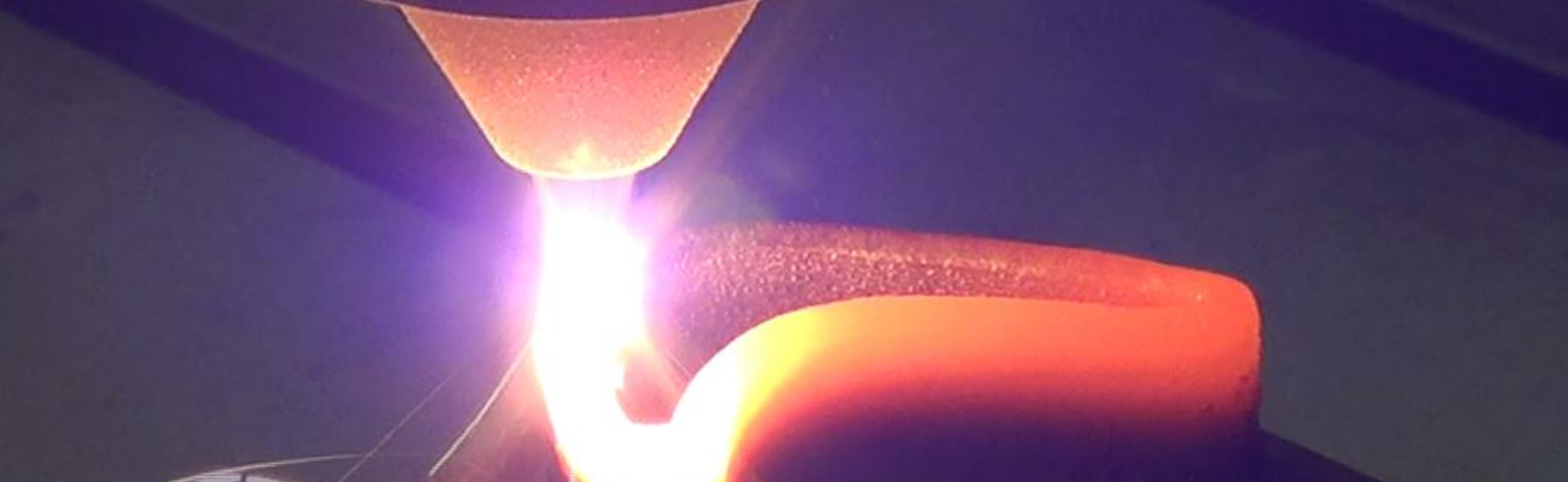


Andreas Saar MBSE Summit - Los Angeles January 25, 2015

Hybrid Manufacturing and 3D Printing

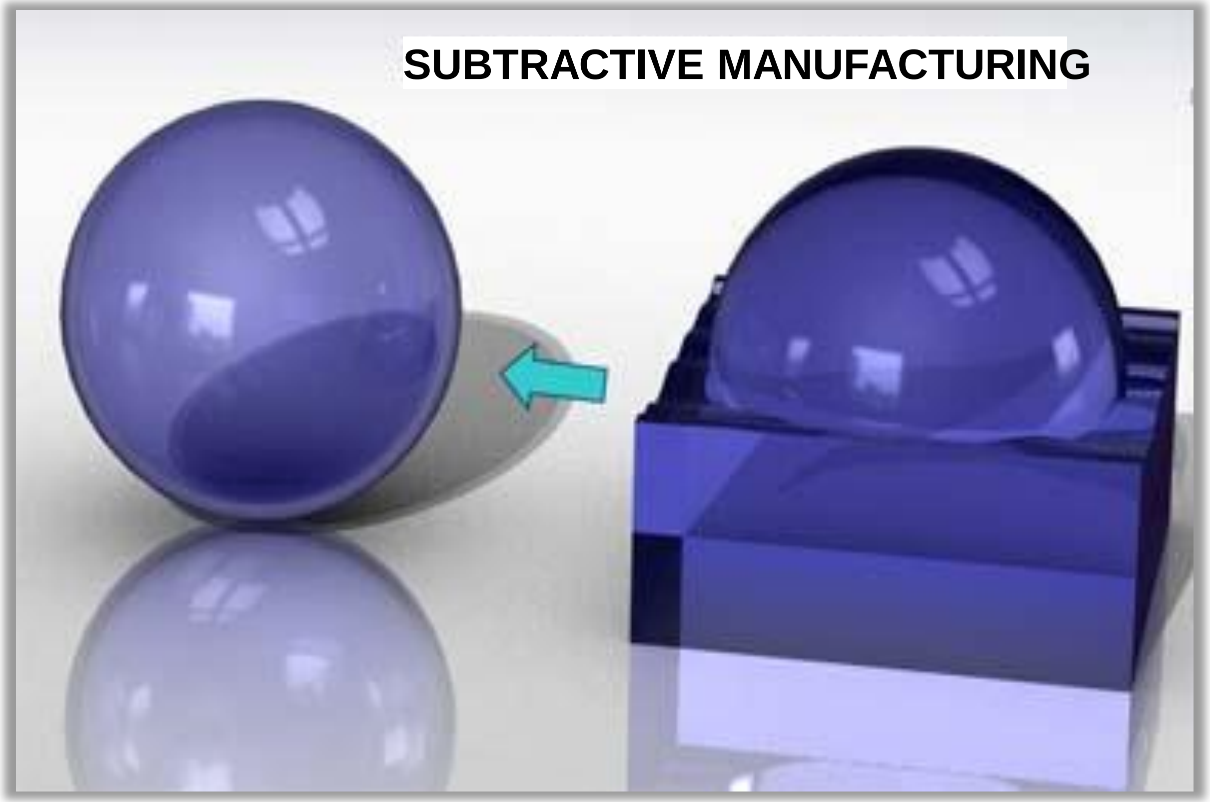
Additive Manufacturing – 3D Printing

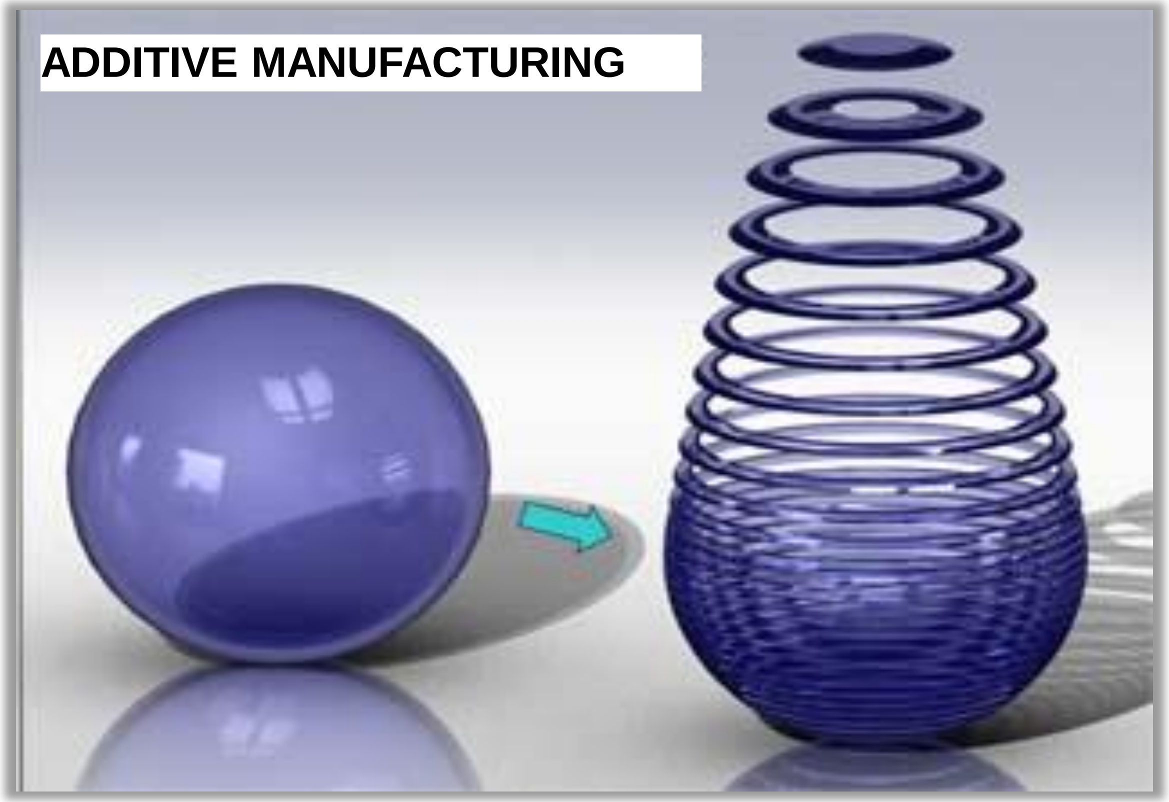
"Additive Manufacturing is an amazing technology with unrivaled capabilities. Its strengths and limitations are polar opposites of established technologies."

