Industrialization of Additive Manufacturing
Siemens is investing in Additive Manufacturing since its early days and pushing its industrialization.

**Additive Manufacturing history of Siemens**

- **1989**: Start of Siemens Corporate Technology R&D Stereolithography.
- **1989**: Start of Siemens Corporate Technology R&D Direct Metal Deposition.
- **2004**: Start of Siemens Corporate Technology R&D Metal Powder Bed Fusion.
- **2006**: Start of Siemens Corporate Technology R&D Ceramic Powder Bed Fusion.

**Gartner's 2015 Hype Cycle for Emerging Technologies**

- **Innovation trigger**
- **Peak of inflated expectations**
- **Trough of disillusionment**
- **Slope of enlightenment**
- **Plateau of Productivity**

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1. STAMFORD, Conn., August 18, 2015
Cimdata Report on 3D Printing and PLM – Key points

Driven by potential for radical part design changes and innovation

A new era of designing for high performance and light weight

AM Market Growth is accelerating

Industrial market is investing heavily

Chart showing AM Market Growth:
- Current Forecast: similar growth pattern

Table showing where leading customers are on their additive manufacturing journey:
- Not interested: 26%
- Researching additive manufacturing: 26%
- Used in traditional applications, like rapid prototyping: 26%
- Experimenting with metals and other advanced materials: 26%
- Using metals and other advanced materials in production: 16%
- Developing additive manufacturing processes, equipment and materials: 5%
Three pillars for Additive Manufacturing applications @ Siemens

1. Rapid Prototyping
   - Product: SGT
   - Component: Turbine Blade
   - Benefit: Significant reduction of time to market
   - Status: Part of standard process

2. Rapid Repair
   - Product: SGT
   - Component: Burner tip
   - Benefit: 10 times faster, easy upgrades
   - Status: In commercial application

3. Rapid Manufacturing
   - Product: SGT
   - Component: Burner swirler
   - Benefit: Optimized design of swirler can only be made via AM technique
   - Status: In commercial application
Comparison of conventionally manufactured component vs. redesigned Additive Manufacturing component

**Conventionally manufactured burner front**
- 13 machined parts, joined by 18 welds.
- Thermal Barrier Coating on front surface.
- External pilot gas feed
- Standard lead time 26 weeks (excl. TBC)
- Weight: 4.5 kg

**AM adapted burner front**
- 1 single part
- Optimized cooling, possible to remove TBC
- Pilot gas feed integrated in structure
- Standard lead time 3 weeks (excl. TBC)
- Weight: 3.5 kg
Additive Unlocks the Next Frontier of Possibility

Basic benefits of Additive

Design:
- Improved performance
- Reduced weight
- Less material
- Equal strength / reduced stress

Manufacturing:
- Greater shape complexity
- Fewer manufacturing steps
- Fewer setups
- Less tooling
- Reduced physical inventory
Additive: The next frontier of performance

**Product Development**

**LIMITLESS FREEDOM:**
- 10x faster development time
- 100x faster design changes
- **optimized designs**
  - reduce weight, increase strength, improve serviceability

**Materials**

**LIMITLESS CONTROL:**
- multiple materials in a single part
- micro-structures
- tune material properties

**Production**

**LIMITLESS AGILITY:**
- 0 cost for greater complexity
- 1 piece lot size
- **finished products**
  - printed as-assembled

**Business**

**LIMITLESS OPPORTUNITY:**
- 0 physical inventory
- on-demand
- product availability
- ∞ customization

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Provide customers with an integrated “end-to-end” Additive Manufacturing Solution leveraging Siemens PLM technologies for the Design, Simulation, and Printing of Products within a managed PLM system connected to MOM and Quality shop floor systems.
Industrializing additive manufacturing
Today's Challenges

Disconnected applications
Multiple data conversions
Uncontrolled workflow
Conventional thinking
Product development for additive manufacturing

