Shaping the Future of Manufacturing

6th International Carbon Composites Conference

Arcachon June 4th, 2018

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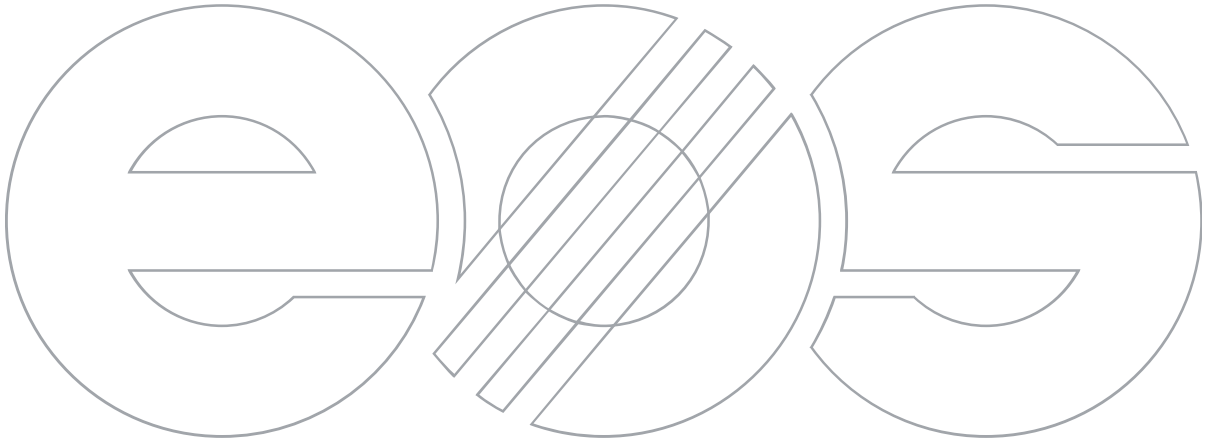
Key Account Manager Aerospace



Agenda

Company & Industry Vision

EOS

Additive Manufacturing today

Customer challenges

EOS Solutions

High Productivity Platforms

Excellent Processing

Connected Manufacturing

Service & Consulting

More than 25 years in Additive Manufacturing

EOS HQ in Krailling, Germany

EOS: technology and market leader for 3D printing solutions

- **EOS** is the **world's leading technology** supplier in the field of **industrial 3D printing** of metals and polymers
- **Family-owned**, founded in 1989
- Headquartered in Krailling near **Munich,** Germany
- **Solution portfolio:** Additive Manufacturing (AM) systems, materials (plastics and metals), software, services and consulting
- Complete **end-to-end solutions:** from part design and data generation to part building and post-processing
- **EOS helps companies leverage competitive advantages in a variety of industries**, such as medical, aerospace, tooling, industry, lifestyle products and automotive
- Revenue FY 16/17: 346 Mio €

Global presence: we are, where you need us

some
1,200 Employees

EOS
Sales & Service
offices in
13 countries

more than
70 distributor
offices
worldwide

3,000
EOS systems
installed
worldwide

49%
Metal systems

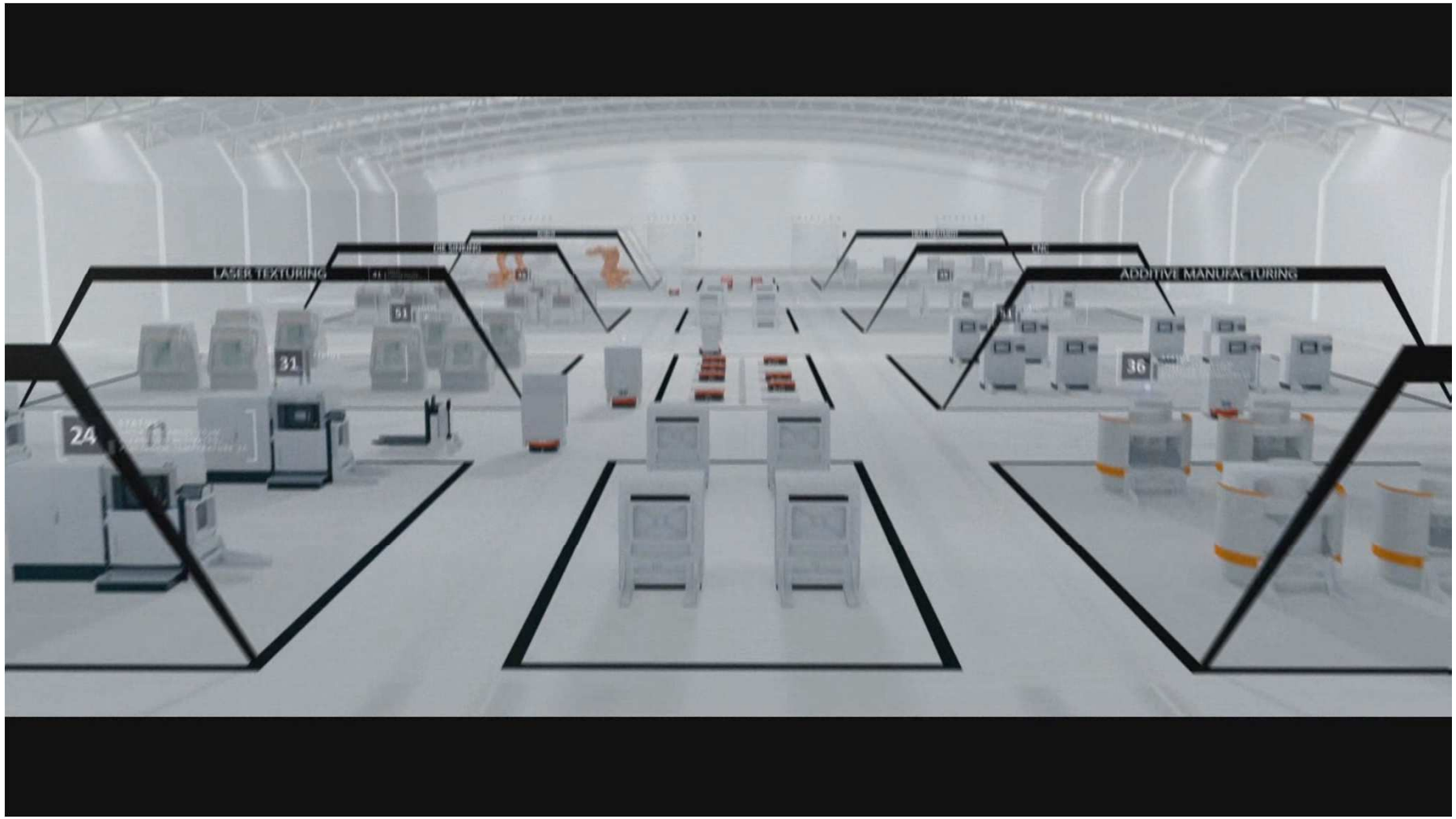
51%
Polymer systems

We are experts
in plastic and metal AM technology …

EOS Vision

Additive Manufacturing is a key technology for advanced industrial production.