Todd Grimm, T.A. Grimm Associates

3D Printing - Additive Manufacturing
What is it really all about?

Additive Mfg or 3D Printing is a group of technologies with one common characteristic of adding material to form a part rather than subtracting material (traditional machining).



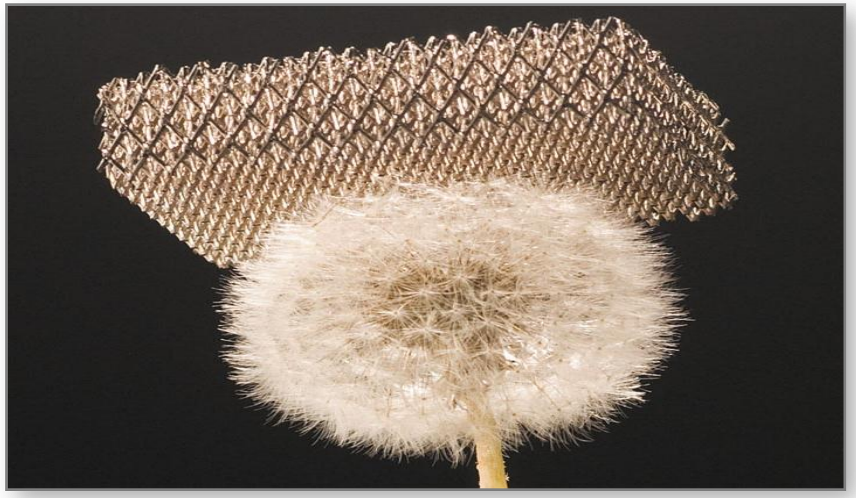


Why Is Additive Manufacturing Important ?

- **It allows you to place material of the desired composition exactly where you want it (and nowhere else)**
- **You can make things that are impossible to make in any other way:**
  - Internal voids, webs, honeycombs, lattice structures
  - Assemblies of parts (in one shot)
  - Internally embedded components
  - Parts with custom non-homogeneous (graded) materials
- **Material composition and placement become design variables**
- **Engineering performance of parts can be dramatically improved**
- **The "catalyst for the next industrial revolution" ???**

Some Amazing Things …

The next industrial revolution? Hype? Oversold?? Maybe, but some amazing possibilities…..



But there are limitations today ...

To print something, you have to design it, which requires effort, creativity, and software

Today's typical solutions: scanning or downloading models from on-line libraries -> Result: lots of rabbits

History of 3D Printing/Additive Manufacturing

SIEMENS

Market penetration

1986
Stereolithography
(SLA) patented by
3D Systems
STL format defined

Mid 1990
Stratasys
introduced Plastic
Extrusion technol.

2001
First Metal
powder printer
by EOS

Hobby market for
Plastic Extrusion
established

3D Printing goes
"Mainstream"

Merger Stratasys
and 3D Objects

Autodesk & HP announce own
printers

1980 1990 2000 2010

Additive Manufacturing
The Additive Hardware explosion

Plastics, Polymers & Resins (specialty materials)

Metals & Alloys

20XX-XX-XX

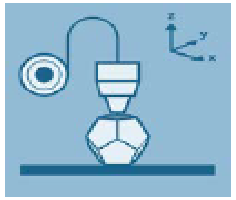
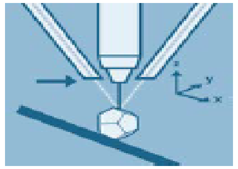
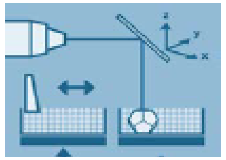
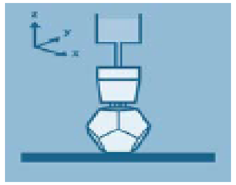
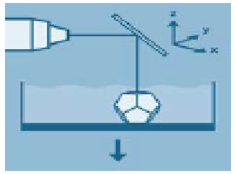
Siemens PLM Software

SIEMENS

3D printer / Additive Manufacturing OEMs

Low cost (Plastics)	Printing Professional (Plastics)	Production Printing (Metal / Ceramic / Sand)	Multi-Axis Additive systems (Metal + Plastics)	Multi-Axis Hybrid systems (Metal + Alloys)
$1000-$5000		$1,000,000		$1,500,000
Materialise innovators you can count on MakerBot Airwolf 3D …80-100 more	Materialise innovators you can count on 3D SYSTEMS TIERTIME voxeljet Stratasys FOR A 3D WORLD™ Autodesk	Materialise innovators you can count on eos ExOne™ DIGITAL PART MATERIALIZATION RENISHAW apply innovation SLM Solutions GmbH CONCEPTLASER hofmann innovation group OPTOMEC® Additive Manufacturing Systems—from NANO to MACRO™ CAD TO METAL® arcam Arcam AB®	CHROMALLOY HUFFMAN CORPORATION SULZER SCIAKY INC. ARBURG	DMG MORI Matsuura

Additive Manufacturing / 3D Printing Technologies

Type	Technologies		Materials
Extrusion	**Fused deposition modeling (FDM)**		Thermoplastics, HDPE, eutectic metals
Wire	Electron Beam Freeform Fabrication (EBF)		Almost any metal alloy
Granular / Powder	**Direct metal laser sintering (DMLS)**		Almost any metal alloy
	Electron beam melting (EBM)		Titanium alloys
	Selective laser melting (SLM)		Titanium alloys, Cobalt Chrome alloys, Stainless Steels, Aluminium
	Selective heat sintering (SHS)		Thermoplastic powder
	Selective laser sintering (SLS)		Thermoplastics, metal powders, ceramic powders
Laminated	Laminated object manufacturing (LOM)		Paper, metal foil, plastic film
Light polymerized	Stereo lithography (SLA)		photopolymer
	Digital Light Processing (DLP)		photopolymer

SIEMENS

So, Why AM is important?

In recent years, 3D printing has come into the media limelight, proclaimed as both the savior of manufacturing in North America and nothing more than a producer of cheap trinkets. Amidst current widespread speculation, 3D printing has proven its relevancy and, judging from its performance on the manufacturing floor these past 25+ years coupled with recent material developments, the technology is heralding a new age of manufacturing. 3D printing, also known as additive manufacturing, is well equipped to transform product development lifecycles with unforeseen design freedom, affordable customization, a manufacturing revolution lowering costs stateside, and encouraging innovation by engineers for unique needs and applications on-demand.

Instead of DESIGNING FOR MANUFACTURING

Additive Mfg Enables the

MANUFACTURE FOR DESIGN.

