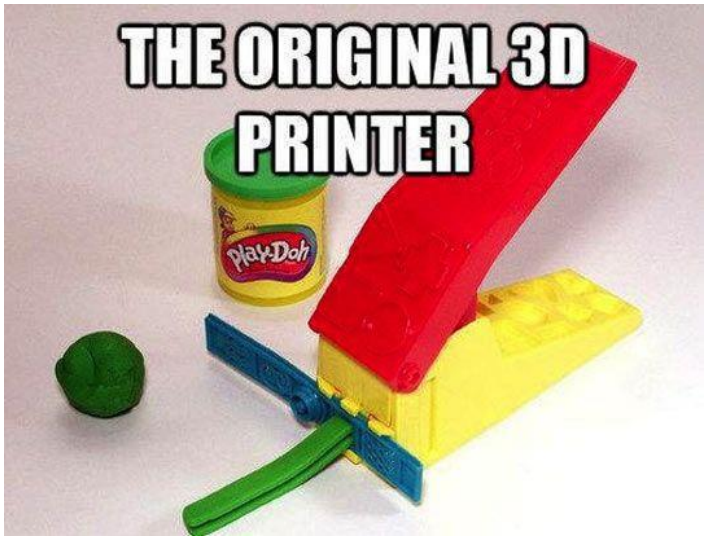
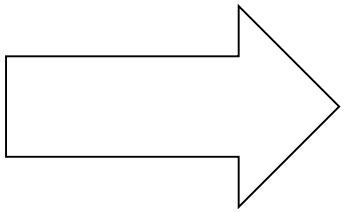
Industrial Additive Manufacturing

Importance of Standardization

Oh how far we have come…





Design for Additive Manufacturing
Traditional and new design workflows supported

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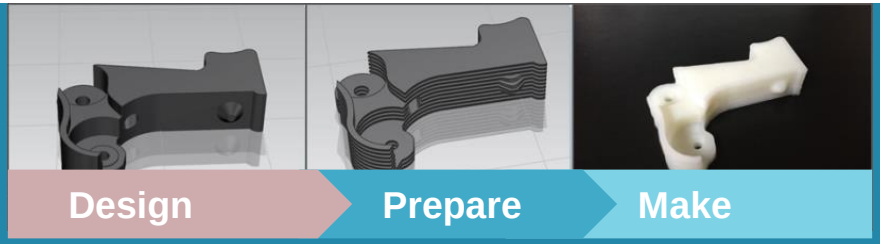
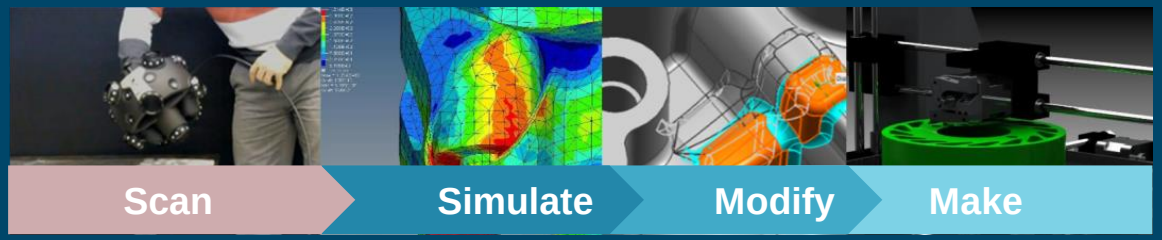
From Traditional
Prototyping



TO…

Scan to print



Optimize to print

Opportunities abound

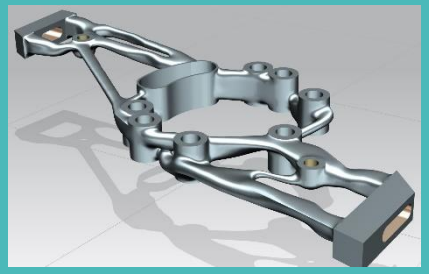
Individualization

LIMITLESS FREEDOM:

Individual part design
one-offs

Personalized products implants, shoes, car parts

Product



LIMITLESS CONTROL:

Weight reduction
light-weight structures – topology optimized geometries

Functional optimization
complexity for free

Manufacturing

LIMITLESS AGILITY:

Part reduction
product simplification

Low series
lot size 1

Finished products
printed as assembled

Business Models

LIMITLESS OPPORTUNITY:

Inventory reduction
zero inventory

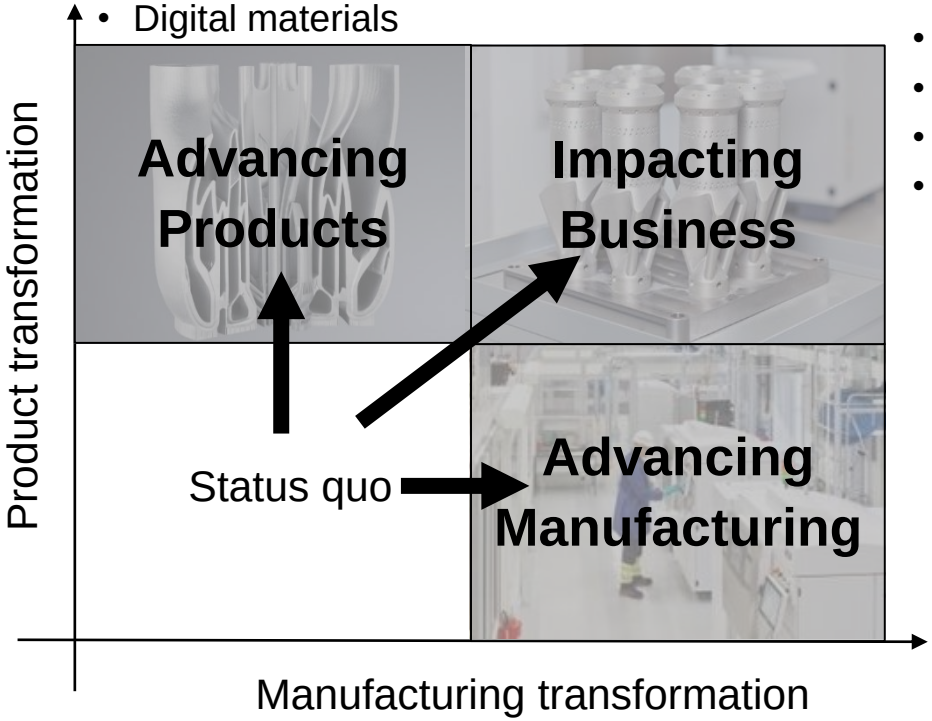
On-demand
product availability

Supply chain

Optimizing Paths for AM

Shift from conventional design to enterprise DFAM

- Scan → modify → print
- Lightweighting
- Assembly simplification
- Functional performance optimization
- Multi-material parts
- Digital materials



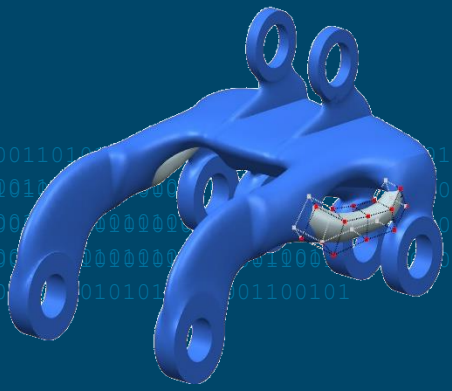
- Individualization
- Replacement parts / digital inventory
- Accelerate innovation cycles
- Design anywhere. Print anywhere.
- Repair parts
- Supply chain restructuring / shrinkage

- Eliminate castings
- Eliminate injection molding
- Rapid manufacturing aids
- Checking / tool fixtures
- Composite part printing
- Low volume (lot size of one)
- Multi-material parts

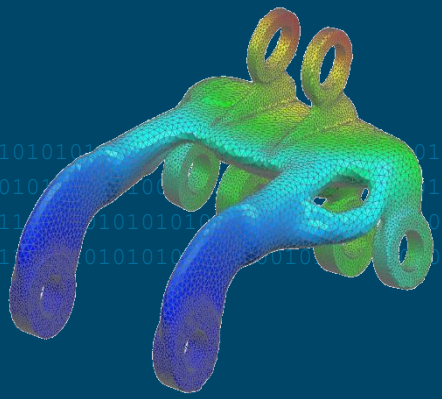
Shift from prototyping / experimentation to mainstream industrial production

How do you achieve Industrialization?

