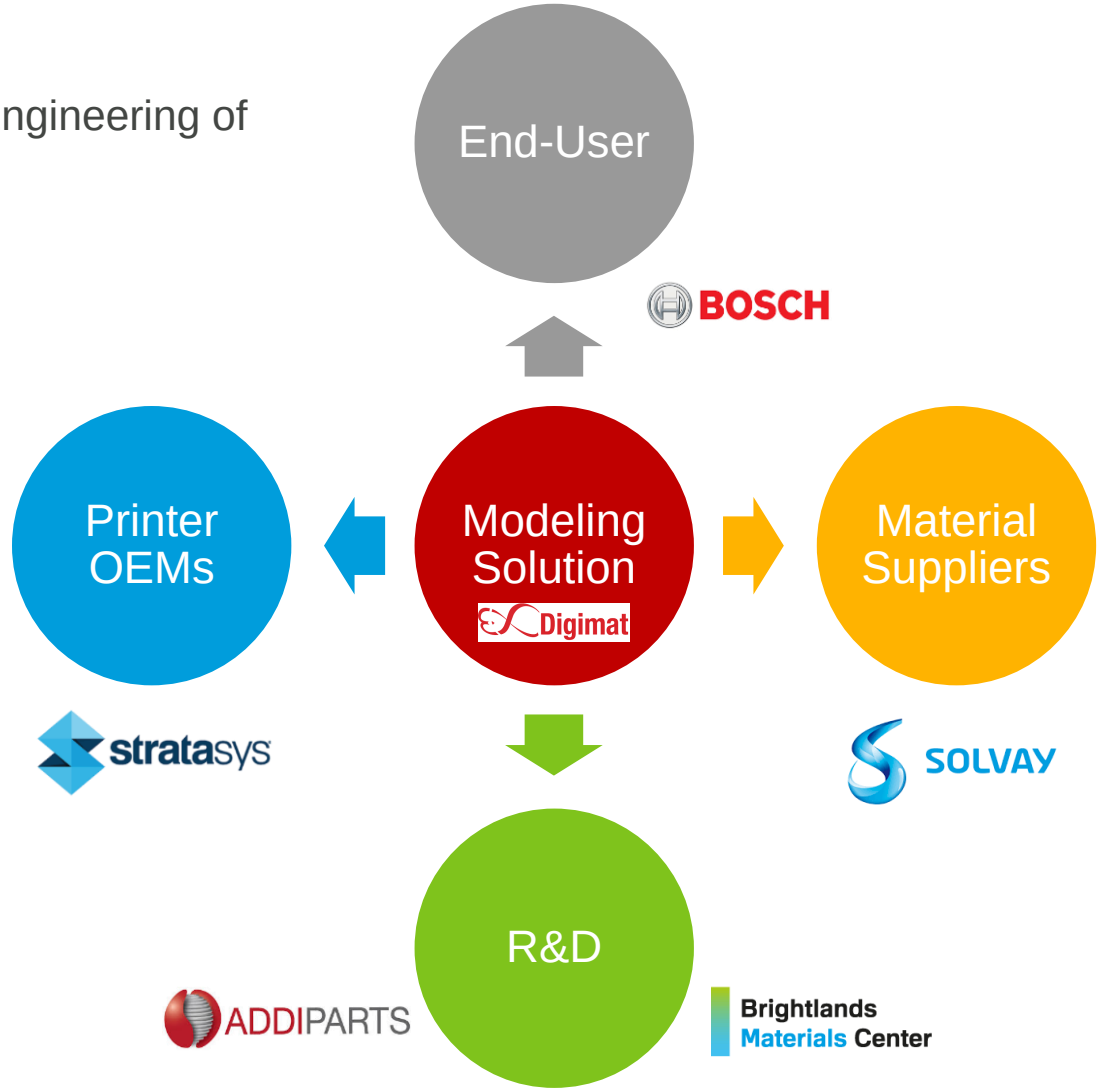
Design	Printer pre-processing	Simulation	Printing	Post-processing	Final part
• Initial CAD	• *.stl • Material • Toolpath • Process parameters		• Material deposition	• Heat treatment • Surface finish	• Minimized Warpage • Minimized Residual stresses • Mastered porosity • **Mastered performance**



Optimisation

e-Xstream Ecosystem for Additive Manufacturing

- Effective and Efficient Engineering of
  - AM Materials
  - Process and
  - Parts



Digimat Additive Manufacturing Solution

Value Proposition: bringing your ideas faster to the market

Print right the first time

- Save material: anticipate printing issues & compensate warpage
- Save time: optimize build setup
- Easy access to printers and materials

Virtual testing of AM materials

- Explore & understand new materials
- Mechanical characterization of lattice structures
- Reinforced materials and advanced material models

Validate your design

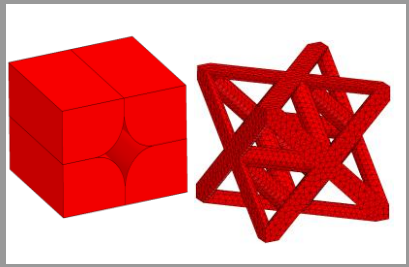
- Compute the as-printed part performance
- Reduce physical production and testing
- Interface with most CAE solvers

"For engineers to unlock the design freedom that additive manufacturing offers, they need tools for accurate and effective analysis. Working with e-Xstream, we're enabling 3D printing to become a high performance production technology."

– Scott Sevcik, VP of Manufacturing, Stratasys

Digimat Additive Manufacturing Solution

FDM (FFF) / SLS

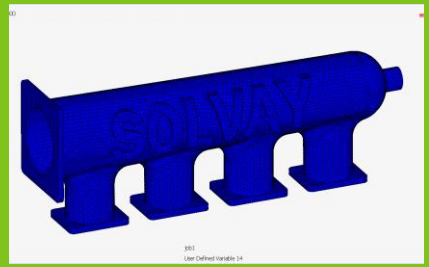


Material Engineering

- Mechanical
- Thermal
- Electrical

Process Simulation

- Warpage
- Residual Stress
- Porosity
- Temperature
- Crystallinity



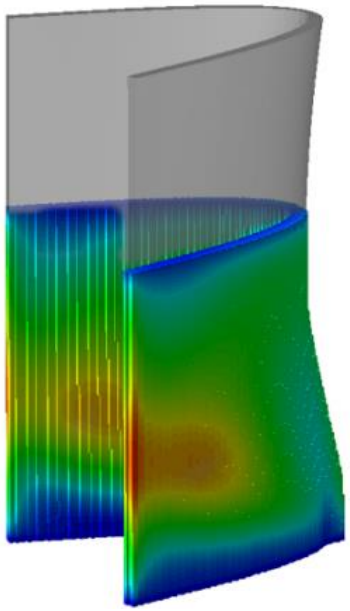
Part Performance

- Stiffness
- Failure
  - Print Direction
  - Reinforcement

Process Simulation

Simulating Effects of Warpage in an AM Composite layup tool

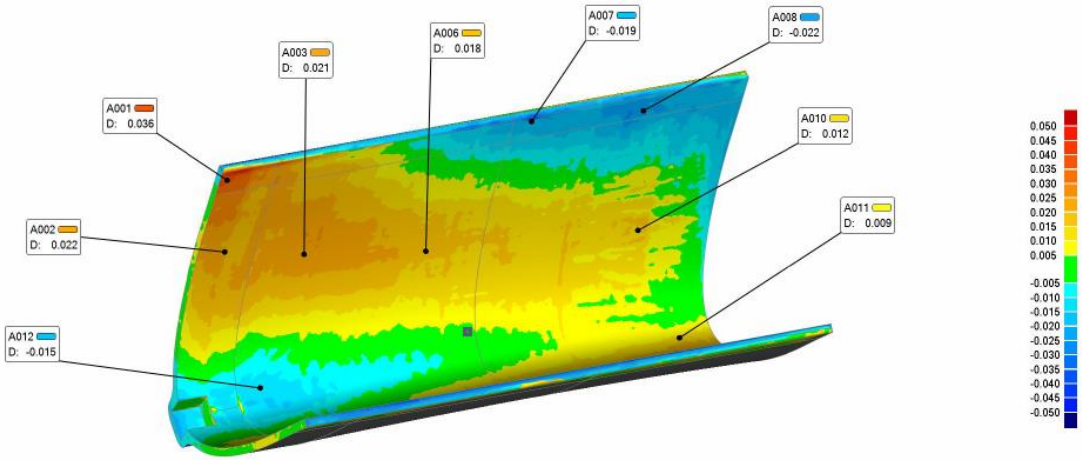
- **Advantages of composite tools**
  - Reduced time-to-market
  - Increased geometry complexity
  - Lowering development and manufacturing costs