Envision a new era of Manufacturing



https://www.youtube.com/watch?v=QC6w4s-kqQQ

Advantages of Additive Manufacturing

Laser sintering offers various advantages over traditional manufacturing processes

Freedom of design

Lightweight

- Static: weight of parts
- Dynamic: moving, accelerated parts

Complex components

- E.g. alternative structures of heat exchangers

Functional integration

Total cost optimization

- Embedded functionality without assembly
- Material efficiency
- No tooling costs

Customization

Individualized parts

- Customer-specific adaptations
- Cost-efficient small series up to 'lot size one'

Time to market

Rapid prototyping

- Fast feasibility feedback of virtual models
- Haptic feedback

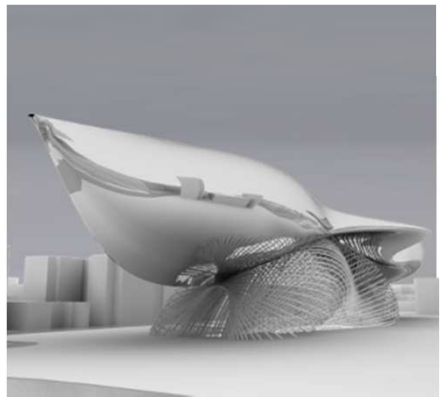
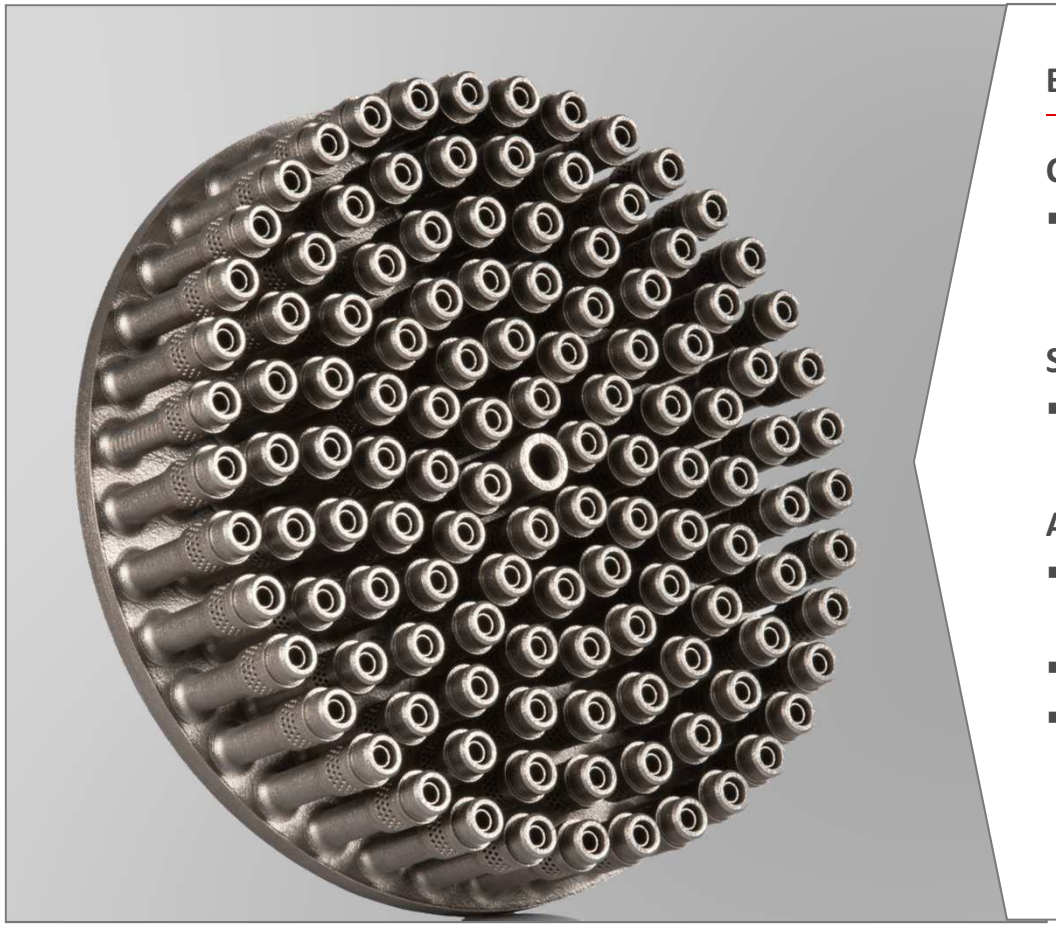


Image sources (left to right): Hettich; EOS; Digital Forming; Eliot Postma, Royal College of Arts, London

One component instead of 248

Example complex components



Baseplate of an injector head

Challenges

- Production of an injector head for rocket engines with as few components as possible and lower unit costs

Solution

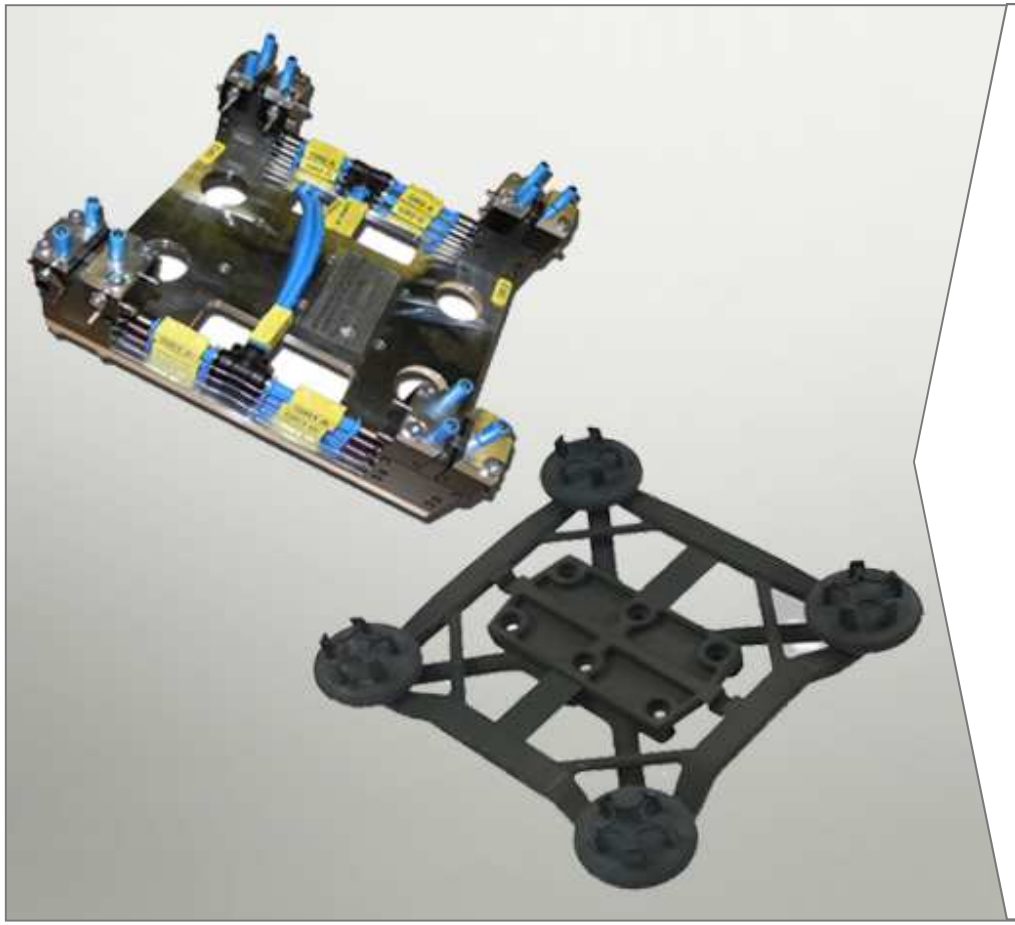
- Additive manufacturing with EOS M 400-4 and functional integration

Advantages

- Simplified: One component instead of 248
- Cost-efficient: 50% lower costs
- Fast: Significant reduction in production time

Functional integration: reduction of lead time, costs and weight

Example functional integration



Lightweight gripper

Advantages

- Base plate generates lightweight stiffness and allows integrated air channels
- Three components vs. 21, leading to less list positions and logistics effort
- LS gripper produced “overnight” – reduction of manufact. time by 17 days
- Cost reduction of -50%
- -86% less weight leading to smaller robot size
- OPEX reduction – Lightweight and smaller build height resulting in shorter cycle times of injection molding machine

Source: Kuhn-Stoff

Customised surgical tools for high precision

Example customisation

Surgical instruments

Application

- Challenge: Manufacturing patient-matched frameless stereotactic fixtures
- Solution: Small-batch production of precision surgical components using FORMIGA P 110

Advantages

- Customised design shortens surgery time
- Parts consolidation resulting in in simpler designs with more features
- Uses less material, faster manufacturing turnaround

Source: Source: FHC, Inc.