Design

Simulate

3D Print

NX and Simcenter
Product development for additive manufacturing

Design
Simulate
3D Print

Data Management and Shop Floor Connectivity

Siemens Production Software and MES Systems

Partnerships

NX and Simcenter
Teamcenter
Simatic IT
REIMAGINE PRODUCTS

• Design with Convergent Modeling™
• Generative design using topology optimization
• Lattice structures
• Design rules for manufacturability
Design for Additive Manufacturing
Traditional and New Design Workflows Supported

From Traditional Prototyping

TO...
Scan to print

Optimize to print

Traditional

Design
Prepare
Make

Scan
Simulate
Modify
Make

Design
Optimize
Validate
Make
Topology optimization

All operations in NX CAD

Multiple load cases

Optimized model can be refined with Convergent Modeling
Design for Additive Manufacturing

Convergent Modeling™ Technology

Work directly with facets, surfaces and solids

Unlimited flexibility to design innovative products

No need for reverse engineering
**Lattices**

Lightweight components and structural integrity

Integrated lattice structure development

Complex geometry represented as facets

* Available soon
Lattices*

Lightweight components and structural integrity

Integrated lattice structure development

Complex geometry represented as facets

* Available soon
Design for Additive Manufacturing

Design rules

Ensure the part manufacturability

Avoid costly re-design when a part is designed and found to be inadequate during manufacturing
# Design for Additive Manufacturing

## Design Rules

<table>
<thead>
<tr>
<th>Wall thickness</th>
<th>Overhang angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set threshold for minimum thickness</td>
<td>Recognize part regions that require support</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Printable volume</th>
<th>Wholly enclosed volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ensure that part fits within the 3D printer build volume</td>
<td>Identify fully enclosed voids within a part</td>
</tr>
</tbody>
</table>
Product development for additive manufacturing

Design

Simulate

3D Print

Data Management and Shop Floor Connectivity

Siemens Production Software and MES Systems

Partnerships
Simulate for Additive Manufacturing

PREDICT PERFORMANCE

• Optimize part design with advanced analysis tools
• Validate product performance
• Simulate additive processes
Topology optimization for analysts

Objectives and constraints at global level

Multiple solutions in the same optimization

Optimization of components within assemblies
Simulate for Additive Manufacturing

Product performance simulation

Validate optimized designs using the advanced capabilities of Simcenter 3D

Generate simulation models to validate convergent body

Access all validation and editing tools in one environment
Simulate for Additive Manufacturing: Validation for impact of Additive Manufacturing process
Example: Simulate powder bed processes – micro scale

Particle Flow / Filling (Discrete Element Modeling – DEM)
Powder manufacture and powder bed distribution

Energy transfer

Melting / Solidification (Volume of Fluid – VOF)
Powder melting simulation (e.g. EBM)
Industrialize Additive Manufacturing
Integrated Additive Solution

Product development for additive manufacturing

Design
Simulate
3D Print

Data Management and Shop Floor Connectivity
Siemens Production Software and MES Systems
Partnerships

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RETOOL MANUFACTURING

• Drive additive manufacturing technologies for real production
• Integrated post-printing machining and inspection programming
• Partnering with industry leaders
Realization for Additive Manufacturing
Smart Model-Driven End-to-End Process

Design and optimization → Print preparation → Validate for AM (Process) → Print → Post-print operations

Smart model-driven process
### 3D Print
### Revolutionary Technologies Supported by NX

<table>
<thead>
<tr>
<th>Powder bed fusion</th>
<th>Multi jet fusion</th>
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<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
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<tr>
<th>Hybrid additive</th>
<th>Multi-axis fused deposition modeling</th>
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<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
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</table>
Powder Bed Fusion

Most widely utilized metal additive manufacturing technology

Print fine internal details and complex features

Near forged part material properties
3D print
Powder Bed Fusion

A model-driven process in NX

Design model

Select a 3D printer

Position / nest parts on build tray

Create support structures

Define the build process

Verify the laser path

Drive 3D printers

Printed part
Additive Postprocessing and Part Finishing

Integrated NX CAM

- Work Cell or Line Definition
- Grinding, Polishing, Machining
- Robot Kinematics and Simulation
- Several Output Formats
- All in one system – NX software
Multi Jet Fusion

