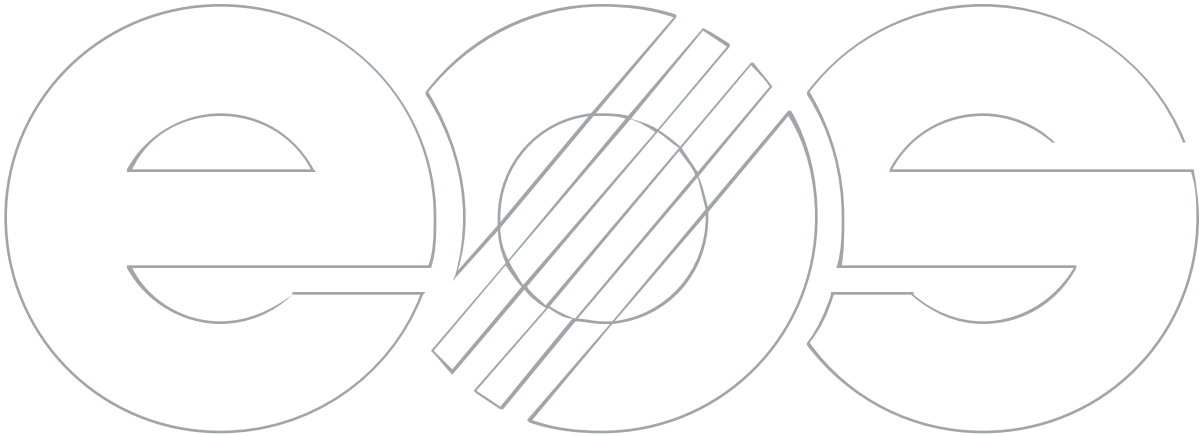
Any shape · Anytime · Anywhere

www.eos.info

# EOS – Leader in e-Manufacturing Solutions

## Corporate Presentation

Settembre 2014



# EOS: Global Presence

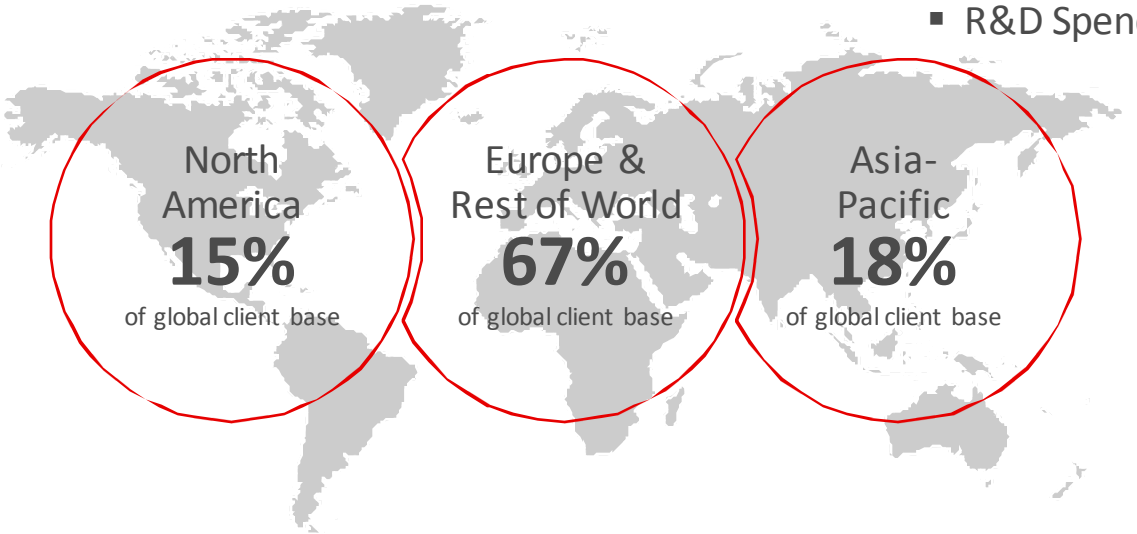
## EOS worldwide installed base

**~ ~1,500 Systems**

- ~40% Metal systems
- ~60% Polymer systems
- ~300 customers with more than 1 system

## EOS global footprint

- Customers in 51 countries
- EOS Sales & Service offices in 11 countries, distribution partners in 22 countries
- More than 600 employees worldwide (74% Germany, 26% International)
- Strong patent portfolio: More than 700 active patents in nearly 100 patent families
- R&D Spendings of approx. 15% of Sales




Source: EOS. Installed base (includes purchased and rented systems) as per 12/2013. Staff figures as per 09/2013.