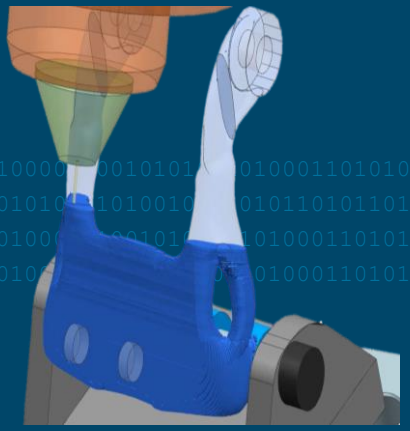
Smart model-driven process



Design



Simulate



3D Print

Data Management and Shop Floor Connectivity

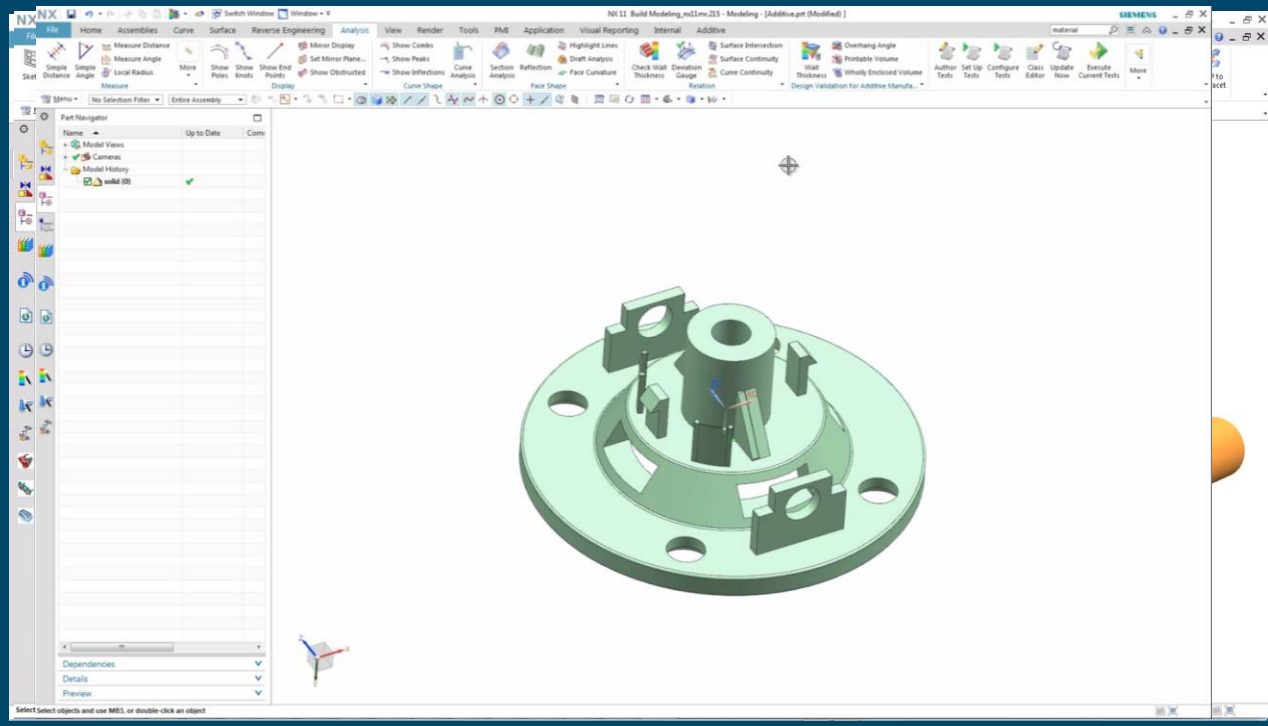
Siemens Production Software and MES Systems

Partnerships

Design for AM

Advancing Products

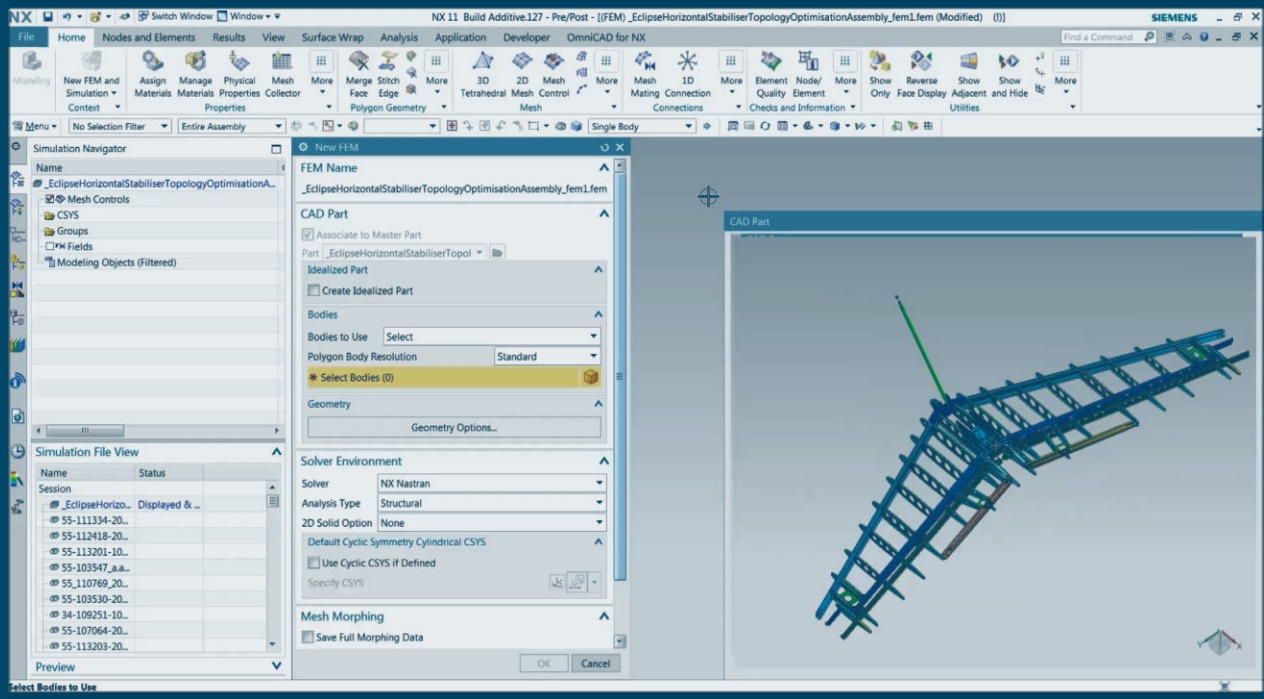
- Generative design using topology optimization
- Design with Convergent Modeling ™
- Lattice structures
- Design rules for manufacturability



Design Evaluation

Product performance simulation

- **Validate optimized designs**
- **Generate simulation models to validate convergent body**
- **Access all validation and editing tools in one environment**

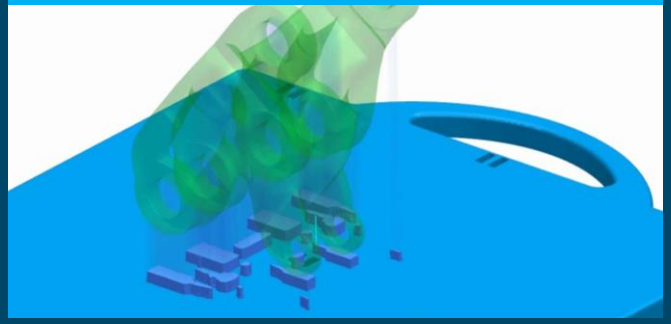


Changing the face of Manufacturing

Advancing Manufacturing

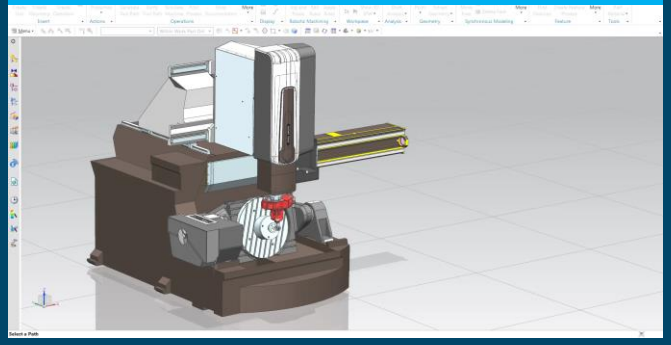
- **Drive additive manufacturing technologies for real production**
- **Integrated post-printing machining and inspection programming**