Source: Additive Manufacturing Process Optimization Using Simulation, Bender Kutub (Stratasys), DigimatUM17, Oct 2017

Behind the Scenes…

- Although the final printed solution realized dramatic cost savings over the competition the first print iteration did not meet the application tolerance requirements due to excessive warpage induced by the printing process
- It took expert knowledge and multiple iterations to manually correct the warpage using nonstandard practices



Source: Additive Manufacturing Process Optimization Using Simulation, Bender Kutub (Stratasys), DigimatUM17, Oct 2017

3D Printing of Plastic Parts

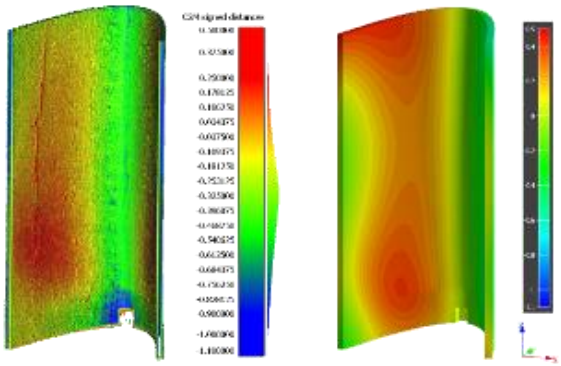
Challenges

- ✓ Additive manufacturing is a true multi-scale challenge
- ✓ Complex thermomechanical loadings during the layer-by-layer deposition of the material
- ✓ Thermal history of the material deposition

Strategy

- ✓ Process simulation via a multiscale approach as a function of process setup and material choice
- ✓ Thermomechanical analysis
- ✓ Predict the resulting warpage

Results

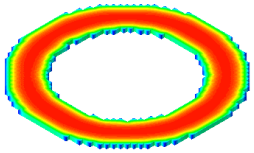


Benefits

- ✓ Reduce trial & errors
- ✓ Gain time & money
- ✓ Warpage compensation

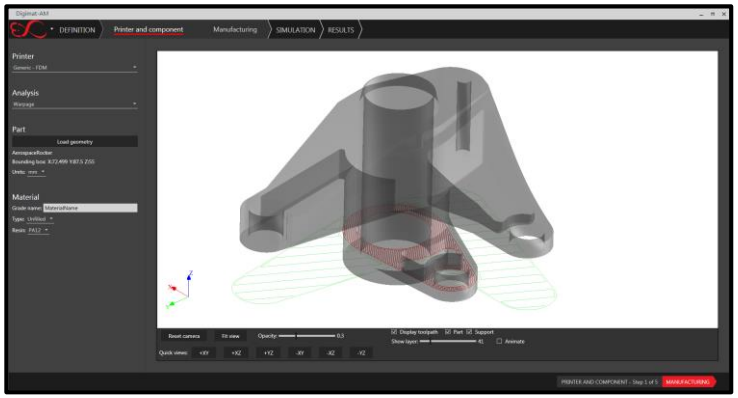
New Key Features in Digimat-AM 2018.1

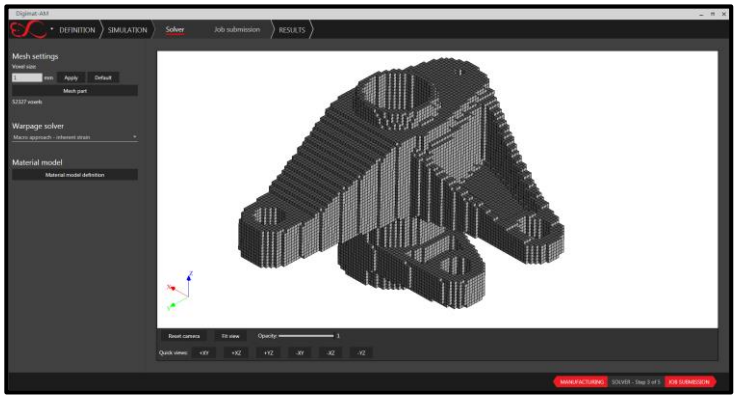
- **Thermal analysis**
  - Analyse local temperature fields to gain a better understanding of the process parameters and optimise your print strategy
- **Thermomechanical analysis**
  - Account for the impact of local temperature distribution and specific toolpaths on deflection and residual stresses
- **Crystallinity**
  - Predict as-printed material crystallinity as a function of material & process parameters
- **Variable density**
  - Predict warpage of partial infill & lattices
- **Thin walls**
  - Predict warpage of thin structures

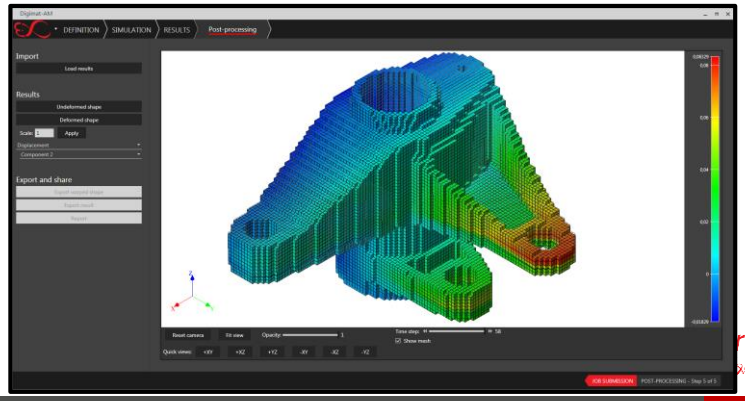


Digimat AM: Process Simulation

- Additive manufacturing processes:
  - SLS
  - FFF/FDM
- Materials:
  - Filled polymers
  - Unfilled polymers
- Predictions:
  - Shrinkage
  - Warpage
  - Residuals stresses
  - Temperature New
  - Crystallinity New
- Simulation method:
  - Inherent strain approach
  - Thermal analysis New
  - Thermomechanical analysis New