# Customers from Numerous Industries Rely on EOS Technology

## OEMs


## Service Providers

shapeways

ACTech

PDS
Plastic Design & Service

HOFMANN
MODELLBAU

FKM
Sintertechnik

Sample customers.

# McKinsey considers 3D Printing one of the 12 potentially most disruptive technologies…

## „12 potentially disruptive technologies”

- Automation of Knowledge Work
- Renewable Energy
- Advanced robots
- Energy Storage
- Next-Generation Genomics
- **3D Printing**
- Cloud Technology
- Mobile Internet
- Autonomous Vehicles
- Internet of Things
- Advanced Materials
- Advanced Oil & Gas Exploitation

## Advantages of 3D Printing

**Productivity advantage**
- Rapid prototyping and serial applications

**Cost advantage**
- Integrated functionality without assembly

**Freedom of design**
- Lightweight
- Complex component

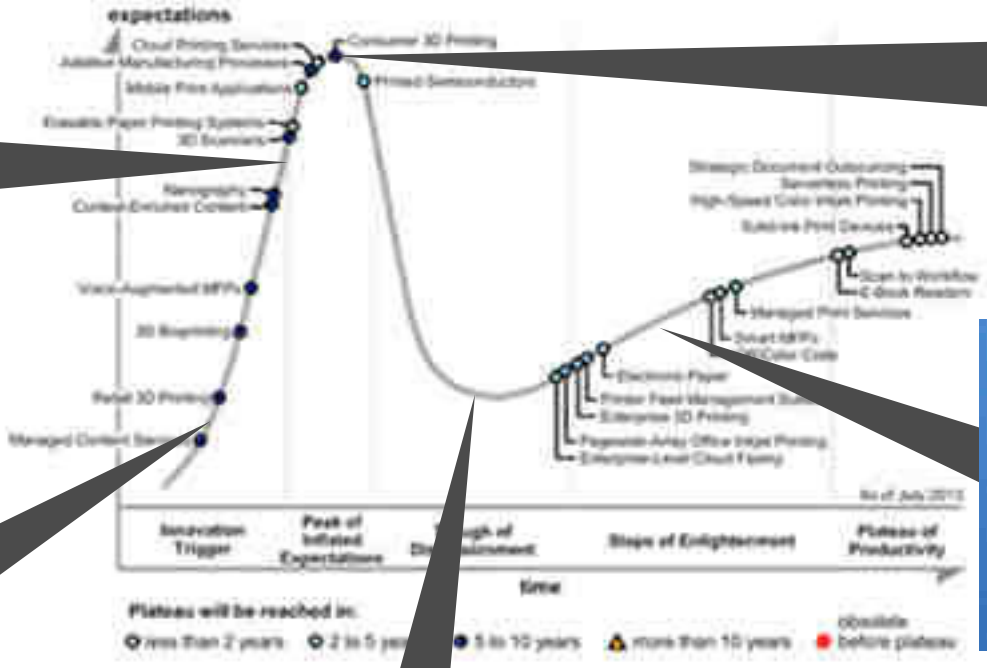
**Customisation**
- Customer specific adaptations
- Cost efficient small series

Source: McKinsey Global Institute Analysis 2013

# „Enterprise 3D Printing“ – we are on the “Slope of Enlightenment”


**“The Manufacturing Technology that will change the World“**

The Economist, 2011





The Economist, 2012




Computerworld, 2013

Source: Gartner (July 2013)

# Tutte le industrie devono affrontare sfide identiche – Additive Manufacturing offre soluzioni uniche

## Sfide del mercato globale

- **Time-to-Market rapido** combinato con cicli di vita prodotto più corti
- **Produttività:** necessità di riduzione dei costi
- **Produzione flessibile** ("factory around the corner")
- **Innovazione** → Miglioramento del valore aggiunto
- **Personalizzazione** dei produtti
- Focus sulla **Sostenibilità**

## Additive Manufacturing vantaggi

**Produttività**
- Prototipia coniugata con produzione di serie

**Vantaggi costi**
- Funzionalità integrata senza assemblaggi

**Freedom of design: libertà progettuale**
- Strutture leggere
- Geometrie complesse

**Customisation**
- Gestione efficiente dei costi per parti uniche oppure piccole serie

# Additive Manufacturing (AM) risponde alle sfide del mercato

## Freedom of Design

- Strutture biomimetiche e leggere
- Ottimizzazione della funzionalità
- Nuovi materiali/nuove proprietà (es. Strutture porose\spugnose)

