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Online-Seminar

# Print First Time Right
## Prozess-Simulation in NX für Pulverbett Verfahren

**Boris Lauber & Helmut Zeyn**

**Unrestricted @ Siemens AG 2019**

# Herzlich Willkommen

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# It’s time to rethink

EVERYTHING

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# Innovationen –
# Inkrementeller Fortschritt bringt keinen Wettbewerbsvorteil

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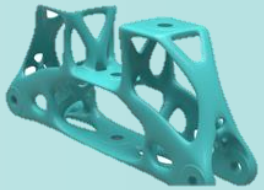
**Produkt Transformation**
Vom konventionellen Design zum Innovativen Produkt

## Neue Produkte

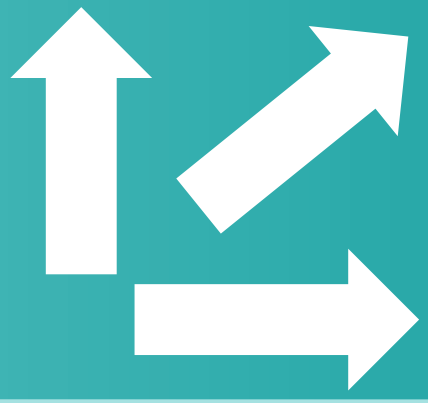
- Reduzierung Gewicht, Material
- Scannen → Produkt
- Verbesserte Performance
- Innovations-Zyklen verkürzen



## Neue Geschäftsmodelle

- Individualisierung, Personalisierung
- Null Inventar – Druck auf Bedarf
- Design überall - Drucken überall.
- Innovation beschleunigen

**STATUS QUO**



## Neue Fertigungs-Möglichkeiten

- Vermeidung von Werkzeugen
- Vereinfachung Montageprozess
- Lieferkette verkürzen
- Erschwingliche Kleinserien

**Transformation der Fertigung**
Anheben vom Prototypen-Bau zur Industriellen Fertigung

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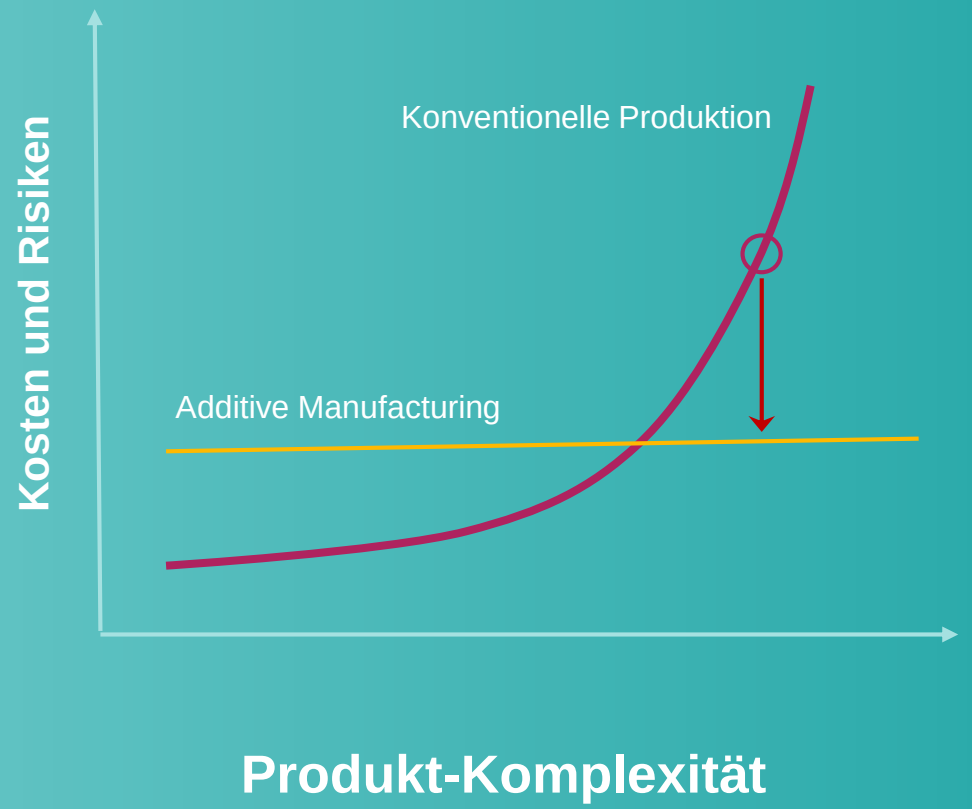
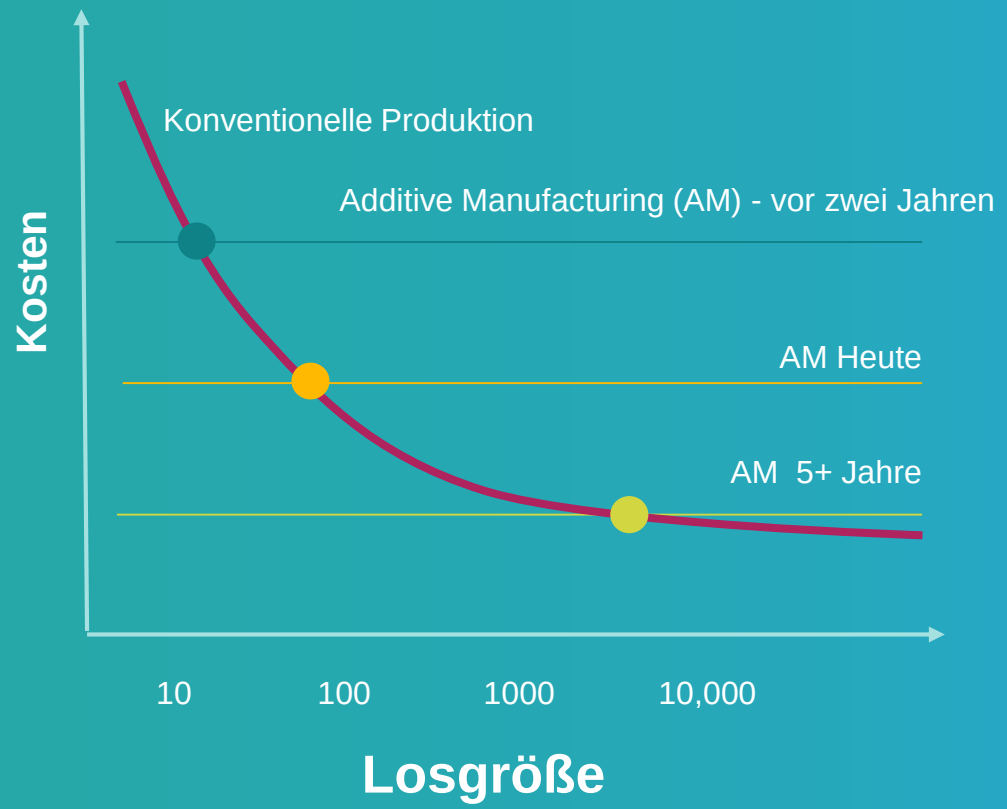
# Treiber der Implementierung von Additiver Fertigung

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# Industrialisierung der Additiven Fertigung
## Unterstützte Druck-Technologien

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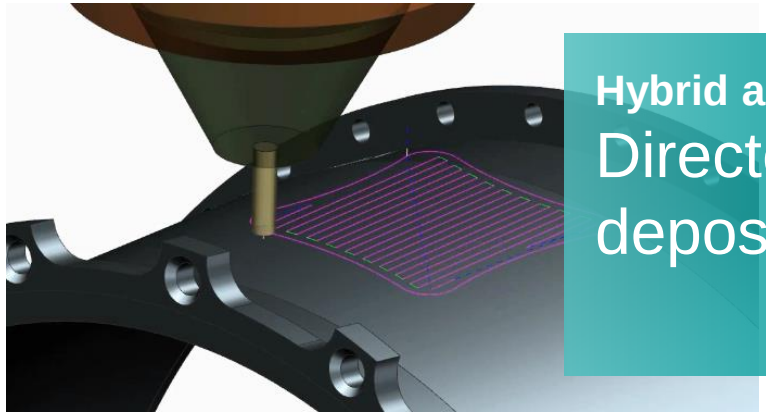
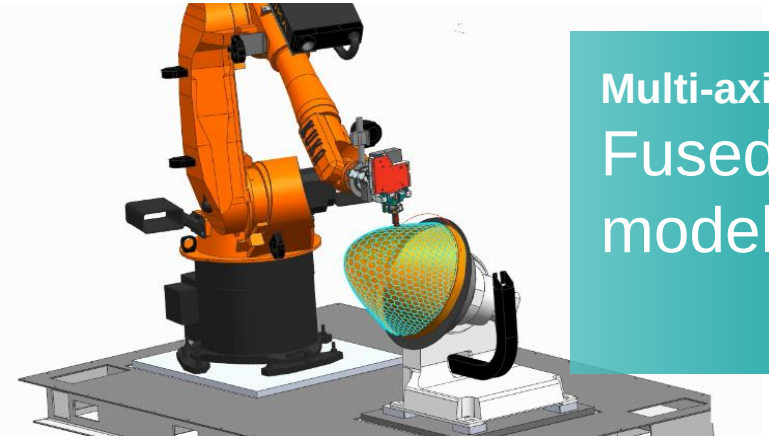


**Hybrid additive**
Directed energy deposition



**Multi-axis**
Fused deposition modeling

**Powder bed fusion**
Laser material fusion

**Multi jet fusion**
Agent jetting/ inkjet technology

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# Sehr unterschiedliches Knowhow erforderlich

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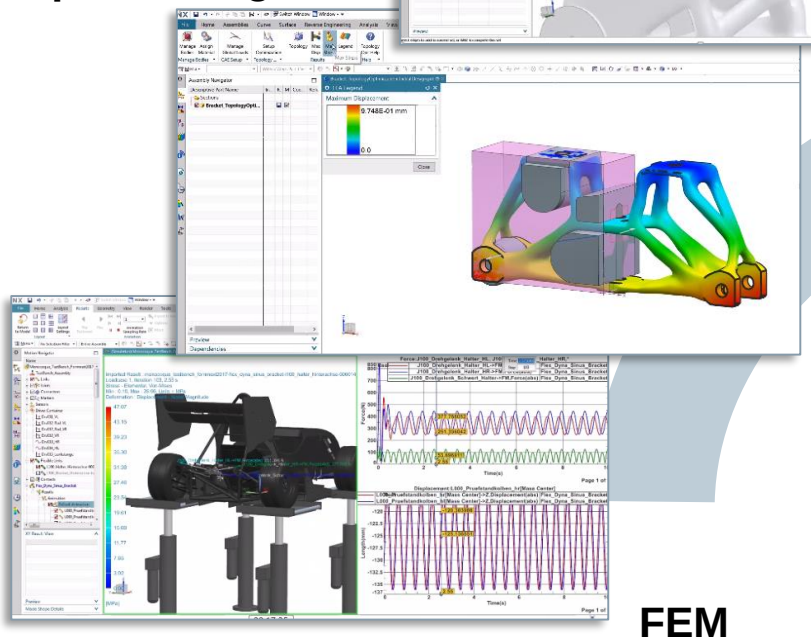
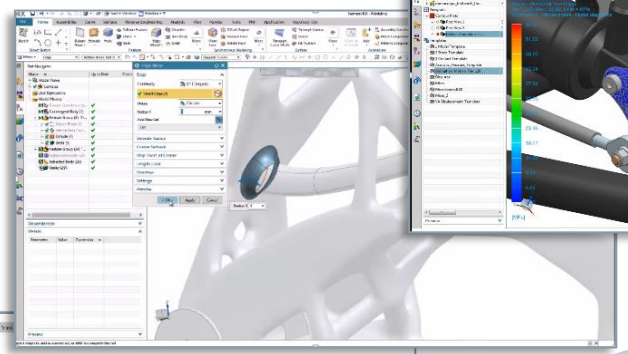
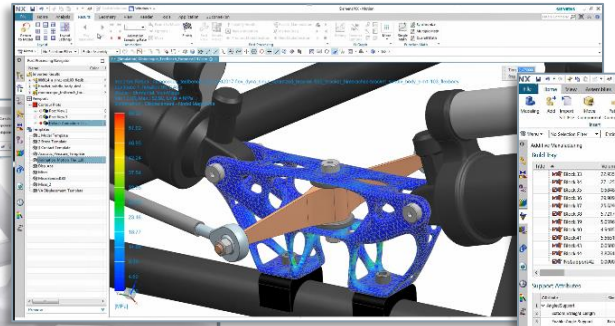
CAD