Powder bed fusion

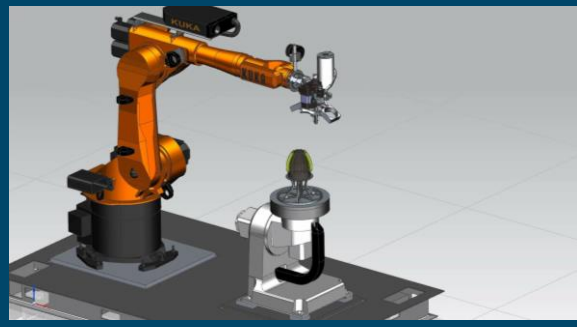


Multi jet fusion

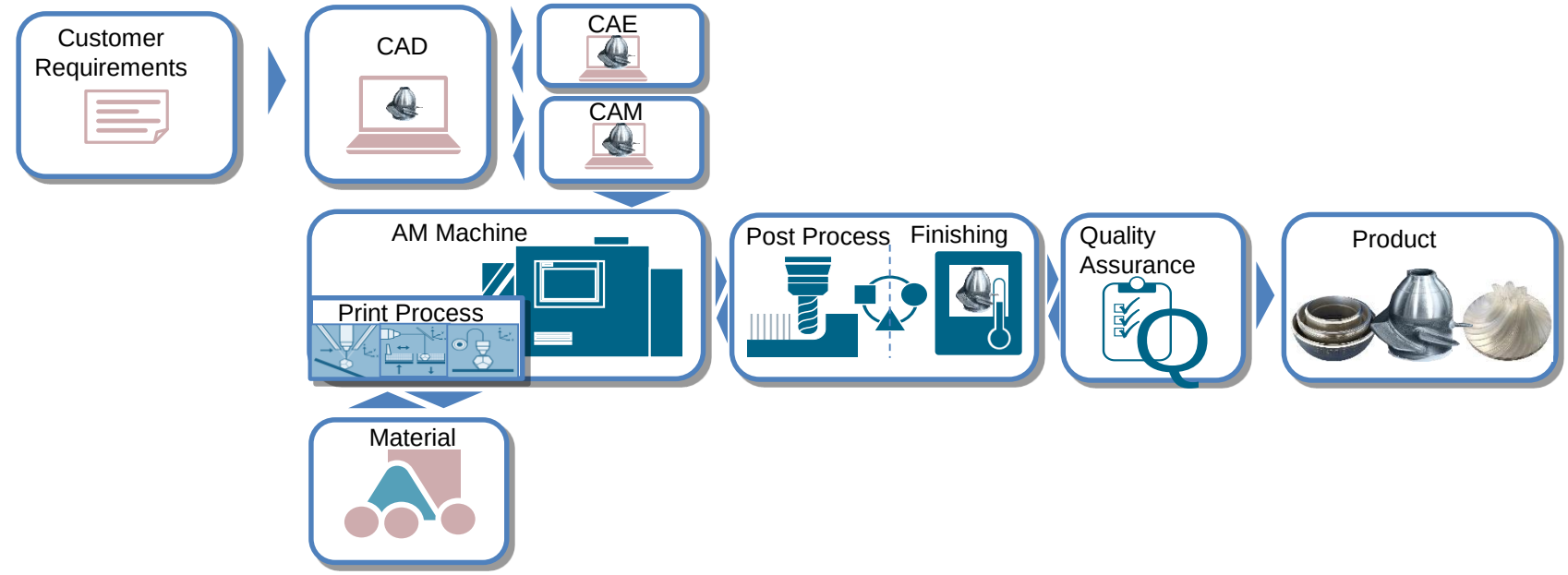
Hybrid additive



Multi-axis FDM



General Climate for AM Today



Conventional thinking	**Multiple data conversions**	**Uncontrolled workflow**	**Disconnected software**	**Certification**

Moving from Prototype to Production

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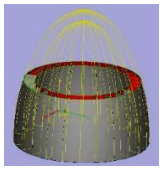
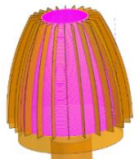
DESIGN AND ANALYZE

PLAN AND MANUFACTURE



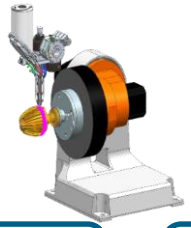
DESIGN

- PART REQUIREMENTS
- MANUFACTURING REQUIREMENTS
- INTEGRATED PRODUCT DEVELOPMENT
- DOCUMENTATION



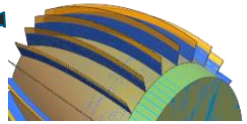
DECOMPOSITION

- PART FILE PREPARATION
- FEATURES & SETUP DEFINITION



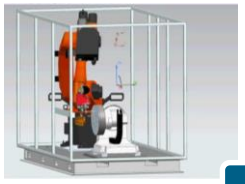
ADDITIVE PLANNING

- DEPOSITION STRATEGY
- SECONDARY OPERATIONS



TOOLPATH GENERATION

- ADDITIVE OPERATIONS
- MULTI-AXIS SLICING DIRECTLY ON MODEL
- SEQUENCING



MACHINE SIMULATION

- MACHINE ENVIRONMENT
- COLLISION, REACHABILITY & SINGULARITY DETECTION

POST

- CAM TO CONTROLLER
- ROBOT TO TABLE SYNCHRONIZATION
- TOOLPATH TO ROBOT PATH CREATION

MANUFACTURE

- PLANNING AND SCHEDULING
- PRODUCTION EXECUTION
- PRINT PART
- VALIDATE PART
- SCADA

CAD/CAE/CAM

MACHINE CONTROL and MONITOR

DATA, PROCESS AND MANUFACTURING OPERATIONS MANAGEMENT

What can happen without comprehensive control?

Holistic Approach

Product Manufacturers

Cloud-based, open IoT operating system

Design
Print Preparation
Finishing & Quality
System Engineering
Process Sim & VC
Throughput Optimization
Machine Control
Data Analytics
Operation / Execution (MOM/MES)
Engineering / Optimization
Security & Quality

1 Product design
2 Production planning
3 Production engineering
4 Production execution
5 Service

Collaboration platform

1 Machine concept
2 Machine engineering
3 Machine commissioning
4 Machine operation
5 Machine services

Security & Quality
Machine design & simulation
Virt. commissioning
Machine Control
Data Analytics
Simulation
Machine commiss.
Automation engineering