Scambiatore di calore a struttura biomimetica

## Riduzione costi

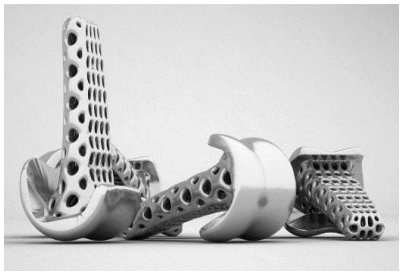
- Produzione "integrata" e diretta di piccole serie oppure parti singole
- Componenti con funzionalità a progetto senza assemblaggi

## Miglioramenti nella produttività

- Rapid prototyping e produzione di serie
- Verifica immediata della progettazione

## Customizzazione

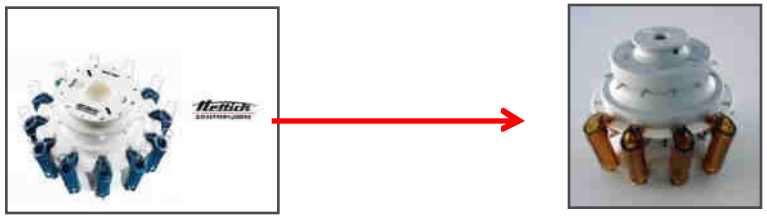
- Articoli "unici" e personalizzati con modalità costruttiva flessibile



# Additive Manufacturing (AM) offre due diverse vie per vincere nel mercato

## Scenario 1: Risolvere vincoli dei sistemi di produzione convenzionali

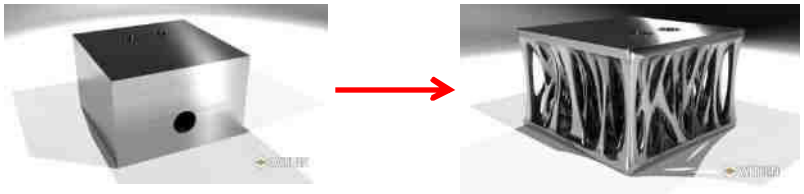
- Riduzione della complessità della parte da produrre
- Riduzione dei costi associati agli attrezzaggi di produzione e\o tecniche di lavorazione ed assemblaggio



Rotore: da 32 componenti a due parti sinterizzate laser + 1 anello di congiunzione, nessun stampo, integrazione funzionale, produzione on-demand su esigenze specifiche dei clienti

## Scenario 2: Consentire approcci di progettazione nuovi

- Geometrie e\o soluzioni di progetto impossibili per tecnologie convenzionali
  - metallo progettato come plastica (spessori sottili, nervature)
  - Alleggerire i componenti



Cavità interne integrate; scambiatore di calore a geometria biomimetica. Pensare prima alla fluido dinamica e quindi alla meccanica associata

**Additive Manufacturing offre diversi approcci vincenti!**

Image sources: Hettich, Within, 3T RPD

# Additive Manufacturing Meets Industrial production – a Paradigm Shift

## Yesterday's requirement

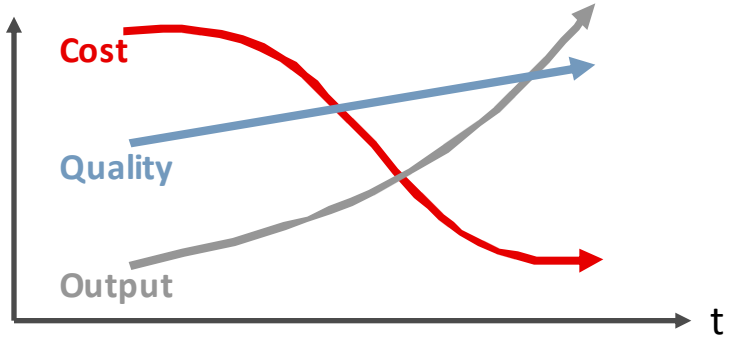
- High flexibility (''one of a kind'')
- Fast turnover time
- Focus on aesthetics/surface structure
- Similar (but not identical) parts