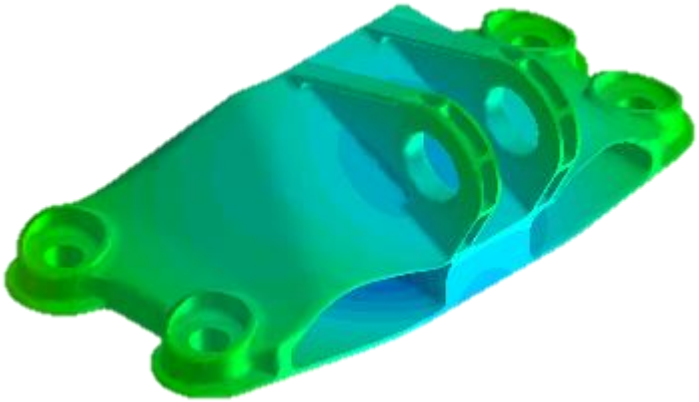


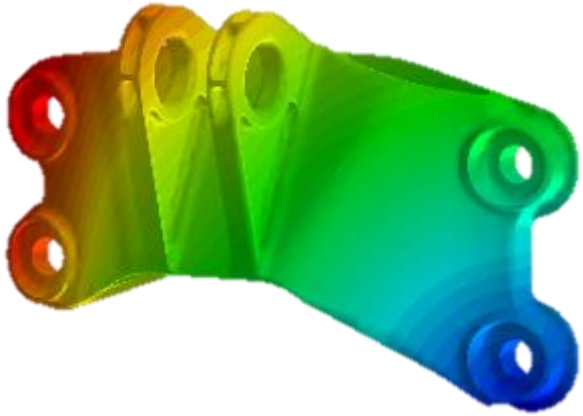




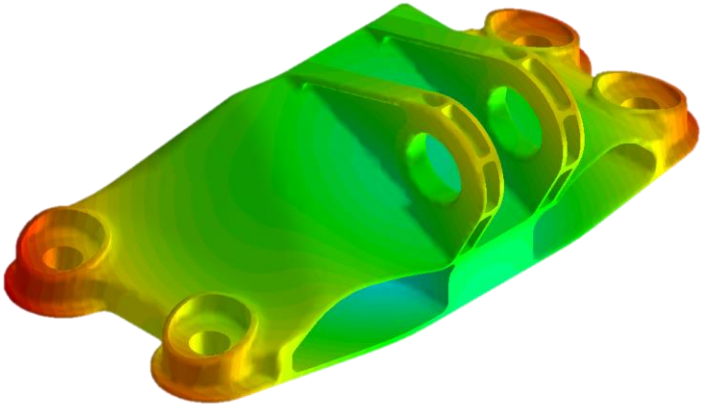
Virtually explore the influence of…

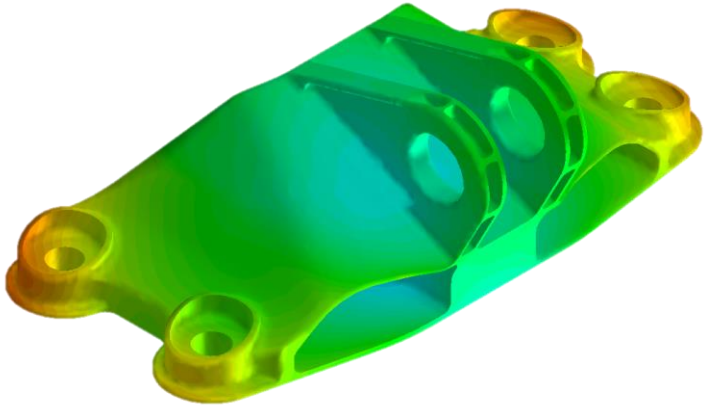
- Printing direction



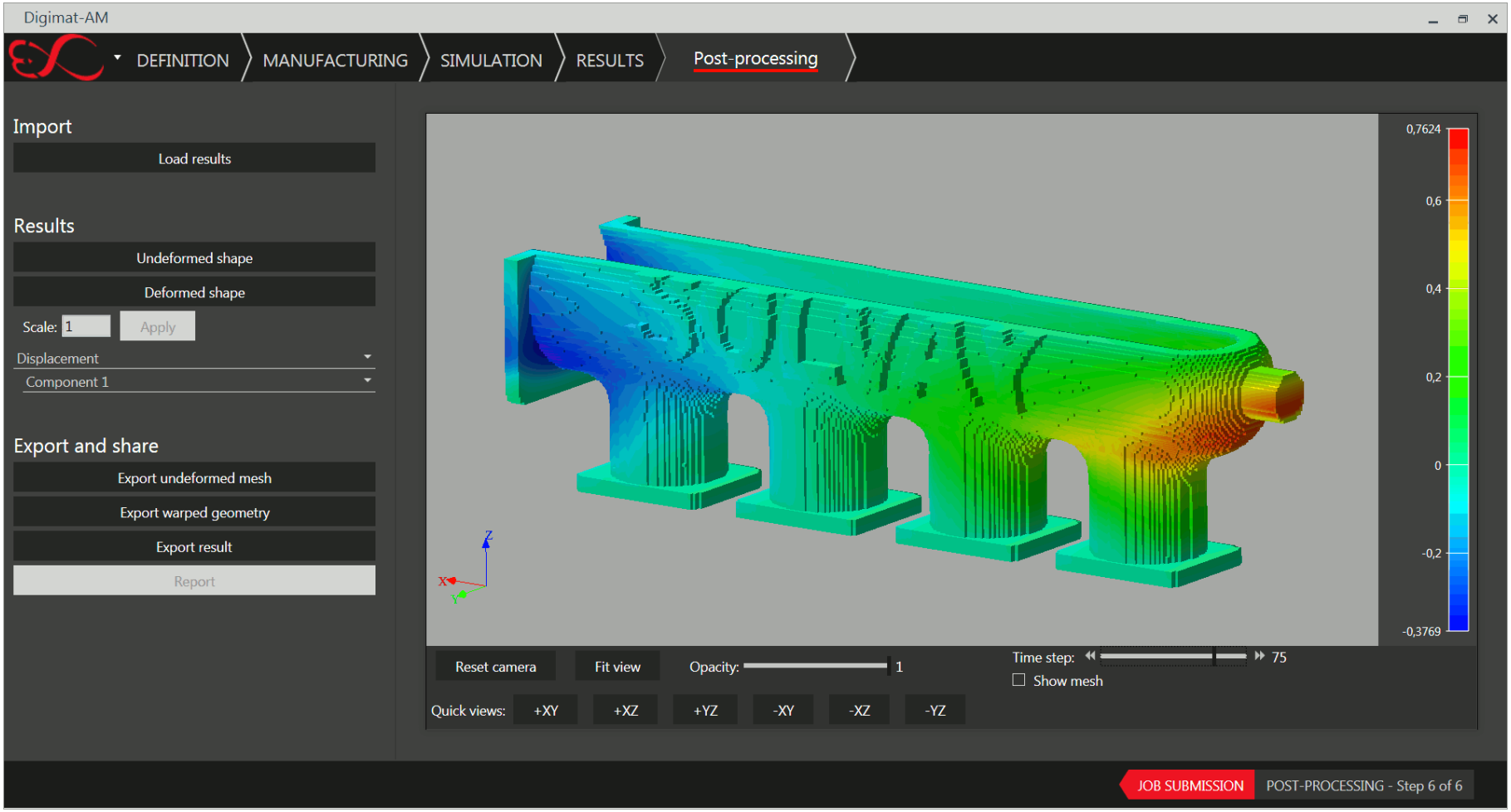


- Material choice (pure ABS vs 30% GB reinforced ABS)





Virtual Printing to Predict Warpage



Case Study

Air Cooler Application

Air Cooler Application

TECHNYL® SERIAL SOLUTION

Material: Technyl® **PA66GF35**

Hot air circulation with cycled pressure

SINTERLINE® FUNCTIONAL PROTOTYPE

Material: Sinterline® **PA6 40% GB**

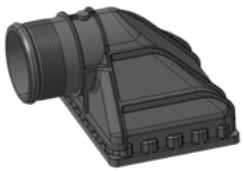
Requirement for design validation:
Burst pressure test at 110°C

Source: Using Digimat to predict the performance of a 3D printed part, Elodie Seignobos, Lucie Berger (Solvay), DigimatUM17, Oct 2017

