The Power of Simulation

Driving Productivity with Additive Manufacturing

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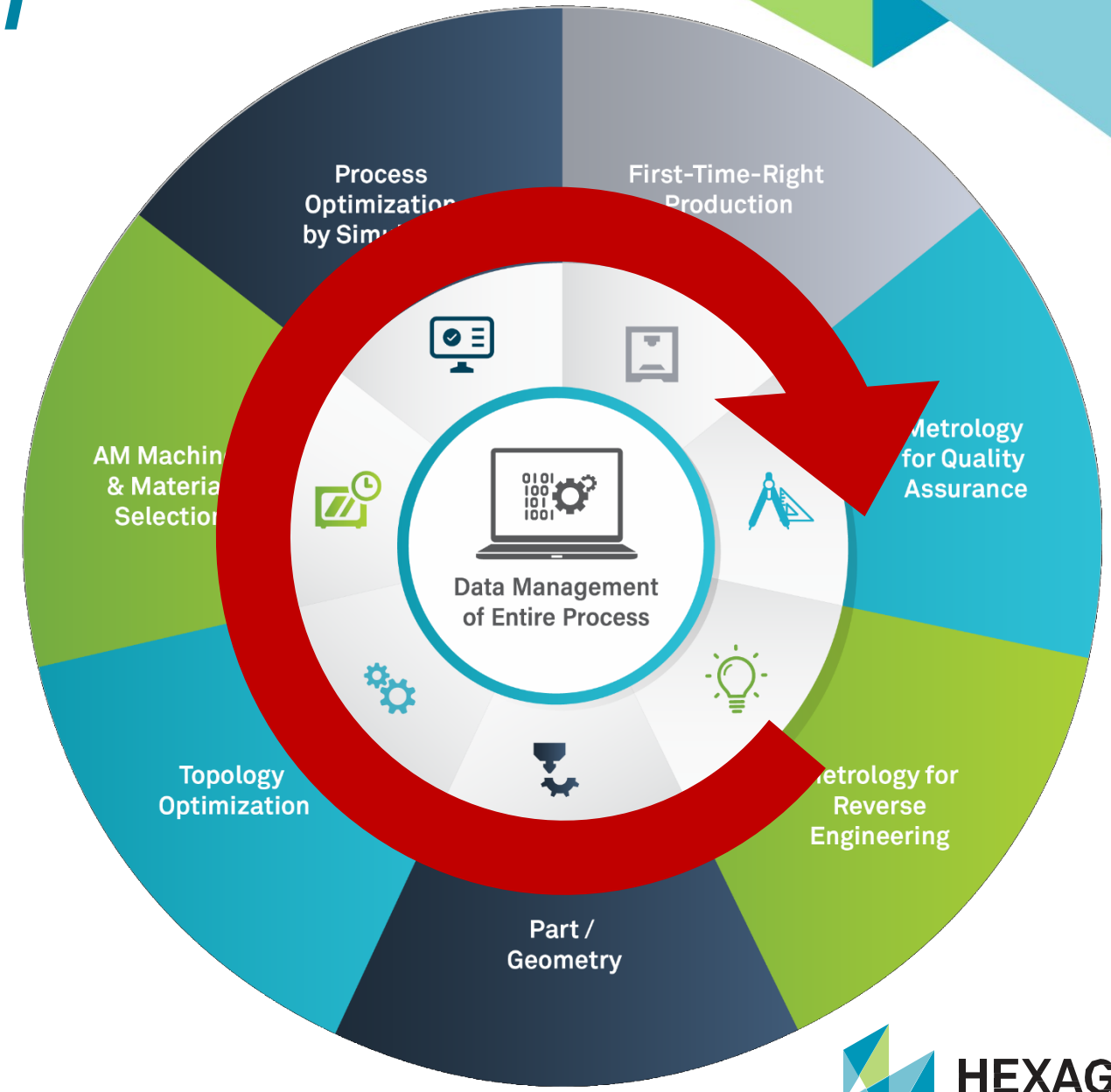

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Solution Demo: Next-Gen Bicycle

Folding bicycle with Additive Manufactured components

Solution Demo: Next-Gen Bicycle

Upper Fork

Bike Saddle

Folding bicycle with Additive Manufactured components

Metrology for reverse engineering.

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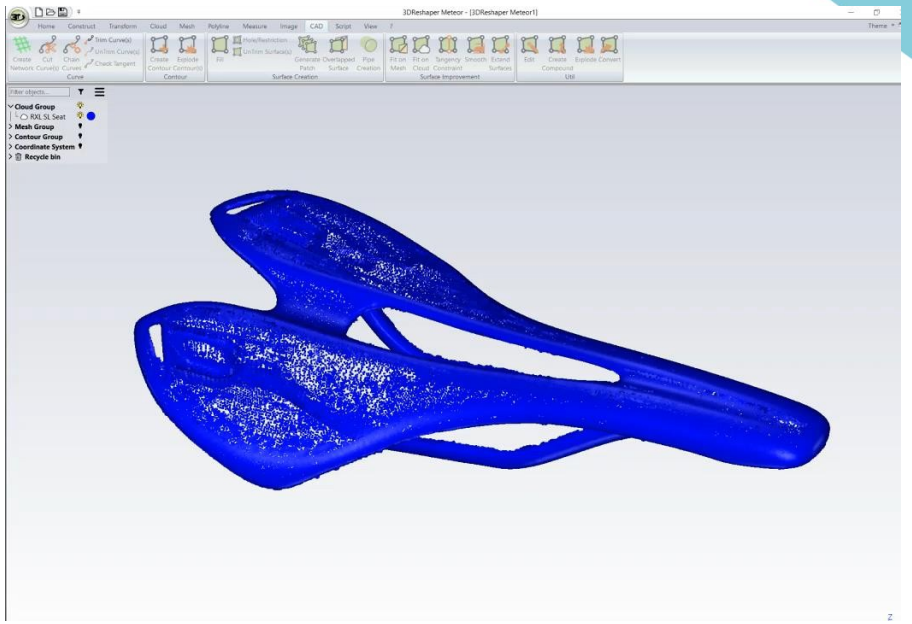
Reverse Engineering / Recreate a Physical Part

- Many customers want to reverse engineer/recreate a physical part:
  - RS5 Laser Scanner -> Point Cloud data -> 3DReshaper -> Geometry



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Part and Geometry.

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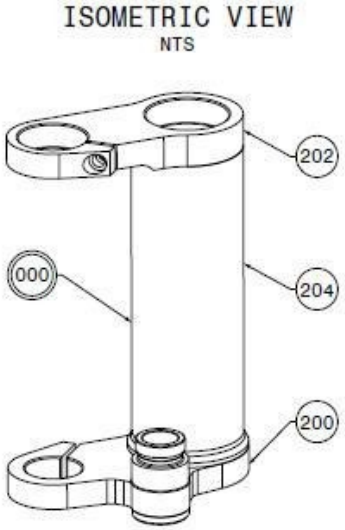
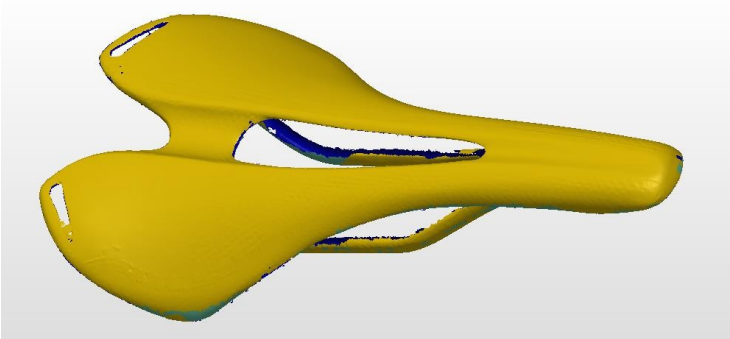
Part / Geometry

- The part/geometry can come from 4 sources:
  1. New design based on buildspace / available volume
  2. Original design from CAD
  3. **Existing design to be re-worked for AM (Bike Fork)**
  4. **Physical part scanned (Saddle)**





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Topology optimization.