**No focus on:**

- Reproducibility
- Up-scaling
- Manufacturing chains

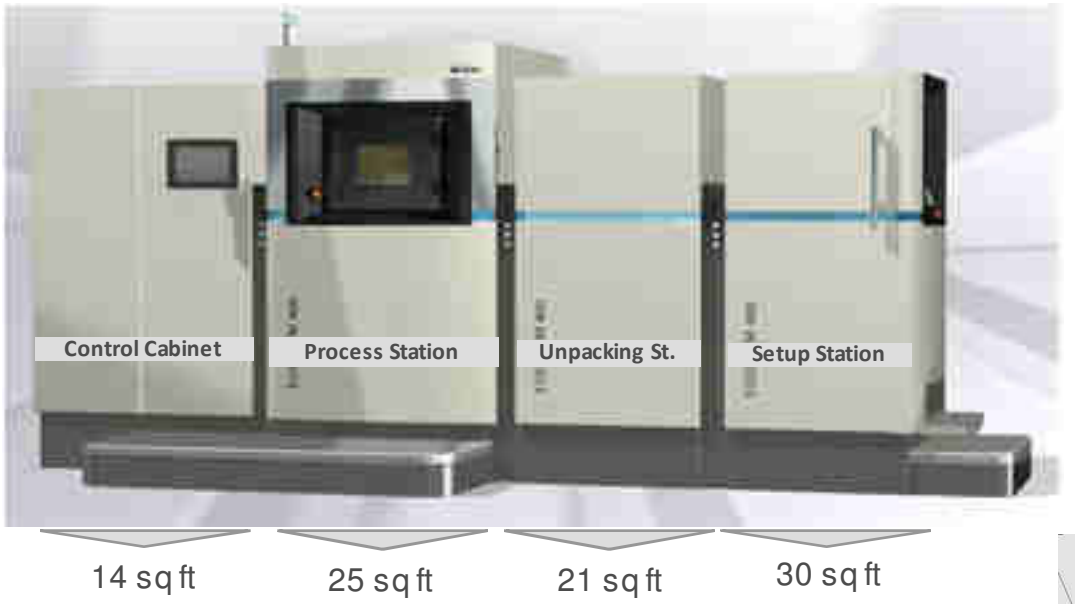
## Future requirements

- Specified part quality
- Economic up-scaling
  - High(er) output
  - Reduced cost-per-part
- End-to-end solution
- High degree of automation
- 100% quality



# The EOS M400 system is designed for integration into a series production environment

## The EOS M400



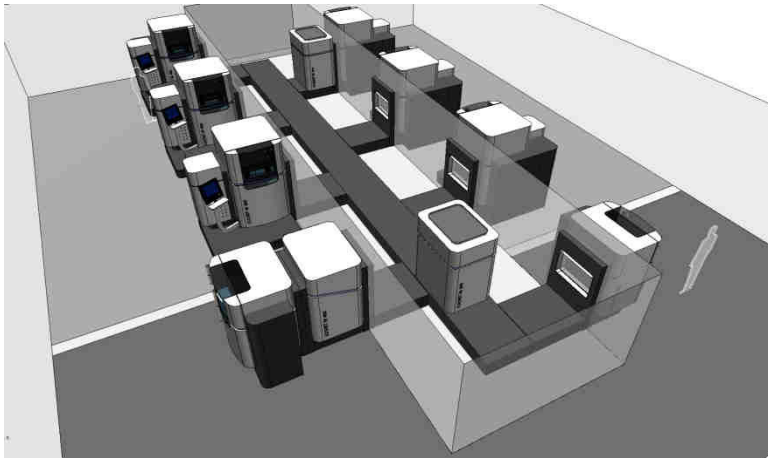

## Further enhanced by

- Automatic Recirculating Powder Handling
- Centralised Cooling Station
- Self-cleaning Filter Units

**Proposed configuration:**

Combining six process stations with one unpacking and set-up station (depending on job time)