Topologie-Optimierung

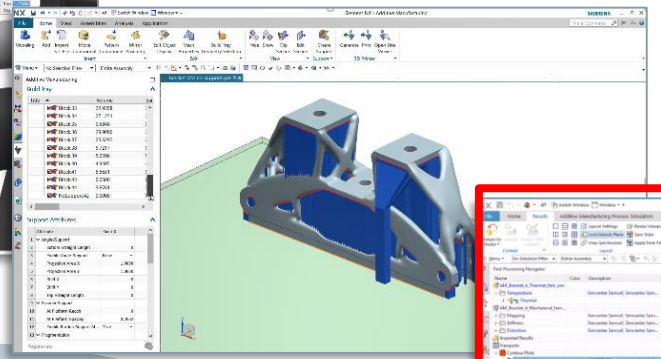




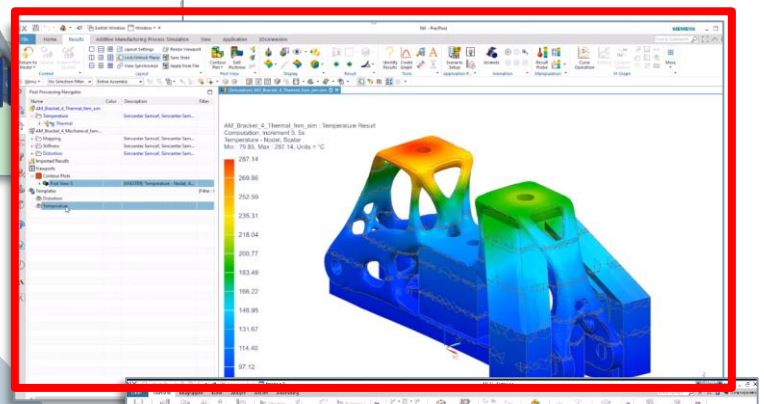


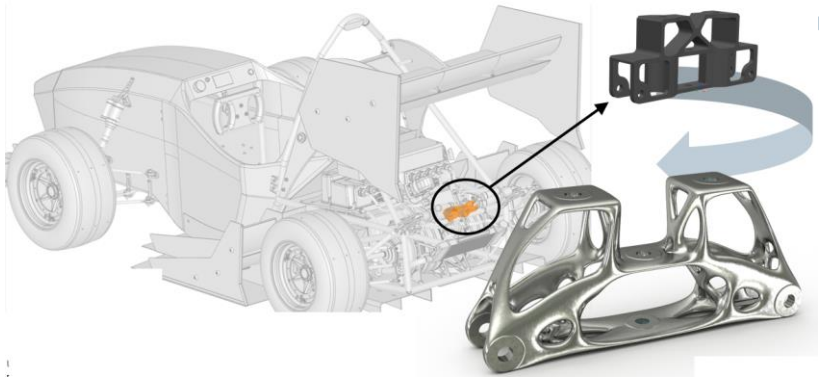
FEM

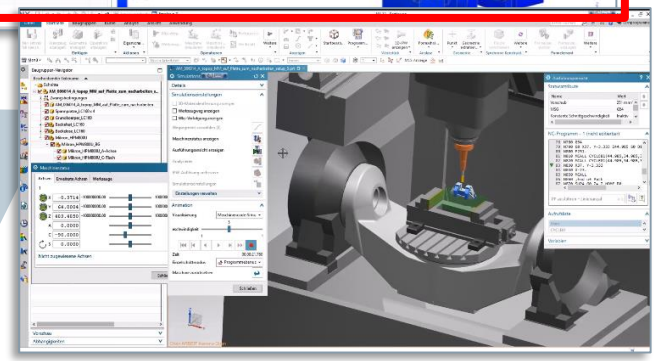
Druck-Vorbereitung



Druck-Simulation







CAM

FEM

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## Simcenter 3D
## Additive Manufacturing

Boris Lauber | Siemens PLM Software

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# Challenges in Additive Manufacturing
## Laser Powder Bed Fusion (LPBF)

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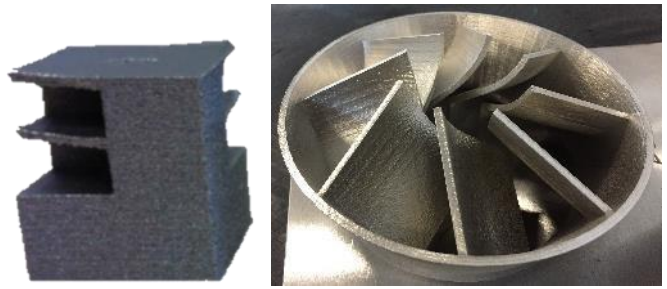
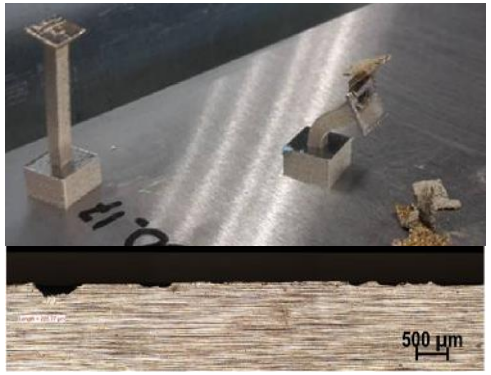
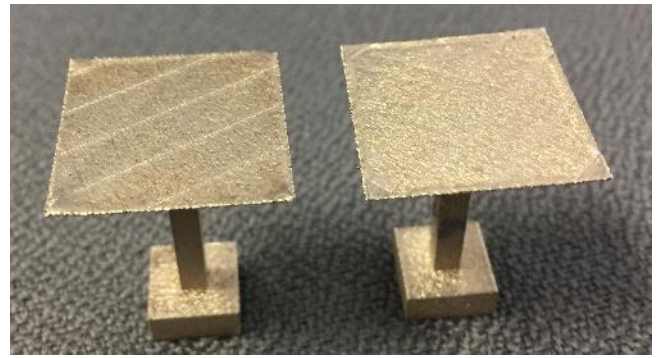
### Thermo-mechanical history



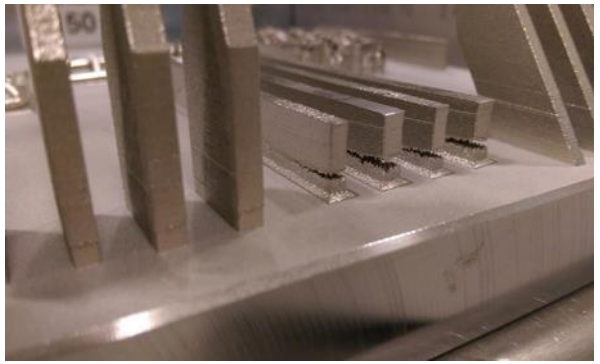
### Recoater collision




### Local overheating

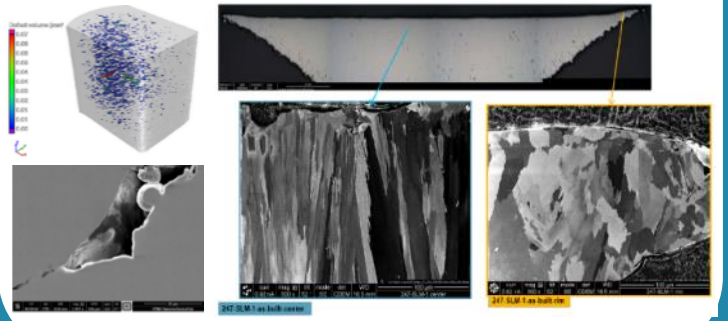


### Support Failure



### Shrink lines

### Microstructure & Defects



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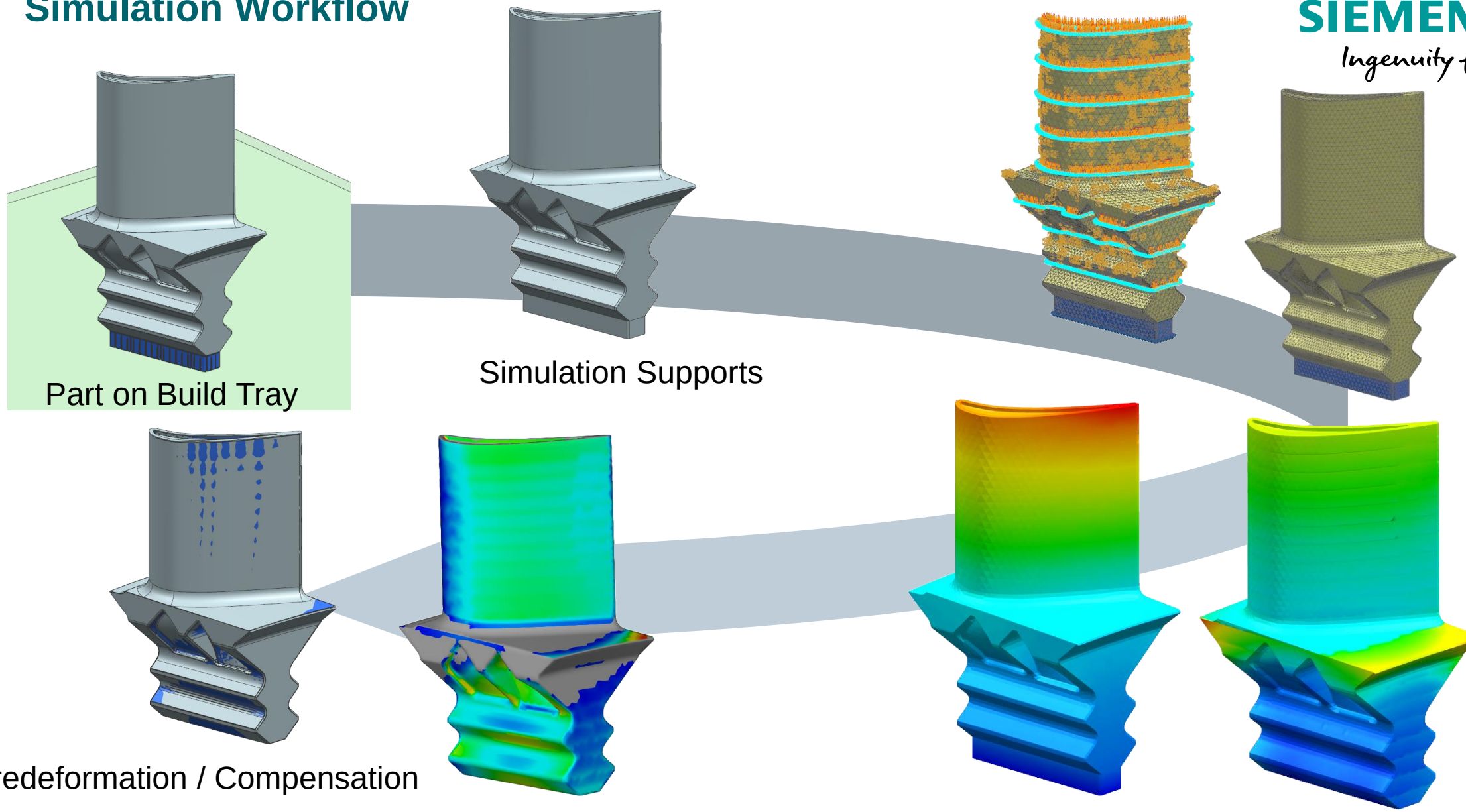
# Simulation Workflow