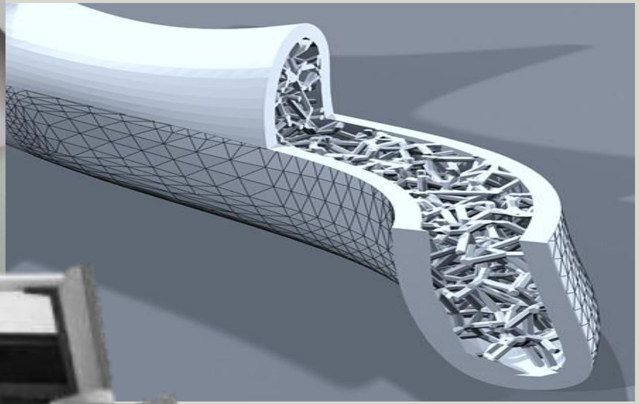
What are the key benefits of Additive Manufacturing?

More design freedom...

Lighter in weight parts…

Lower production costs...

Less parts in an assembly



Industy applications for additive manufacturing

Aerospace and Defense

- Low-volume / complex parts
- Lightweight structures
- Adaptive repair

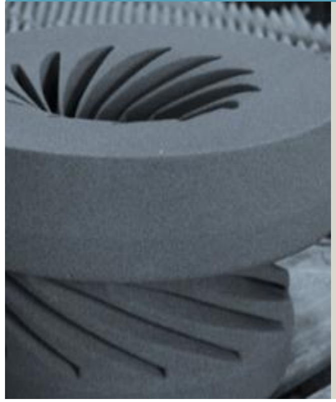
Medical and Dental

- Personalized products
- Improved designs
- Special surface patterns

Automotive

- Prototyping
- Race, luxury, exotic cars
- Low-volume / high precision
- Mass customization

Casting Mold and Tooling



- Cost & time adantage
- Higher efficiency tools
- Improved part accuracy

Example of Additive Manufacturing
Aircraft Engine Door Hinge

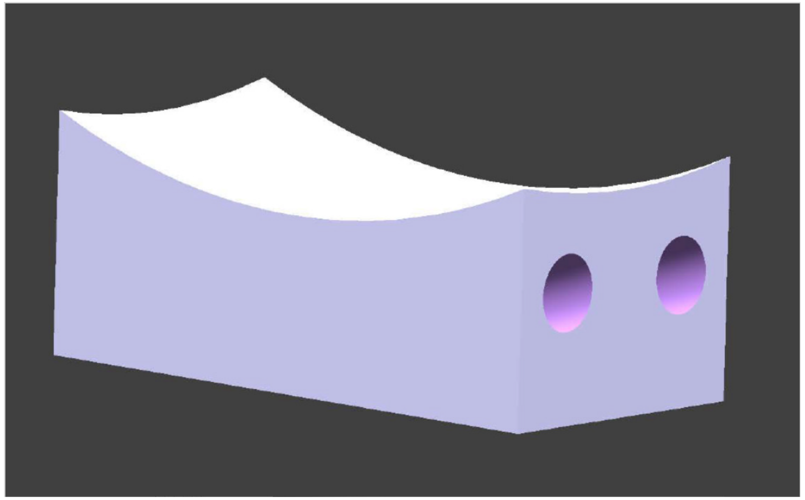
Traditional Manufacturing

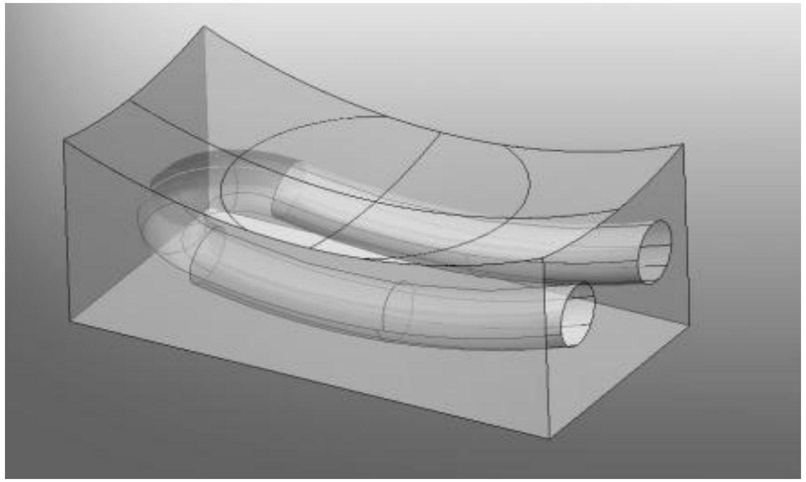
Additive Manufacturing

50% weight savings

same performance

Examples of Additive Manufacturing Cooling Channels





Cooling Channels with uniform distance to the part surface for optimum cooling conditions

Heat exchanger with maximized efficiency

Complex Parts

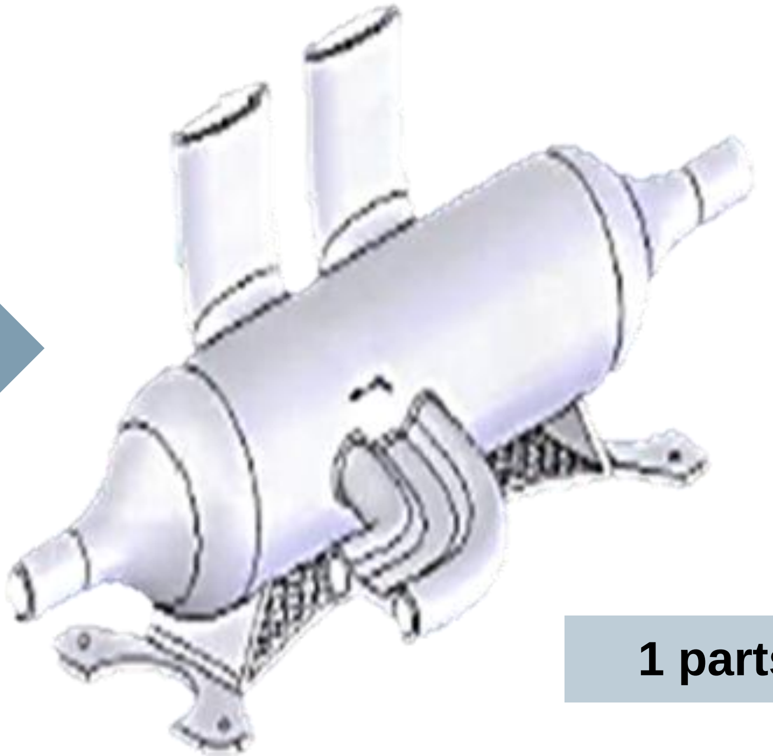
Complex Hydraulic part

GE Fuel Nozzle

Examples of Additive Manufacturing
Multiple parts combined into one

TRADITIONAL	ADDITIVE

12 parts



1 parts

What has changed in the last years?