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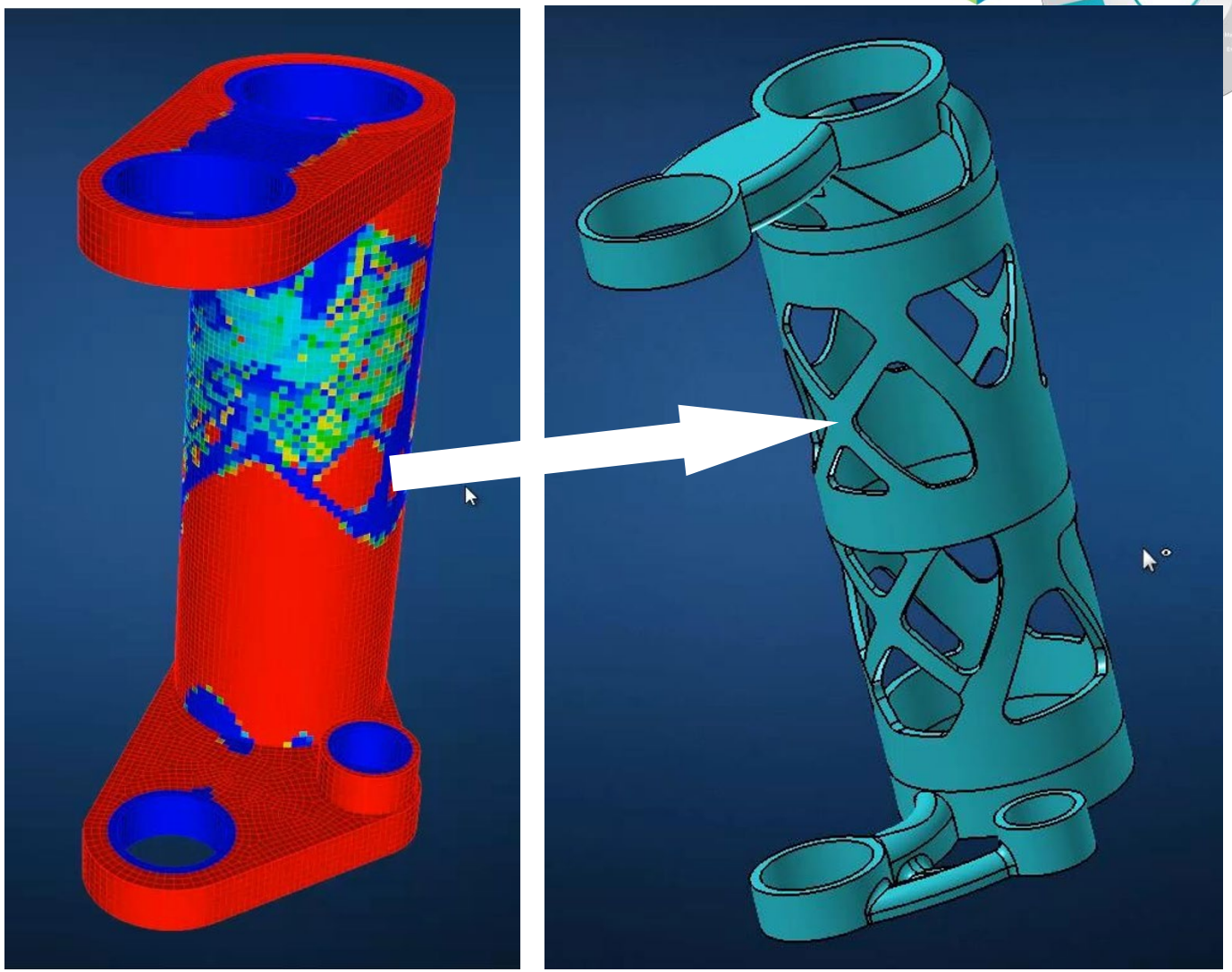
Topology Optimization for AM

- Benefits
  - Used in early design to obtain designs that will withstand the loads and minimize the weight
  - For 3D printing, topology optimization will also minimize cost and printer time
  - Can be used to redesign existing components
  - Accounts for manufacturing constraints



MSC Apex

MSC Nastran

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AM Machine & Material Selection.

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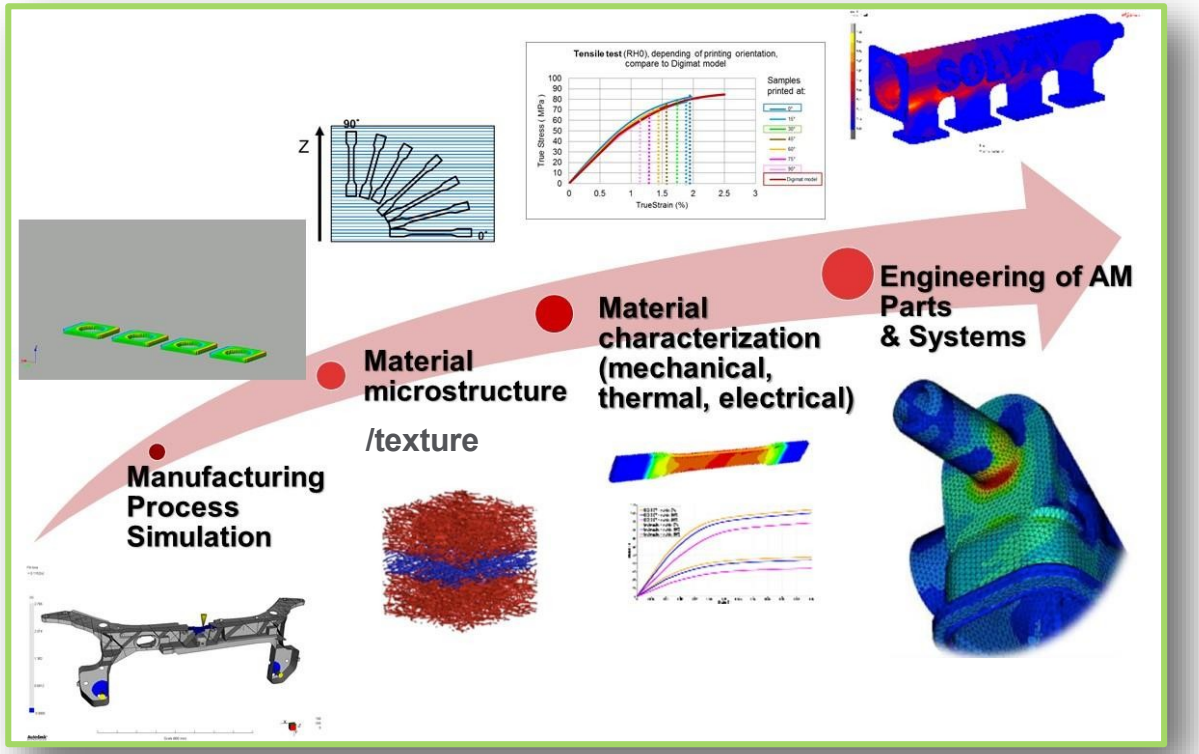
Machine and Material Selection