- Saving ~ 50% of valuable floor space
- Saving ~ 20% invest



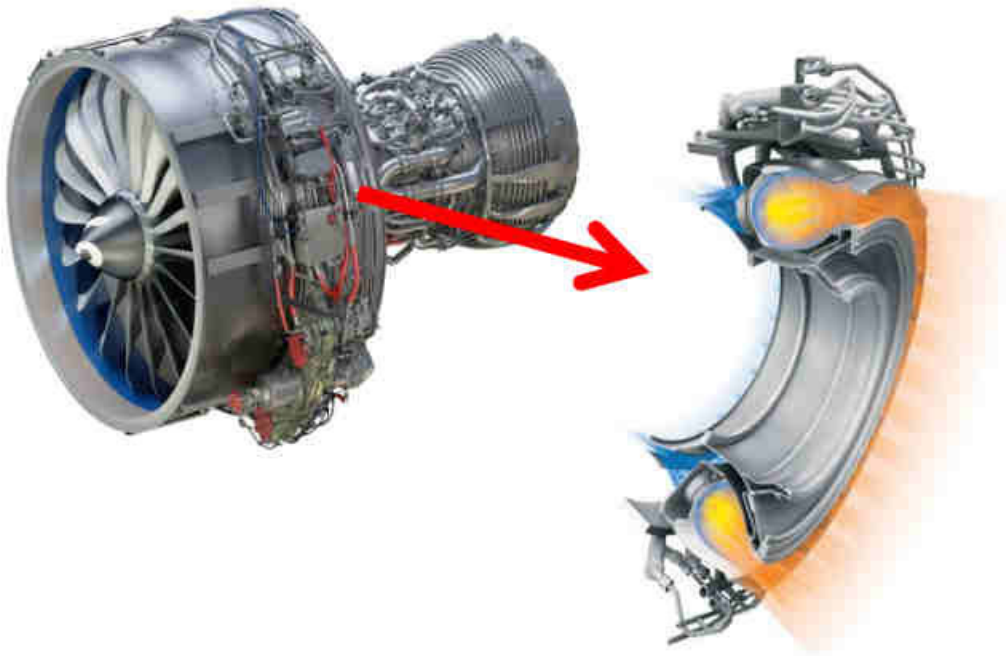
# Supply Chain Shift – Direct to Part

From → To

imagination at work

Source: GE – Greg Morris - Additive Metal Applications within the Aerospace Industry

# LEAP 56 Next Generation Fuel Nozzles



- 40K+ Annual Production
- 5x more durable
- 25% less weight
- 20 pieces to 1

imagination at work

# We see big OEMs to start setting up production

## Example General Electric Aviation

David Joyce
president and CEO

- 19 fuel nozzles to be installed on every CFM LEAP engine (more than 4500 sold)
- 100.000 additive parts will be manufactured by GE Aviation by 2020
- 1.000 lbs potential reduction in weight of a single aircraft engine through additive production
- 300 plus 3D printing machines currently in use across GE

Source: Morris Technologies, General Electric

# Business Positioned in Line with Market Demand: EOS Offers Solutions for Many Industries

**Market priorities**

- Sustainability
- Productivity
- Customisation

Rapid Prototyping | Aerospace | Medical | Industry | Tooling | Lifestyle | Automotive

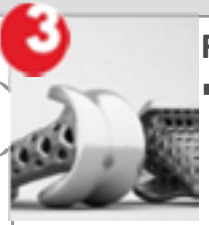
**EOS Distribution Channels:** Regional, Industry-Specific, Distributors, Sales Partners

**EOS Portfolio**

| Products | Solutions | Services |
|---|---|---|

1 **Design***
- Application specific (e.g. lightweight)