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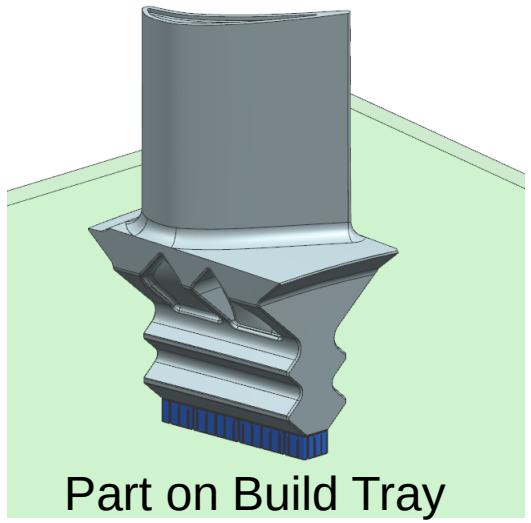
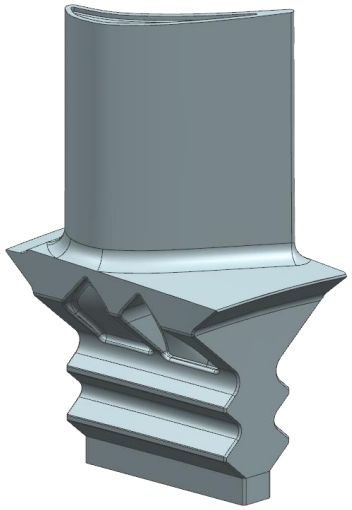
# Simulation Workflow



Part on Build Tray



Simulation Supports

- Build Preparation is done on in the Additive Manufacturing Module of NX
- Simulation is fully integrated into the AM Workflow
- Position, Build Space, Support structures are reused for Simulation

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NX - Gateway

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File | View | Render | Assemblies | Analysis | Tools | Application | NX Utilities

Find a Command

Window | Zoom | Scale 2.1977 | Show and Hide | Work Layer 1 | Move to Layer | Layer Settings | Edit Section | Clip Section | See-Thru All | More | Preferences | Edit Object Display | Export Image | Capture Studio Image | Edit Background | Face Edges | Facet Edges | Smooth Edges | Reduce Edge Bleed-through | True Shading | VR

Window | Zoom | Visibility | Visualization | Imme...

Menu | No Selection Filter | Entire Assembly

Part Navigator

| Name | C. | U. | Cor |
|---|---|---|---|
| Model Views | | | |
| Cameras | | ✓ | |
| Model History | | ✓ | |
| Body (0) | | ✓ | |

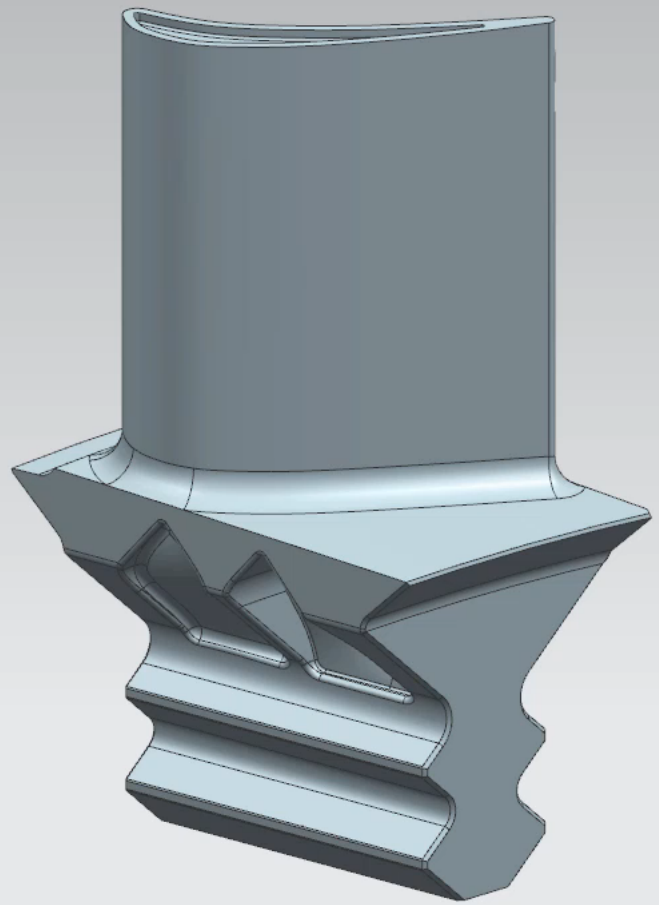
Dependencies

Details

| Parameter | Value | Expression |
|---|---|---|

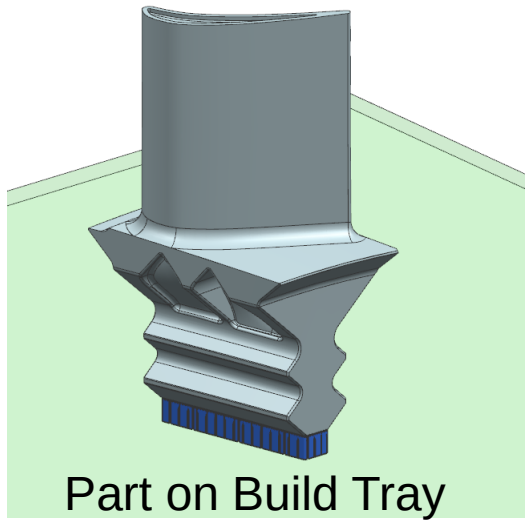
Preview

Welcome Page | Siemens_Demo_Blade.prt

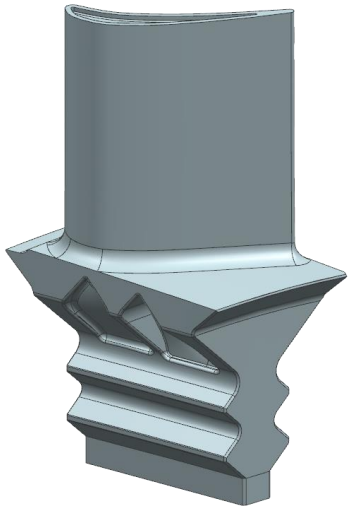


Select objects and use MB3, or double-click an object

# Simulation Workflow

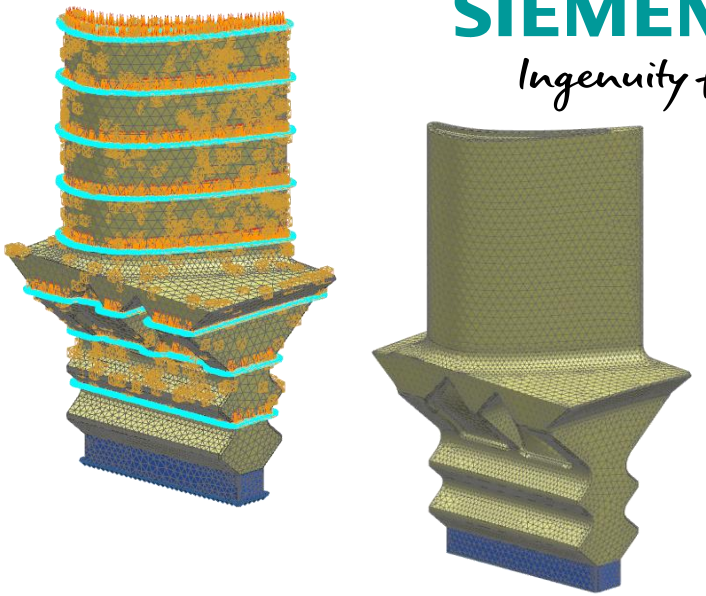


Part on Build Tray



Simulation Supports

Thermal and Mechanical Model



- Separate Meshes for Thermal and Mechanical Analysis
- Exact Meshing of the Geometry

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# Simcenter 3D Additive Manufacturing
## Support homogenization