- Most extensive support of multiple AM technologies
  - Metal Additive
    - Selective Laser Melting (SLM)
    - Direct Metal Laser Sintering (DMLS)
    - LaserCUSING®
    - Electron Beam Modeling (EBM)
    - Laser Metal Deposition (LMD)
    - Direct Metal Deposition (DMD)
    - Direct Energy Deposition (DED)
    - Laser Cladding
  - Polymer Additive
    - Fused Filament Fabrication (FFF)
    - Fused Deposition Modeling (FDM)
    - Selective Laser Sintering (SLS)

- Material properties
  - Material library
  - Reverse engineering
  - Micro-mechanical material modeling
  - Partnerships with material suppliers



Supporting an Open Ecosystem

RENISHAW apply innovation™
Arcam EBM a GE Additive company
eos
stratasys
SLM SOLUTIONS
materialise
DSM BRIGHT SCIENCE. BRIGHTER LIVING.
SOLVAY asking more from chemistry®
+ others

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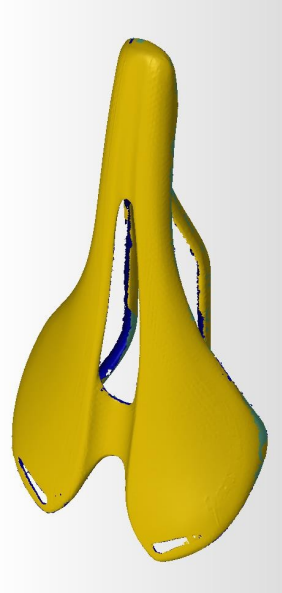
Machine and Material Selection

Solution Demo: Next-Gen Bicycle

Partnered with NIAR at Wichita State University for printing of the components

Stratasys Fortus 900mc for saddle (Polycarbonate)



EOS280 for fork tube (Titanium powder)

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Process Optimization by Simulation.

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First-Time-Right 3D Printing

- **Virtual Printing simulation utilizes inherent strain method**
  - Implementation: Voxel mesh technique, Inherent strain method, Layer based
  - Inherent strains
    - Comprise: Plastic strains, thermal strains, creep strains and phase transformation strains
    - Reflect: Material and manufacturing parameters
    - Specific to an (Individual) machine
    - Are orthotropic by nature
  - Benefit: Extremely fast in computational time
  - Results: Part distortion, Residual stress results

- **Calibration can done via physical coupon print or micro-mechanical modeling**

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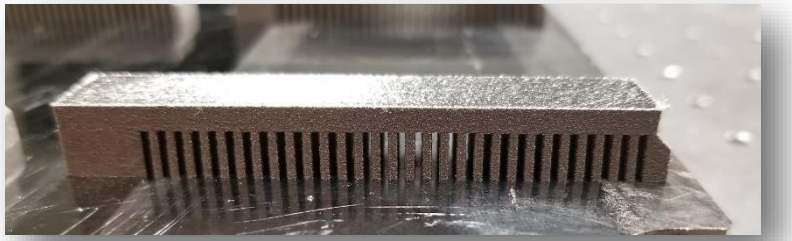
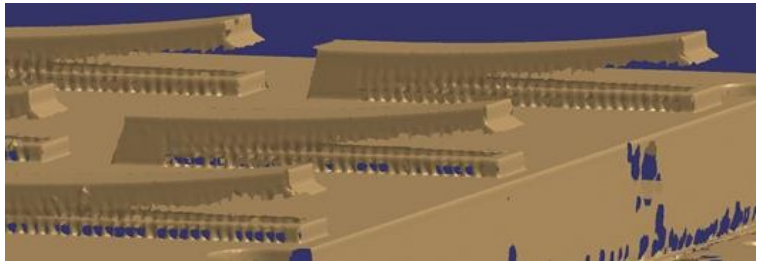
-> Calibration via printing cantilever coupons

- Each machine prints in a unique way
- Printer quality can change over time
- Different areas of the plate/cell have different thermal performance

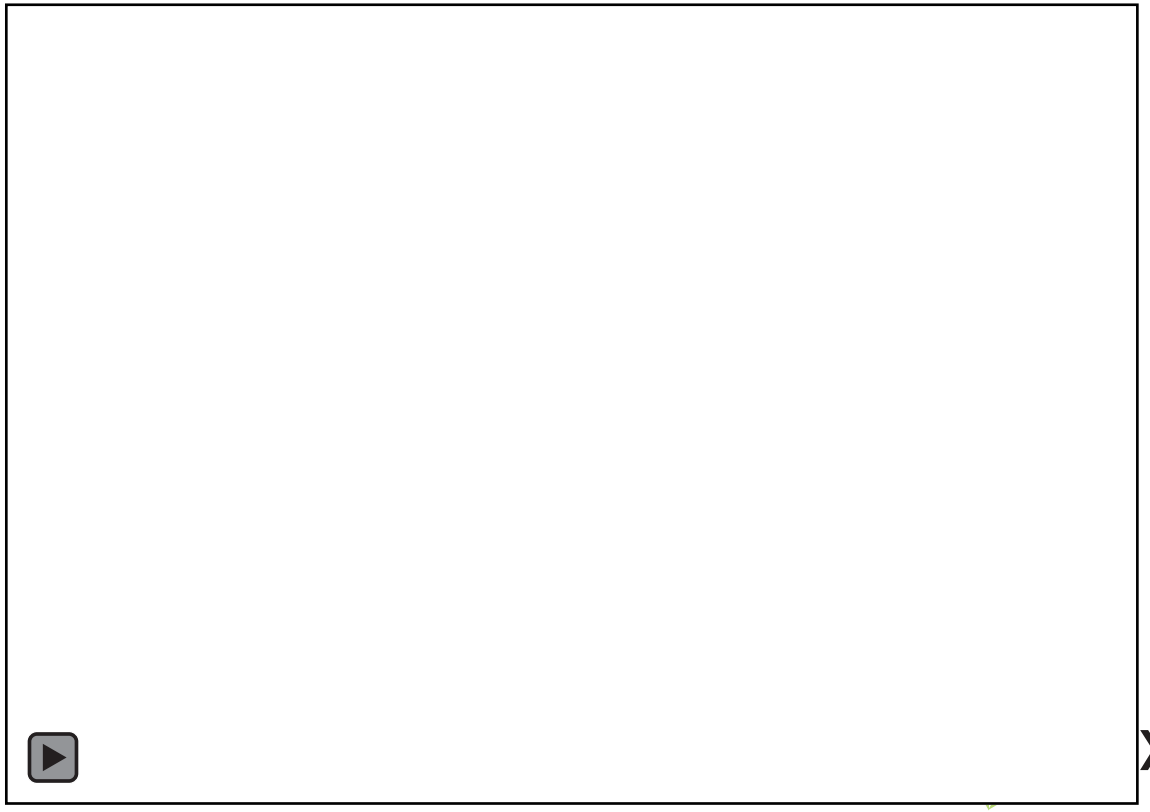
Calibrate machine performance by printing cantilever beams and measuring their deflection when cut