Technology transition from prototyping to production

Plastics

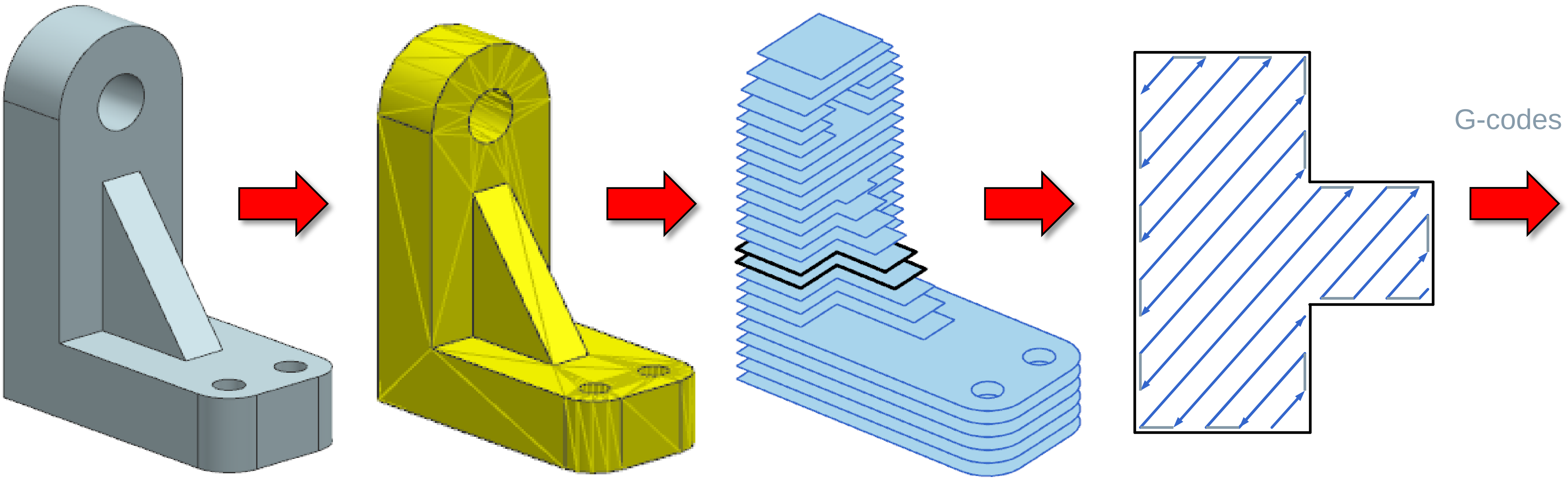
- New methods
- Many more materials
- Higher accuracy (production quality)
- Less expensive hardware
- Smaller machines
- Ease of use
- Improved scanning

Metals

- New material technologies
  - Powder materials
  - Higher precision
- New processes
  - Hybrid Manufacturing
  - Electro Beam Melting
- Printing of larger sized parts, performance

High growth in Government and Industry investment in R&D

Standard 3D printing process steps



CAD model → **Facets (STL)** → **Slices** → **Filling** → **G-codes**

Compute slices

Each slice is “filled”

STL Problems and Solutions

- **Almost all 3D printing today relies on STL data.**
- **But the STL format has many problems:**
  - **Verbosity**
  - **No connectivity (topology) information.**
  - **No units, color, or material information**
- **Two new file formats: AMF and 3MF**

AMF Format

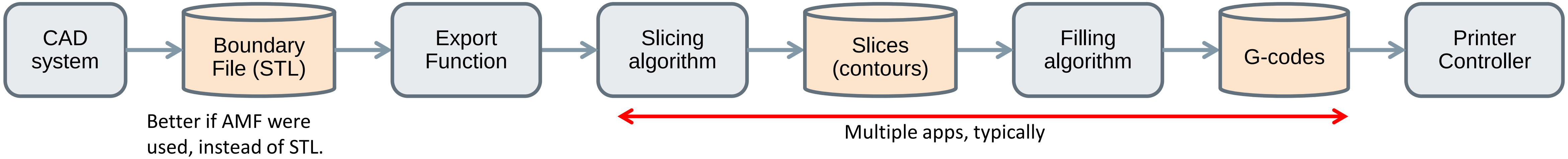
- Mostly designed by Hod Lipson from Cornell
- ISO standard ??? ISO / ASTM52915 – 13
- XML text format, then (optionally) zipped
- Explicit mesh topology
- Colors for material, volume, vertex, or triangle
- Graded materials defined by composition functions
- A "constellation" is an array of copies
- Curved triangles, optionally

3MF Format

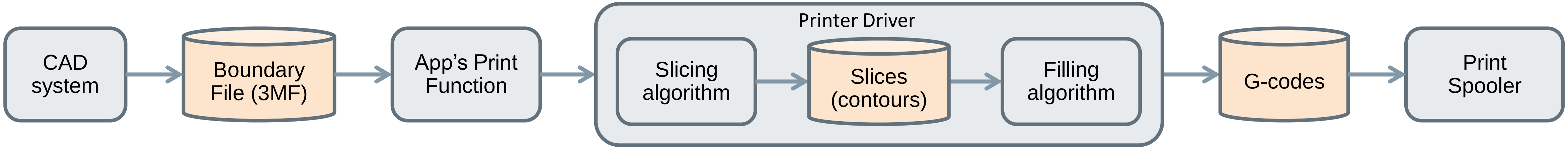
- Invented by Microsoft, November 2013
- Zipped XML, like MS Office docs
- Triangle mesh or a set of "slices"
- Slices consist of strings of curves
- Uses tiled 3D texture for regular lattice
- Rectangular lattices, but not cylindrical
- No graded materials ?
- Integrated into Win8.1 print pipeline

New vs Old way of 3D printing

Old Way (Today STL or AMF)



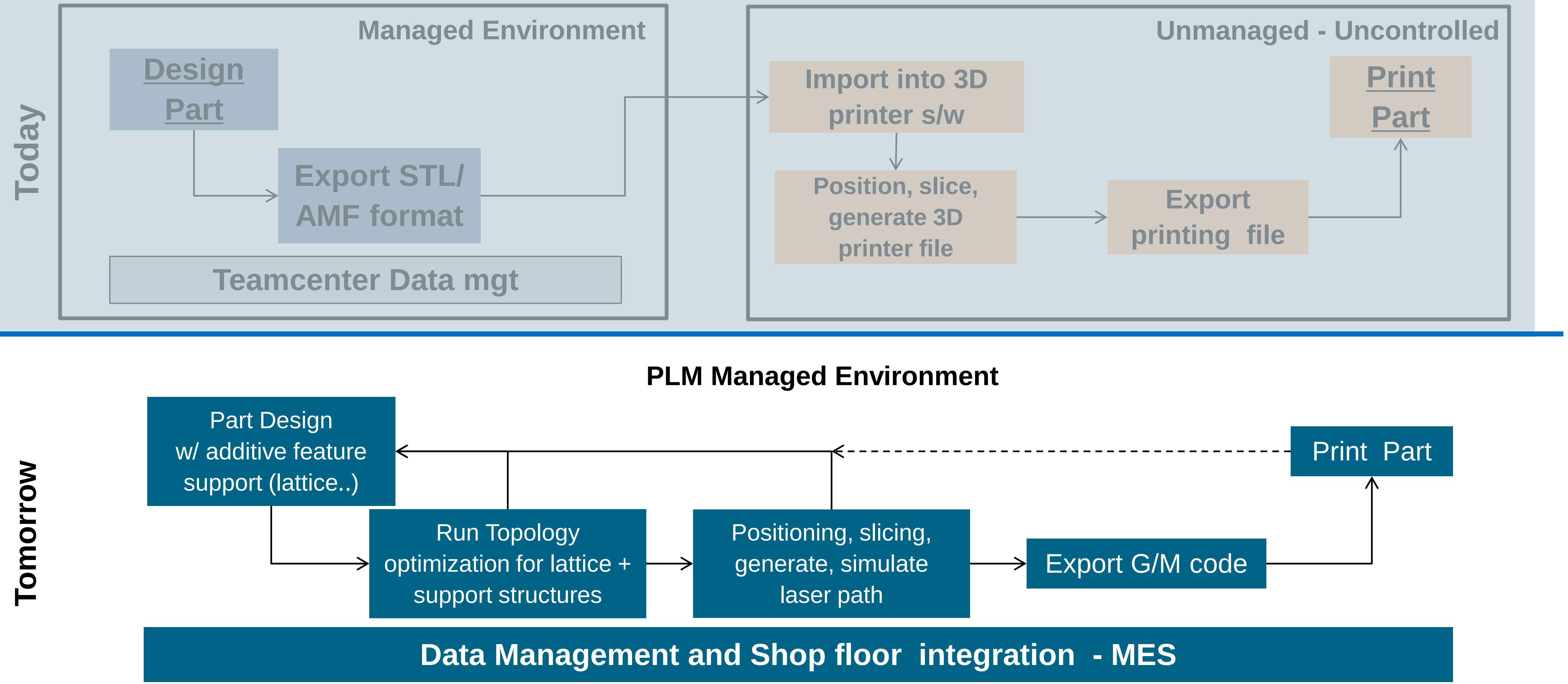
New Way (MS proposal)