Premium AEROTEC, EOS and Daimler prepare the next generation of industrial 3D printing

Image Courtesy of Premium Aerotec

Customers from a broad spectrum of industries rely on EOS technology

OEMs

Service Providers

Sample customers.

The technology is evolving…

Yesterday:
Prototyping

Technological capabilities

Today:
Pre-production

- Part quality
- Process robustness
- Cost per part

By 2020:
Production ramp-up

- Quality control
- Differentiation
- Total cost (TCO)
- Automation
- Technology integration

EOS solutions to enable serial production

High Productivity Platforms

Direct Metal Laser Sintering systems

EOS M 100

Proven DMLS quality for small-scale production

Build volume: Ø 100 mm x 95* mm

Laser: 200 W Yb-fiber, focus diameter 40 µm

EOS M 290

Proven DMLS quality with enhanced quality management

Build volume (wxdxh): 250 x 250 x 325* mm

Laser: 400 W Yb-fiber laser, focus diameter 100 µm

EOS M 400

Proven DMLS Quality for the production of large parts

Build volume (wxdxh): 400 x 400 x 400* mm

Laser: 1000 W Yb-fiber, focus diameter 90 µm

EOS M 400-4

Proven DMLS Quality with up to 4x higher productivity

Build volume (wxdxh): 400 x 400 x 400* mm

Laser: 4x 400W Yb-fiber, focus diameter 100 µm

SMALL FRAME | MEDIUM FRAME | LARGE FRAME

*Height including building plate

Metal high quality materials

Currently over 16 powder alloys with more in development

Family	Metal Alloy
Aluminium	EOS Aluminum AlSi10Mg
Cobalt Chrome	EOS CobaltChrome MP1
	EOS CobaltChrome RPD
	EOS CobaltChrome SP2
Maraging Steel	EOS MaragingSteel MS1
Nickel Alloy	EOS NickelAlloy HX
	EOS NickelAlloy IN625
	EOS NickelAlloy IN718
Stainless Steel	EOS StainlessSteel 17-4PH
	EOS StainlessSteel 316L
	EOS StainlessSteel CX
	EOS StainlessSteel GP1
	EOS StainlessSteel PH1
Titanium	EOS Titanium Ti64
	EOS Titanium Ti64ELI
	EOS Titanium TiCP Grade 2

Polymer Laser Sintering systems

FORMIGA P 110

Compact system for small and medium sized parts with best detail resolution

Usable build size
200x250x330 mm

EOS P 396

Fastest polymer laser sintering system in the world! Effectively isotropic part properties.

Usable build size
340x340x600 mm

EOS P 770

Double-head system for high throughput production and/or large parts.

Usable build size
700x380x580 mm

EOSINT P 800

For high-performance polymer parts.

Usable build size
700x380x560 mm

Production scale

SMALL SERIES | FLEXIBLE | LARGE SERIES | LARGE Specialised SERIES

Polymer high quality materials

15 materials: the largest OEM-portfolio of Laser Sintering materials

Family	Material name
PA 12 unfilled	PA 2200
	PA 2201
	PrimePart® PLUS (PA 2221)
PA 12 colored	PA 2202 black
	PA 2105 (gum colored)
PA 12-GB	PA 3200 GF
PA 12-AL	Alumide®
PA 12-CF	CarbonMide®
PA 12-FR	PA 2210 FR
	PrimePart® FR (PA 2241 FR)
PA 11 unfilled	PA 1101
PA 11 black	PA 1102 black
Elastomer (TPE)	PrimePart® ST
Polystyrene (PS)	PrimeCast® 101
Polyaryletherketone (PAEK)	EOS PEEK HP3

Polymer high quality materials

EOS and ALM – a strong partnership

Standardisation

Repeatable, consistent part quality
part-to-part, job-to-job,
machine-to-machine

Individualisation

Rapid materials solutions development
custom, low- and mid-volume production

Parametersets for complementary laser sintering
Materials from ALM are developed for EOS P 396.

EOS P 800

First Laser Sinter System for the high-performance polymers

EOS P 800

Technical data of the EOS P 800

Workarea (Frame size)

- Width 700 mm (768 mm)
- Length 380 mm (418 mm)
- Height 250 mm (580 mm)

Laser

- 2 CO_2 Laser, Wave length 10.6 µm
- Power 2 x 70 W

Features

- Build platform reduction possibility to minimize powder invest: reduction down to 350mm x 230mm, 350mm x 280mm or 350mm x 340mm possible

Validated and qualified EOS Parameter:

EOS PEEK HP3, 120µm layer thickness

Processing temperature up to 385° C.
Optimzed process chamber
Online Laser Power Control (OLPC)

Source: EOS

Material properties - EOS PEEK HP3

Basic mechanical properties

Basic powder properties

- Powder density: 0,43 ± 0,01 g/cm³
- Density after sintering: 1,315 ± 0,01 g/cm³

Mechanical key figures

- Modulus of elasticity (x,y): 4250 ± 150 MPa
- Tensile strength (x,y): 90 ± 5 MPa
- Breaking elongation (x,y) : 2,8 ± 0,2 %

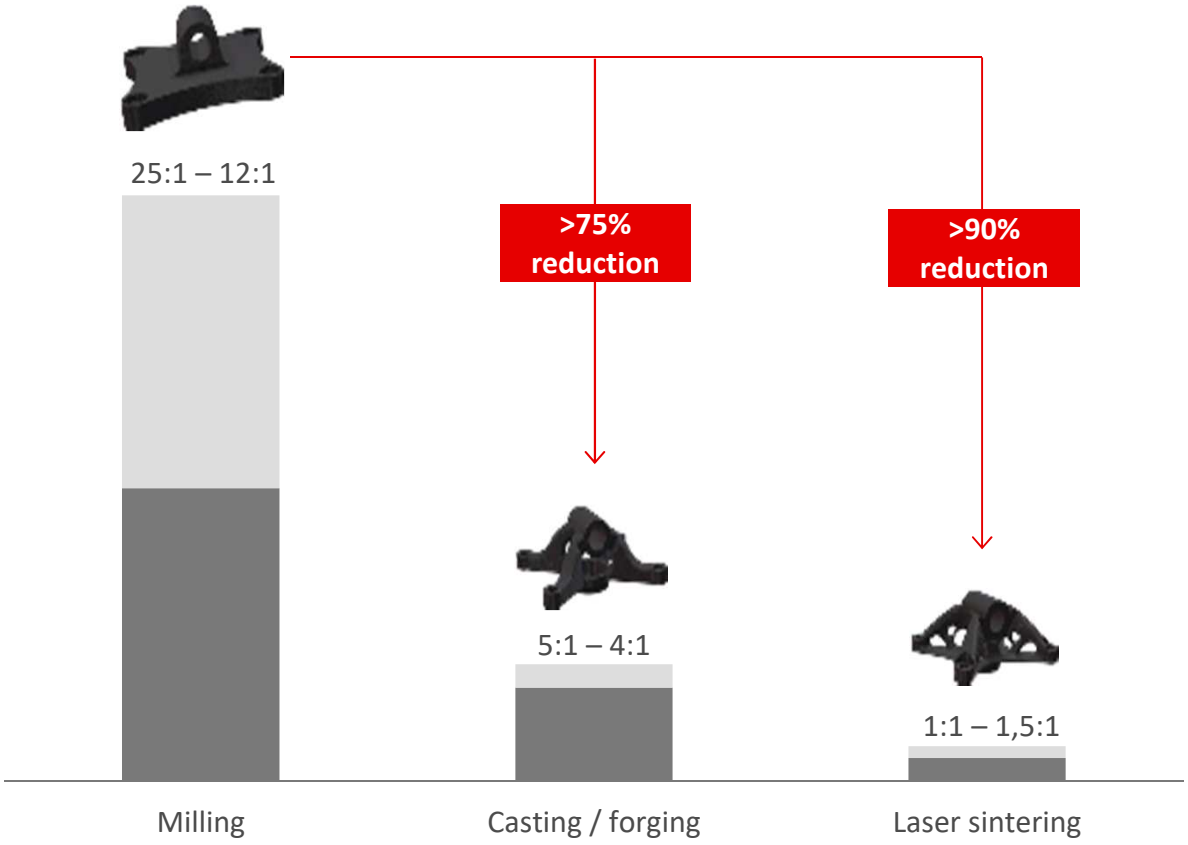
Thermal properties

- Melting point: 372 °C
- Glas transition (Tg): 164 °C
- Thermal deformation stability:
  - HDT A (1,82 MPa)[1)]: 206 °C
  - HDT B (0,45 MPa)[1) 2)]: 352 °C
- Endurance temperature:
  - Electrical: 260 °C
  - Mechanical static: 240 °C
  - Mechanical dynamic: 180 °C

Source: EOS, violin manufactured out of PEEK HP3 on a EOSINT P 800 machine

EOS P810 FOR PEKK-CF
ADDITIVE MANUFACTURING

Buy-to-fly ratio: Do not throw away your raw material!