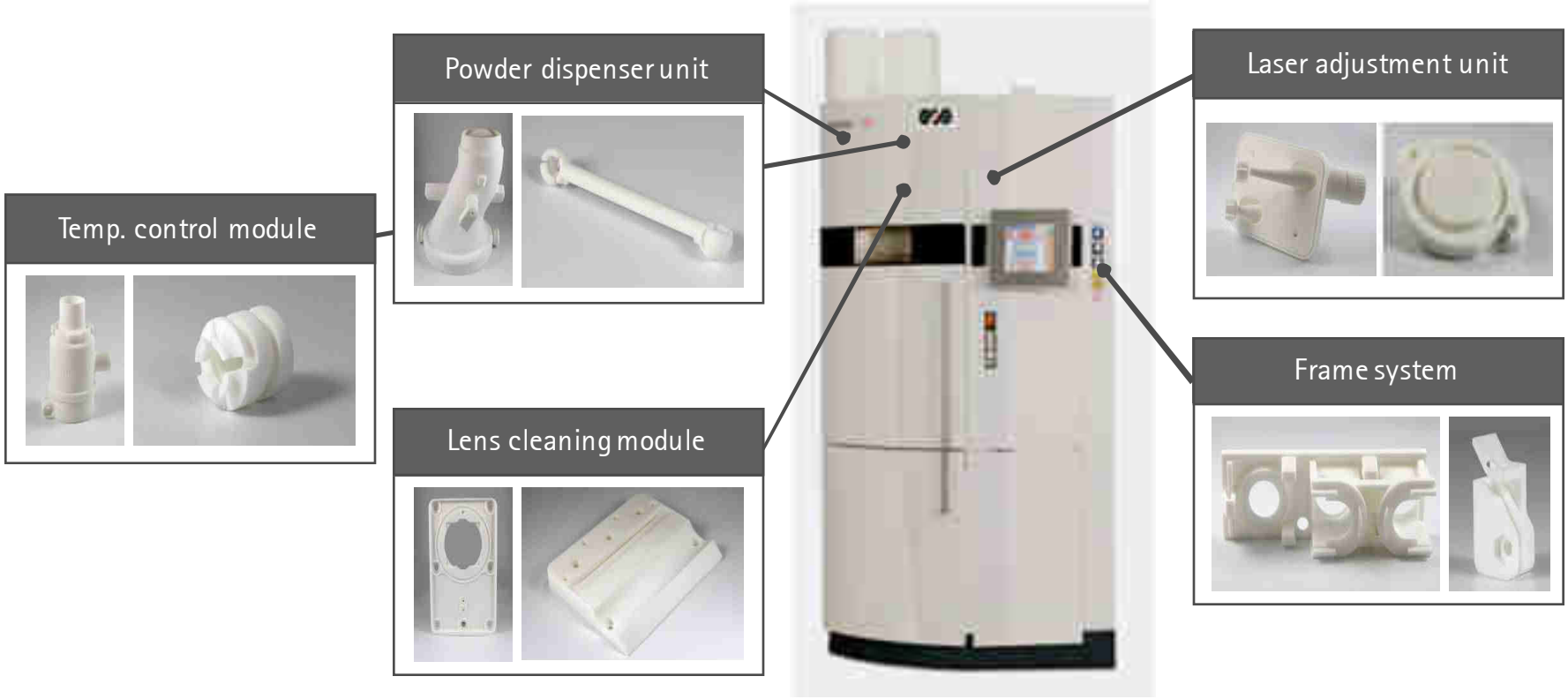
2 **Build**
- Systems
- Material
- Software
- Process
- Service



3 **Finish***
- Surface engineering

*With EOS technology partners

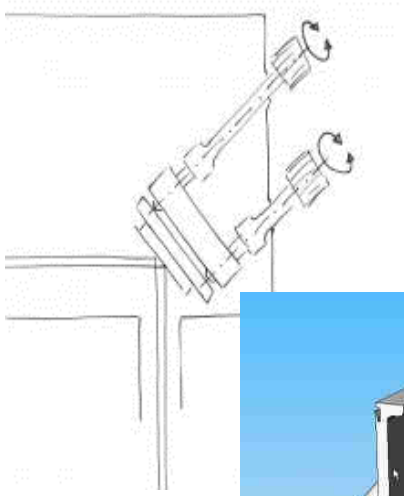
# Oltre 30 parti in plastica sinterizzata utilizzate nel sistema FORMIGA P 100

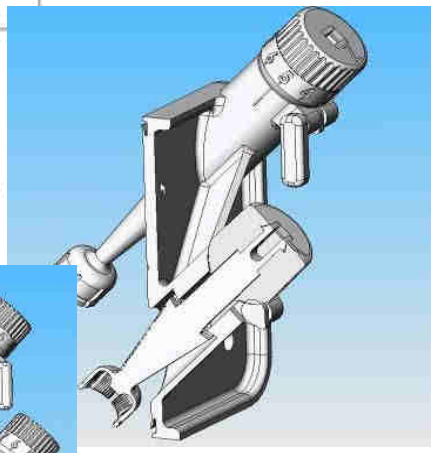


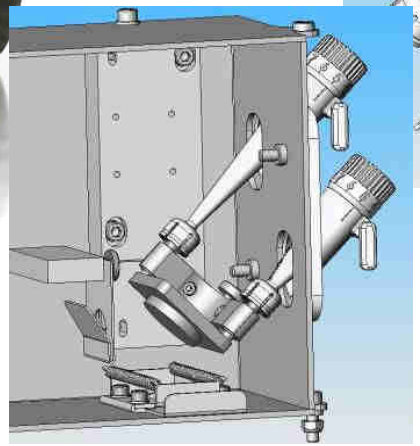
# Componenti ad alta integrazione funzionale

## Supporto specchio

- Dispositivo di aggiustamento fascio laser in direzione Y e Z
- Materiale: PA 2200
- Funzionalità integrate
  - Sedi eccentriche per movimenti di centraggio
  - Bordo di chiusura elastico con effetto guarnizione