Benefits of New Way:

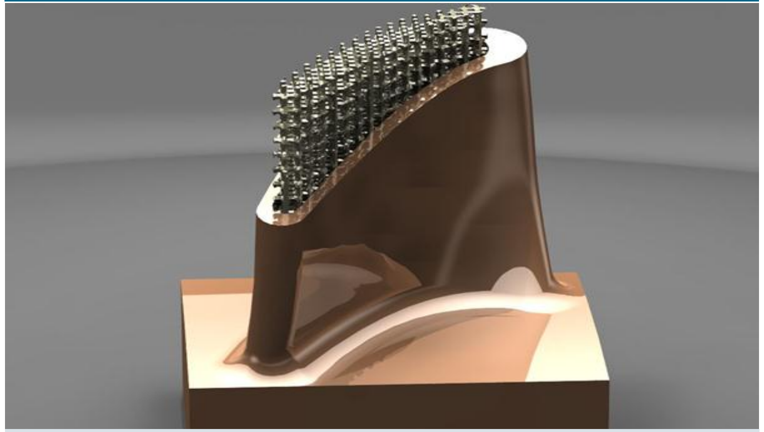
- Simpler for user: slicing/filling/sending all hidden inside application's "Print" function and printer driver
- Clear separation: only the driver knows about the printer; upstream processes are device-independent
- Familiarity: leverages user's knowledge of existing 2D printing infrastructure (discovery, spooling, etc.)
- But, making this work might require a hugely complex "Print" dialog

PLM enabled Additive Manufacturing process



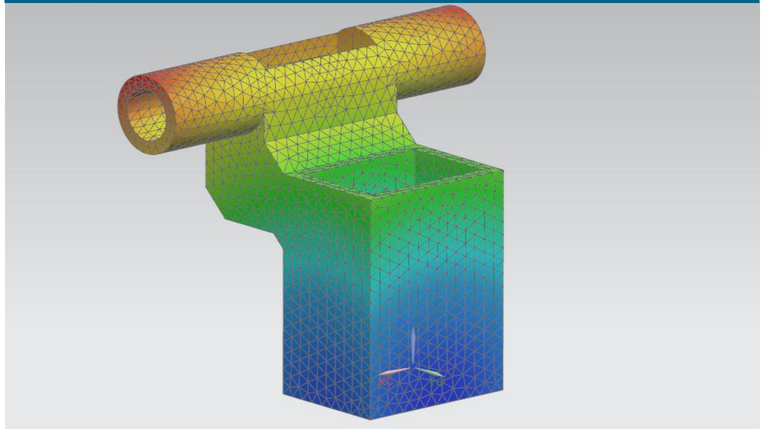
Integrated Additive Manufacturing Technology

Design (CAD)



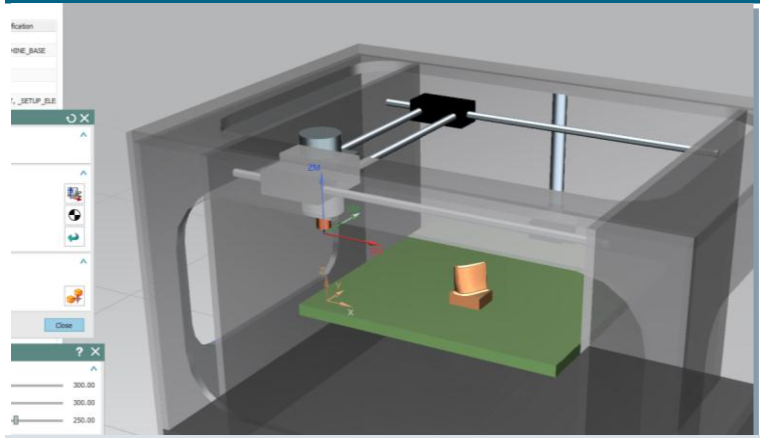
- Design of light weight structures (lattice/honeycomb)
- Complex surface pattern
- Support structures
- Implementation of Additive Mfg design rules & conditions
- Multi-material support

Analyze (CAE)

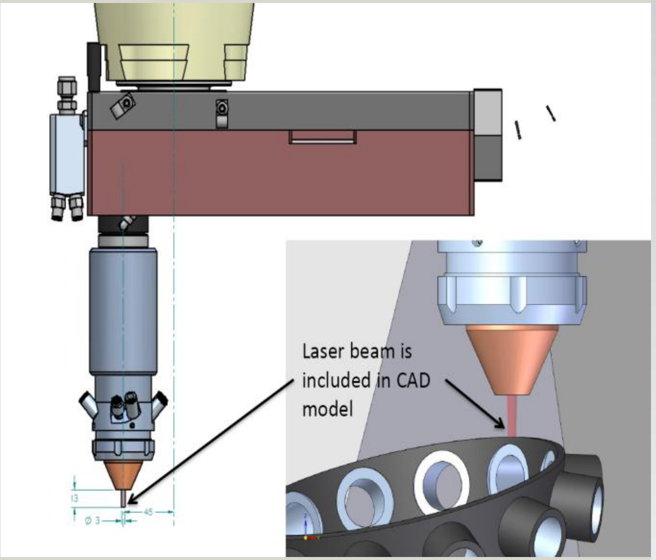


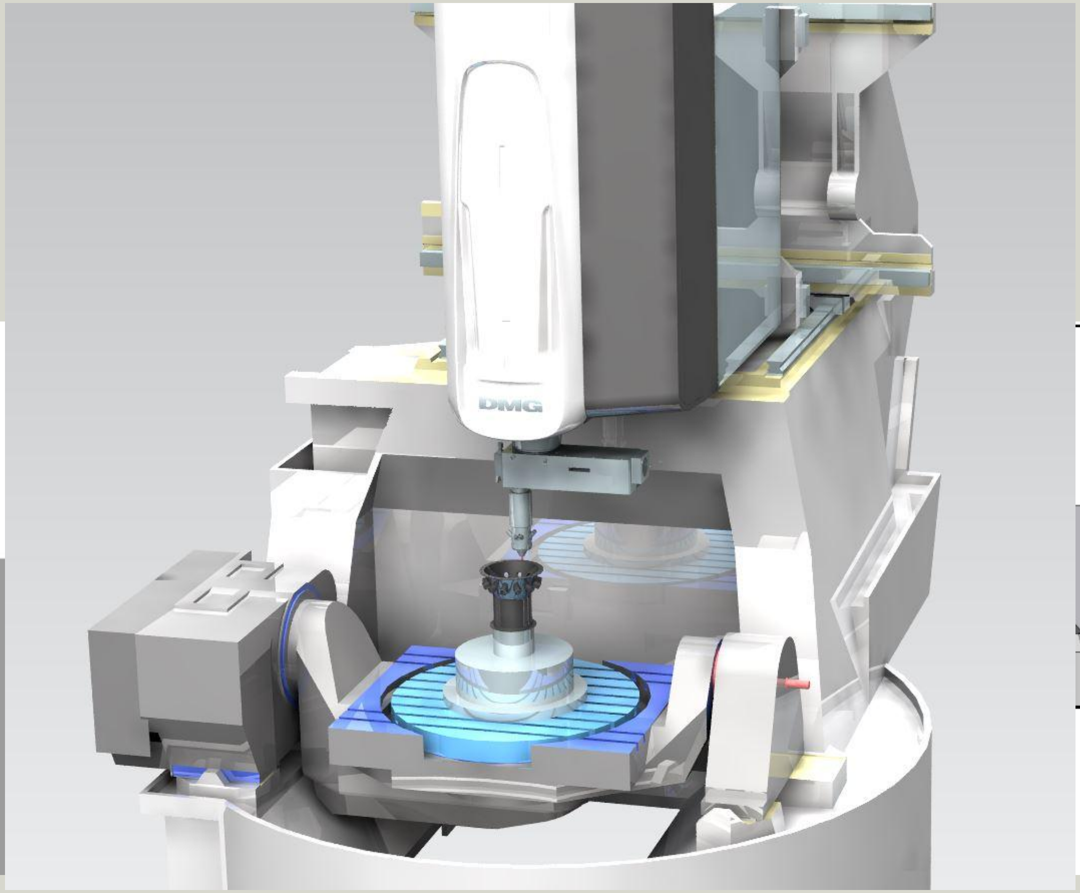
- Topology optimization tools
- Deformation calculation
- Laser power regulation
- Level based analysis
- Heat flow analysis