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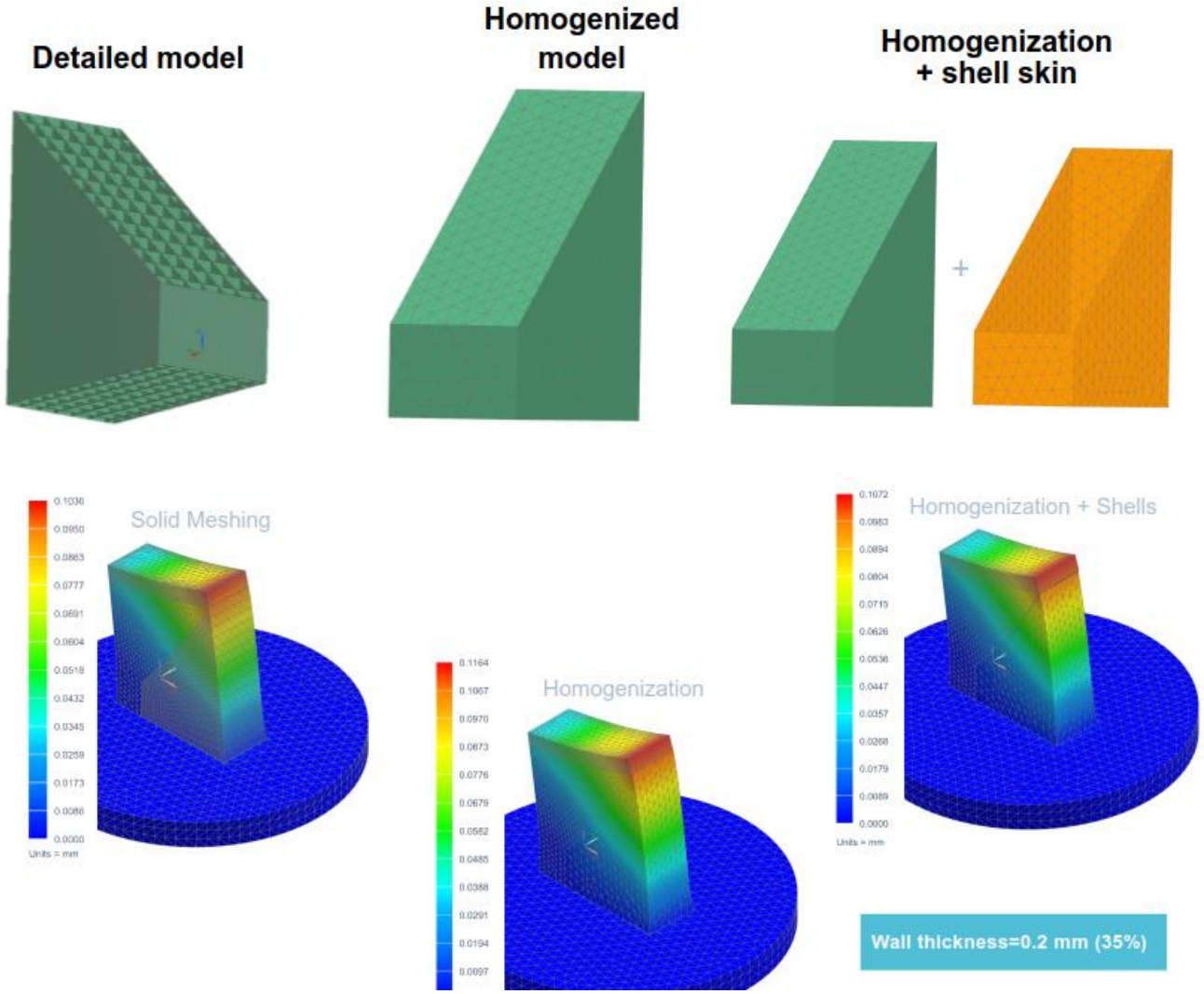
- Virtual Materials Characterization (VMC) to homogenize support structure
- Integrated in Simcenter 3D AM
- Possibility to implement homogenized values manually

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# Simcenter 3D Additive Manufacturing
## Meshing and Layer Slicing

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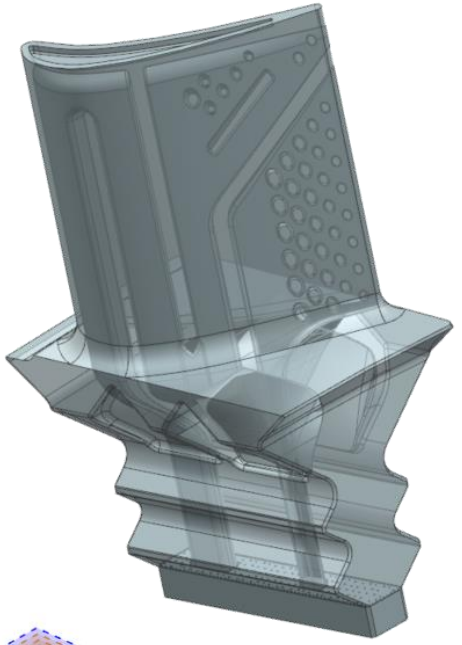
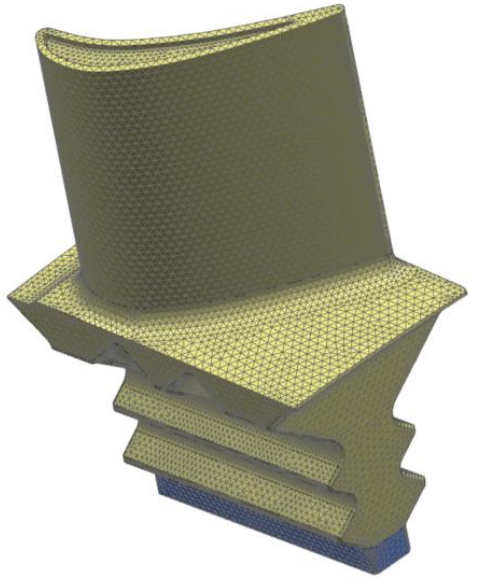
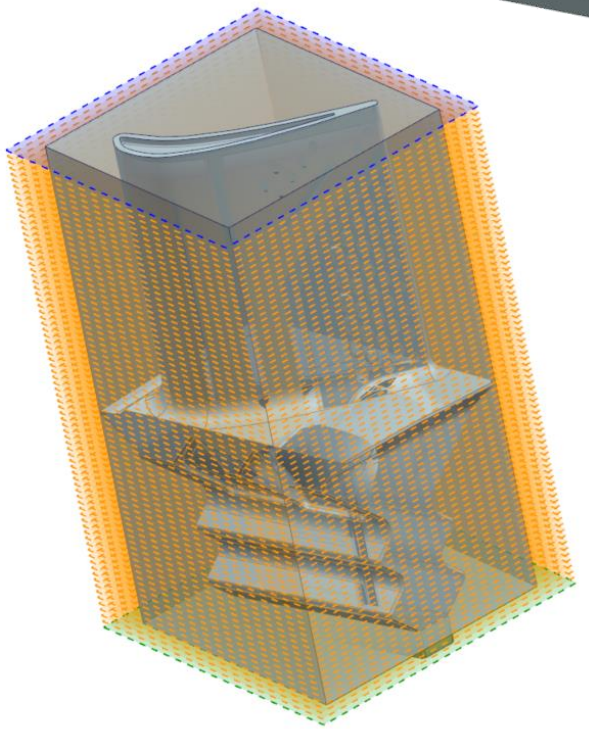
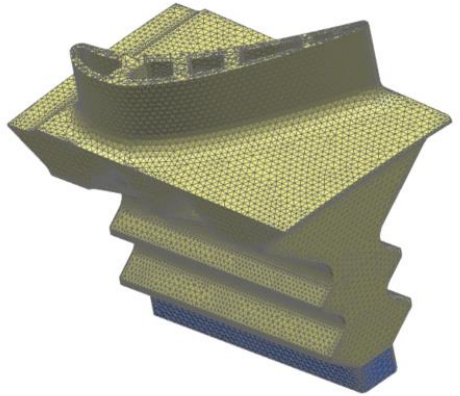
Meshing
- Simcenter 3D meshing capabilities is used to generate high fidelity 3D Meshes
- Detailed meshing allows to consider geometric details like cooling channels

Slicing
- Powerful Slicing algorithms for building the layer based models
  - Mesh based slicing for thermal analysis
  - Solver based slicing allows to realize 1mm super layers for Simulation of the mechanical distortion









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NX - Additive Manufacturing

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File | Home | View | Assemblies | Process Simulation | Analysis | Application | NX Utilities

Find a Command

Generate Simulation Supports | Assign Simulation Supports | Show Simulation Supports | Clear Simulation Supports

Support Generation

Start Simulation Process

Simulation

Menu | No Selection Filter | Entire Assembly

Additive Manufacturing Navigator

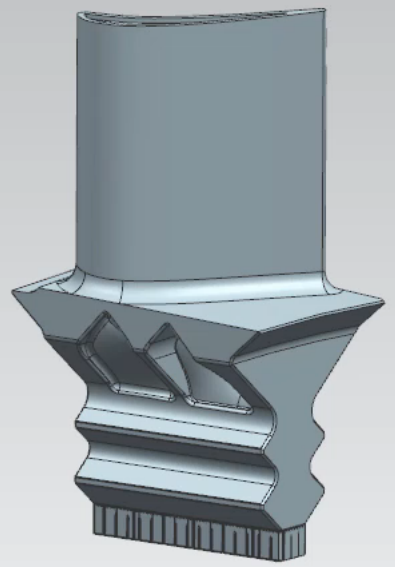
Build Tray

| Title | Type |
| --- | --- |
| Large, square platform, ... | |
| Siemens_Demo_Blade | Part |

Support Attributes

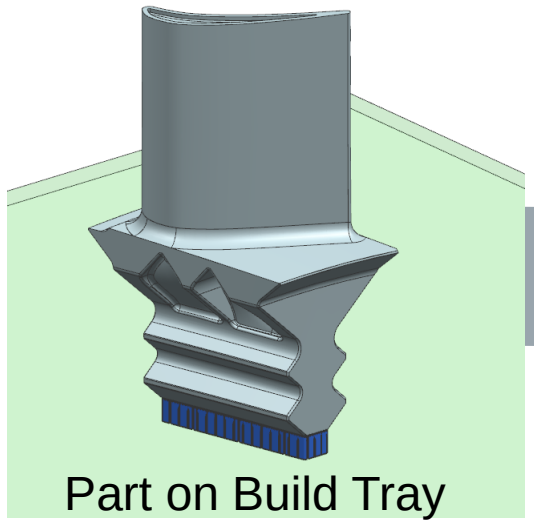
Regenerate

Welcome Page | Siemens_Demo_Blade.prt | additive_manufacturing1.prt

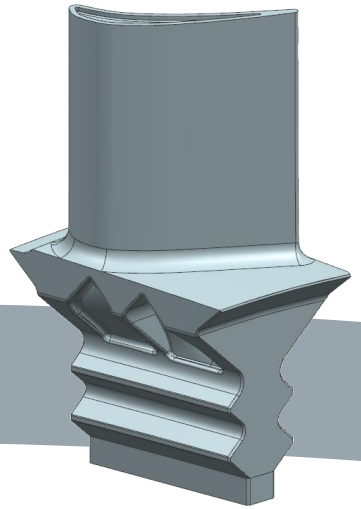


Generated simulation bodies for 1 support(s).