Buy-to-Fly Ratio

The weight of the purchased raw material divided by the weight of the final part

Source: EOS expert, http://www.manufacturing-today-europe.com/2016/10/13/additive-value/

Parts made from ALM HT-23 offer…

Lightweight & high stiffness

Low cost per part

Inherently non-flamable

High temperature resistance & sterilizable

Superior Chemical resistance

Isotropic part properties

Ultra-low outgassing & great barrier properties

Excellent tear/wear properties (despite CF)

Light but strong applications

Recyclable powder leading to lowest CPP for HT-material

e.g. complies with FAR 25.853

Parts withstand temp. of >250°C

Resistant against hydrocarbons (fuels, lubricants) & many acids

Easy to design/ engineer

Applications possible which “needed metals” in the past

Applications with sliding elements: ball bearings etc.

HDT@0,45 MPa = 275°C
HDT@1,82 MPa = 212 °C

Technical highlights EOS P 810

Heated and vented laser window

Innovation! Minimum residuals & low cleaning effort

Process speed increased significantly

Fastest possible process for high performance polymers

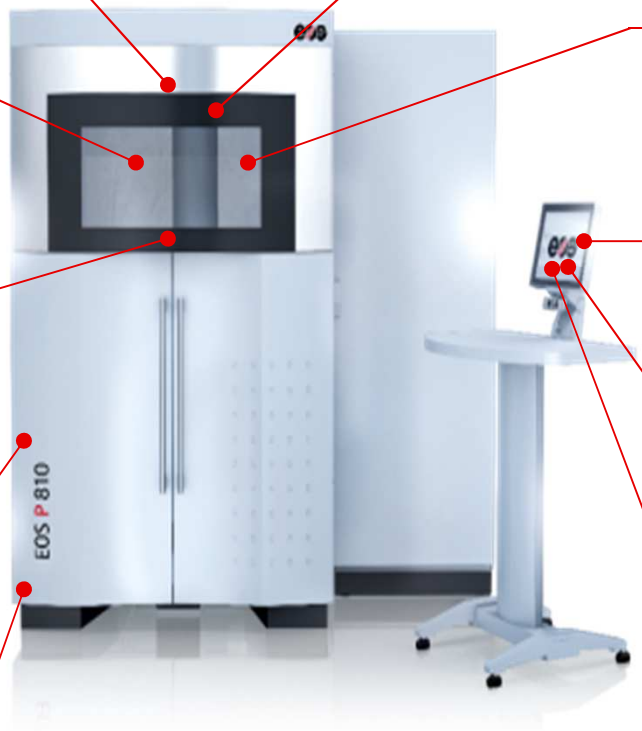
Large usable build size (volume)

700x 380x 380 mm (>100 liters)
→ parts up to 880 mm length buildable

IPCM P plus enabled at lower price

MQS (73k$) , Docking Station (18k$) and Multibox (7k$)

New improved state-of-the art chiller



Improved thermal management

4 additional heating elements for most homogeneous heat distribution

Improved Monitoring

Monitoring of all heating elements & continuous laser power monitoring

Cool Down Curve Editor feature

Develop own/other materials and adjust the cool down process

SmartScaling feature

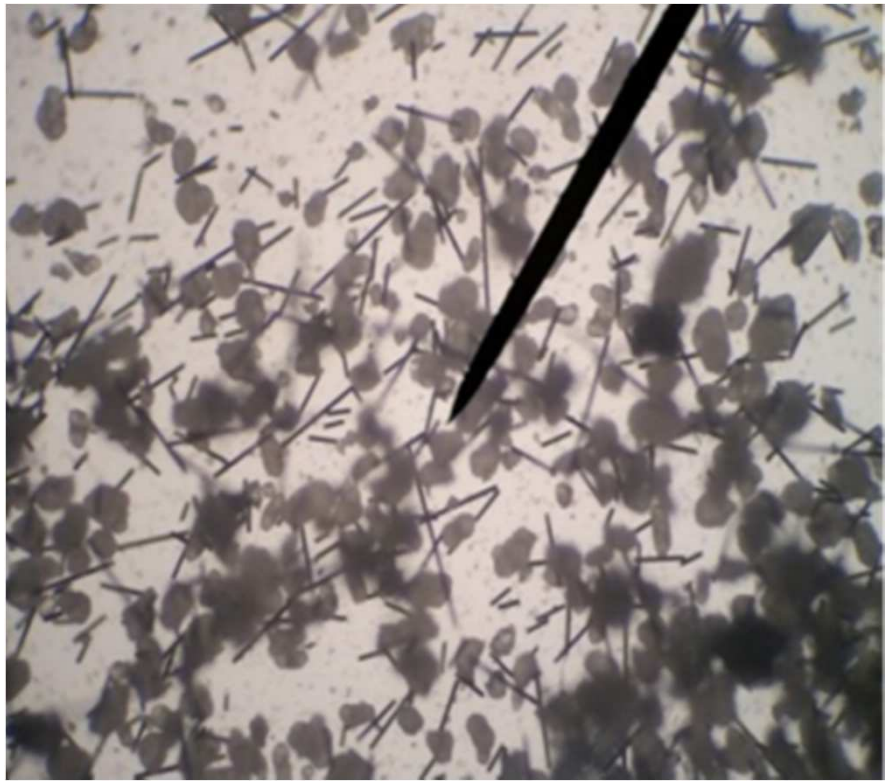
Shrinkage compensation through software→ best dimensional accuracy