test





simulation



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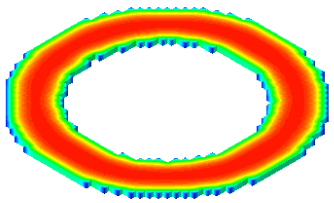
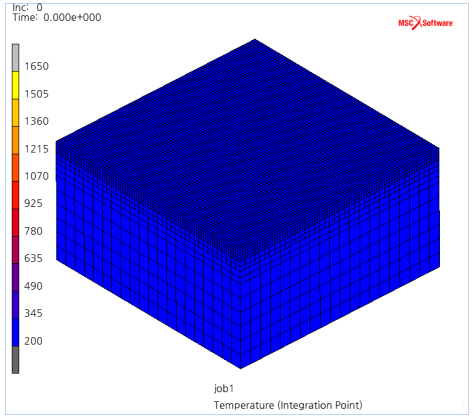
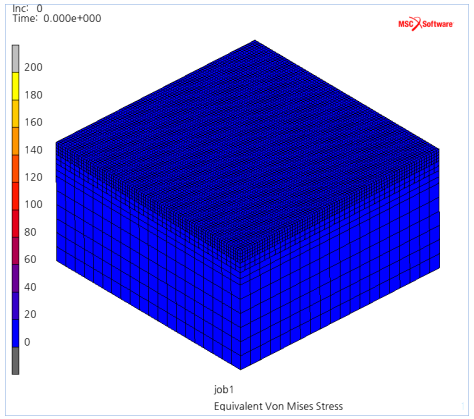
-> Calibration via micro-mechanical modeling

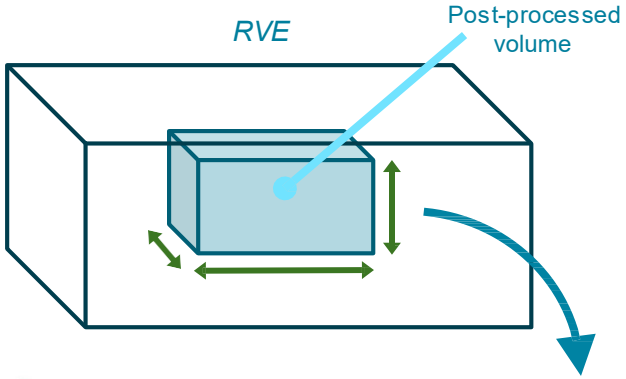
- Model materials, porosity and interface at micro-level
- Create RVE (Representative Volume Element)
- Accounts for specific process/material parameters

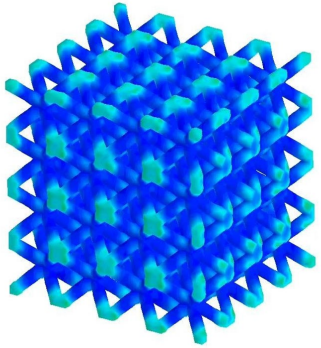
Coupled thermo-mechanical simulation to compute (instead of measure) inherent strain











$\varepsilon_{11} = -0.00335$
$\varepsilon_{22} = -0.00304$
$\varepsilon_{33} = -0.00218$

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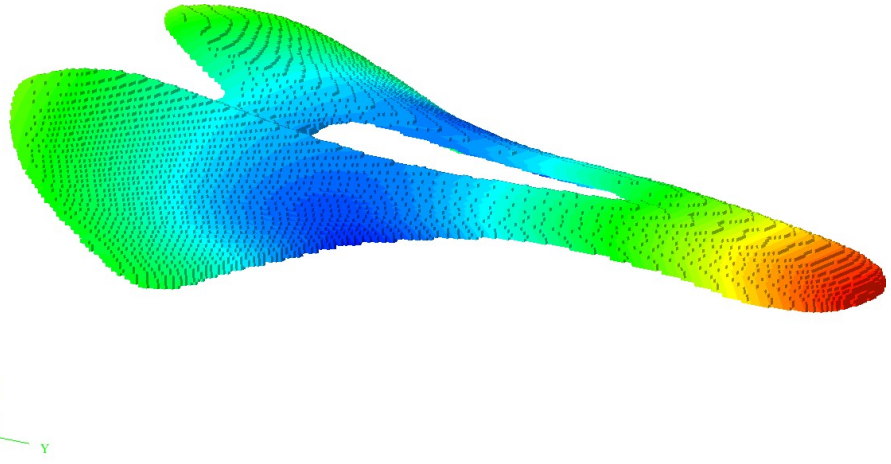
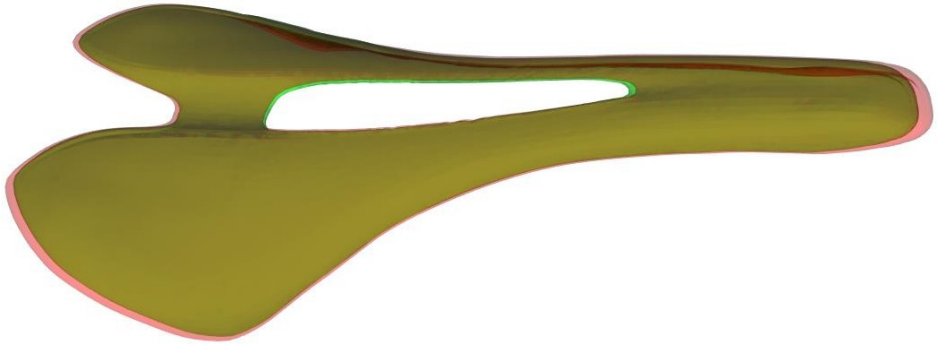
-> Then, you simulate and optimize the print

Print simulation of the saddle (FDM - Polycarbonate)