# Simulation Workflow

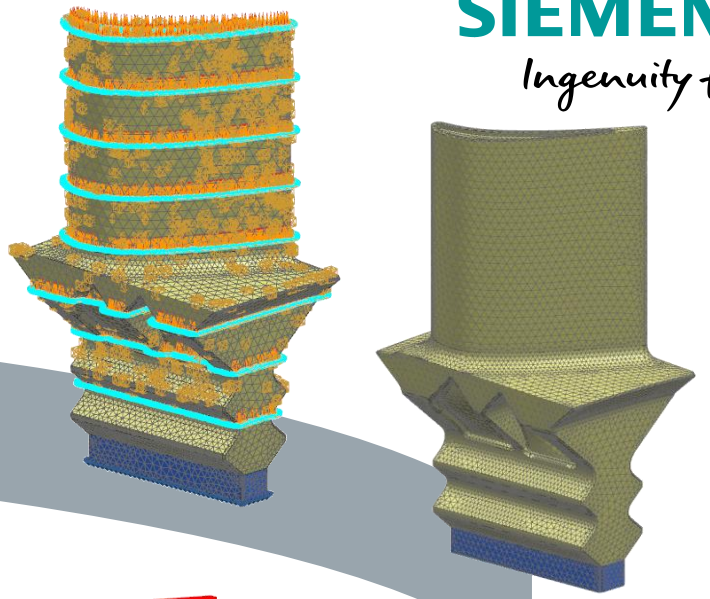


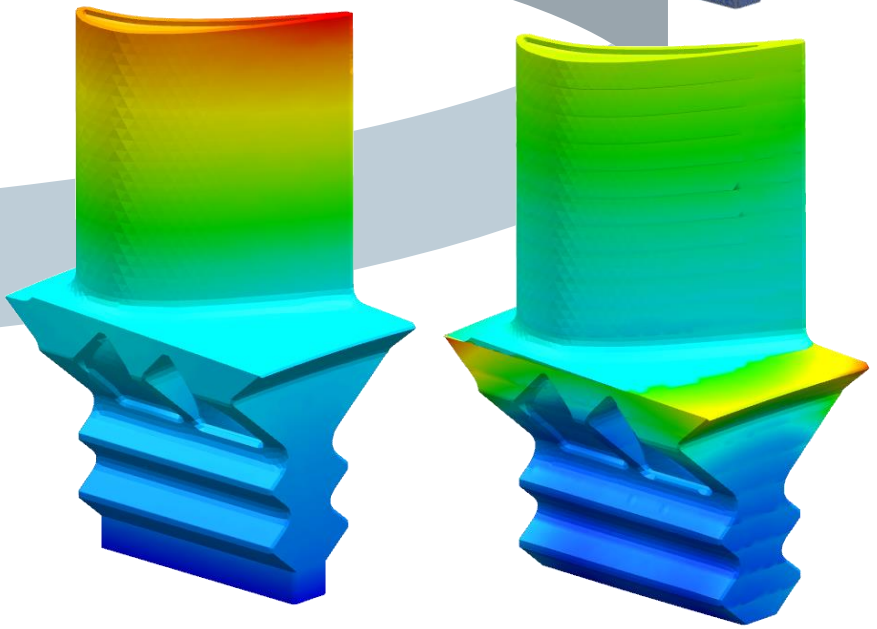
Part on Build Tray



Simulation Supports

Thermal and Mechanical Model





Thermal and Mechanical Results

- Full Thermo Mechanical Analysis
- Non-linear Solution

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# Powder Bed Fusion Process Simulation

## Simcenter 3D Additive Manufacturing

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**Goal:**

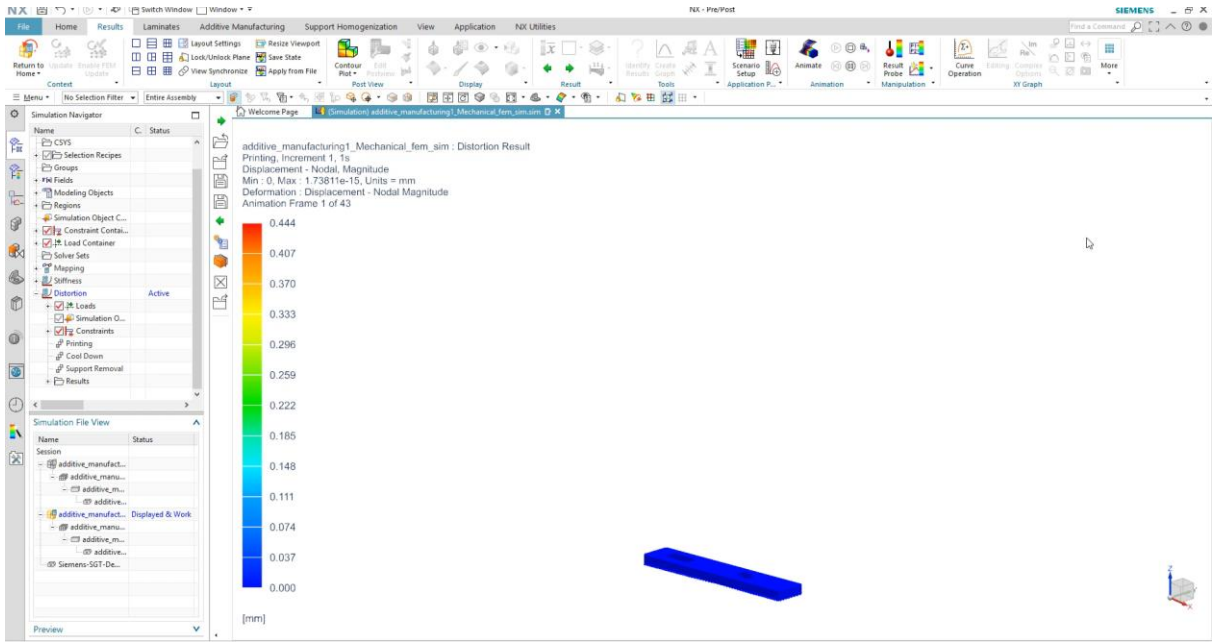
- Enable feedback of  SLM process outcome to Process Engineer and CAD designer

**Avoid:**

- Too high distortion after manufacturing
- Global & local over-heating

**Challenge:**

- Producing a part sized around 100mm requires
  - ~ 3000 slices
  - ~ 10-20 hours of production time
  - ~ 5 millions of exposure vectors (5mm each)
  - ~ 25 km of “tool path”
- **Extreme spread of time- and length scales**

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# Simcenter 3D Additive Manufacturing
## Macro-scale Mechanical Model

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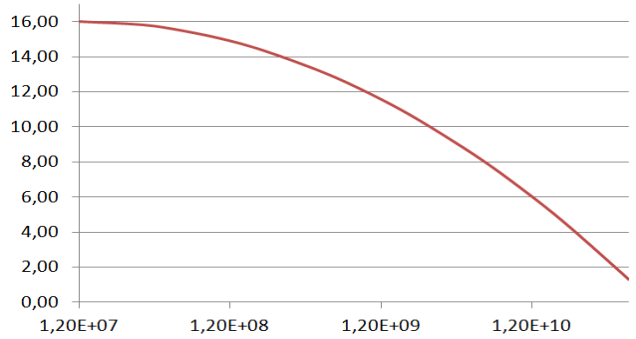
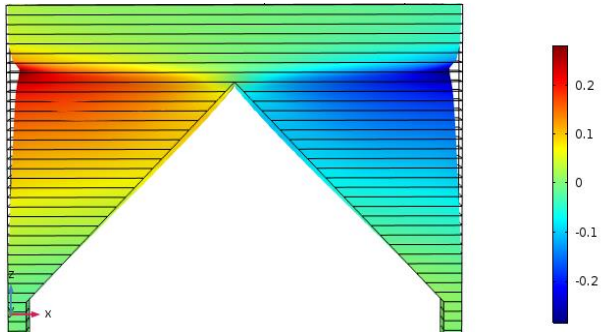
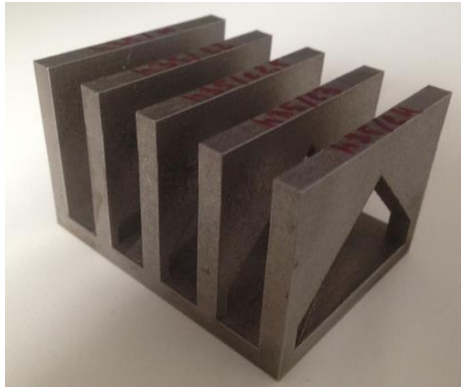
- Simulate thermal shrinkage of **whole layers** instead of single tracks
- z-step 500µm-1mm instead of 30-50µm (super-layers w/ effective material parameters)
- effective super-layer parameters must be extracted from meso scale simulations (or from experiments)
- Whole-part simulation possible
- Unique Siemens Feature: enhanced inherent strain model.

**Effective layer Shrinkage Parameter must be a function of the stiffness**

- calibration: Build und measure bridges of extract effective shrinkage





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# Simcenter 3D Additive Manufacturing
## Simulation Architecture

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**Simcenter 3D AM (Macro-Scale)**

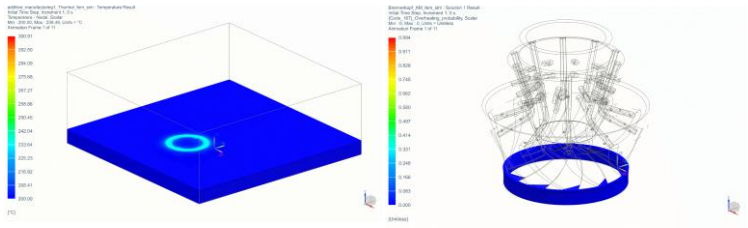
**NX CAD**
**Geometry compensation**

**NX AM**
**Build preparation**

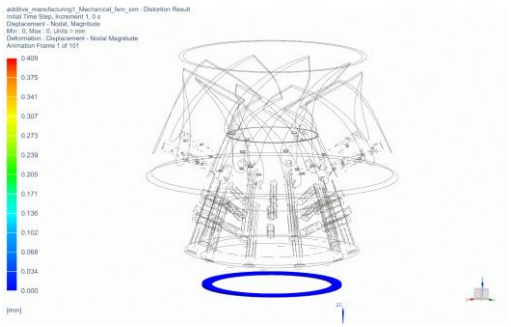
**Build Processor**

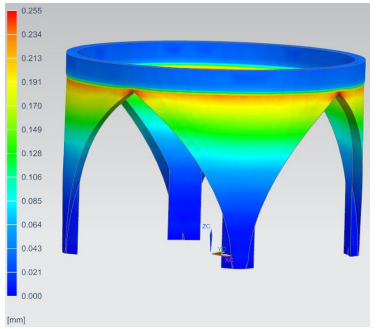
**Thermal assessment**

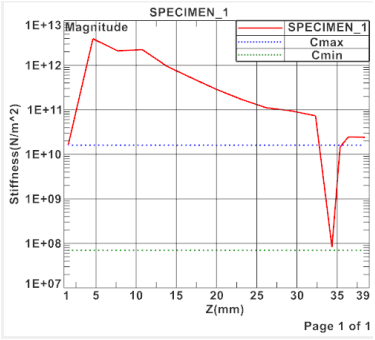
**Local overheating likelihood**



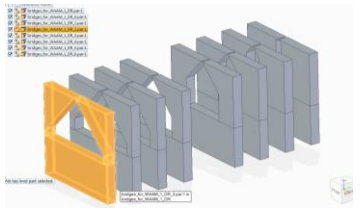
**Calculation of thermo-mechanical distortion**

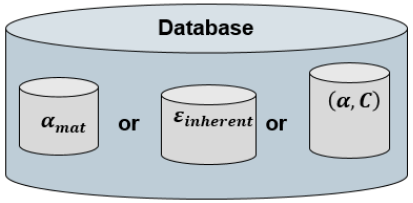







**Standardized experiment**



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# Simcenter 3D Additive Manufacturing
## Local overheating