Optimized Additive Manufacturing Workflow

↳ Same workflow than injection technology

DESIGN



PRINTER SET UP

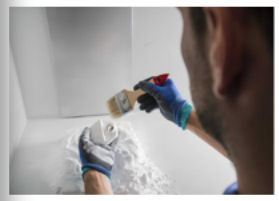
SIMULATION

1 Material modeling

2 Structural analysis

3 Process modeling

PRINTING



→ Print right 1st time

FINAL PART

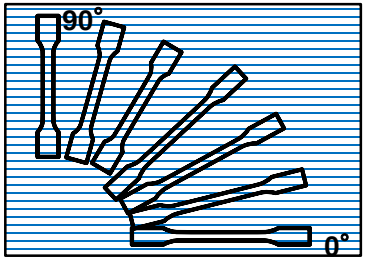
→ Minimize warpage

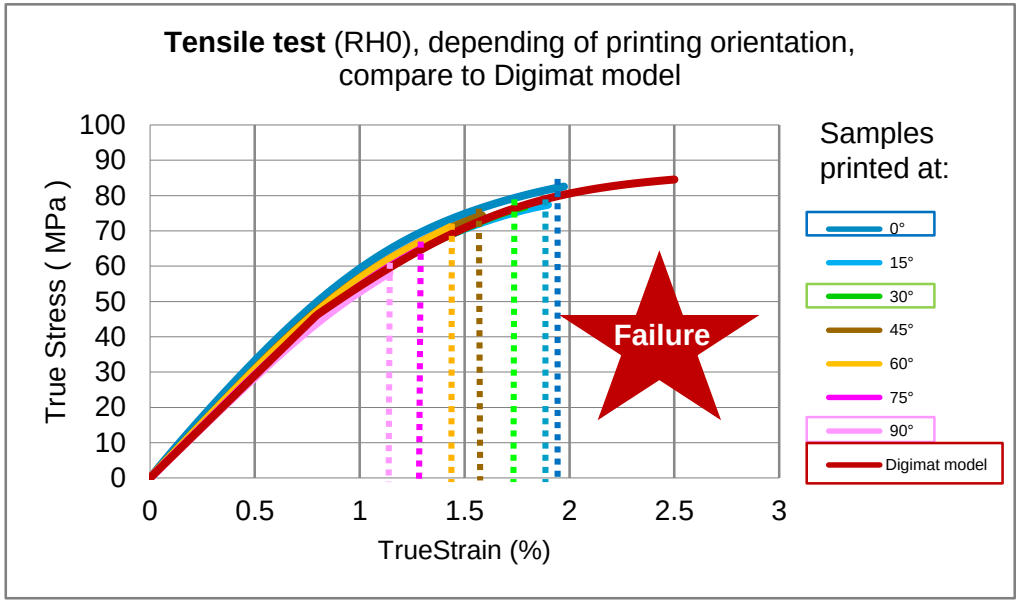
→ Mastered performance

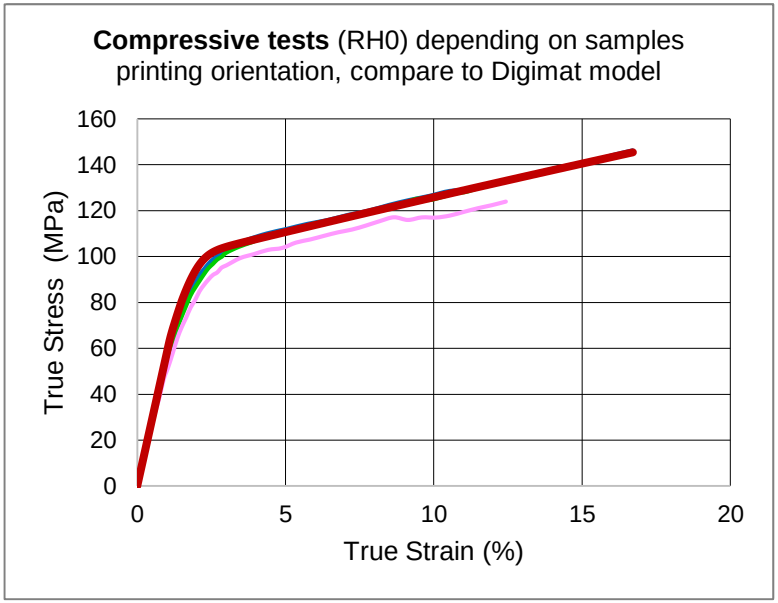
Source: Using Digimat to predict the performance of a 3D printed part, Elodie Seignobos, Lucie Berger (Solvay), DigimatUM17, Oct 2017

Characterisation of Sinterline Powder

- Glass beads reinforced polyamide
- Tensile + compression test
  - Isotropic stiffness of material
  - Traction and compression plasticity dependency → Drucker-Prager model



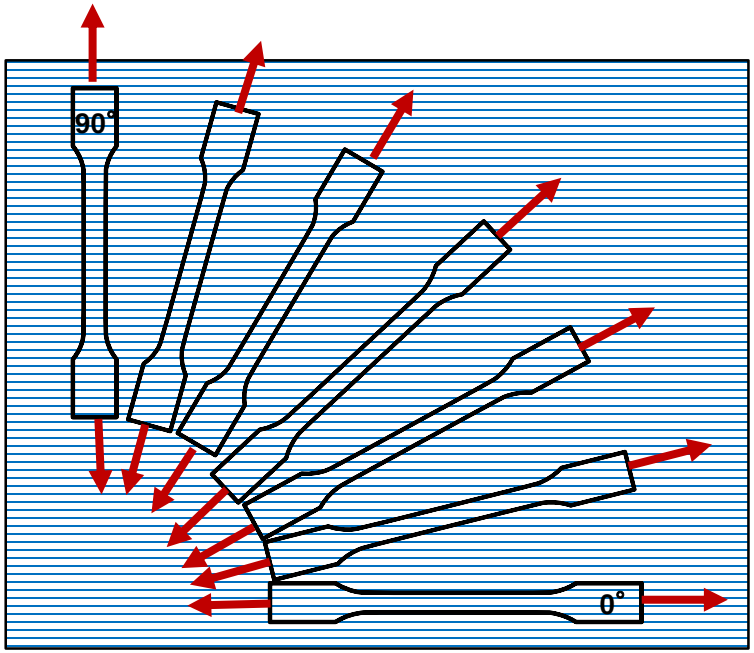


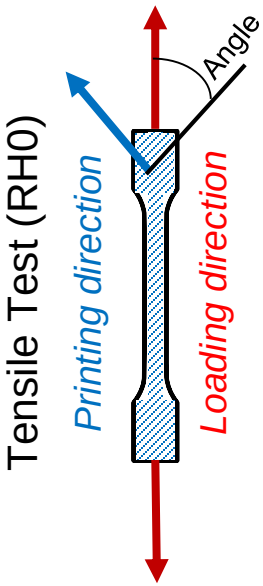


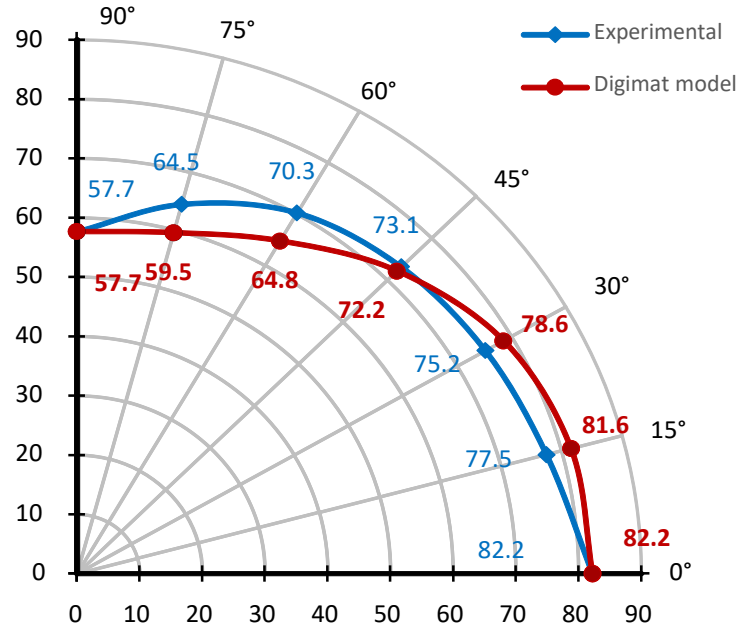
- **Effect of printing direction on:**
  - → Stiffness and stress-strain shape = negligible
  - → Strength (Strain/Stress at Failure) = important

Multiscale Modelling of Sinterline (PA6+40%GB)