Co-innovation ecosystem

Machine Builders

Digital Enterprise

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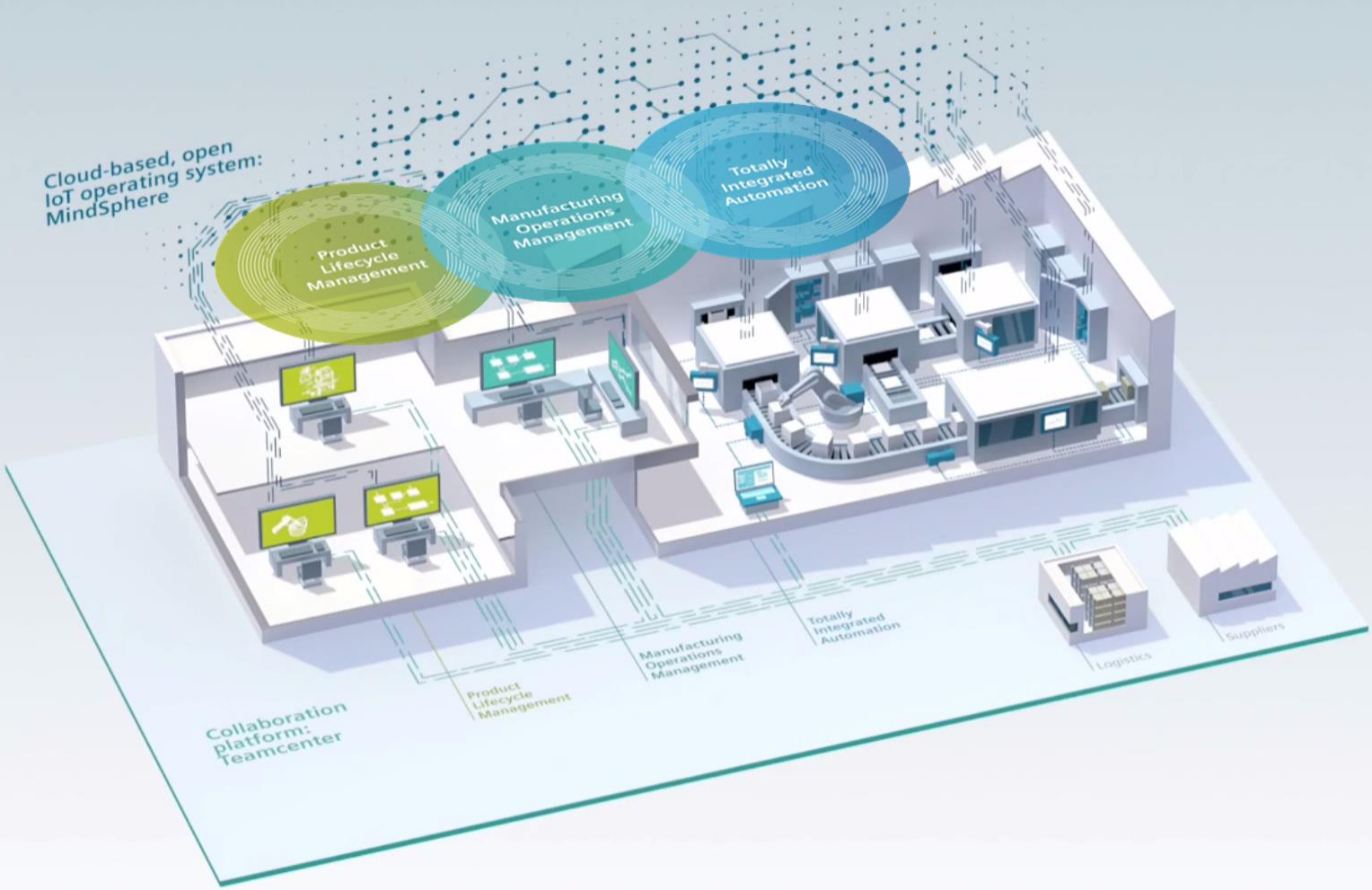

AM Eco-system

- **A global, digital collaboration platform for distributed, industrial additive manufacturing (AM) and co-innovation solutions**
- **Our digital platform links together an ecosystem of product developers, experts, manufacturers, 3D printing machine OEMs, AM material vendors and software providers**
- **Our digital platform provides a secure, transparent and automated process from idea to finished-part delivery**

The Digital Twin

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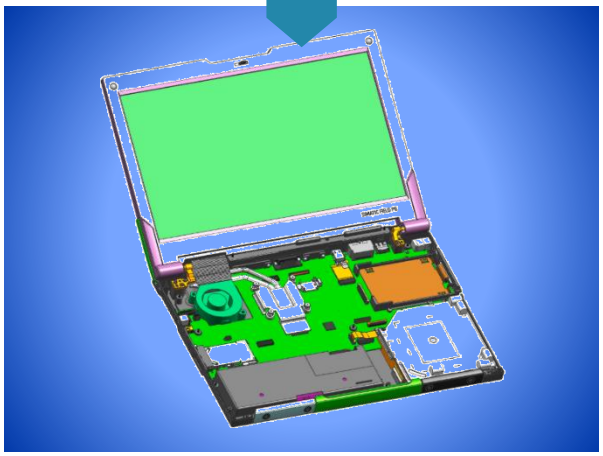
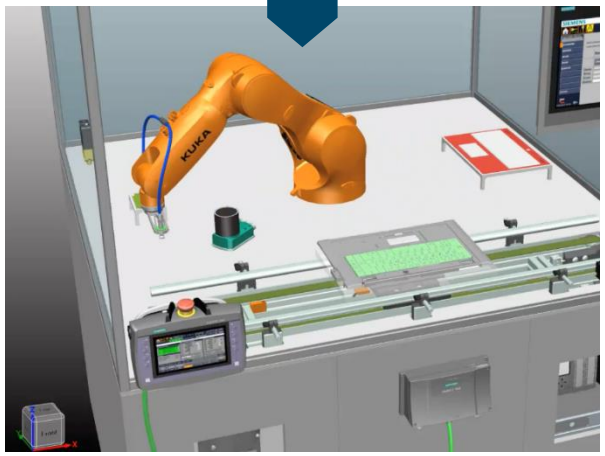
Cloud-based, open IoT operating system

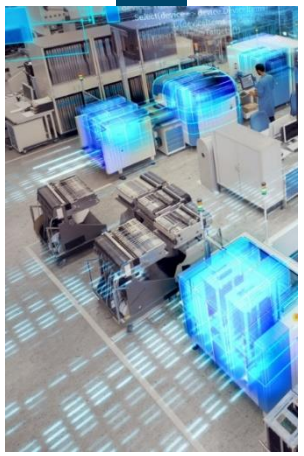
feed back insights to continuously optimize product and production