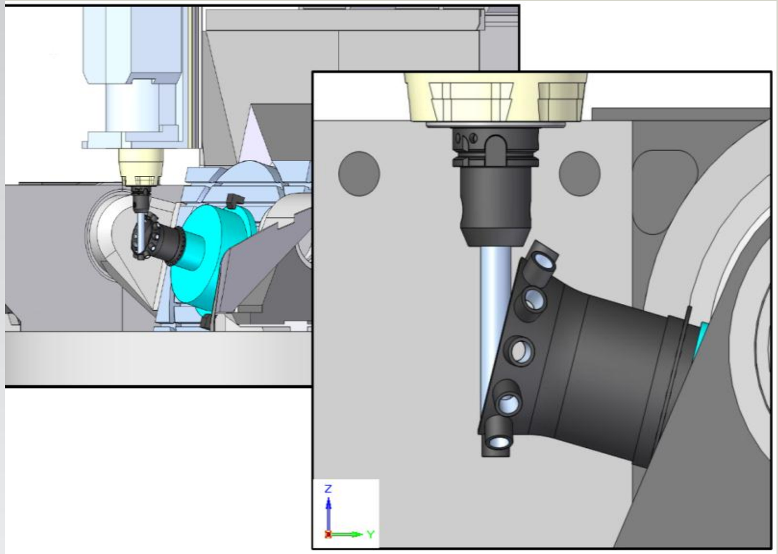
Manufacture (CAM)



- Multi-axis Additive solution
- Multi channel solution
- Additive mfg cut patterns
- Direct printer interfaces
- Standard data formats (STL, AMF, 3MF)







What is Hybrid Manufacturing?

Build it. Finish it. In one system.

What is Hybrid Manufacturing ?

Hybrid Manufacturing

=

Additive

+

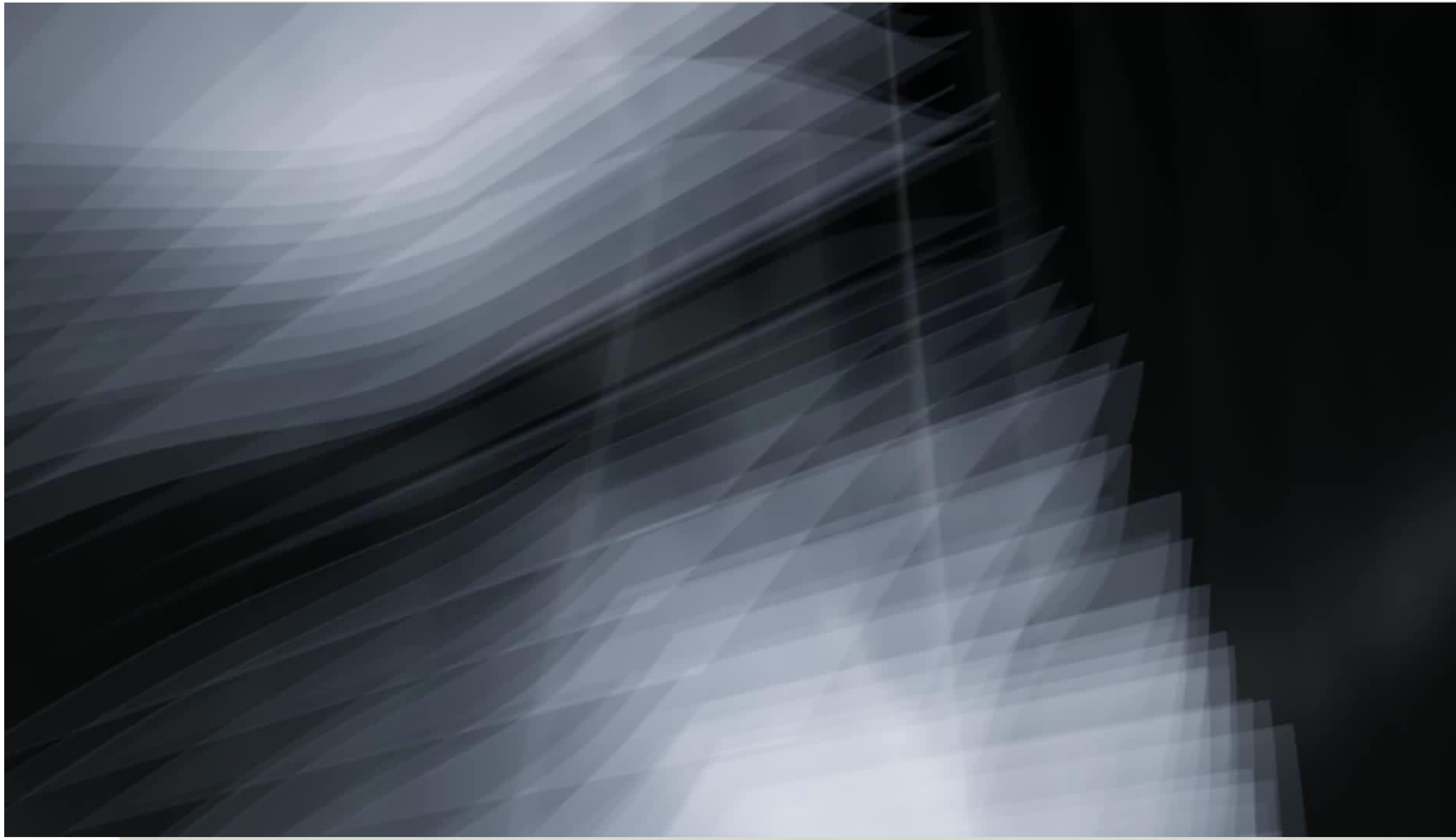
Machining

IN ONE SYSTEM

Additive (Direct Metal Laser Sintering)	**Machining**

SIEMENS

DMG MORI LASERTEC 65 Hybrid 5-Axis Machine tool



DMG MORI

Hybrid Manufacturing Equipment

- Siemens PL and DMG Mori are collaborating in the development of a Hybrid Manufacturing Solution
- Prototype shown at IMTS in Chicago
- Field tests are planned for Q4/2014
- Solution be released in Q1/2015
- Available for 2 machine configurations:
  - Lasertec 65
  - Lasertec 4300

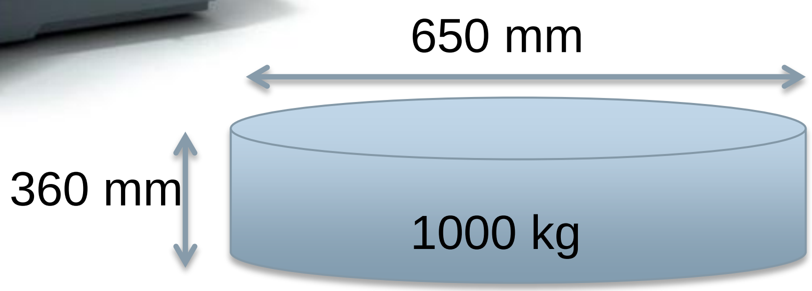
Deposition Rate in Stainless Alloy – 0.9 Kg per hour/KW