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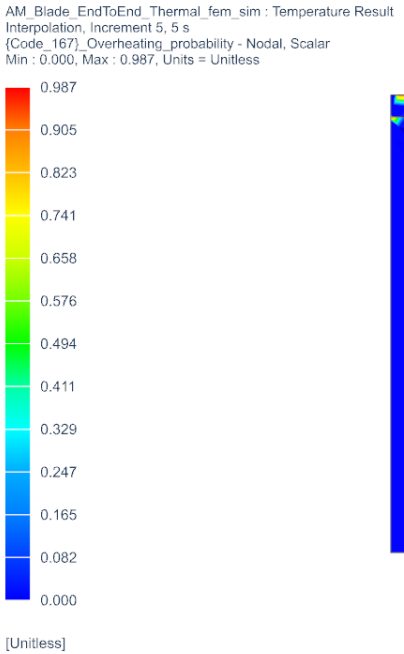
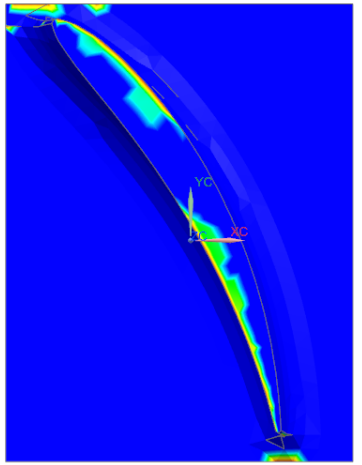
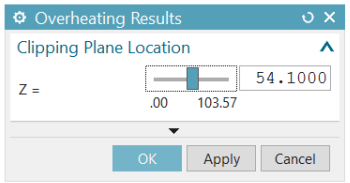
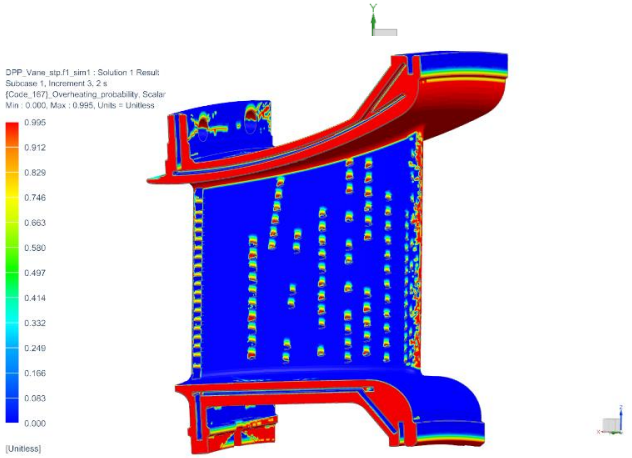
Ingenuity for life

- Local overheating visualized layer by layer in 2D
- Possibility to have a 3D vision on the local overheating
- Part of the thermal analysis and short computational time



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# Simcenter 3D Additive Manufacturing
## Stiffness calculation – shrink lines

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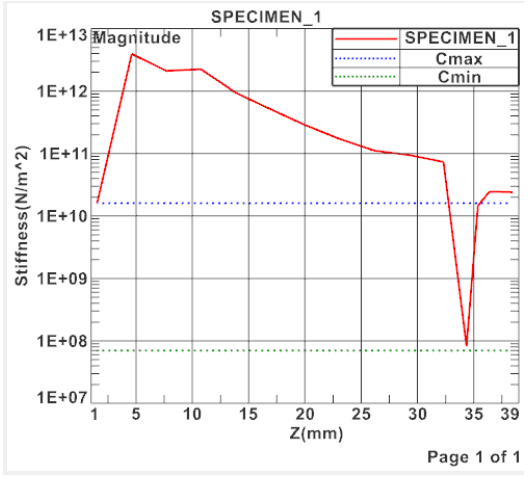
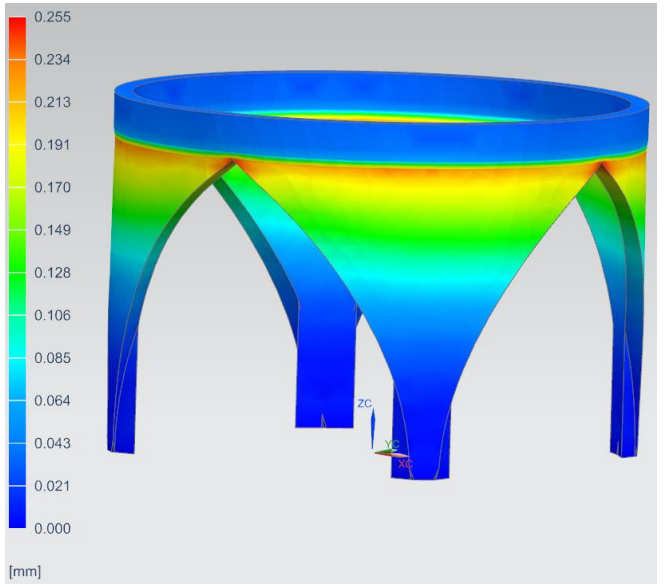
- Stiffness analysis layer by layer to identify the areas of potential severe distortions or shrink defects
- 2D curve with layer stiffness information



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# Simcenter 3D Additive Manufacturing
## VTT Validation case

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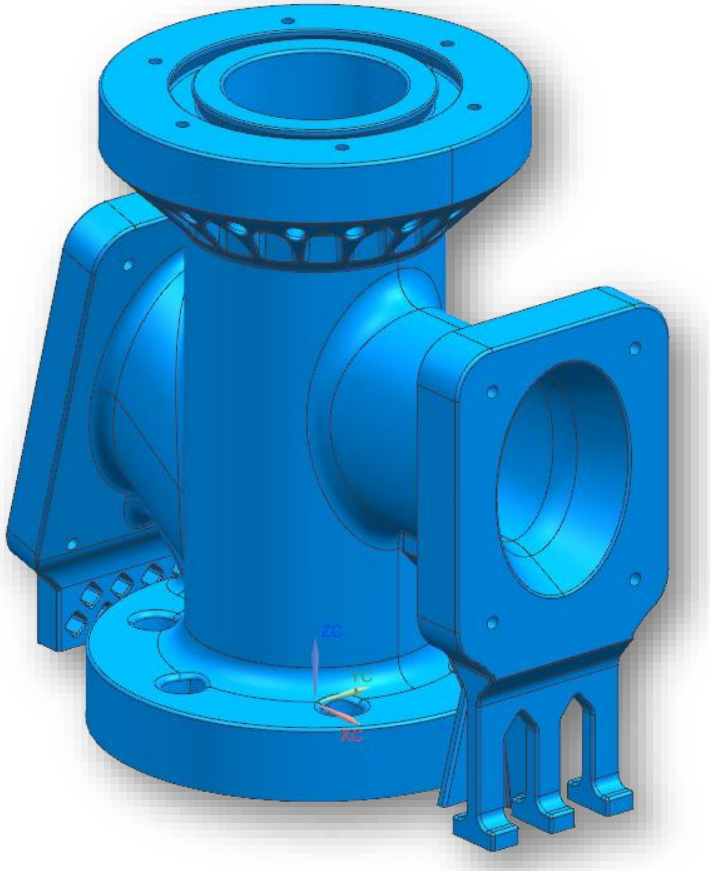
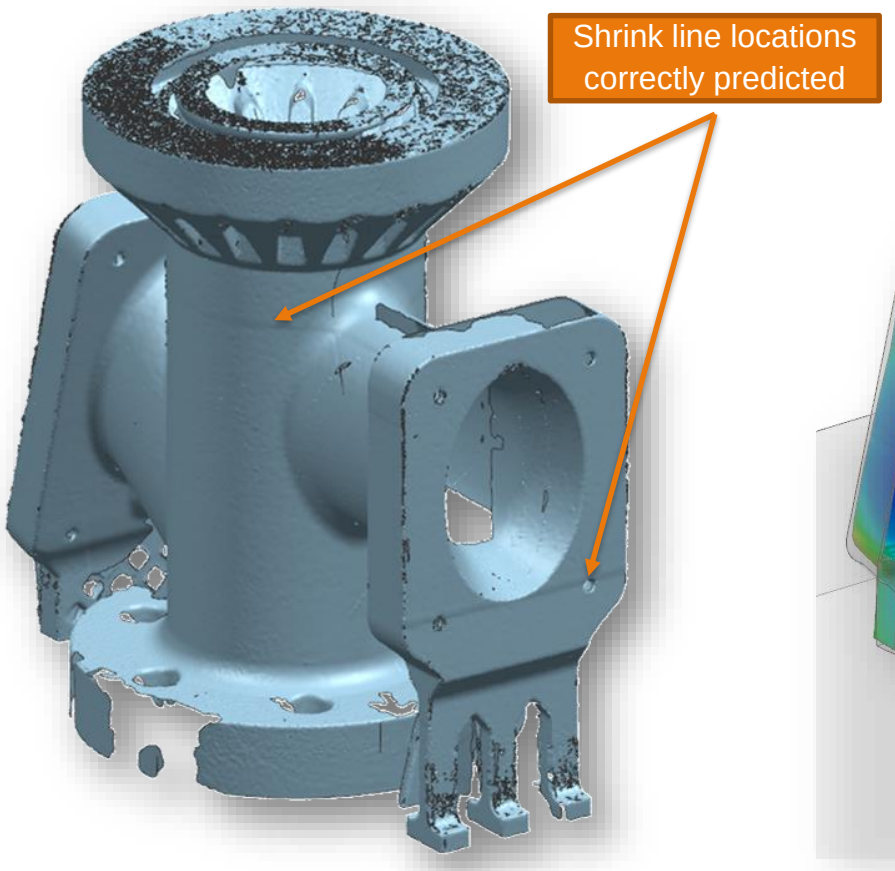
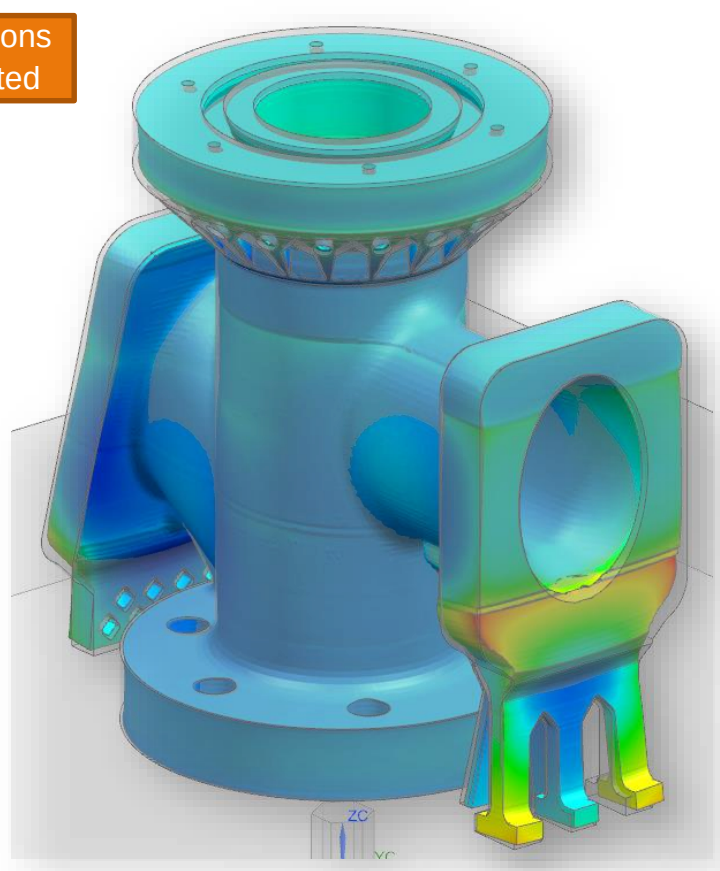
Original CAD



Optical scan (CCAM)




Simulation



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NX - Pre/Post

SIEMENS

File | Home | Nodes and Elements | Results | Laminates | Additive Manufacturing | Support Homogenization | View | Application | NX Utilities

Find a Command

Load Simulation Process | Save Simulation Process — Simulation Process Files

Global Settings | Process/Material Parameters — Printer Settings

Define Thermal Slicing | Define Mechanical Slicing — FEM Preparation

3D Tet Mesh — Mod...