- Modeling of failure dependency on printing orientation



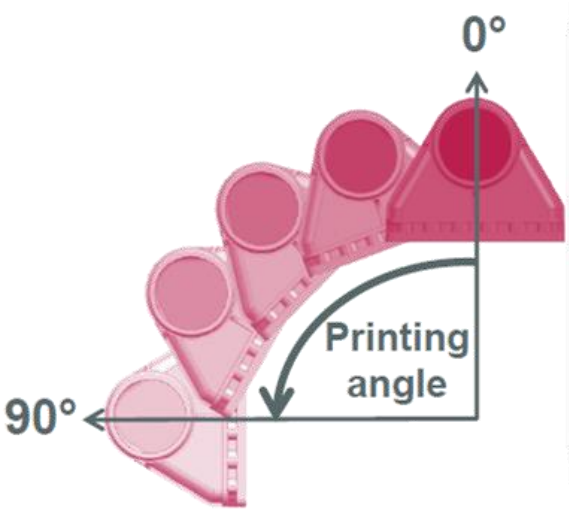


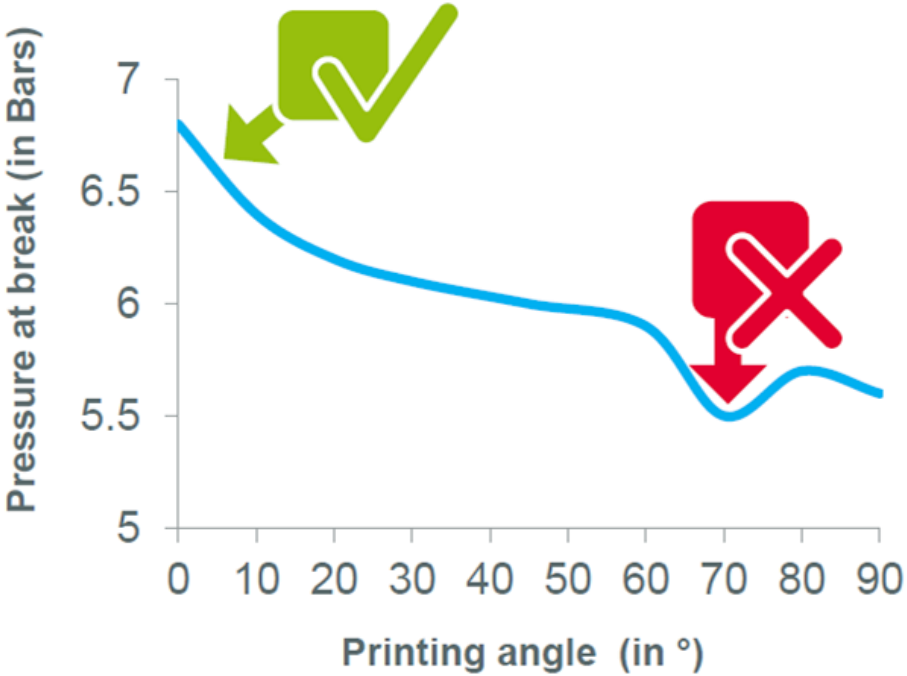


- Tsai-Wu generalized transversely isotropic criterion (stress-based), applied at the composite level.
- Standard deviation max 5.7 MPa

Air Cooler Application – Mechanical Performance

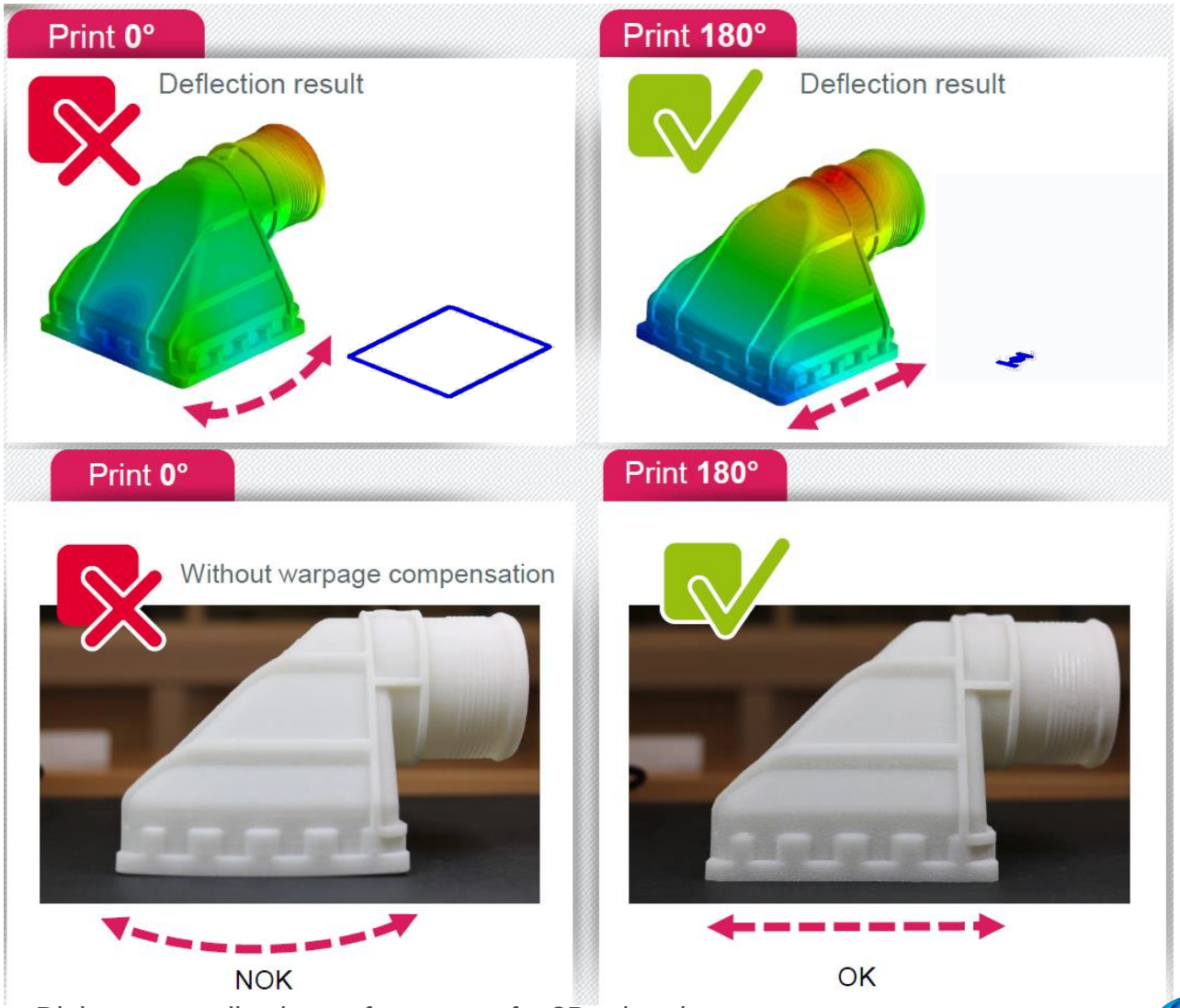
- Mechanical Performance of the Air Cooler as function of the printing direction