# Freedom of design: alleggerire la meccanica

## Parti Dinamiche

- Parti accelerate\decelerate
- Masse in rotazione
- Esempio:1g dinamico nelle valvole equivale a 2Kg di peso statico

## Parti Statiche

Esempio: una riduzione di 100Kg di peso statico significa un minor consumo di circa 0,5l per 100Km

# Sedile per auto. Studio concettuale per integrare funzionalità ergonomiche a peso ridotto.

Grande risparmio in peso

Alto comfort grazie ad elementi adattivi a funzione passiva

Adattaori pneumatici

Sistemi di ventilazione integrati

Attuatore pneumatico

Ventilazione

Integrated functionality: (examples)

Source: M. Kandler, Frauenhofer IPA

# The Freedom of Design Allows to Integrate Two Seperate Functional Parts in One Design

## Oil Separator and Cooler

**Application**

- Integration of two usually separated parts: oil separator and cooler
- Upper part: deposits oil from air by centrifugal force (rough surface enhances effect)
- Lower part: oil tank with maximized surface for cooling-down effect
- Reduction of space and weight
- Additive Manufacturing only way to build this part

**Product details**

- Dimensions: ca. 450x260x180 mm


1) Compared to last seasons wheel suspensions manufactured with investment casting
Source: Rennteam Uni Stuttgart, Within, EOS

# Integrated Cooling Channels Help to Reduce Weight and Increase Performance

## Lattice Structure Brake Disk

**Application**

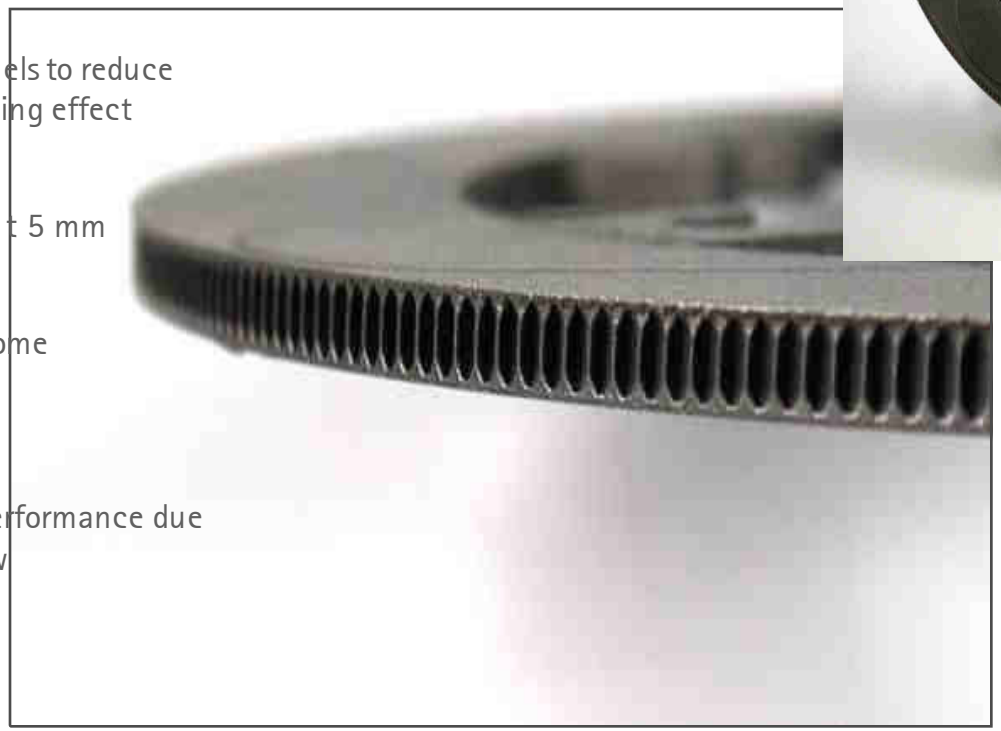
- Conceptual brake disk for formula student race car
- Integrated cooling channels to reduce weight and optimize cooling effect

**Product details**

- Dimensions: d 230 mm; t 5 mm
- Weight: 390 g
- Material: Cobalt Chrome

**Advantages**

- Reduced weight by 25%
- Significant increase of performance due to controlled cooling flow