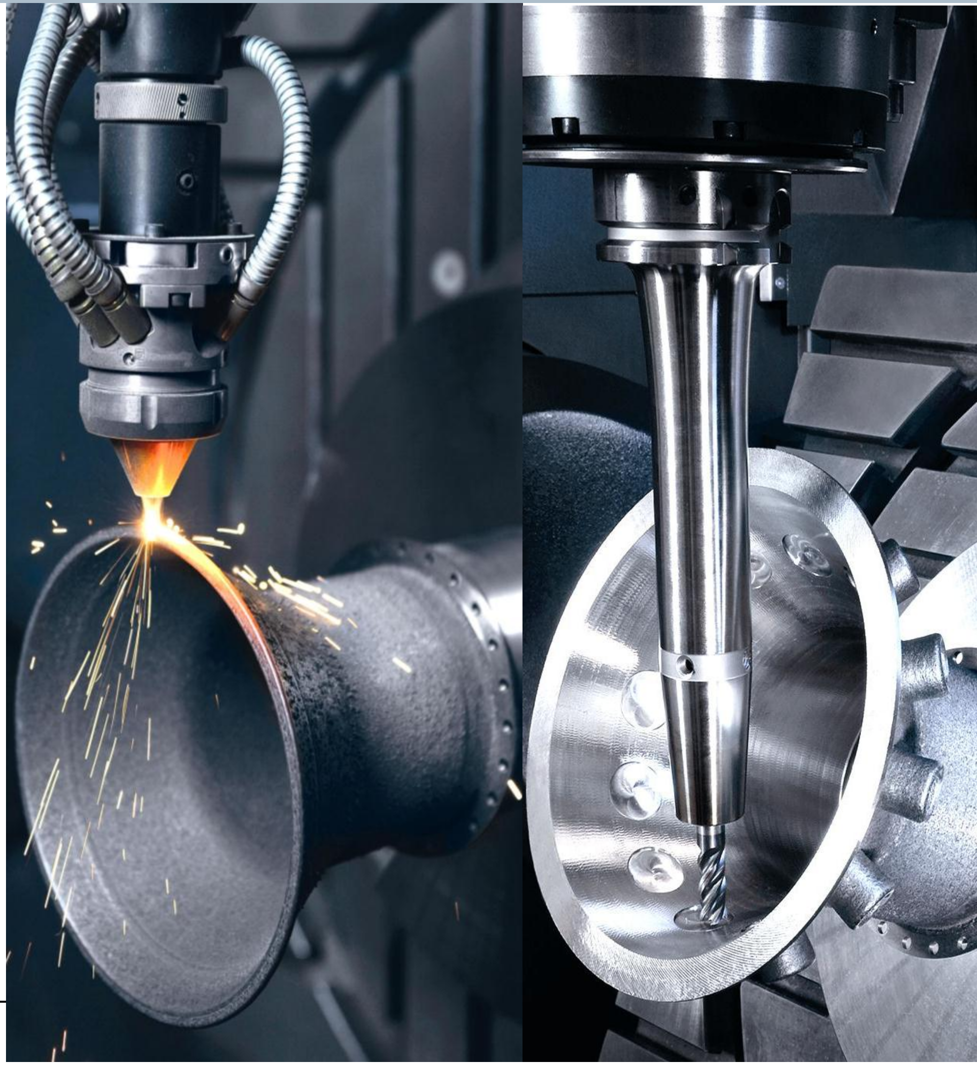
Machine Platforms

Deposition Rate in

Stainless Alloy –

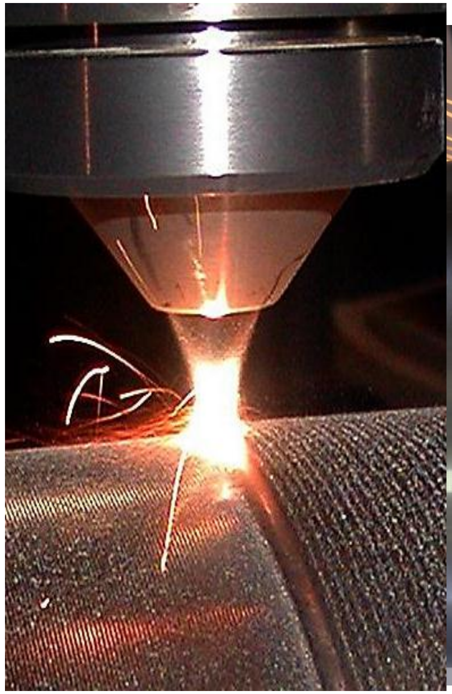
0.9 Kg per hour/KW

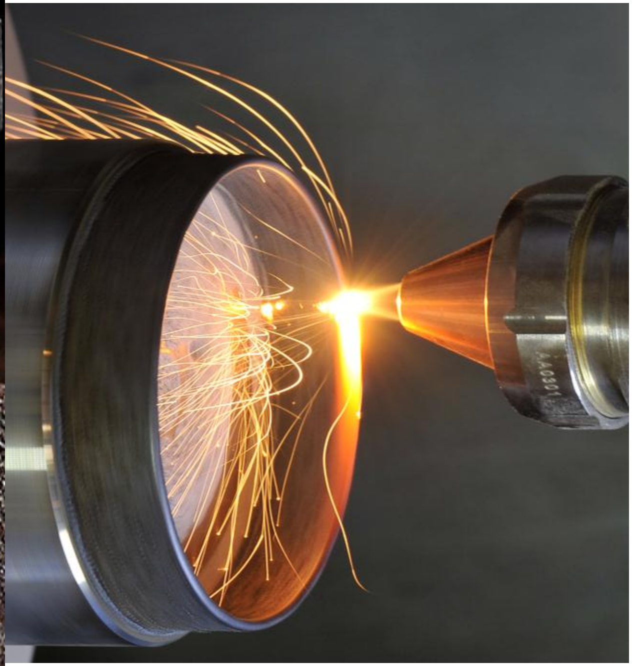




DMG MORI

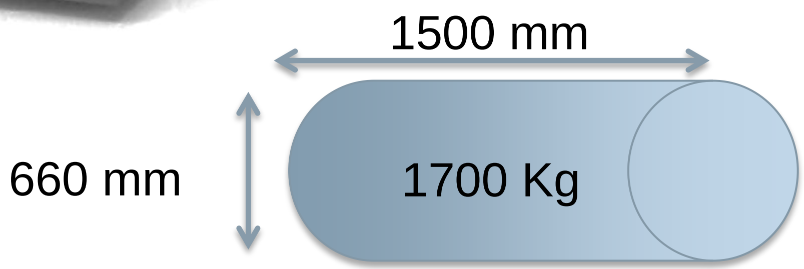
Machine Platforms





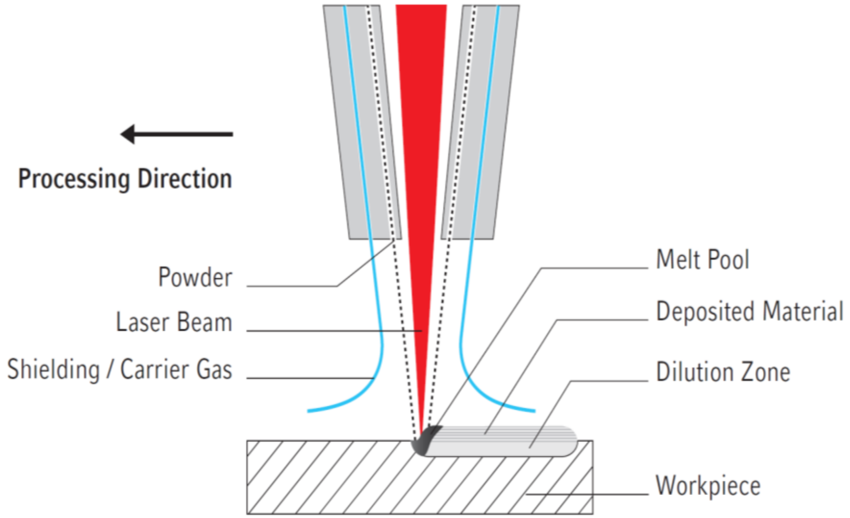
Deposition Rate in

Stainless Alloy – 0.9 Kg per hour/KW



Benefits of a Hybrid system

- Eliminate the deficiencies of a pure AM system:
  - Surface Finish, Accuracy
  - Complete a part
- The powder spray systems vs powder bed:
  - Faster deposition – 10x to 40x faster
  - Excellent material quality (density)
  - Larger work envelop
  - Lower material cost
- Five Axis system
  - Grow the part in multiple directions
  - No need to build complex support structures