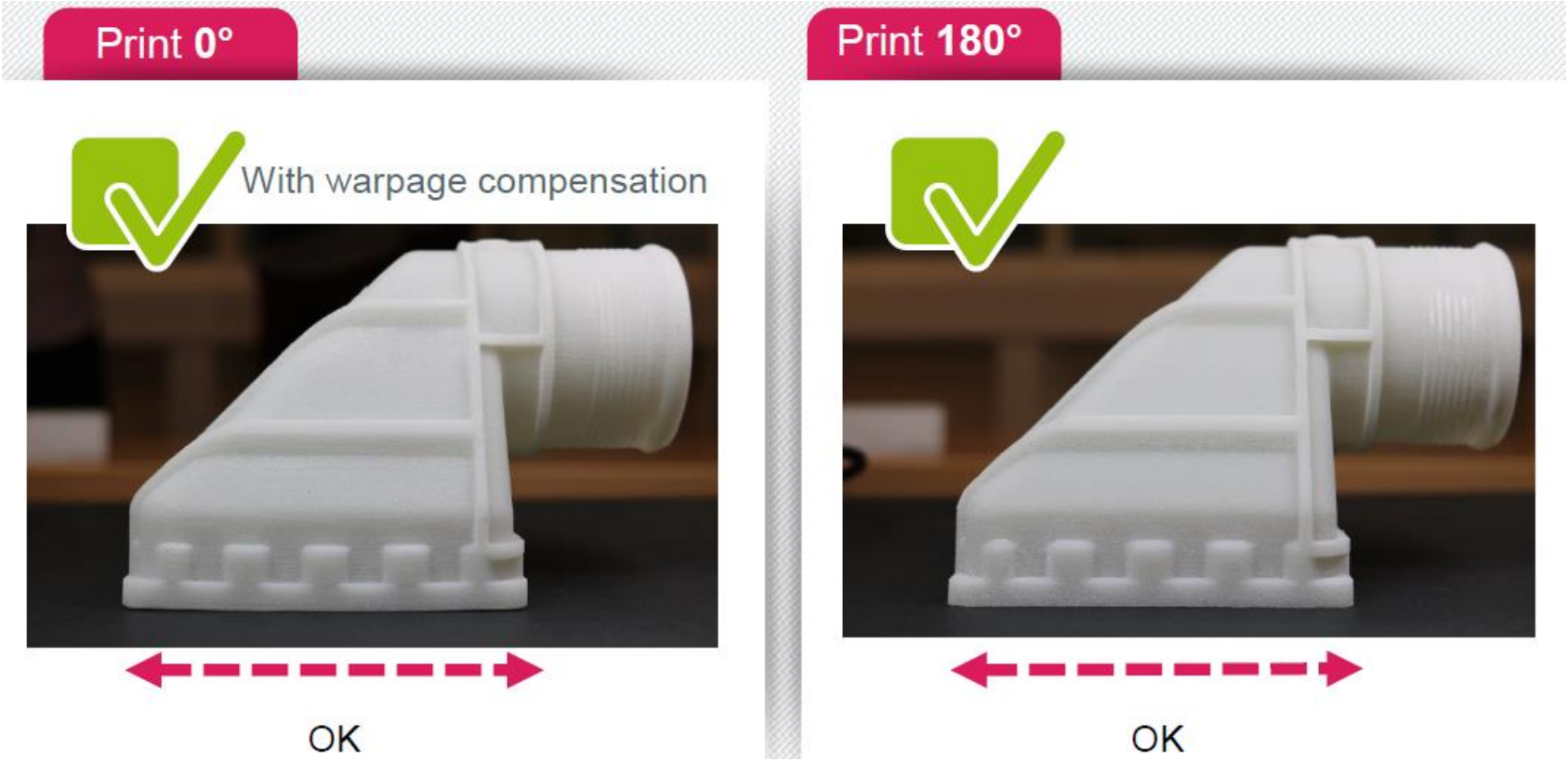
Source: Using Digimat to predict the performance of a 3D printed part, Elodie Seignobos, Lucie Berger (Solvay), DigimatUM17, Oct 2017

Warpage depends on printing orientation



Source: Using Digimat to predict the performance of a 3D printed part, Elodie Seignobos, Lucie Berger (Solvay), DigimatUM17, Oct 2017

Warpage compensation with Digimat AM



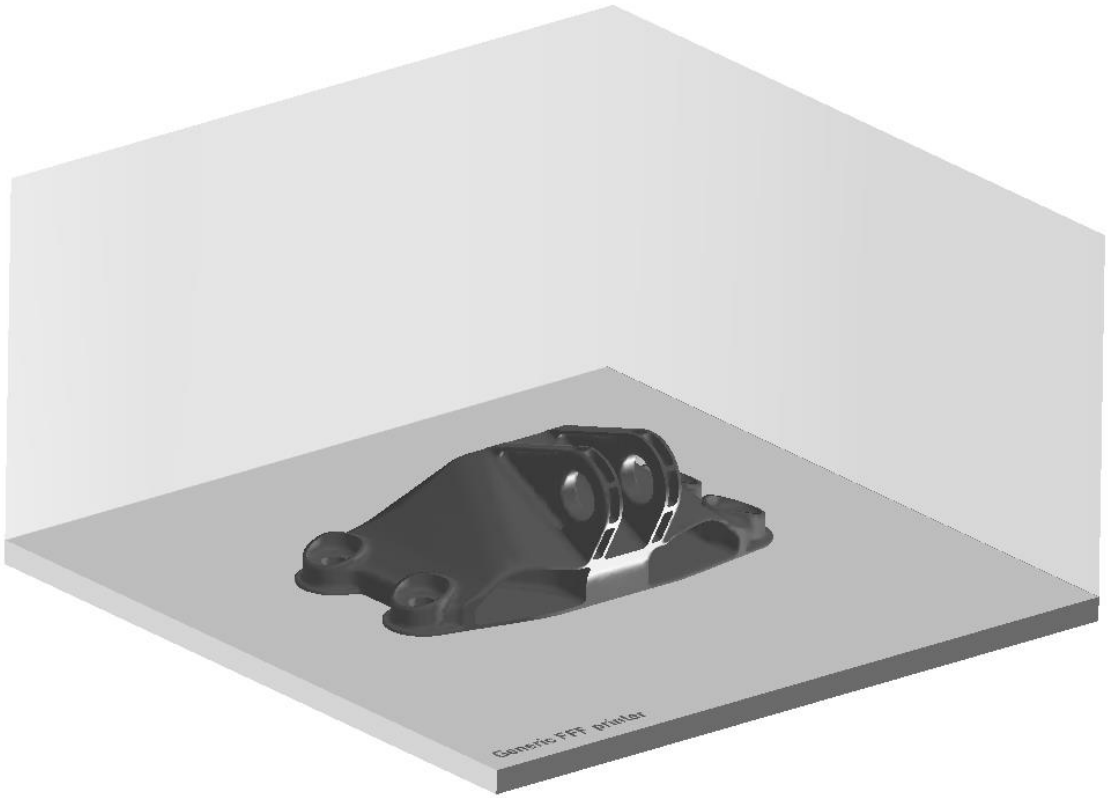
Source: Using Digimat to predict the performance of a 3D printed part, Elodie Seignobos, Lucie Berger (Solvay), DigimatUM17, Oct 2017

Case Study

Warpage Compensation

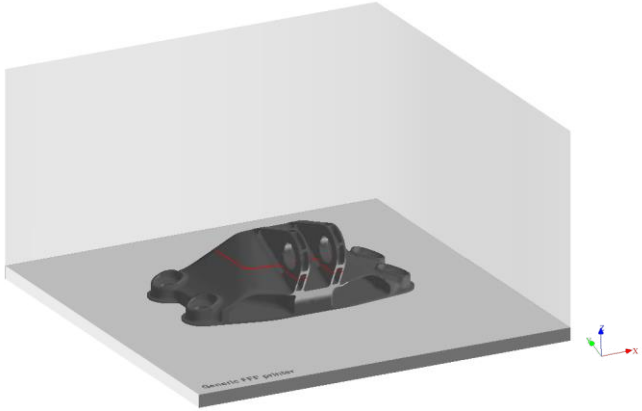
Objective

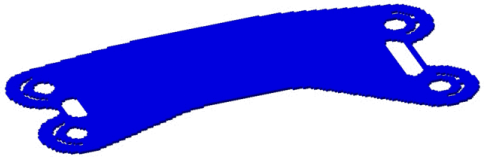
- Print engine bracket part via FFF and ensure dimensional accuracy
  - ABS material
  - Generic FFF printer

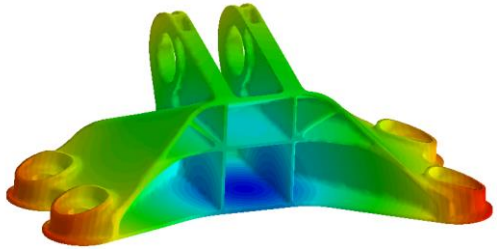


Warpage Prediction

- Material: ABS
- Manufacturing process definition
  - FFF
  - Toolpath
  - Process parameters