Digital Twin of the product

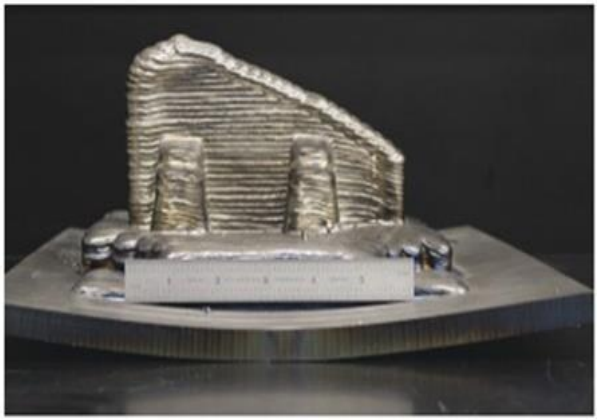


Digital Twin of the production

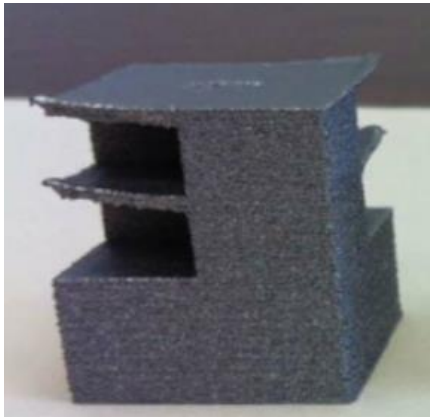


Digital Twin of the performance

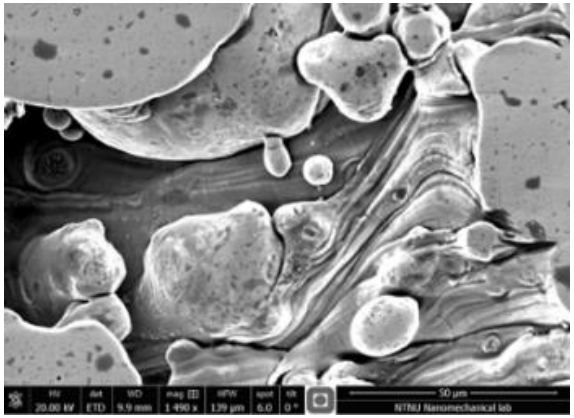
Predicting Build Issues



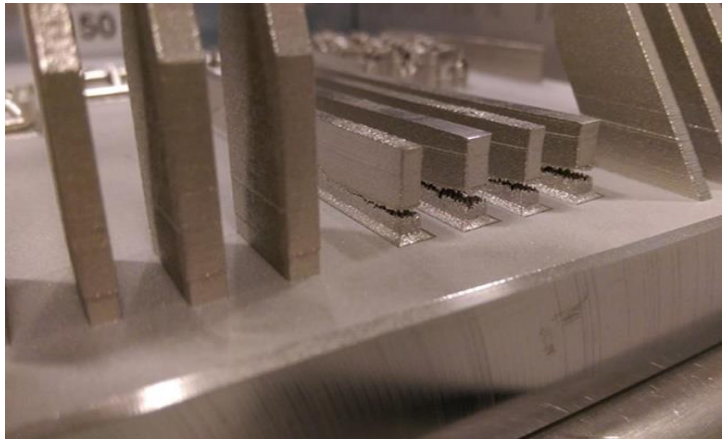
Courtesy of Sciaky



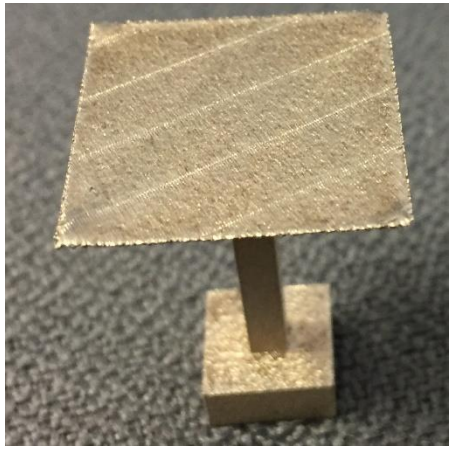
Distortions



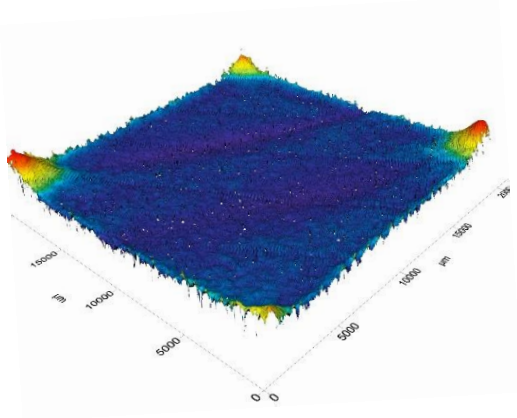
Defects



Build failure



Local over-heating



Predictive DfAM

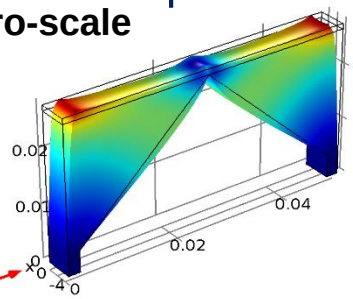
- **Residual Stresses**
- **Distortions**

- **Over-heating**
- **Meltpool morphology**

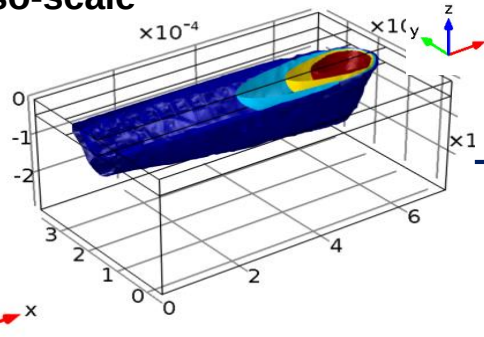
- **Porosities**
- **Powder distribution**

SAMCEF Multiphysics

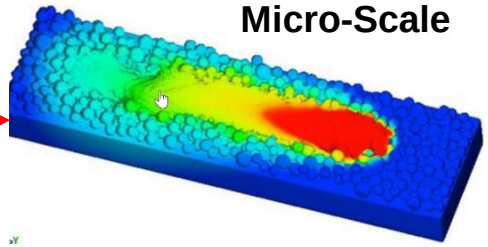
Macro-scale



Meso-scale

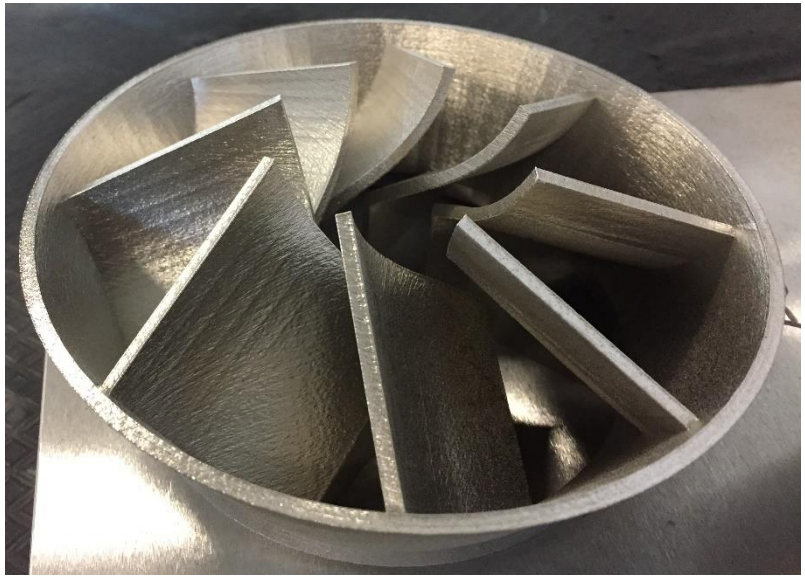


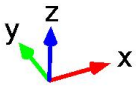
Micro-Scale

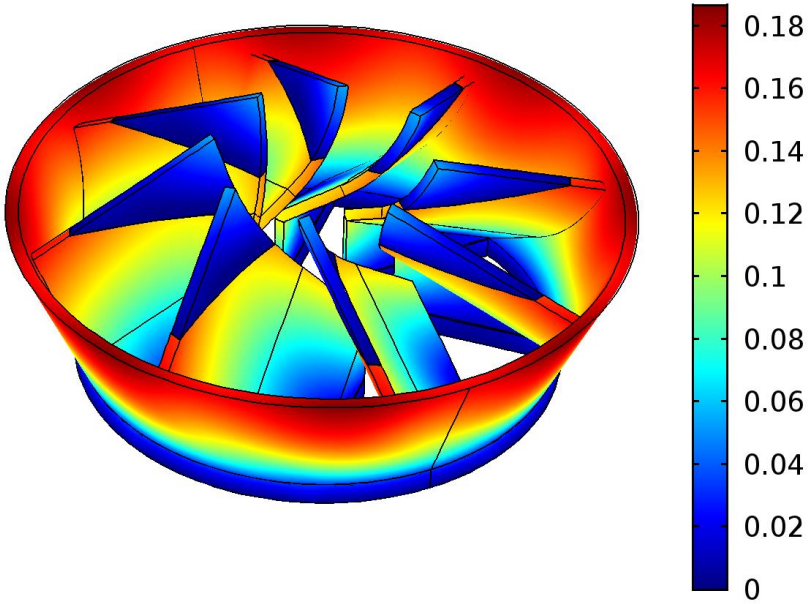


Case Study on Inconel 718, SLM process

- **Distortion calculation has been performed, based on effective values of multilayer shrinkage**