Print plastic parts using a process similar to inkjet printing

Make parts with high dimensional accuracy and improved properties

Build parts 10 times faster
Design model

Select a build tray
Add components to the build tray
Automatically nest parts in 3D
Define/adjust the build process
Drive multi jet fusion 3D printers

Printed parts
Hybrid Additive Manufacturing

Combining 3D printing with CNC technology on one machine

Complex, large-size parts with internal cavities

Eliminate support structures
Hybrid Additive Manufacturing

Marine industry example

FROM: 6-8 weeks
To: 36 hours
Multi-Axis Fused Deposition Modelling

Build composite parts in various sizes

Leverage robots flexibility to print parts of any complexity

Eliminate support structures
Integration of Stratasys’ advanced extrusion technology, Siemens MC industrial motion platform and Siemens PLM design-to-product workflow
Product development for additive manufacturing

Data Management and Shop Floor Connectivity

Siemens Production Software and MES Systems

Partnerships
Data Management and Shop Floor Connectivity

**Single source of data**
- Manage all the manufacturing data
- Re-use proven data and processes

**Connect engineering to the shop floor**
- Deliver the correct data to production
- Establish a closed-loop process
Manufacturing Operations Management
Embed AM activities in the overall production process

Manage all pre / post 3D printing operations

Order management

Additive manufacturing management
Operator guidance and checklist
Print job file management
Powder and substrate management

Full production data tracking

* Available soon
Secure Manufacturing
On Premise & Supplier Collaboration

OEM

- NX CAM (Machining)
- NX CAM (HYBRID AM)
- NX CAM (Multi-Axis ME)
- NX AM (LMF)
- NX Build Tray Manager
- NX CMM

Teamcenter Platform
- Omneo
- TC Shop Floor Connect

Cloud Based Data Analytics
- MindSphere
- SINALYTICS

In-bound Technical Package (Digital Asset)
- Physical Component

Outbound Technical Package (Digital Asset)
- Physical Component

Supplier
- Supplier 1234

Physical Component

Runtime Data

ID3D
- Trumpf Truprint 100
- Sno 1234567

ID3D
Secure Digital Content Distribution
System Overview (Proof of Concept)

1. Create design and start post process
2. Enter business and design rules and **encrypt**
3. Upload **encrypted file, design and business certs**
4. Save business and design rules
5. Request **authorization cert and download encrypted file**
6. Select file, verify rules and **decrypt** if verification passes
7. Execute program
Siemens Partnerships with Additive Manufacturing Industry Leaders

**TRUMPF**
TRUMPF and Siemens are driving the industrialization of additive manufacturing

**EOS**
EOS integrates EOSPRINT software into Siemens NX to build on Siemens’ end-to-end additive manufacturing solution

**HP**
Siemens to collaborate with HP Inc. to elevate 3D printing from prototyping to full production

**DMG MORI**
DMG Mori and Siemens partner to deliver hybrid additive manufacturing

**Stratasys**
Siemens and Stratasys partner to incorporate additive manufacturing into volume production

**Materialise**
Materialise collaborates with Siemens to advance additive manufacturing
Digitilized Additive Manufacturing Process

Initial design → Design space → Optimize → Adapt design → Prepare for printing* → Validate → Finish and inspect → Final part

* Powered by Materialise technology
## Siemens PLM NX Additive Manufacturing Products

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<th>Name</th>
<th>Availability</th>
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<tr>
<td>NX13110</td>
<td>NX MACH 3 Additive Manufacturing with Convergent Bundle</td>
<td>Now</td>
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<tr>
<td>NXS30110</td>
<td>NX Additive Manufacturing with Convergent Sticky Add-on</td>
<td>Now</td>
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<td>Hybrid/Additive Manufacturing Package for DMG Mori Lasertech 65 Family</td>
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<td>Additive Manufacturing Add-On</td>
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<td>NX Multi-Axis Deposition Add-On</td>
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Learn More

Web
www.siemens.com/plm/additivemanufacturing

NX Manufacturing Forum
www.siemens.com/plm/community/nx/manufacturing

Manufacturing 360 tablet app
Available from Apple Store or Google Play
Contact us

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Realize innovation.