Industrial
Additive
Manufacturing

Importance of Standardization
Oh how far we have come…
Design for Additive Manufacturing
Traditional and new design workflows supported

From Traditional Prototyping

Design → Prepare → Make

TO...

Scan to print

Scan → Simulate → Modify → Make

Optimize to print

Design → Optimize → Validate → Make
Opportunities abound

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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

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Shift from conventional design to enterprise DFAM

Product transformation

Manufacturing transformation

Advancing Products

Status quo

Advancing Manufacturing

Impacting Business

• 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
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

Productivity Simulation

HP Multi jet Fusion

Hybrid additive

Multi-axis FDM
General Climate for AM Today

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- Customer Requirements
- CAD
- CAE
- CAM
- AM Machine
- Print Process
- Material
- 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

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Product Manufacturers

Cloud-based, open IoT operating system

Design
- Print Preparation
- System Engineering
- Process Sim & VC
- Throughput Optimization
- Security & Quality

Engineering / Optimization
- Finishing & Quality
- Operation / Execution (MOM/MES)

Securities
- Machine Design & Simulation
- Machine Commissions
- Machine Control
- Data Analytics

Co-innovation ecosystem

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

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

Collaboration platform

Machine Builders

Micro-factories and job shops
- Engineering community
- Software providers
- Expert services
- Materials
- Part buyers

Elysis
Parker
Northrop Grumman
Boeing

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Digital Enterprise

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AM Eco-system

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- 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

Micro-factories and job shops
Engineering community
Software providers
Expert services
Materials
Machines
Equipment vendors
Part buyers

co-innovating
The Digital Twin

Cloud-based, open IoT operating system

feedback 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

Distortions

Defects

Build failure

Local over-heating

Courtesy of Sciaky
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: $2 \times 0.19 = 0.38$mm
The journey to Industrialized AM

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Customer Requirements → CAD → CAE → CAM → AM Machine → Post Process → Finishing → Quality Assurance → Product

- Material
- Print Process
- AM Machine

Conventional thinking
Multiple data conversions
Uncontrolled workflow
Disconnected software
Certification
Begins with collaborative development
Extends into Machine Integration
Followed by Post Operations

Customer Requirements → CAD/CAE/CAM → PLM → Data Management → Manufacturing Operations Management → ERP → Order Parts

AM Machine

Print Process → Part and Process

Material → Handling

Post Process → Finishing

G1 X1.1 Y4.2
G1 X2.5 Y3.4

Part and Process

010101
0100100
Lastly the certification process

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- Customer Requirements
- CAD/CAE/CAM
- PLM
  - Part and Process
  - Manufacturing Operations Management
- Data Management
- ERP
- Order Parts
- AM Machine
  - Print Process
- Material
  - Quality Assurance
- Post Process
- Finishing
- Handling
- Products
- Order Parts
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
Design for Additive Manufacturing
Traditional and new design workflows supported

From Traditional Prototyping

TO...

Scan to print

Optimize to print

Generative Design

Design → Prepare → Make

Scan → Simulate → Modify → Make

Design → Optimize → Validate → Make

System Generated Design → Validated → Make
Let’s not be this guy
Thank You!