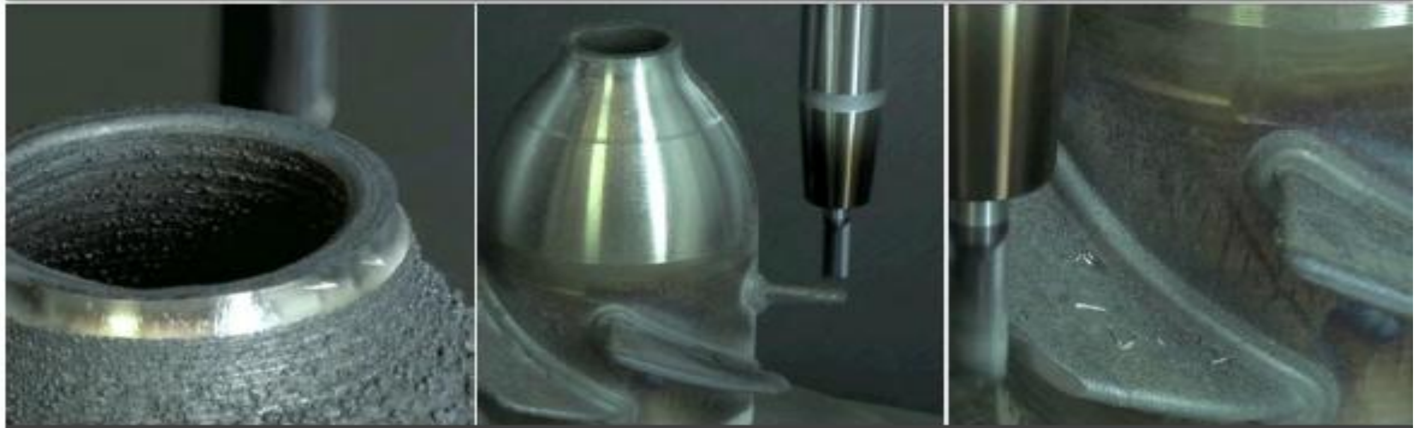


Example: Turbo wheel in stainless steel

LASERTEC 65 *3D*

SIEMENS

Additive Manufacturing Process: 273 min



Subtractive Process (Milling) : 155 min

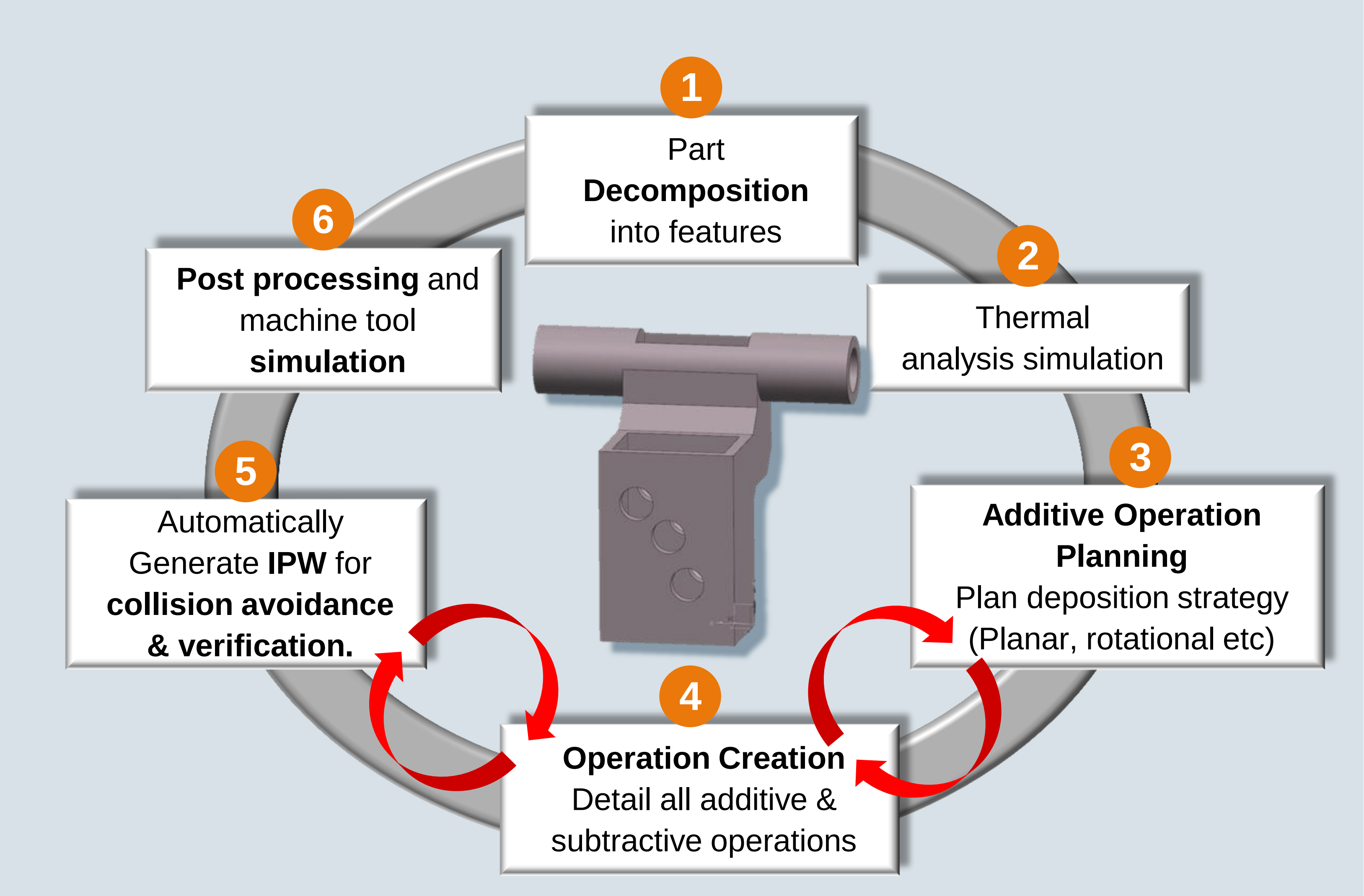
DMG MORI

Siemens PLM Technology supporting the Hybrid Mfg process

SIEMENS

Key Benefits:

- “All in one” system
- Associativity across the entire process
- Full visualization / simulation
- Collision control for both processes
- Multi axis + specialist additive operations
- Laser power control



Enablers and Obstacles

Materials

- Number of materials introduced is growing rapidly – supply chain needs to be developed
- Material plays an important role in the entire process

Process

- Some processes are well established (STL printing)
- Others need research and time to develop reliable results
- AM impact on design and engineering is underestimate
  - Software will be a key enabler
  - Mainstream CAD/CAM/CAE system need to adopt to AM requirements

Economics

- Low-medium quantity, medium to high complexity
- Post processing for finishing or other treatment or Hybrid

Skills

- Need rethinking from start to end for all people involved in the PLM process
- AM skill sets need to be developed

Thank you

Additive Manufacturing

Changing the way products are made

Andreas Saar

Vice President
Manufacturing Engineering Solutions
Siemens PLM – Cypress, CA
andreas.saar@siemens.com

Dave Madeley

Senior Strategist and Key Expert
Manufacturing Engineering Solutions
Siemens PLM – UK
dave.madeley@siemens.com