Diameter from CAD : 133mm

Measured Distortion : 0.4mm

Simulated distortion : 2*0.19=0.38mm

The journey to Industrialized AM

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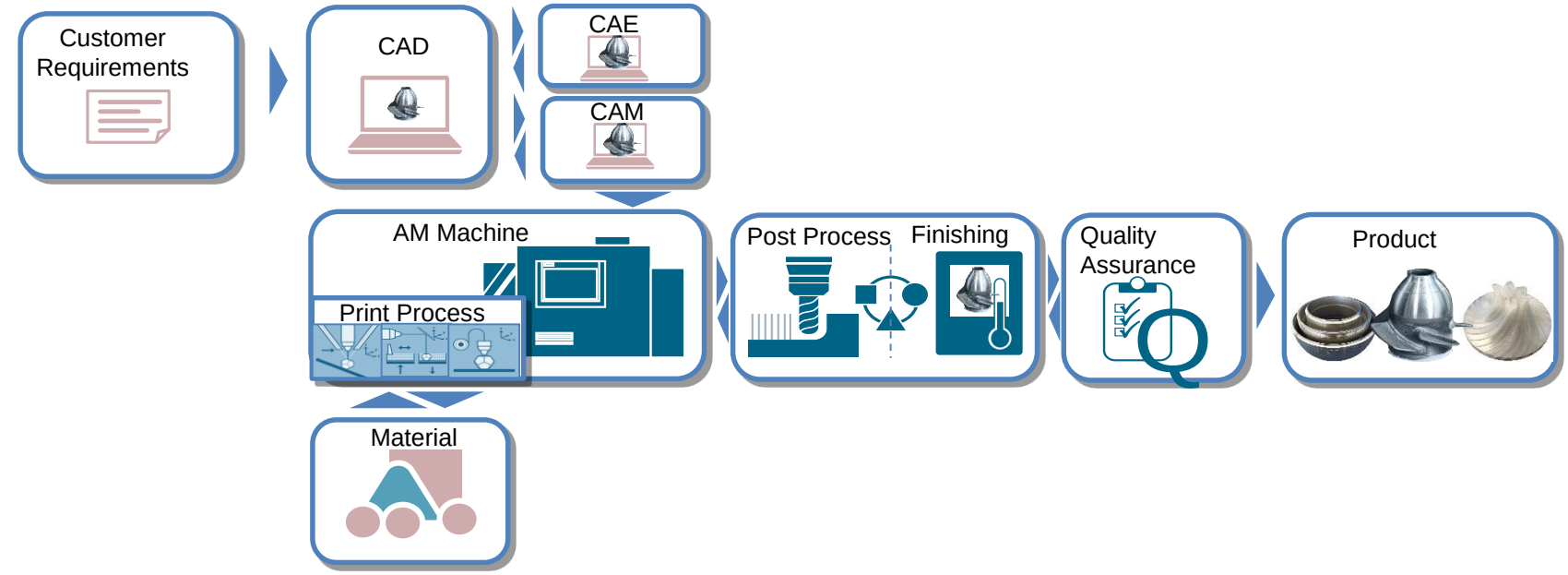
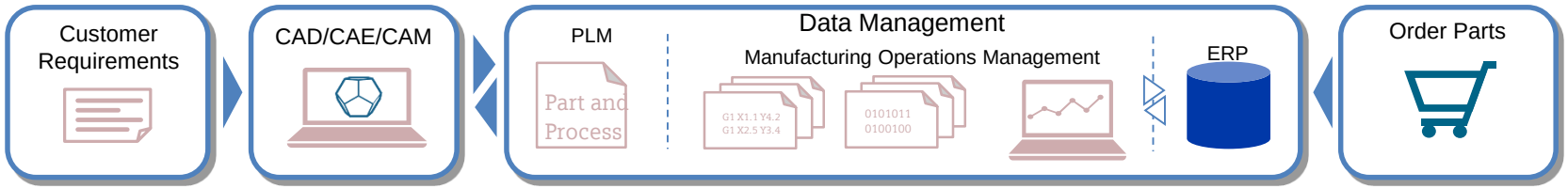
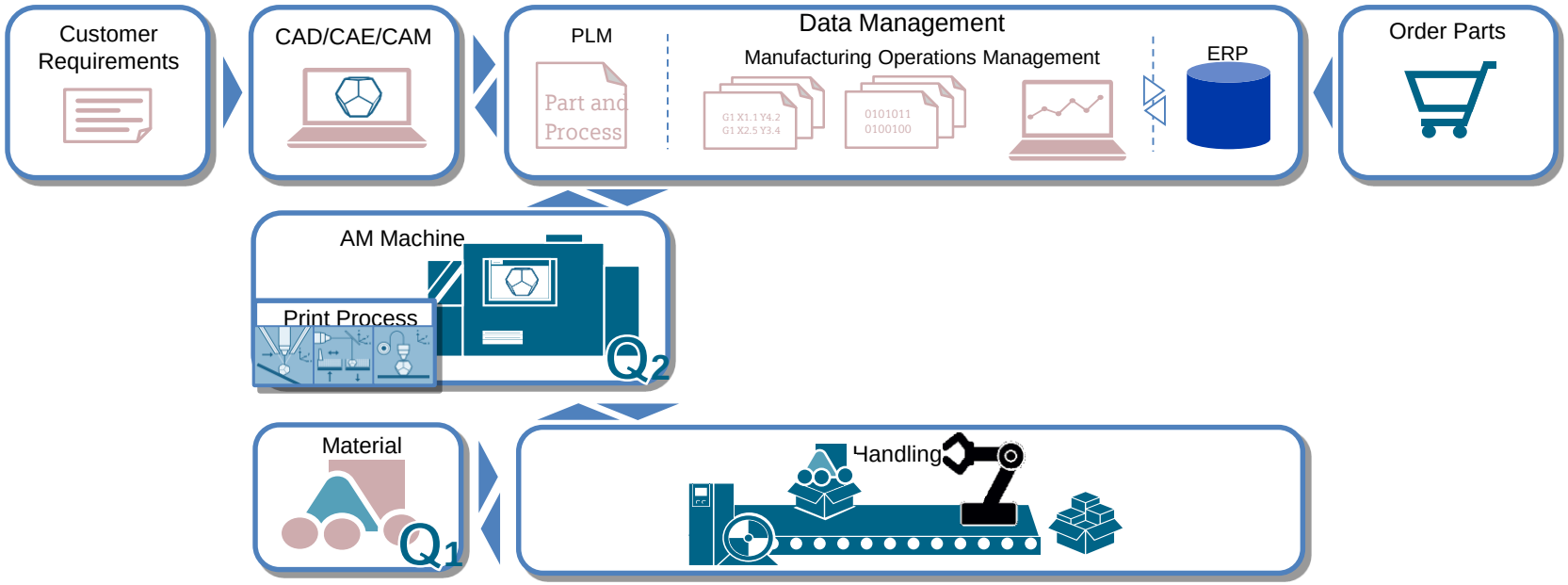


Conventional thinking	Multiple data conversions	Uncontrolled workflow	Disconnected software	Certification