Export warpage compensation geometry



Green = as-designed

Red = distortion compensation

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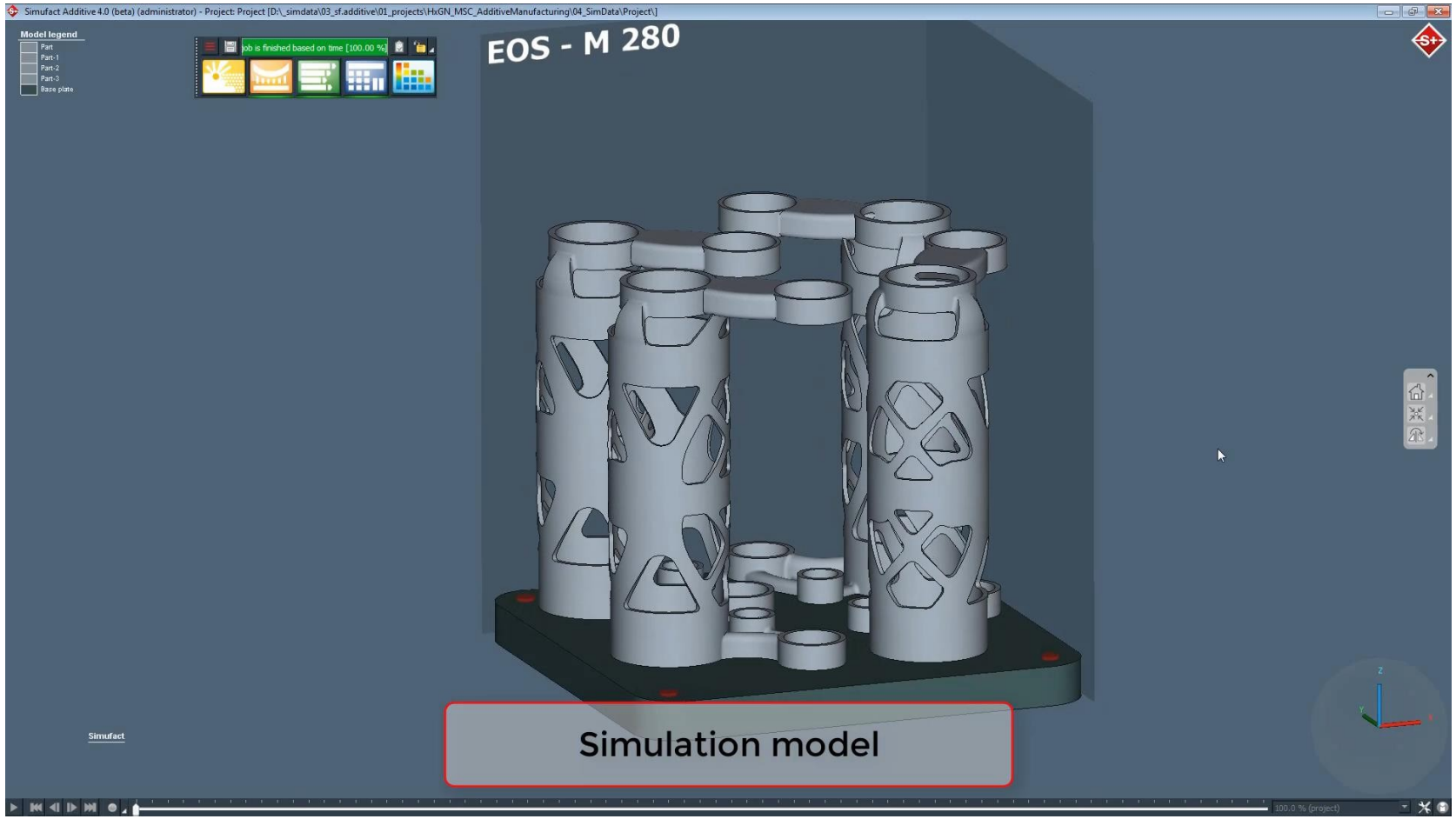
-> Then, you simulate and optimize the print

Forks (Titanium powder)



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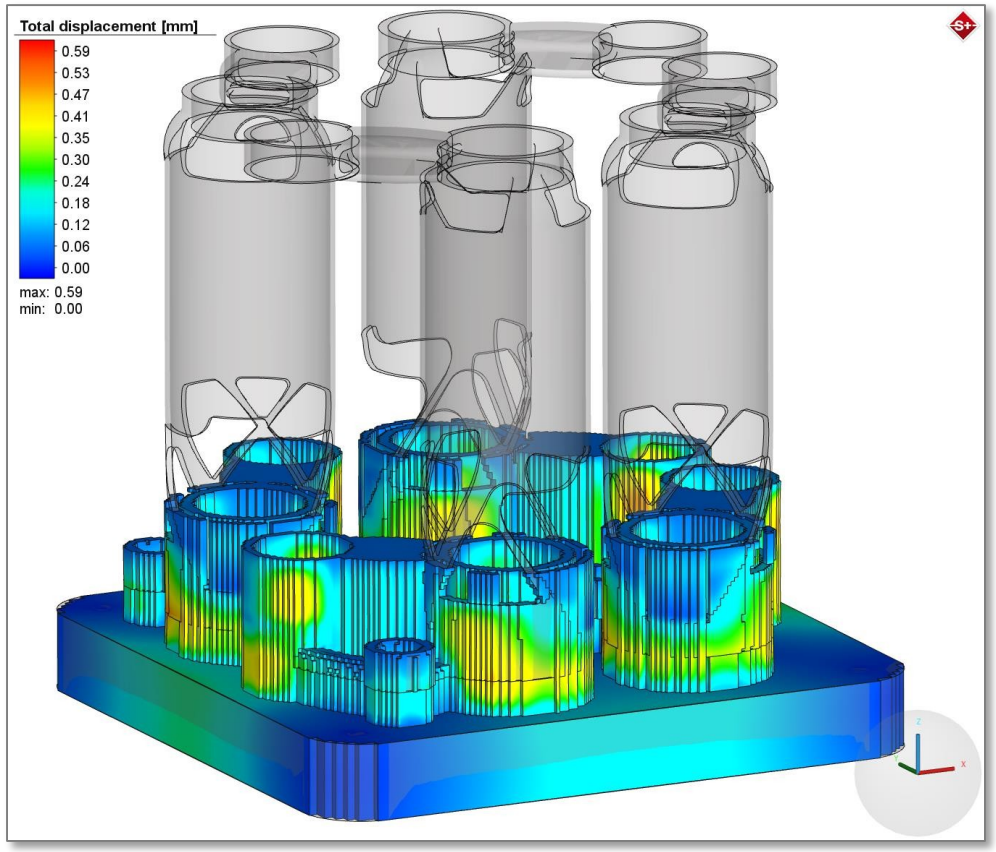
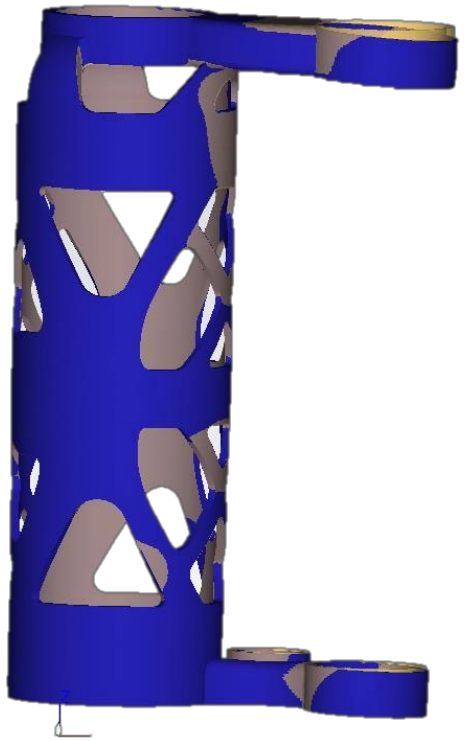
-> Then, you simulate and optimize the print

Forks (Titanium powder)

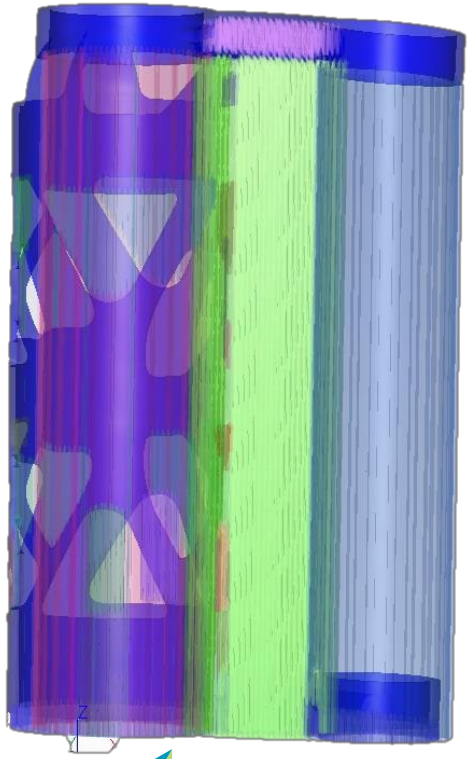


Gold = initial

Blue = distortion compensation



Final geometry with Optimized support structure



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First Time Right Production.