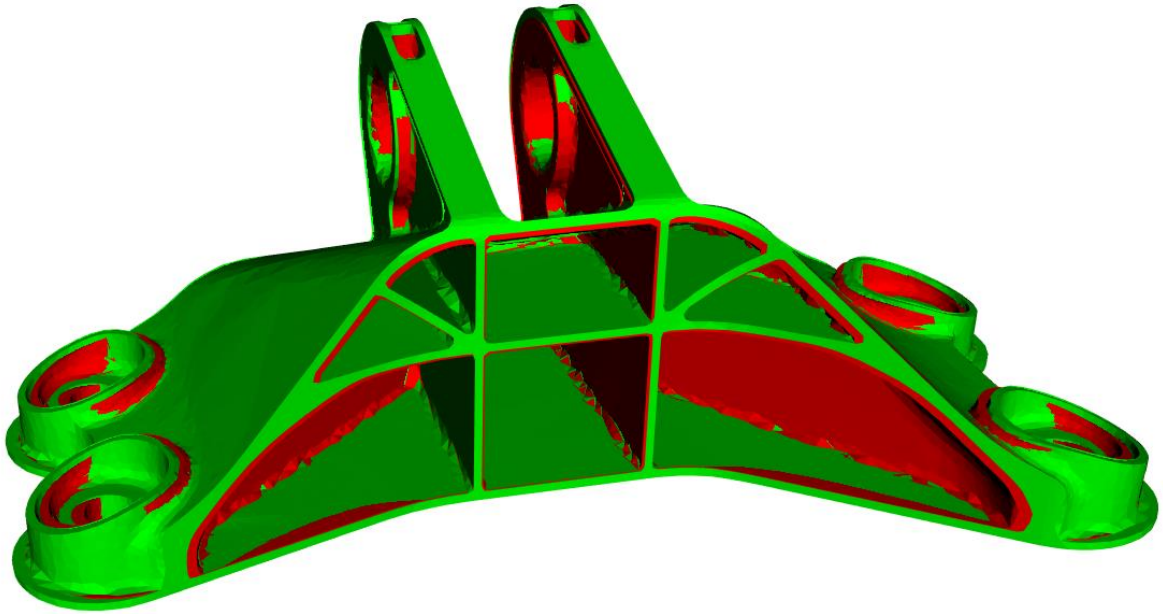




Manufacturing setup → Process Simulation → Warpage prediction

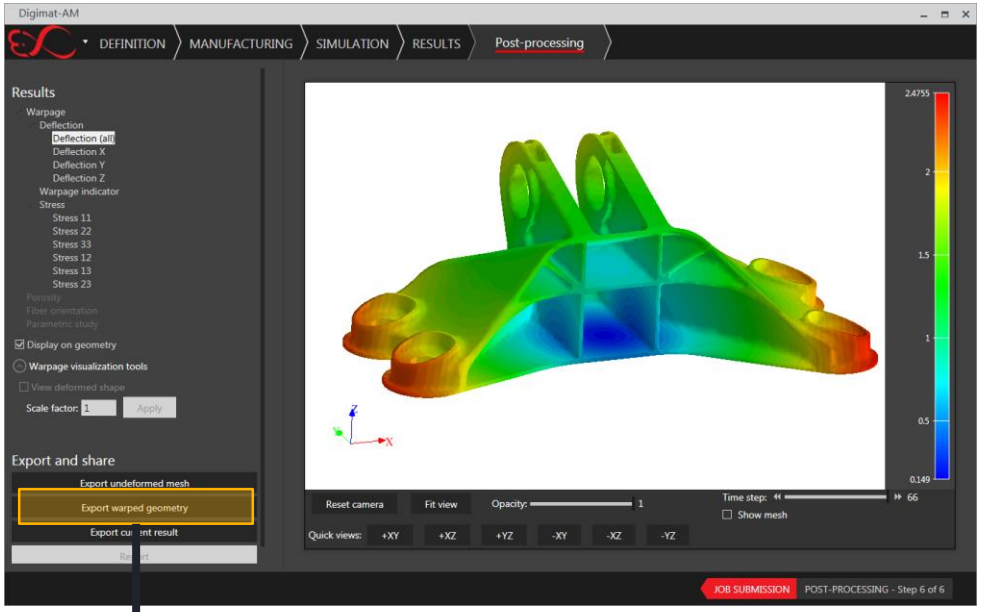
Warpage Evaluation

- Comparison of
  - **As-designed** geometry and
  - **As-printed** geometry (warped geometry)

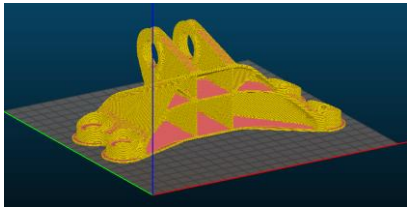


- As-printed part does not respect the geometry of the designed part

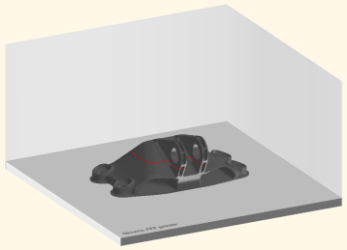
Warpage Correction



Export counter-warped geometry .stl file and restart pre-processing & virtual printing