EOSAME feature

Homogenization of energy input per volume element

In-depth ALM HT-23
Comparison: dry-blended & encapsulated CF-material

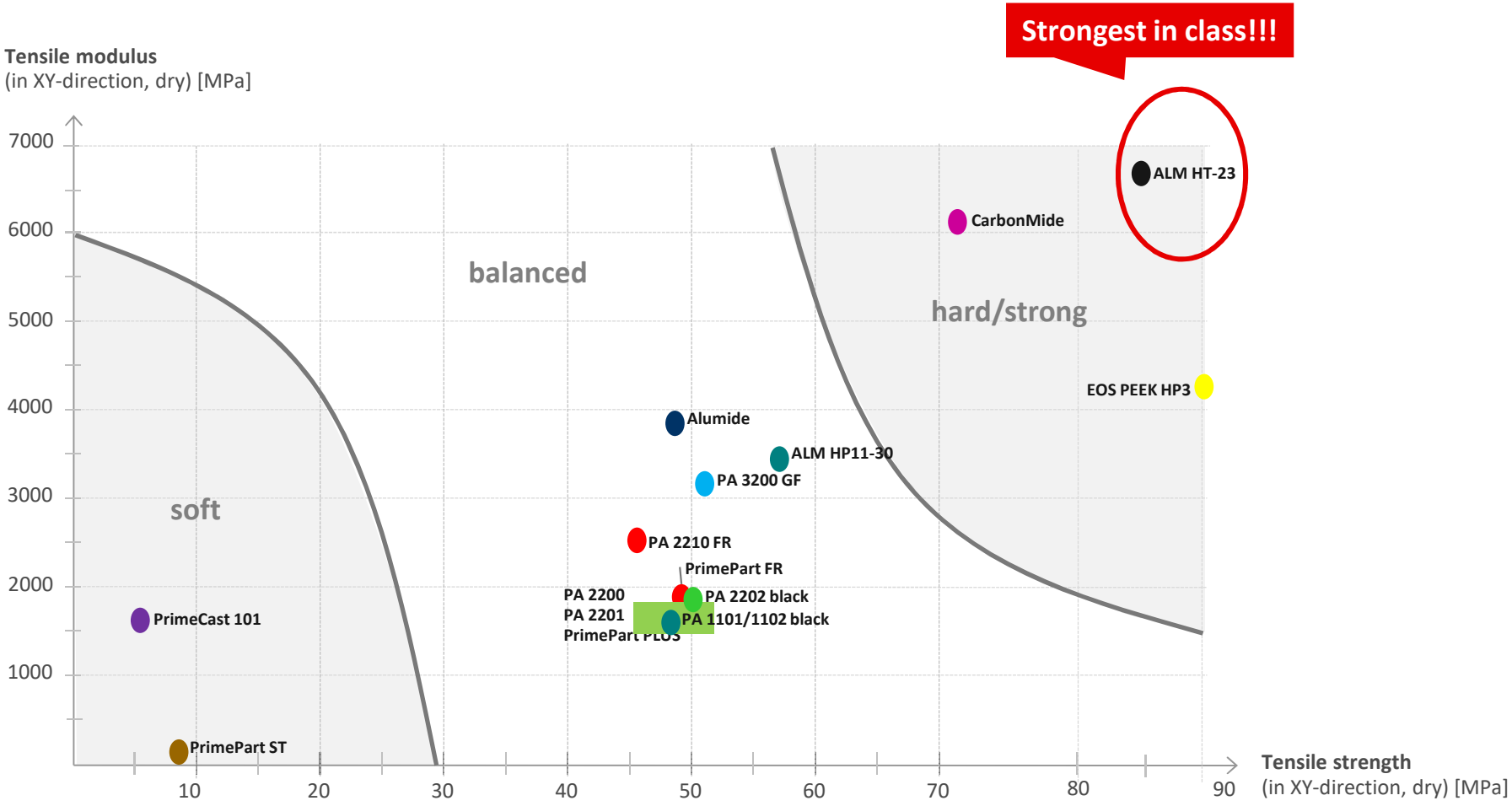
PA12-CF, CarbonMide (dry-blended)



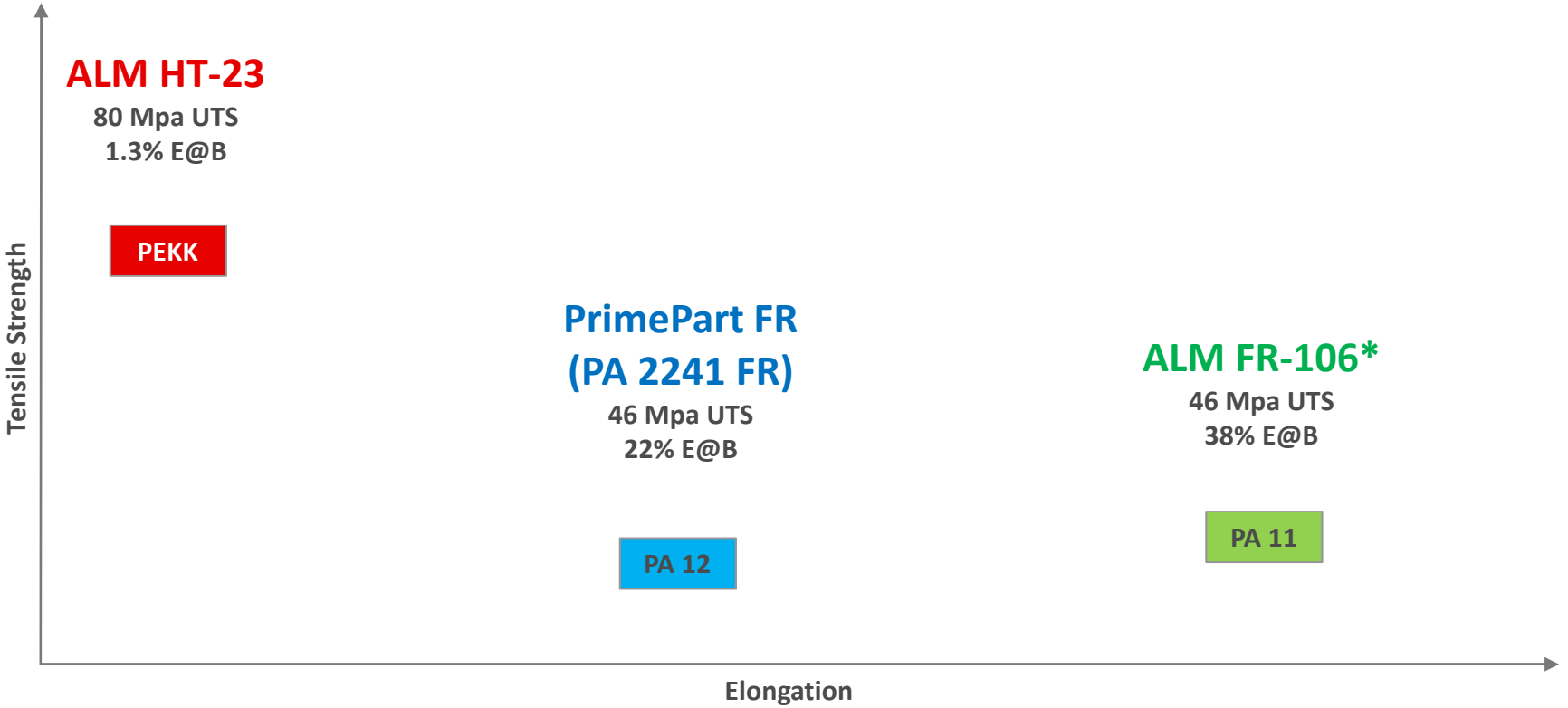
PEKK-CF, ALM HT-23 (compounded & ground)

Source: Developing a New Material for Stronger 3D Prints, Steven Kubiak, Manufacturing Engineer, SDM

Mechanical part properties: strongest in class



The most complete portfolio of FR aerospace materials



The 3 materials from EOS & ALM meeting the most relevant aerospace regulation: FAR 25.853 (60 Second Vertical Burn)

* Additionally meeting Boeing Spec. BMS 8-401 (60 sececond vertical burn, smoke & toxicity testing)

Expected industries of interest & fields of application

SPACE

COMMERCIAL AIRCRAFTS

INDUSTRIAL incl. Oil&Gas

- Manifolds
- Pump housing
- Seals
- Bearings (Ball or Dry)