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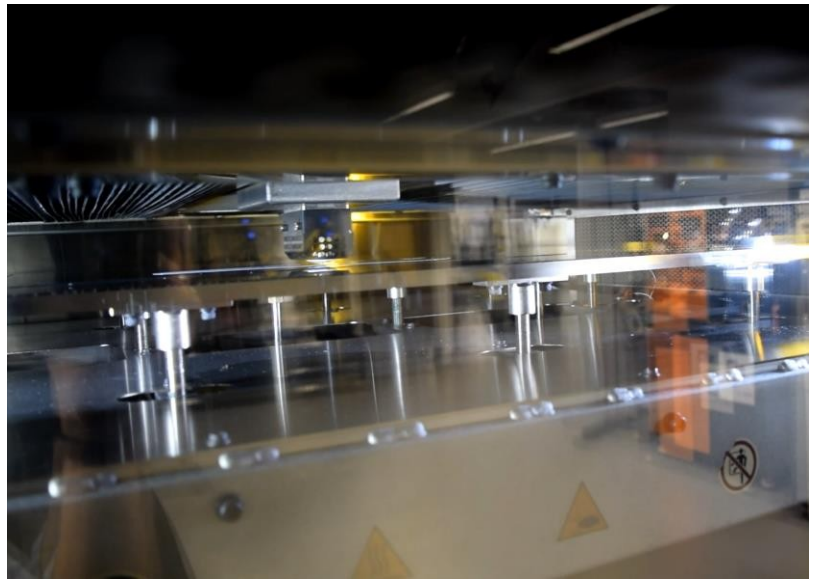
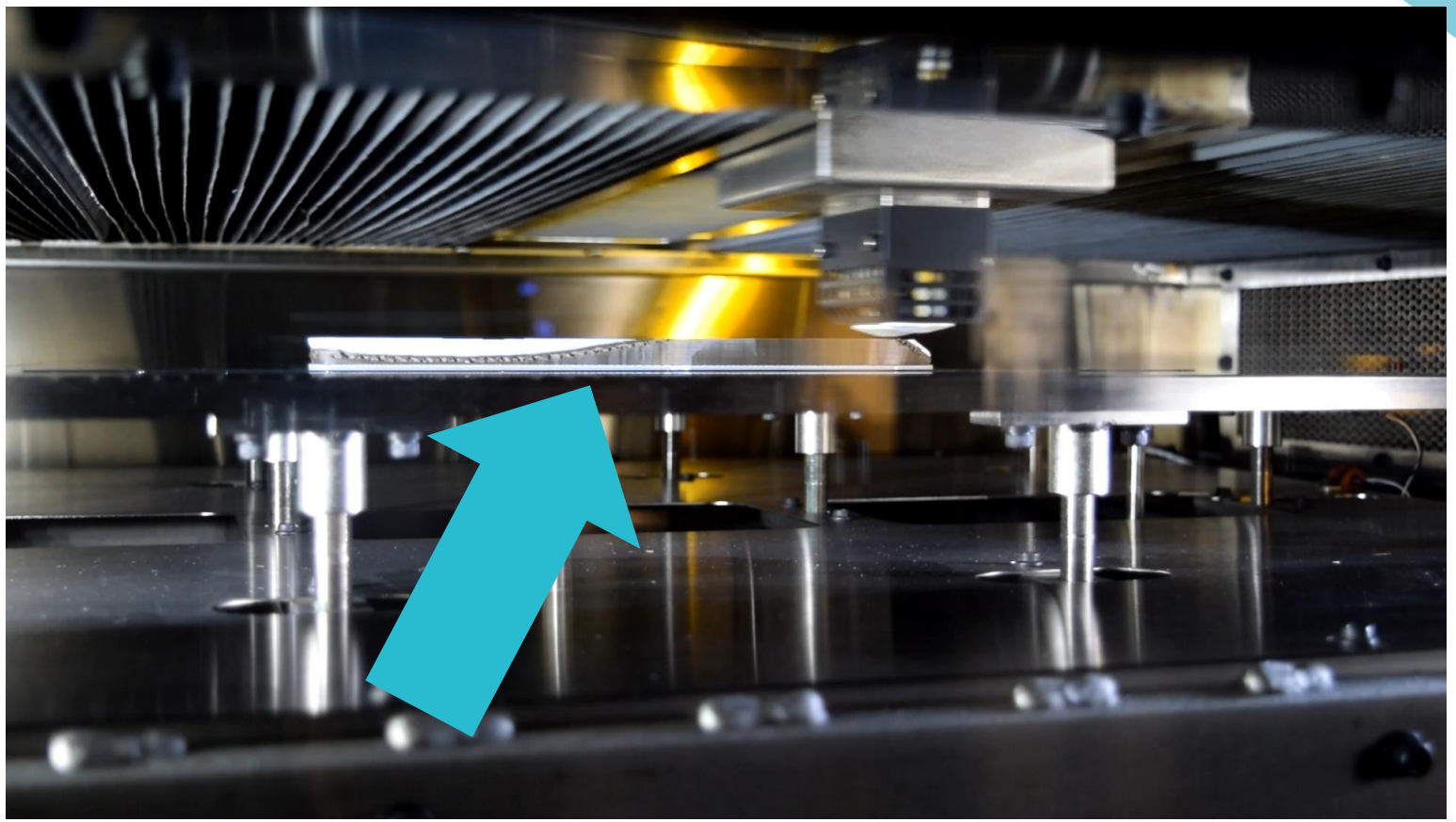
Data Management of the Print Process | Capturing the Digital Thread