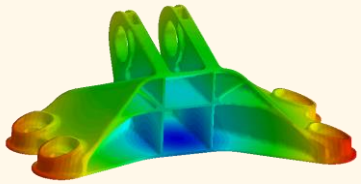


Compensated geometry slicing



Manufacturing setup

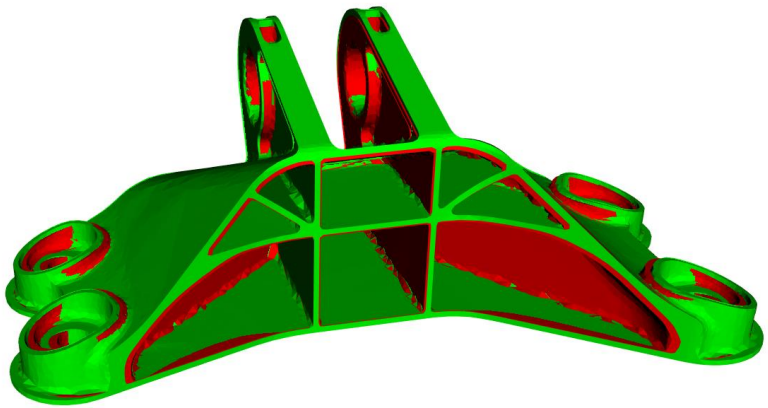
Manufacturing simulation



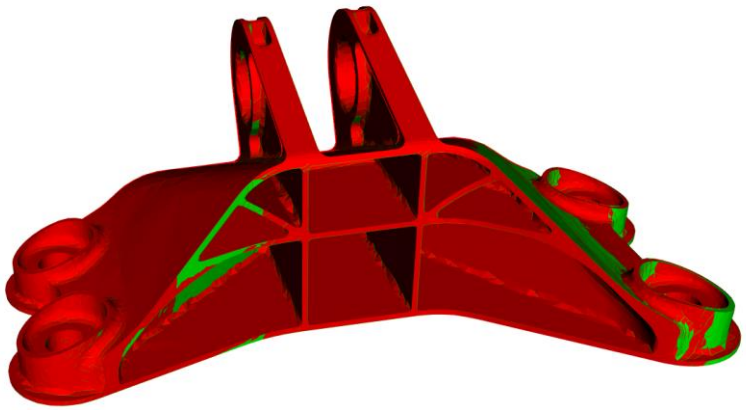
Warpage prediction

Corrected Geometry Evaluation

- Comparison of
  - **As-designed** geometry
  - **As-printed** geometry



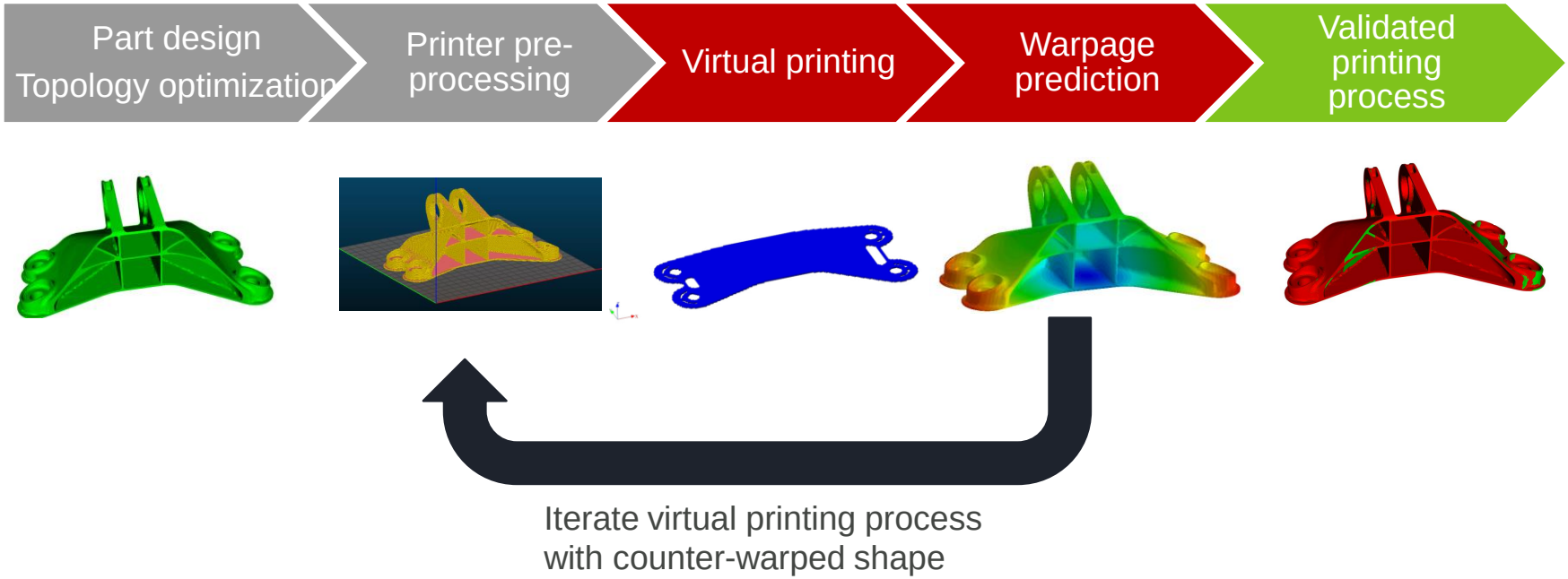
Before compensation



After compensation
with process simulation

- Compensated geometry can then be used for physical printing and to print right the first time!

Warpage Correction: Workflow



- Highly efficient process
  - Iteration loop in less than 1h

Conclusions

Digimat AM: Developed to serve the markets needs

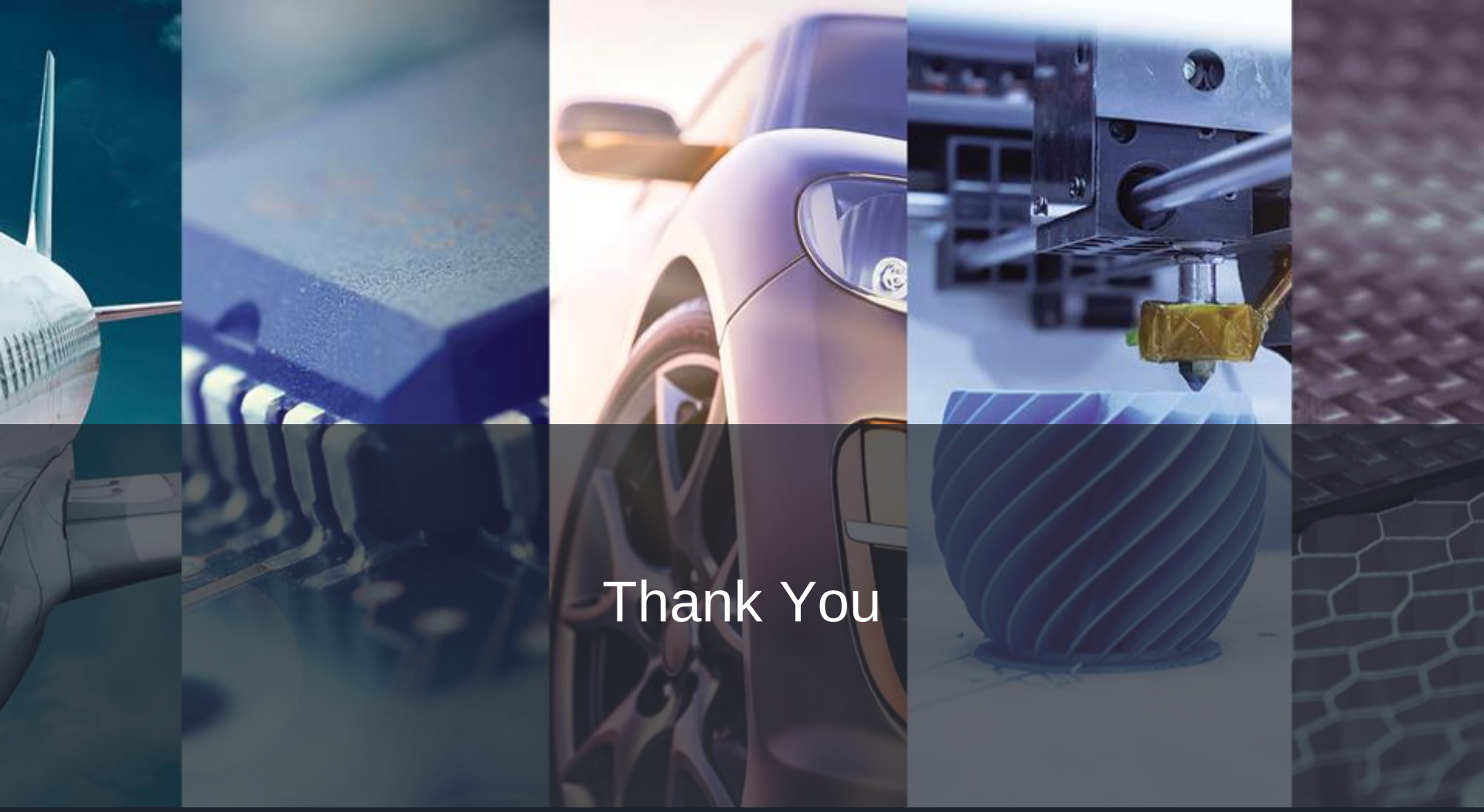
- **Comprehensive modelling solution developed in partnership with the complete ecosystem**
- **Simulate the manufacturing process**
  - Improve part quality
  - Anticipate printing issue with simulation
  - Time & material saving
  - Capture AM technology potential
- **Virtual testing of efficient materials**
  - Design, understand and test (new) systems
  - Reinforced materials and advanced material models
- **Accurate, efficient and predictive FEA to guide design**
  - Design & validate parts by accounting for the microstructure
  - Reduces physical productions and testing

Digimat USERS' MEETING 2018
Prague | Oct 8-11

e-Xstream ENGINEERING MSC Software Company 15 YEARS MATERIAL INNOVATION

- **The material modelling** conference
  - **8-11 Oct 2018**
  - **Occidental Praha Hotel**
  - **Prague, Czech Republic**
- The four-day event includes
  - insight of our **Material Vision 2020**
  - Digimat **Roadmap**
  - inspiring **keynotes**
  - best-in-class **industry presentations**
  - Digimat **ecosystem** and
  - unlimited **networking** opportunities with more than **180 attendees**.
- **Attend our AM round table & training**

➢ Register today at e-Xstream.com



Thank You

ESTREAM ENGINEERING

MSC Software Company