ELECTRICS / ELECTRONICS

- Connectors & switches
- Test sockets
- housings

AUTOMOTIVE Under-the-hood

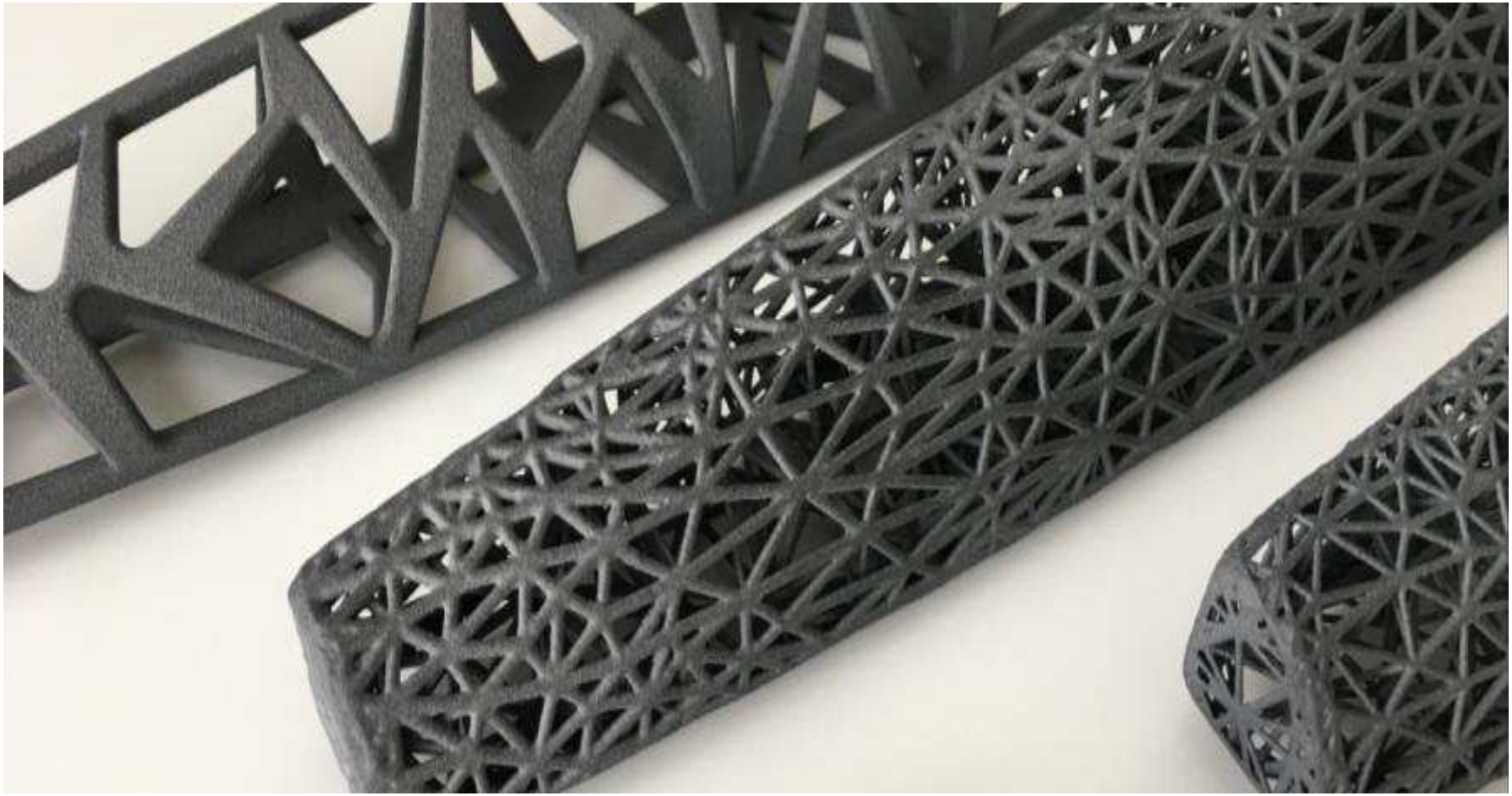
MEDICAL Chirurgical tools/ instruments

Picture source: Google pictures; several sources

Applications Aerospace
Air ducts

Source: EOS

Applications Aerospace
Structural parts / Light weight arm rest



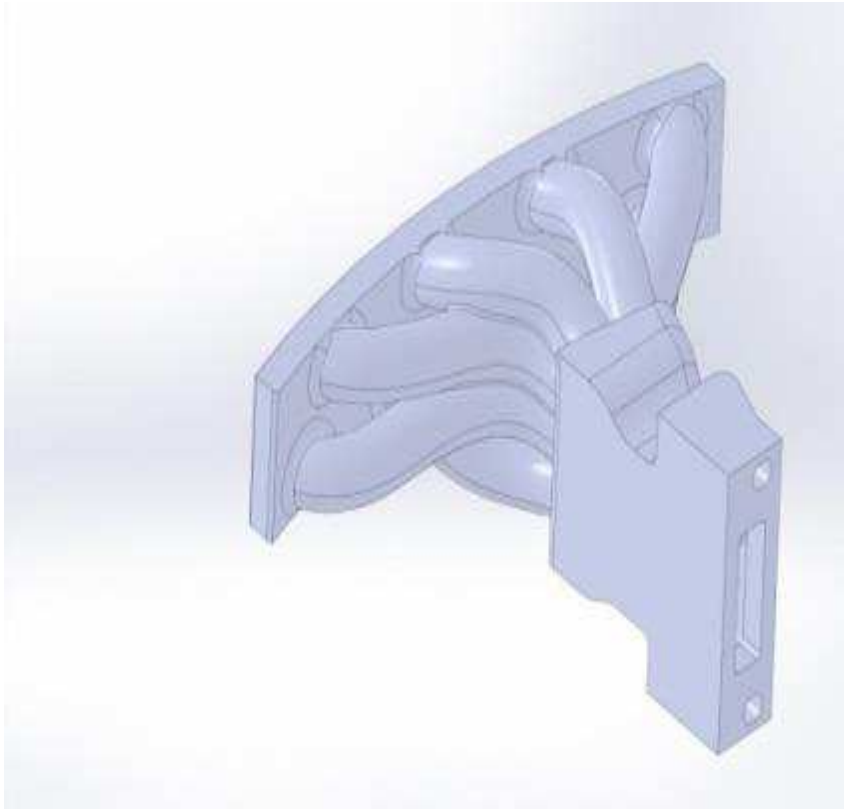
Source: EOS

Applications Industry
Pump housing

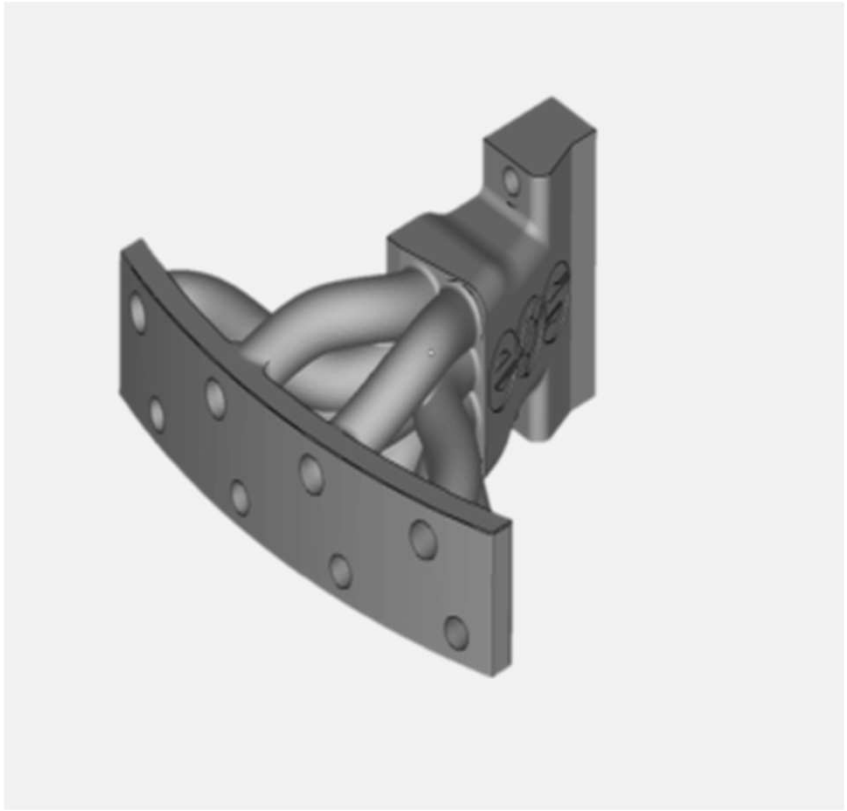
Source: Valeo

Applications Industry
Radial manifold of combustor-HP turbine

Metal machined



Laser Sintered



Part weight reduced from 271g to 87g with the new design → 68% weight reduction

Source: University of Exeter, European consortium FP7 project FACTOR (http://www.factor-fp7.eu)