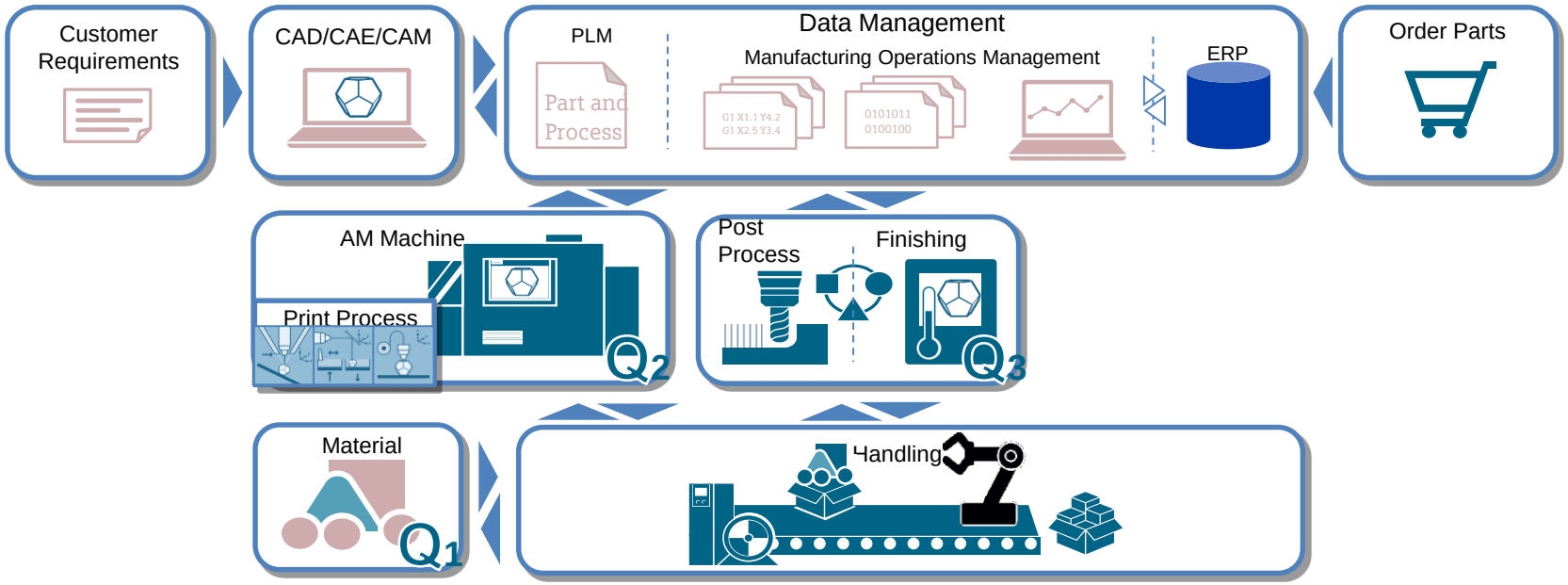
Begins with collaborative development



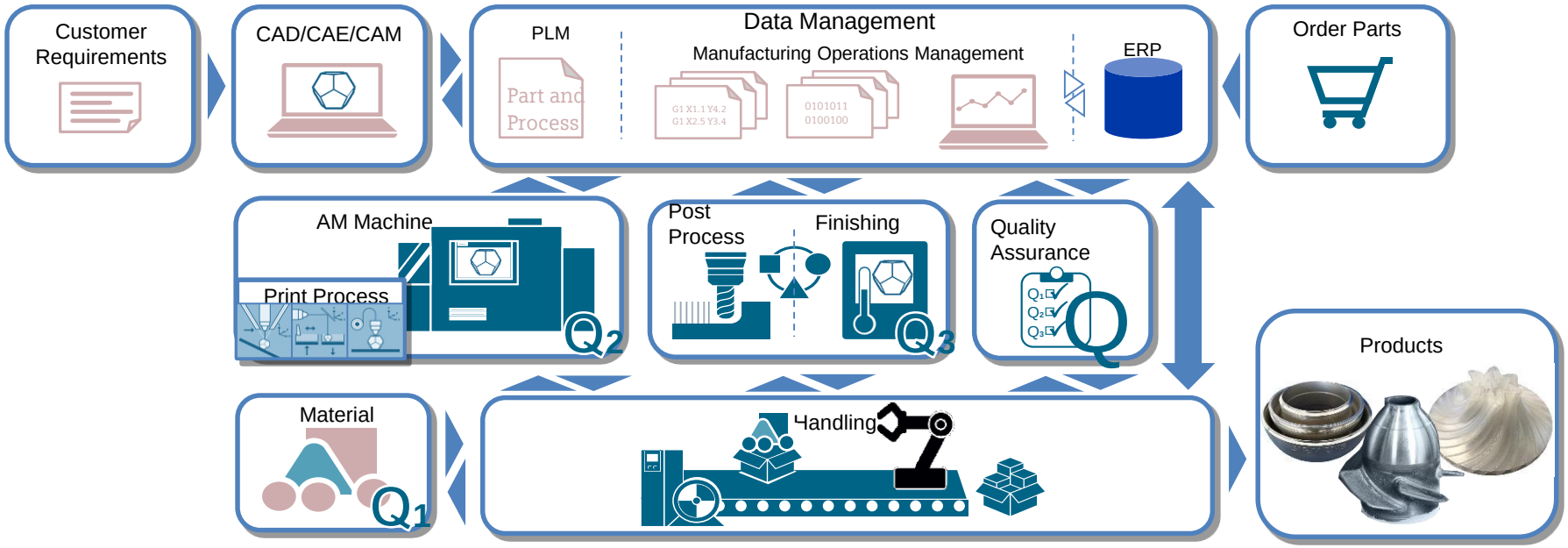
Extends into Machine Integration



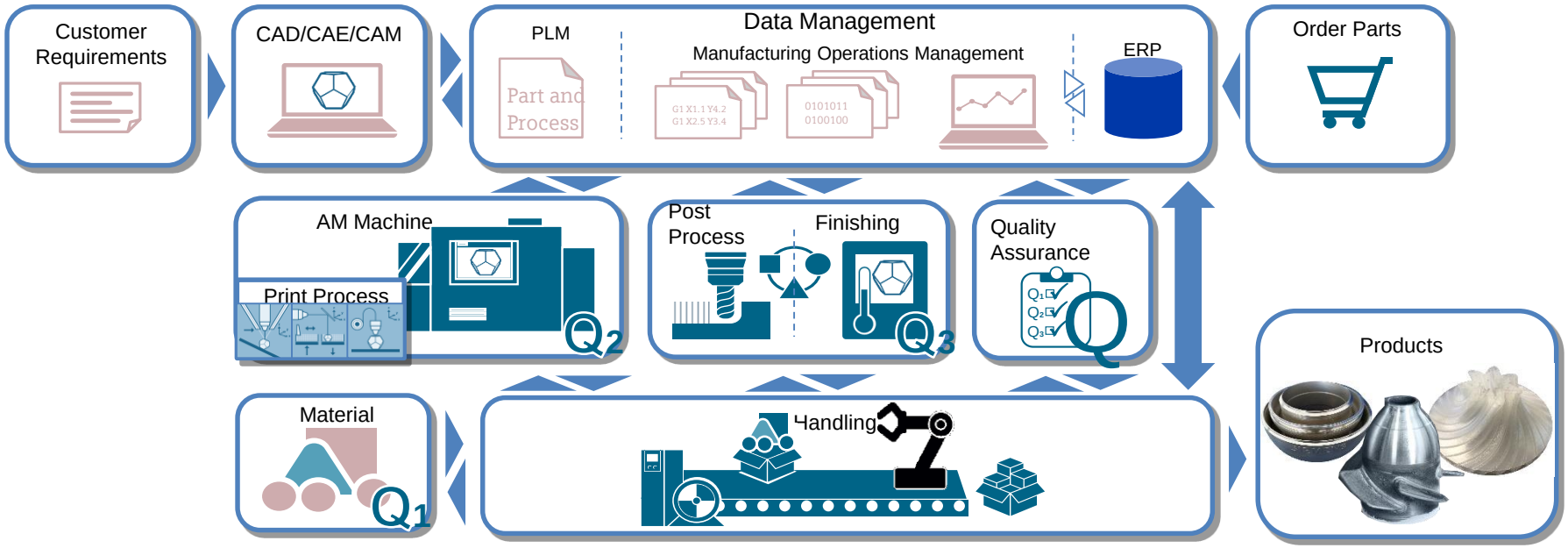
Followed by Post Operations



Lastly the certification process

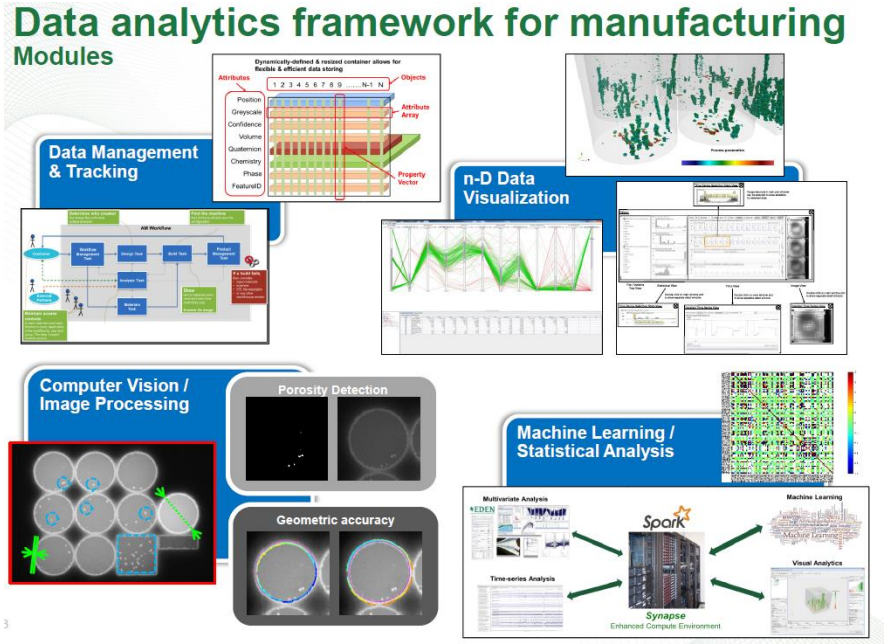


All together comprises an Industrialized Approach



What can help us get there?