Computation Options | Solve Simulation — Simulation Process Solve

Thermal Results | Distortion Results | Stiffness Curves | Local Overheating Results | Recoater Collision Detection | Compensate Model — Post Processing

Menu | No Selection Filter | Entire Assembly

Welcome Page | (FEM) additive_manufacturing1_Mechanical_fem.fem

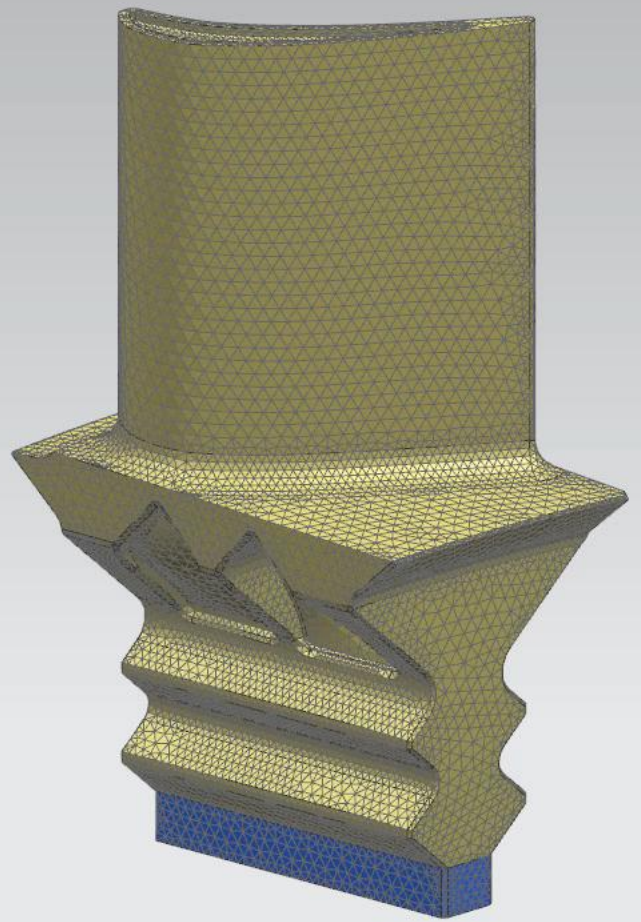
Simulation Navigator

| Name | C. | Status | Filter |
|---|---|---|---|
| additive_manufacturing... | | Displayed & W... | |
| additive_manufactur... | | | |
| Polygon Geometry | | | (Filter : Off) |
| Mesh Controls | | | |
| 3D Collectors | | | (Filter : Off) |
| Connection Colle... | | | |
| CSYS | | | (Filter : Off) |
| Selection Recipes | | | (Filter : Off) |
| Groups | | | (Filter : Off) |
| Fields | | | (Filter : Off) |
| Modeling Objects | | | (Filter : Off) |

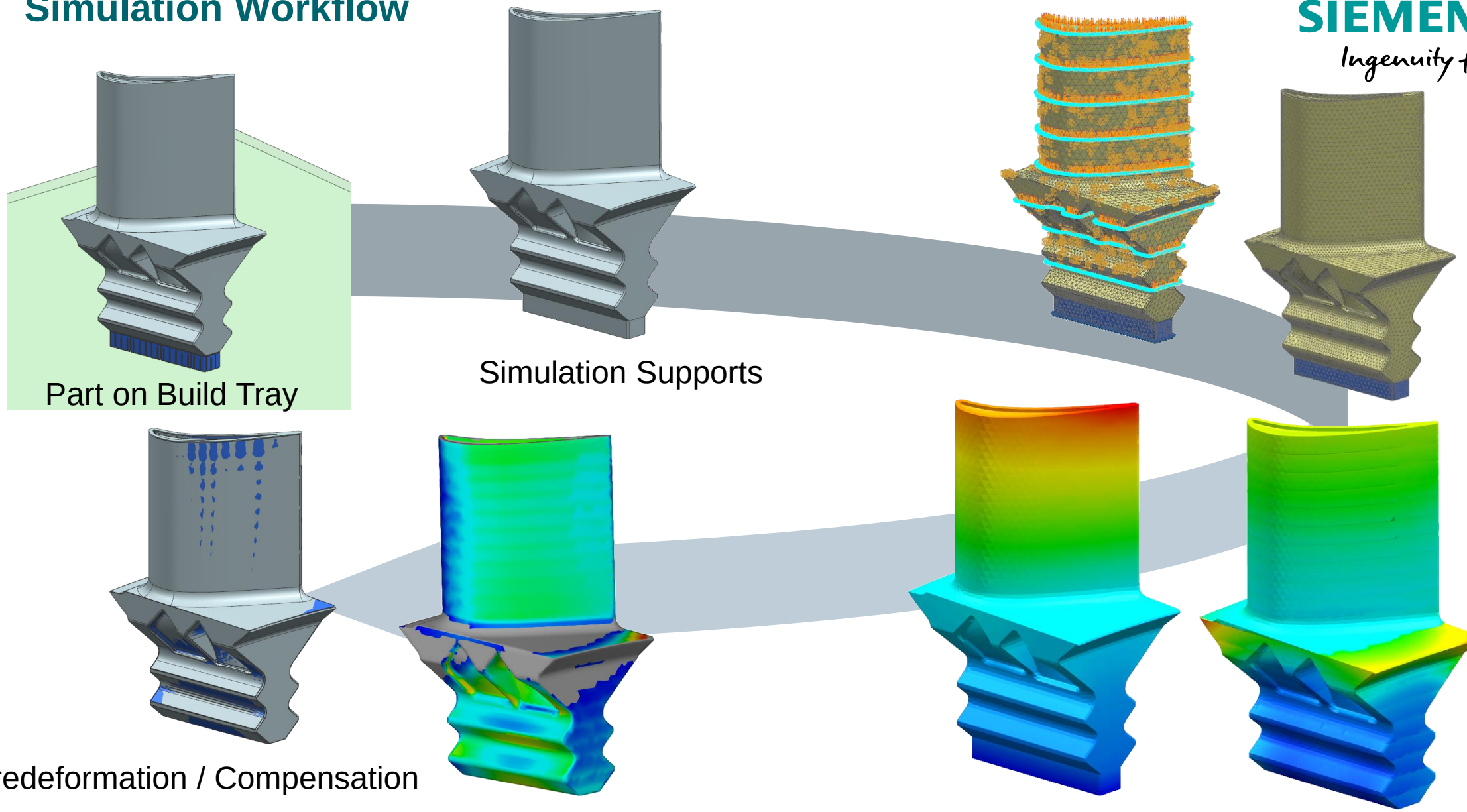
Simulation File View

| Name | Status |
|---|---|
| Session | |
| additive_manufact... | |
| additive_manu... | |
| additive_m... | |
| additive_manufact... | Displayed & Work |
| additive_manu... | |
| additive_m... | |
| Siemens_Demo_Bl... | |

Preview



# Simulation Workflow

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# Build process simulation ensures jobs print First-Time-Right

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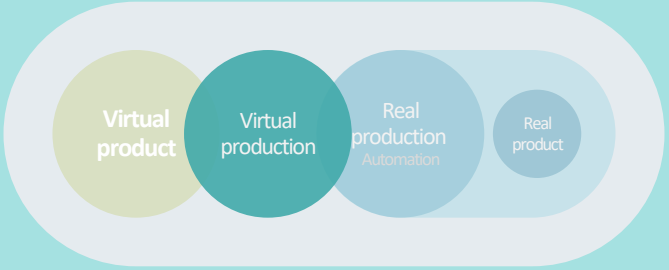
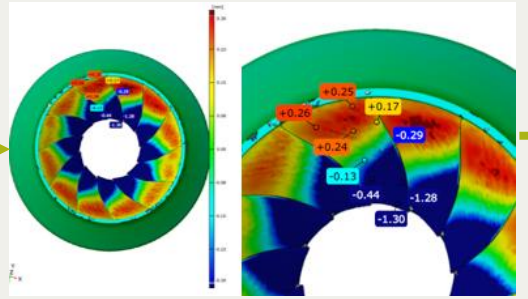
Virtual detection and elimination of distortion, overheating and other defects with build process simulation leading

**from “try and see” to First-Time-Right.**

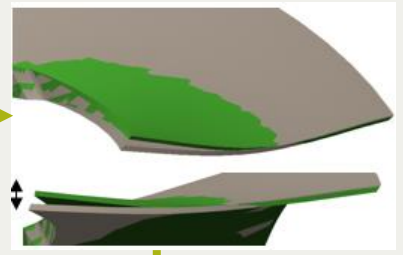



Product design with supports

Simulate and predict distortions

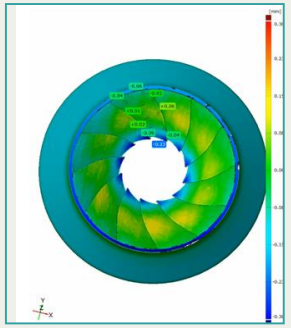



Calculated compensated geometry



Re-parenting supports

Re-Simulate with compensation



No

ok

Yes

Print preparation

Print first-time-right

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NX - Pre/Post

SIEMENS

File | Home | Results | Laminates | Additive Manufacturing | Support Homogenization | View | Application | NX Utilities

Find a Command

Load Simulation Process | Save Simulation Process | Simulation Process Files

Global Settings | Process/Material Parameters | Printer Settings

Solve Simulation

Thermal Results | Distortion Results | Stiffness Curves | Local Overheating Results | Recoater Collision Detection | Compensate Model | Post Processing

Menu | Within Work Part Or

manufacturing1_Mechanical_fem_sim.sim

Simulation Navigator

| Name | C. | Status | Filter |
|---|---|---|---|
| additive_manufacturing... | | Displayed & W... | |
| additive_manufa... | | | |
| CSYS | | | (Filter : C |
| Selection Recipes | | | (Filter : C |
| Groups | | | (Filter : C |
| Fields | | | (Filter : C |
| Modeling Objects | | | (Filter : C |
| Regions | | | (Filter : C |
| Simulation Object C... | | | (Filter : C |
| Constraint Contai... | | | (Filter : C |
| Load Container | | | (Filter : C |
| Solver Sets | | | (Filter : C |
| Mapping | | | |
| Stiffness | | | |
| Distortion | | Active | |
| Loads | | | (Filter : C |
| Simulation O... | | | (Filter : C |
| Constraints | | | (Filter : C |
| Printing | | | |
| Cool Down | | | |
| Support Removal | | | |

Simulation File View

| Name | Status |
|---|---|
| Session | |
| additive_manufact... | |
| additive_manu... | |
| additive_m... | |
| additive... | |
| additive_manufact... | Displayed & Work |
| additive_manu... | |
| additive_m... | |
| additive... | |
| Siemens_Demo_Bl... | |