Applications Electric/Electronic Housing

Source: ATI

HT-23 Material Characteristics

Mat/prop	HT Matrix min. value
Tg	>145°C
Applicable for applications up to 250°C (500°F)	
UTS at 22°C in X,Y,Z	>60MPa (z), >80MPa (x,y)
Tensile Modulus at 22°C	>6GPa
Dimensional accuracy(200mm Z)	+/- 1.4 mm
Min sinter-able wall	2.0mm
UV, Chem resistance	yes, yes (typical for PAEK)
Specific gravity	≤ 1.4 g/cm³
Max water Sorption by volume Δ%	<2%
VB, smoke, toxicity	pass, according to FAA CFR 14 25.853
Radiant, OSU	pass,
Max Build Volume	640mm x 320mm x 280 mm
Refresh Rate (new, used)	60:40

P810

Technical data EOS P 810	
Building volume	700 x 380 x 380 mm (27.6 x 15 x 15 in)
Laser type	CO_2; 2 x 70 W
Building rate	up to 10 mm/h (0.4 in/h); up to 2.7 l/h
Layer thickness (ALM HT-23)	120 µm*
Precision optics	F-theta lenses, high-speed scanners
Scan speed during building process	up to 2 x 6 m/s (23 ft./sec)
Power supply	32 A / 400 V
Power consumption	typical 3.9 kW, maximum 10 kW
Dimensions (W x D x H)	
System	2,500 x 1,300 x 2,190 mm (98.4 x 51.2 x 86.2 in)
Recommended installation space	min. 4.8 m x 4.8 m x 3.0 m (189 x 189 x 118 in)
Weight	approx. 2,300 kg (5,071 lb)

FACT PROJECT

This poster is part of the FACT project managed by IRT Jules Verne (French Institute in Research and Technology in Advanced Manufacturing Technologies for Composite, Metallic and Hybrid Structures). The author wish to associate the industrial and academic partners of this project, respectively AIRBUS, ARKEMA, DAHER, DEDIENNE, EOS, LIEBHERR-AEROSPACE TOULOUSE, SAFRAN, TOBECA, ZODIAC ENGINEERING, CANOE, I2EN – Université de Nantes et CNRS, PIMM - CNRS et ENSAM

EOS P 500

laser sintering of plastic parts on an industrial scale

- The innovative manufacturing platform produces high-quality components at the lowest cost-per-part
- Thanks to clever hardware interfaces and accessories, the uptime of the EOS P 500 increases by up to 75% compared to predecessor systems and competition models
- The system processes polymer materials at operating temperatures of up to 300°C enabling maximum material flexibility
- Automated interfaces and optimized accessories reduce the cycle time drastically and ensure building process of several days duration.

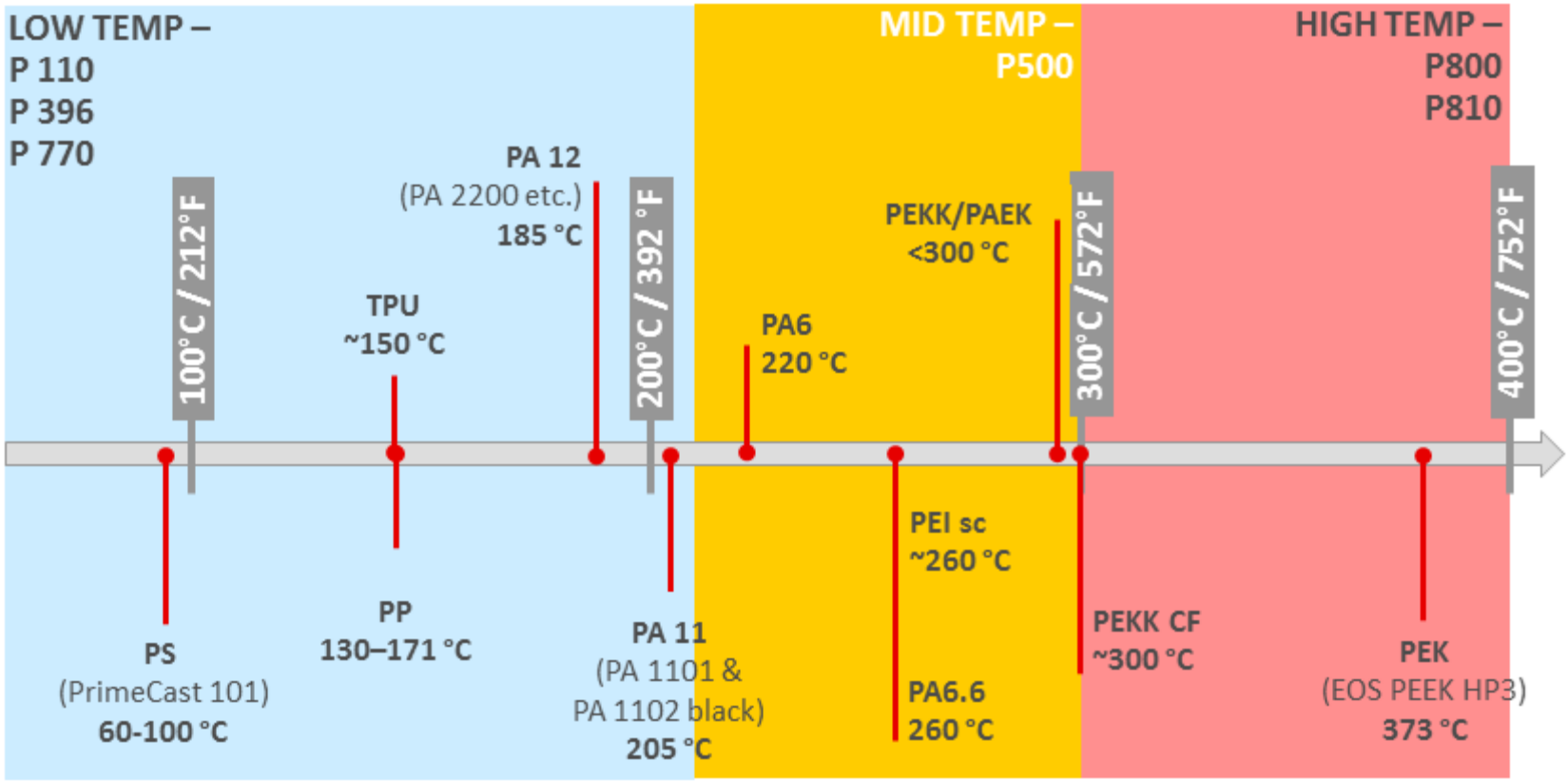
EOS P 500

https://www.youtube.com/watch?v=xeJ_olX7MDE

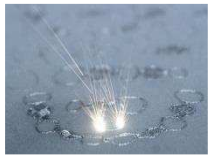
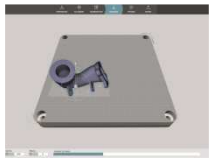
P500

Technical data EOS P 500	
Building volume	500 x 330 x 400 mm (19.7 x 13 x 15.7 in)
Laser type	CO2, 2 x 70 W
Building rate	up to 40 mm/h (1.6 in/h); up to 6.6 l/h
Layer thickness (depending on material)	0.06 mm (0.00236 in), 0.10 mm (0.00394 in), 0.12 mm (0.00472 in), 0.15 mm (0.00591 in), 0.18 mm (0.00709 in)
Precision optics	F-theta lens, surface module, high-speed scanner
Scan speed during building process	up to 2 x 10 m/sec (32.8 ft/sec)
Power supply	400 V/100 A; max. power consumption 80 A
Dimensions (W x D x H)	
System	3,400 x 2,100 x 2,100 mm (133.9 x 82.7 x 82.7 in)
Recommended installation space	min. 7.2 x 5.2 x 3 m (284 x 205 x 118 in)
Weight	approx. 7,000 kg (15,432 lb)
Software	
EOSYSTEM with EOSAME feature, EOSPRINT 2 with SmartScaling feature and EOS ParameterEditor, EOSCONNECT, EOSTATE Powderbed	

Application Temperature Range



EOS excellent processing program

High quality materials		Variety of quality approved materials
Validated EOS processes		Validated processes for excellent part quality from the start
Process development tools		Open process development environment
System & Process monitoring		Integrated monitoring suite