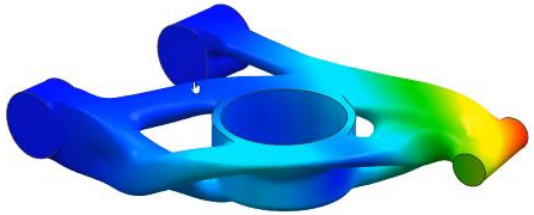
- **A focus on standards**
  - **Nadcap - provides independent certification of manufacturing processes for the industry**
  - **ASTM - Subcommittee F42.05 on Materials and Processes**
  - **3MF**
  - **Data Analytics for Mfg**
  - **ISA-95 for AM**

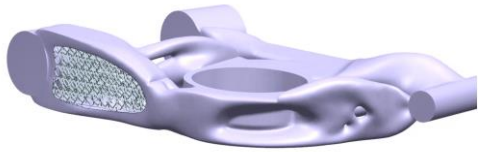


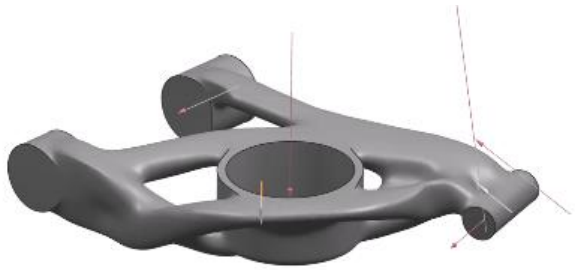
Standards Drive Design and Manufacture

- **ASTM - Subcommittee F42.05 on Materials and Processes**
- **3MF**
- **Data Analytics for Manufacturing**
- **ISA-95 for AM**
- **Topology Optimization**
- **Simulation**

Generative Design Mixer







Design for Additive Manufacturing
Traditional and new design workflows supported

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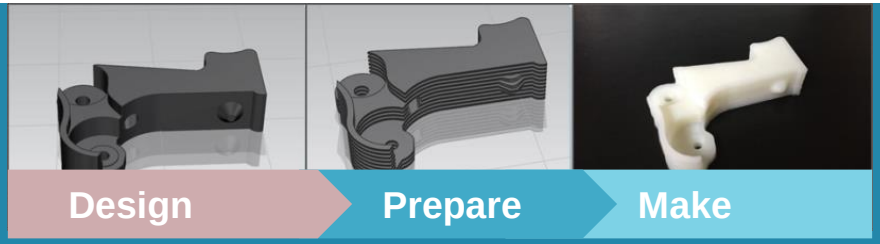
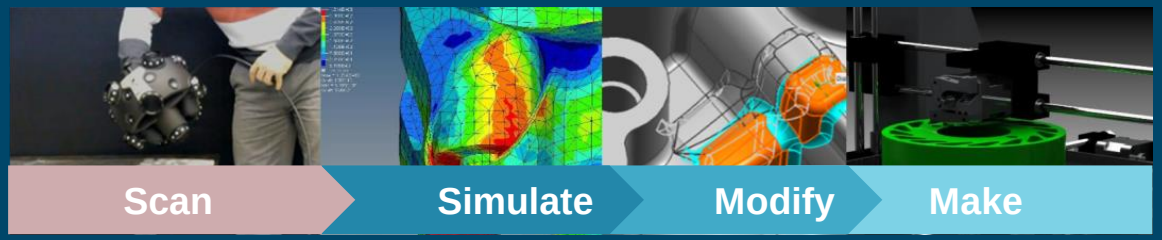
From Traditional
Prototyping



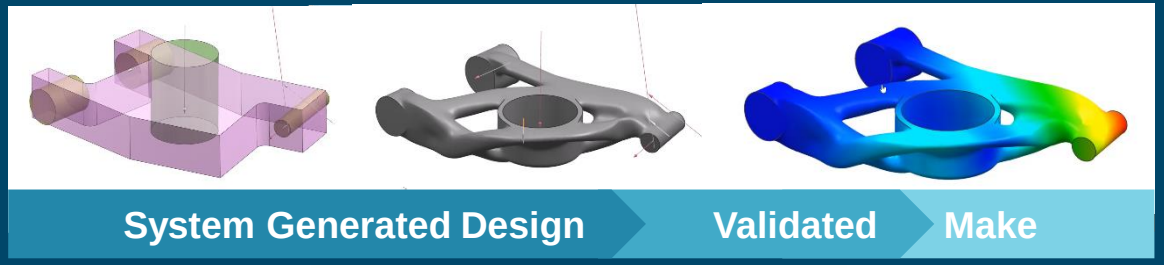
TO…

Scan to print

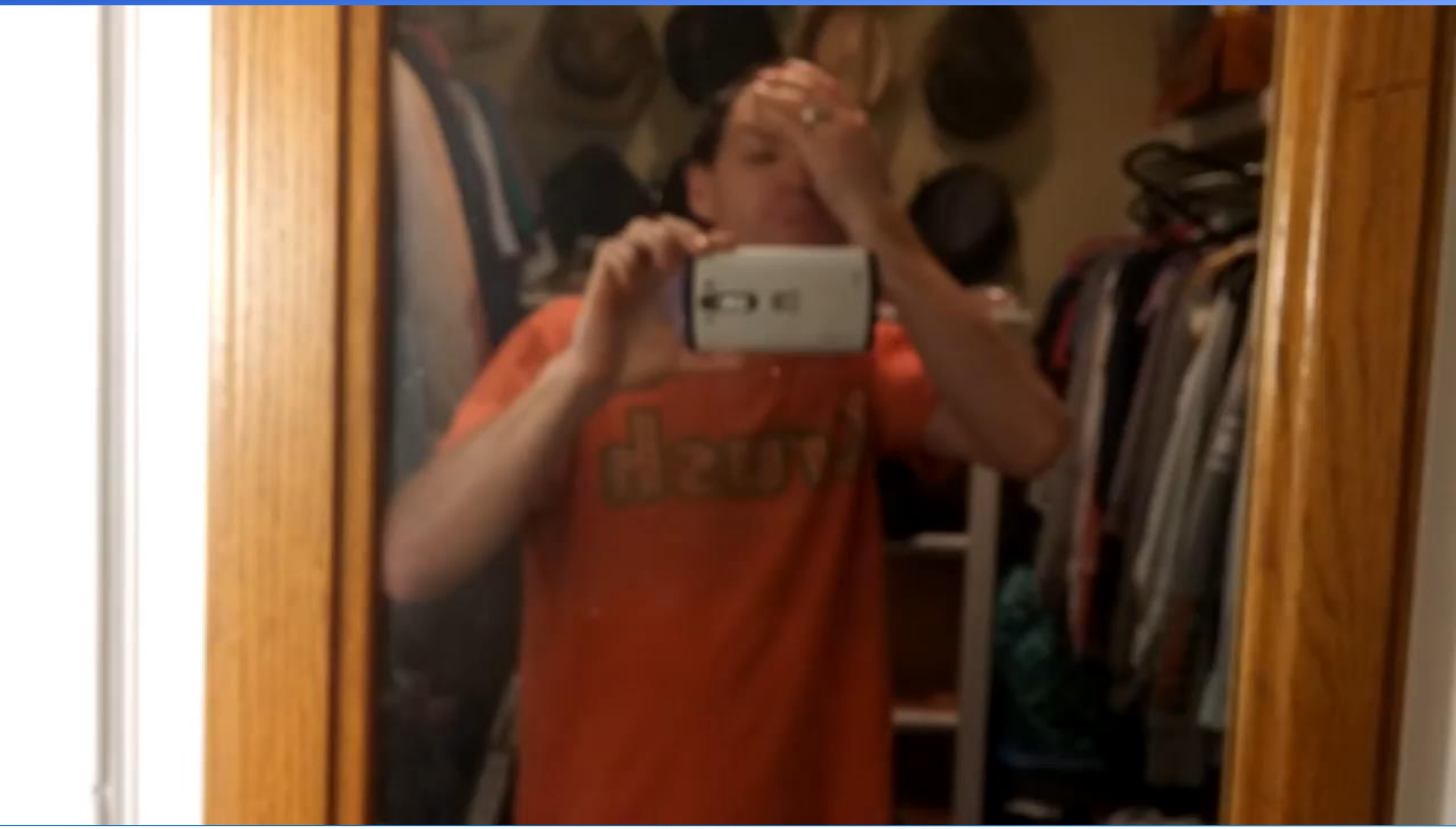


Optimize to print

Generative Design



Let’s not be this guy



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Thank You!