Preview

Compensation Options

Compensation Factor

Value

- Default: -1.0
- Deformed: 1.0
- User Defined

OK | Cancel

ZC

XC

Z

X

# Simcenter 3D Additive Manufacturing
## Additive Manufacturing Process Simulation

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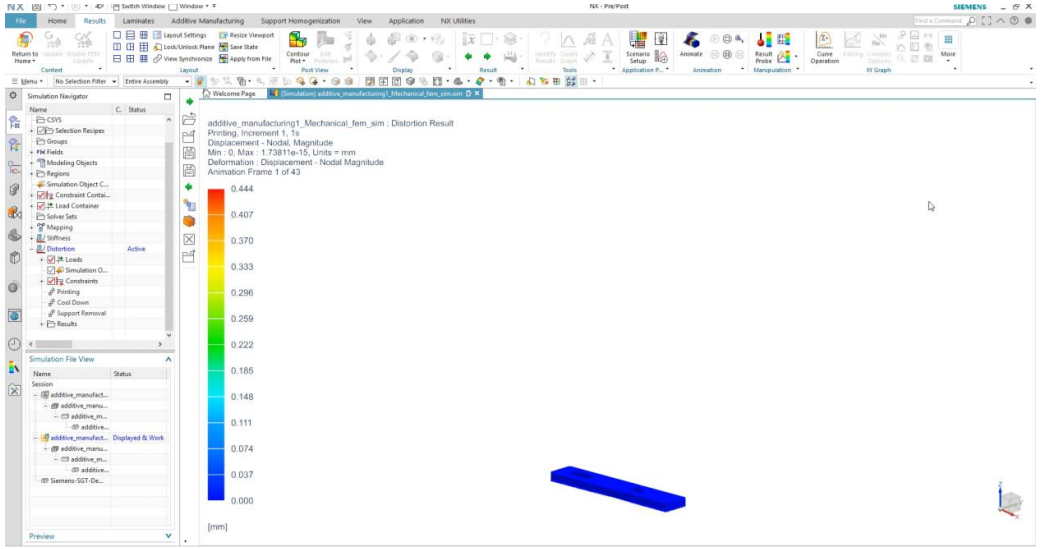


- New Simcenter 3D Product to analyse the 3D printing process for Powder Bed Fusion.
- Seamlessly integrated with NX Additive Manufacturing
- Open architecture and physics based modeling
- Digital twin of production to simulate:
  - Temperature with and without powder
  - Probability of overheating
  - Distortion before support, after heat treatment as build
  - Compensation workflow
  - Prediction of shrink lines
  - Recoater interference
  - Stiffness calculation

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# Sehr unterschiedliches Knowhow erforderlich

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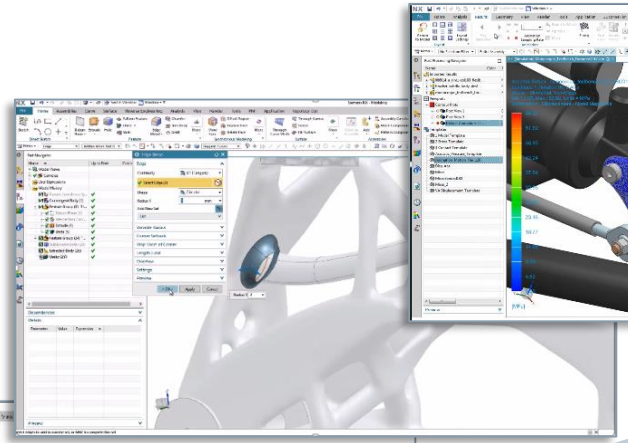
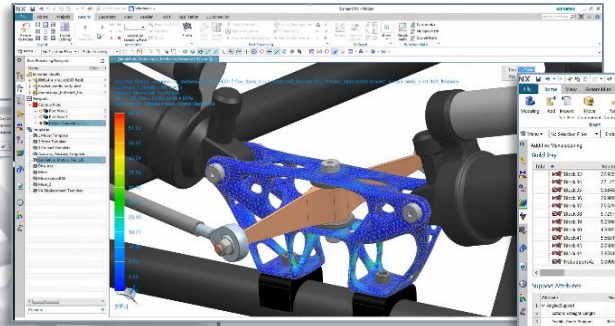
CAD

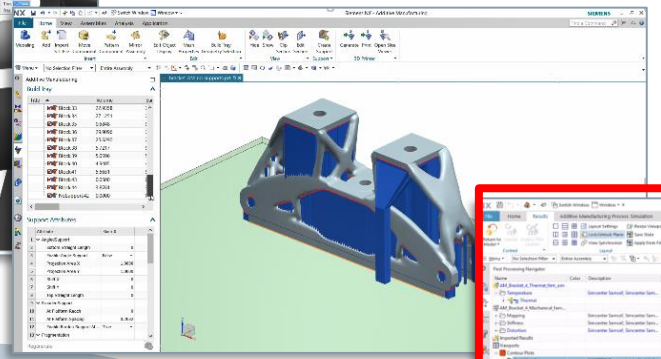
Topologie-
Optimierung



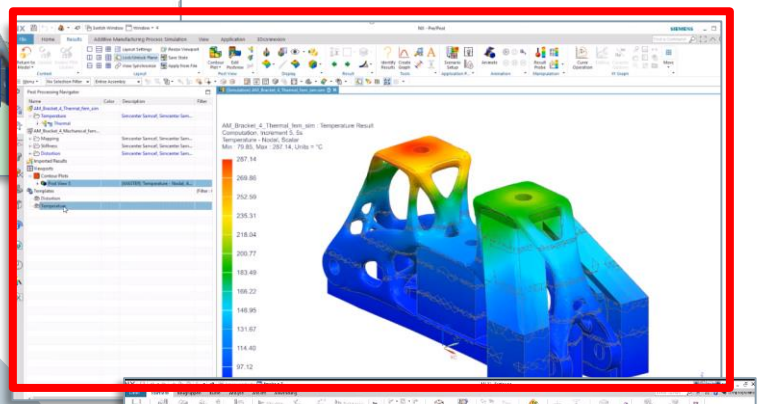


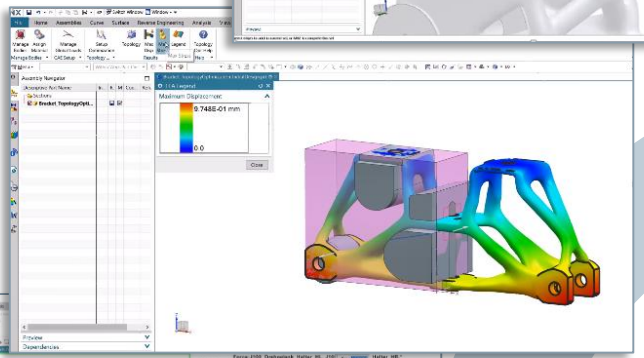
FEM

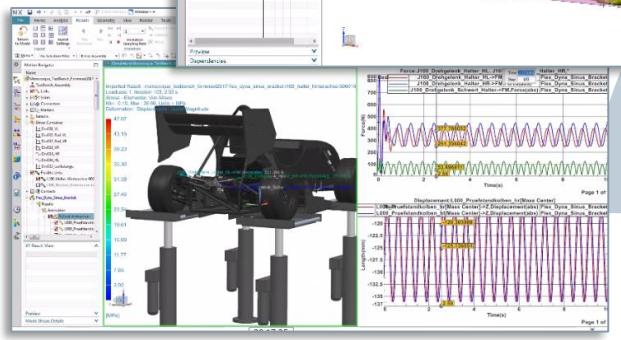
Druck-Vorbereitung



Druck-Simulation







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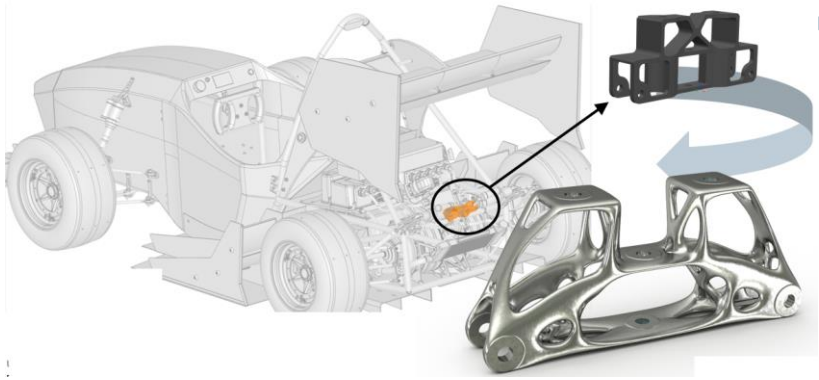

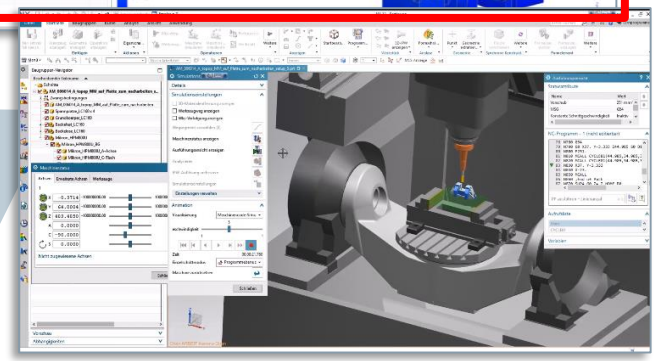

CAM

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# Gemeinsame Entwicklung mit Siemens Coporate Technology und Anwendern

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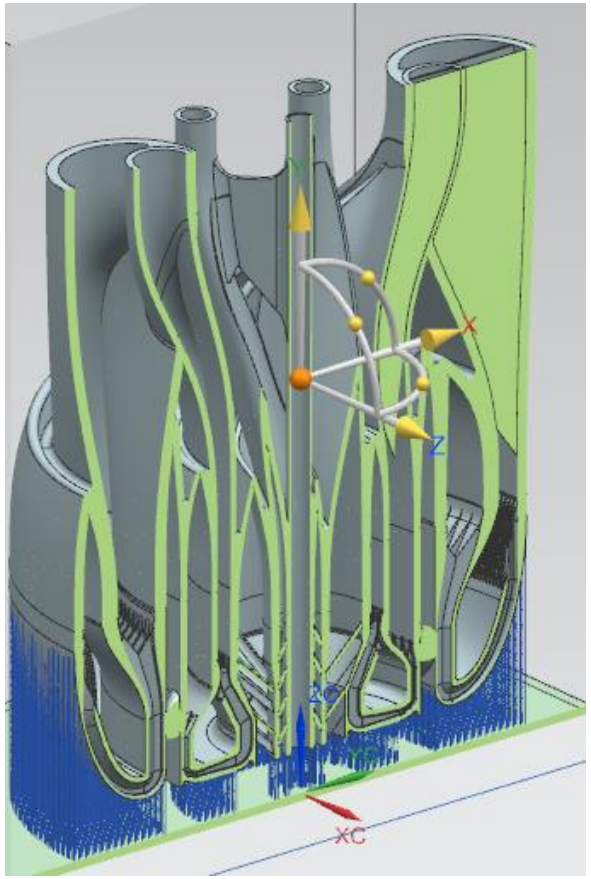


purmundus challenge 2018
3rd prize

**Jury:**
„High efficient complexity of geometrie“

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Additive Manufacturing
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