Printing the saddle





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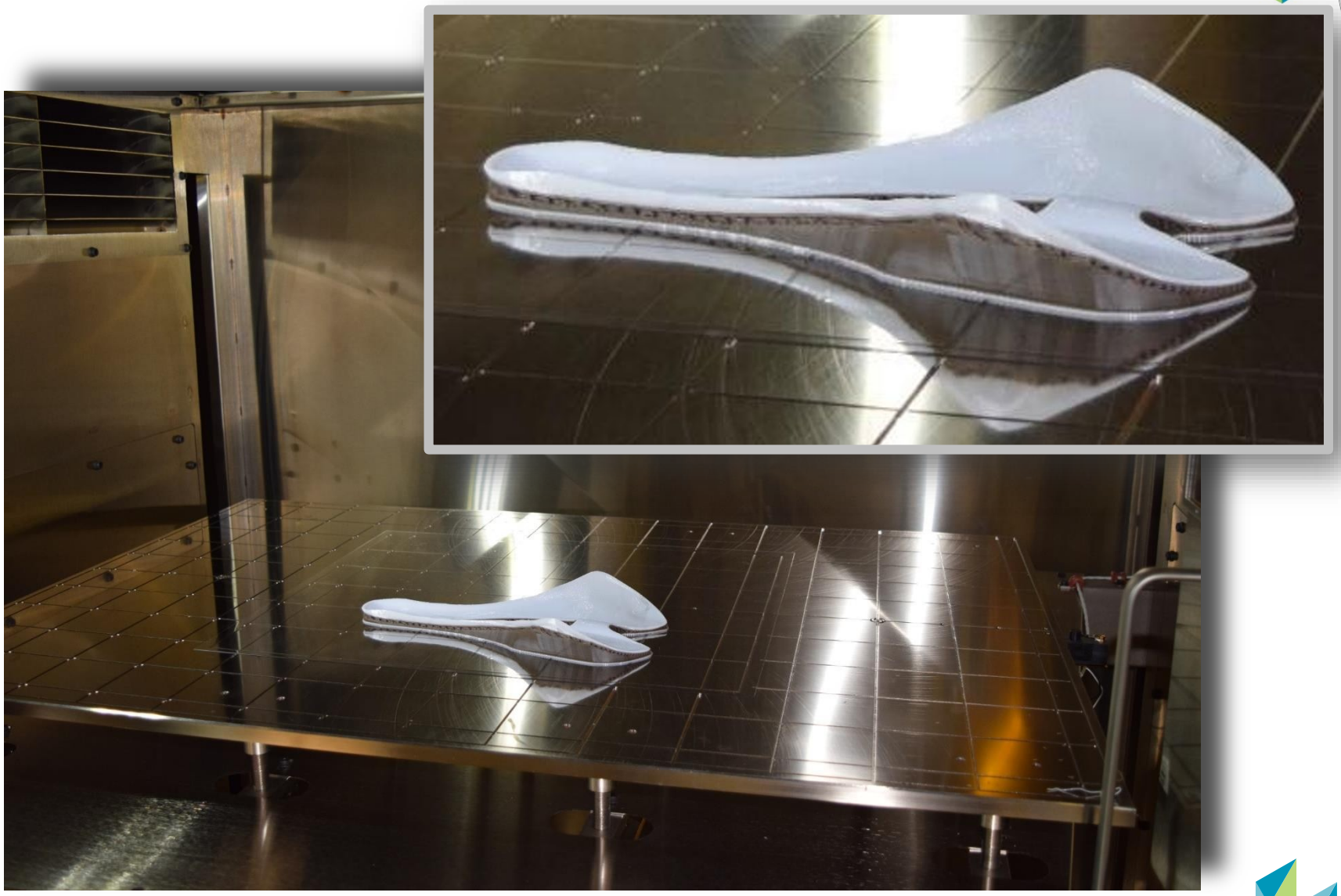
Data Management of the Print Process | Capturing the Digital Thread

Printing the saddle



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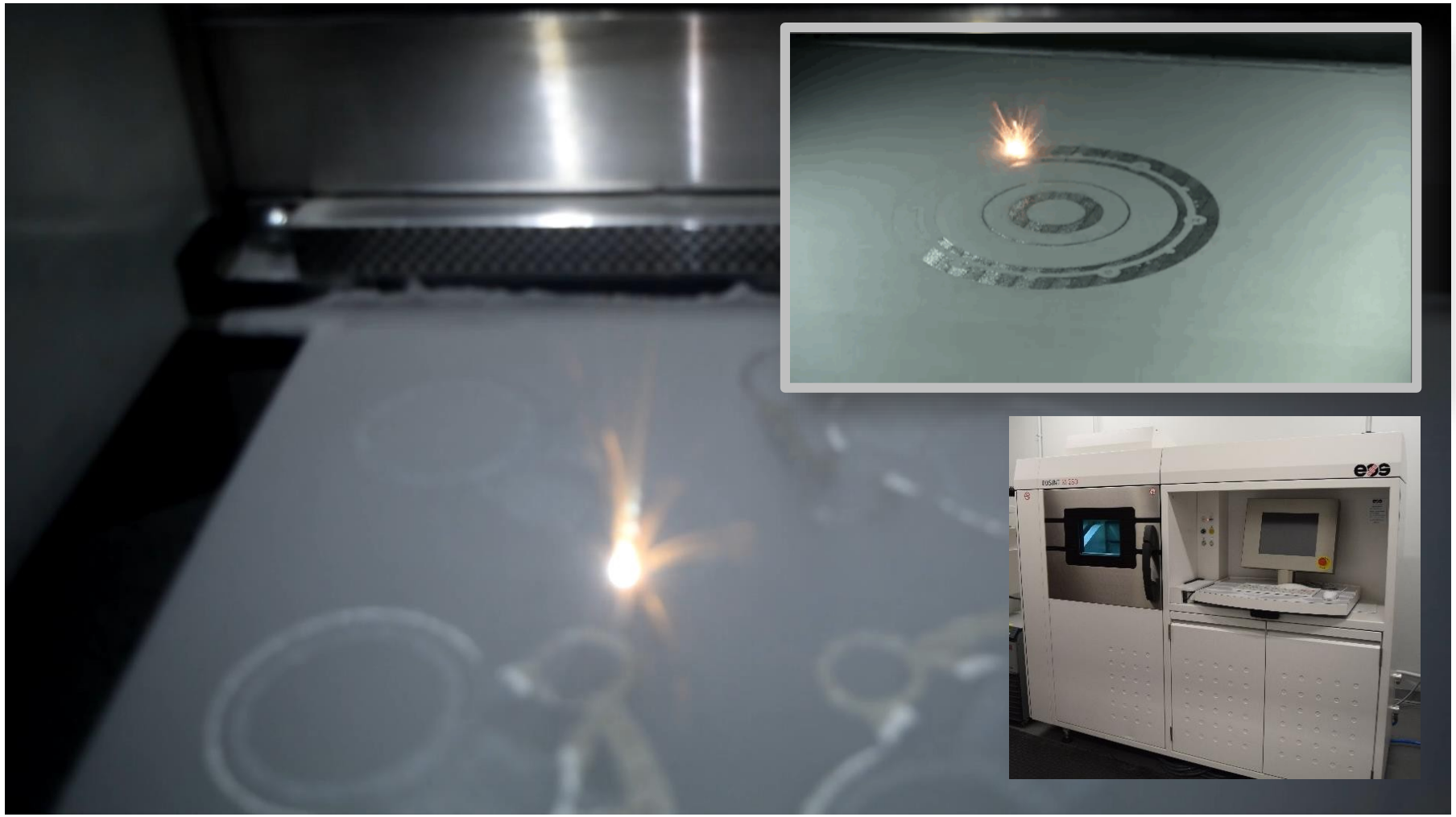
Data Management of the Print Process | Capturing the Digital Thread

Printing the fork



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Data Management of the Print Process | Capturing the Digital Thread

Commercial AM Data Sources

Maintain Pedigree of Recycled Powder

Store/Track Virgin Powder Properties

Store complete AM Process Data
- process, machine, environment, part, build details
- store in-situ data
- store post process data

Inputs/recommendations for Design for AM

Simulation of as-designed as-manufactured parts

AM Powder / Fiber → AM Process → AM Post-Process → Test Data → Data Reduction → Design Data → CAE Models

Part quality database for correlation to virtual & reference data

Retrieve batch level material data & machine info

Provide/track inputs to build & post processing

Track all inspection & test data associated to build

Virtual Simulation

Simufact Additive

digimat

MMPDS

Correlate as-manufactured material data to virtual prediction

Calibrate virtual model to physical machine

MaterialCenter

Metrology for Quality Assurance.