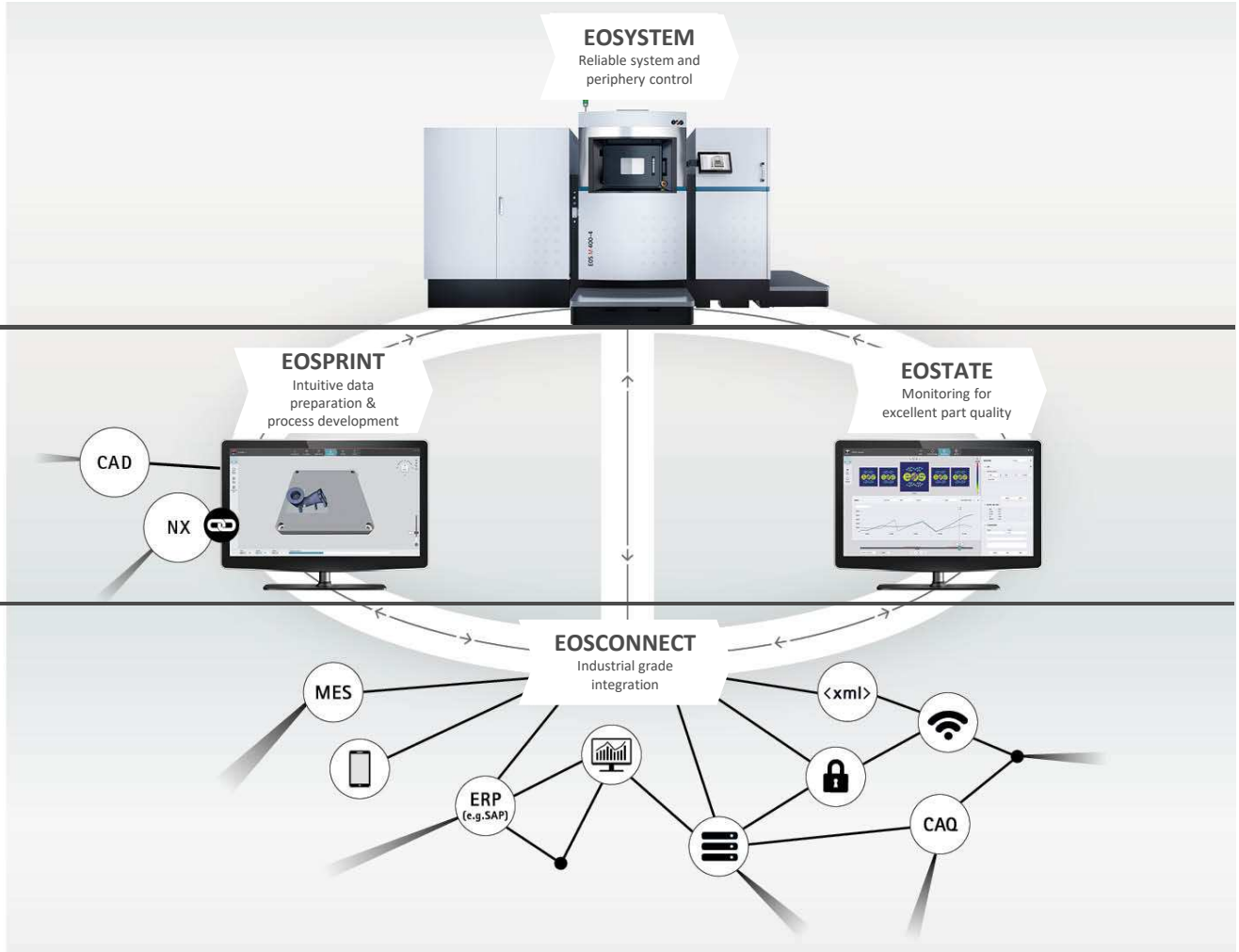
Ensuring reliable part quality.

EOS software

High Productivity Platforms

Excellent Processing

Connected Manufacturing



Service & Consulting

An integrated portfolio of value-adding services

Technical Services

Installation & Qualification

Maintenance & Repair

Collaboration models

Ensuring optimum system performance

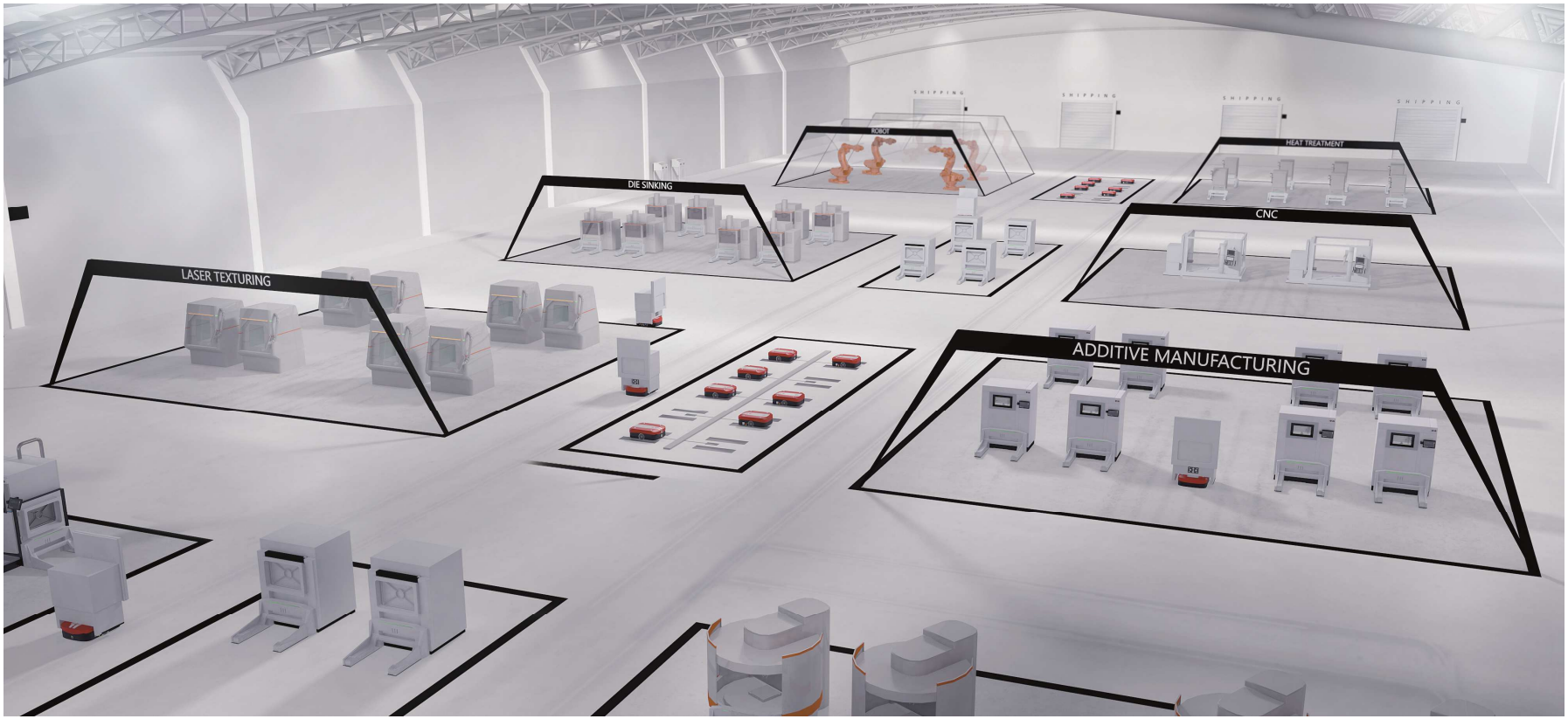
Training Services

Transferring know-how to customers

Additive Minds

Excellence in Industrial 3D printing

» Our fascinating technology offers tremendous possibilities – and our customer enablement offer helps you fully exploit them! «



» Together, we shape the future of manufacturing! «