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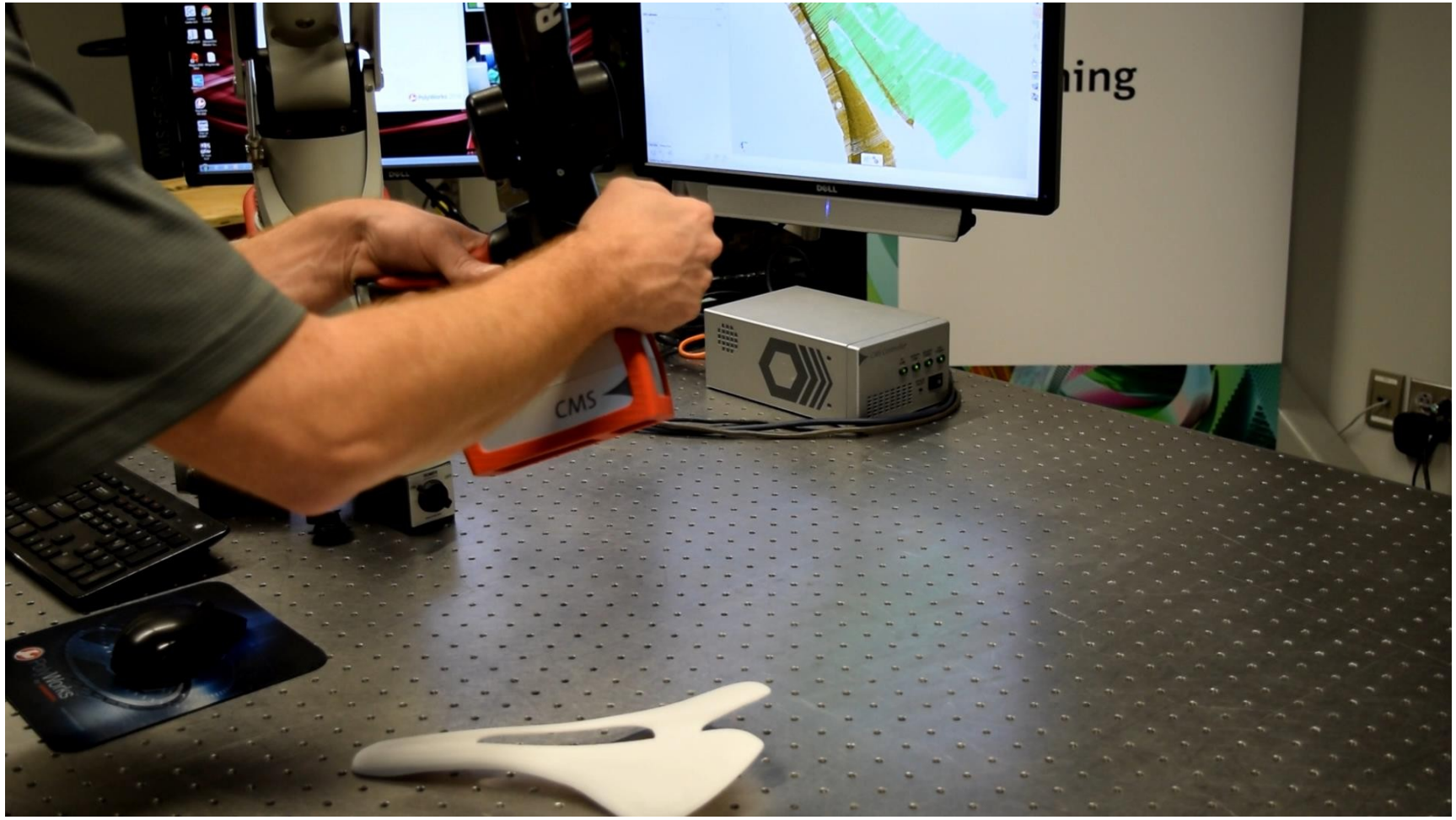
Metrology

Inspection of the printed part by acquiring a point cloud.



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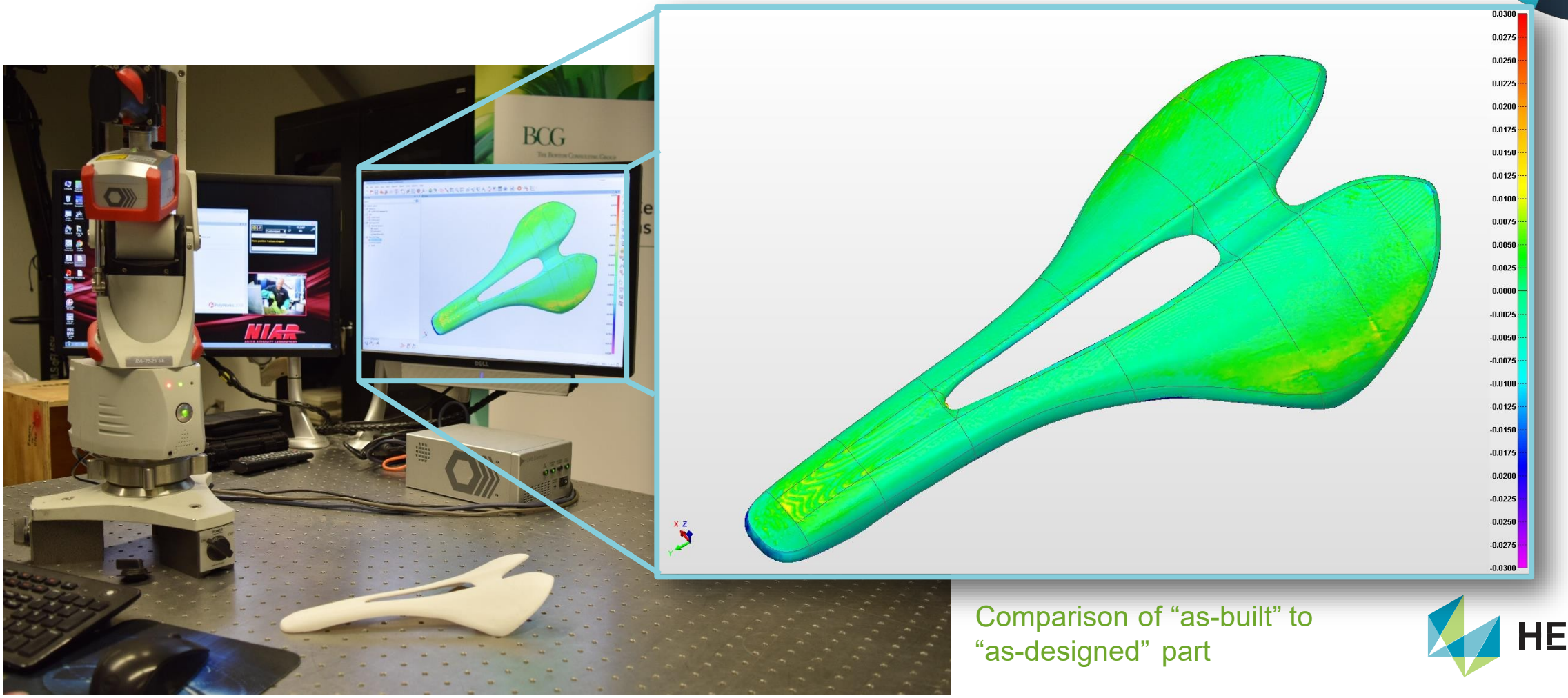
With Hexagon & MSC Software; you can

plan, optimize, validate and replicate

high quality additively manufactured parts



Comparison of “as-built” to “as-designed” part

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THANK YOU!

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