Source: ka.race.ing Karlsruhe , EOS

# Topology Optimized Wheel Suspension with Increased Stiffness of 20% and Reduced Weight of 35%

## Wheel Suspension

### Application

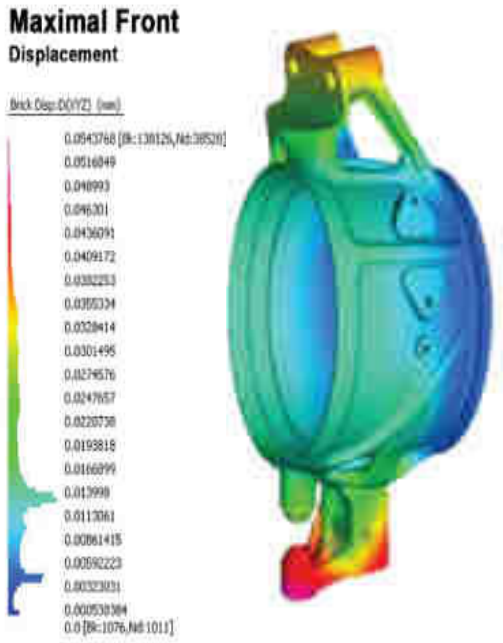
- Extreme light and stiff wheel suspension
- Topology optimized & customized design
- In cooperation with Within software

### Product details

- Weight: Front 435 g/Rear 390 g
- Max. forces: ca. 100 MPa
- Material: Aluminum

### Advantages

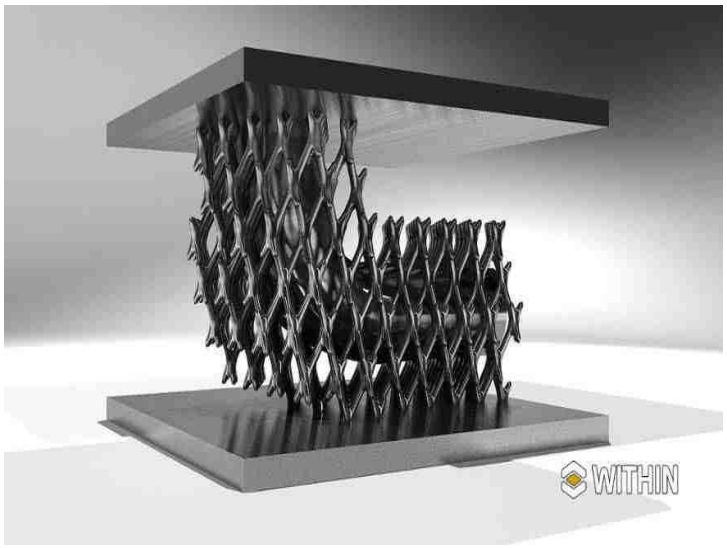
- Weight savings 22% (front), 35% (rear) [1)]
- Increased stiffness of 20%
- Fast production and high accuracy

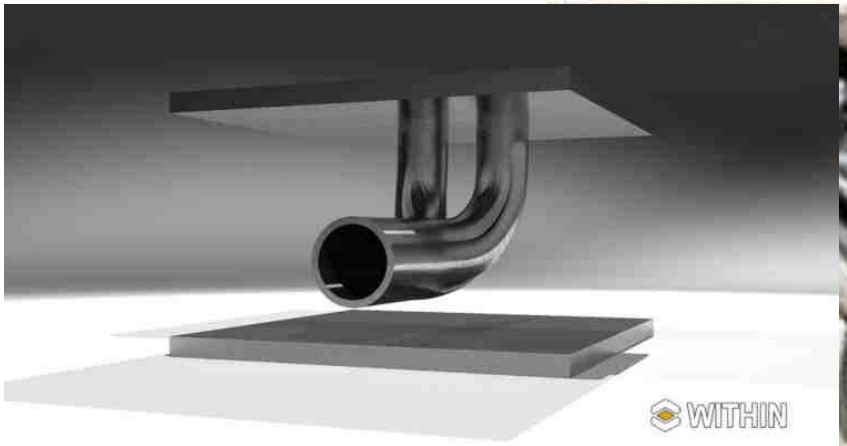



1) Compared to last seasons wheel suspensions manufactured with investment casting

# Strutture alleggerite e progettate per soddisfare esigenze specifiche (ottimizzazione della fluidodinamica e dello scambio termico combinati con riduzione del peso )

- Strutture geometriche disegno biomimetico
- Progetto con cavità e pareti sottili
- Manicotto con angoli sformati e sezione variabile per ottimizzazione fluido-dinamica. Geometria che integra uno scambiatore di calore
- Costruzione (PH1) in 25 ore



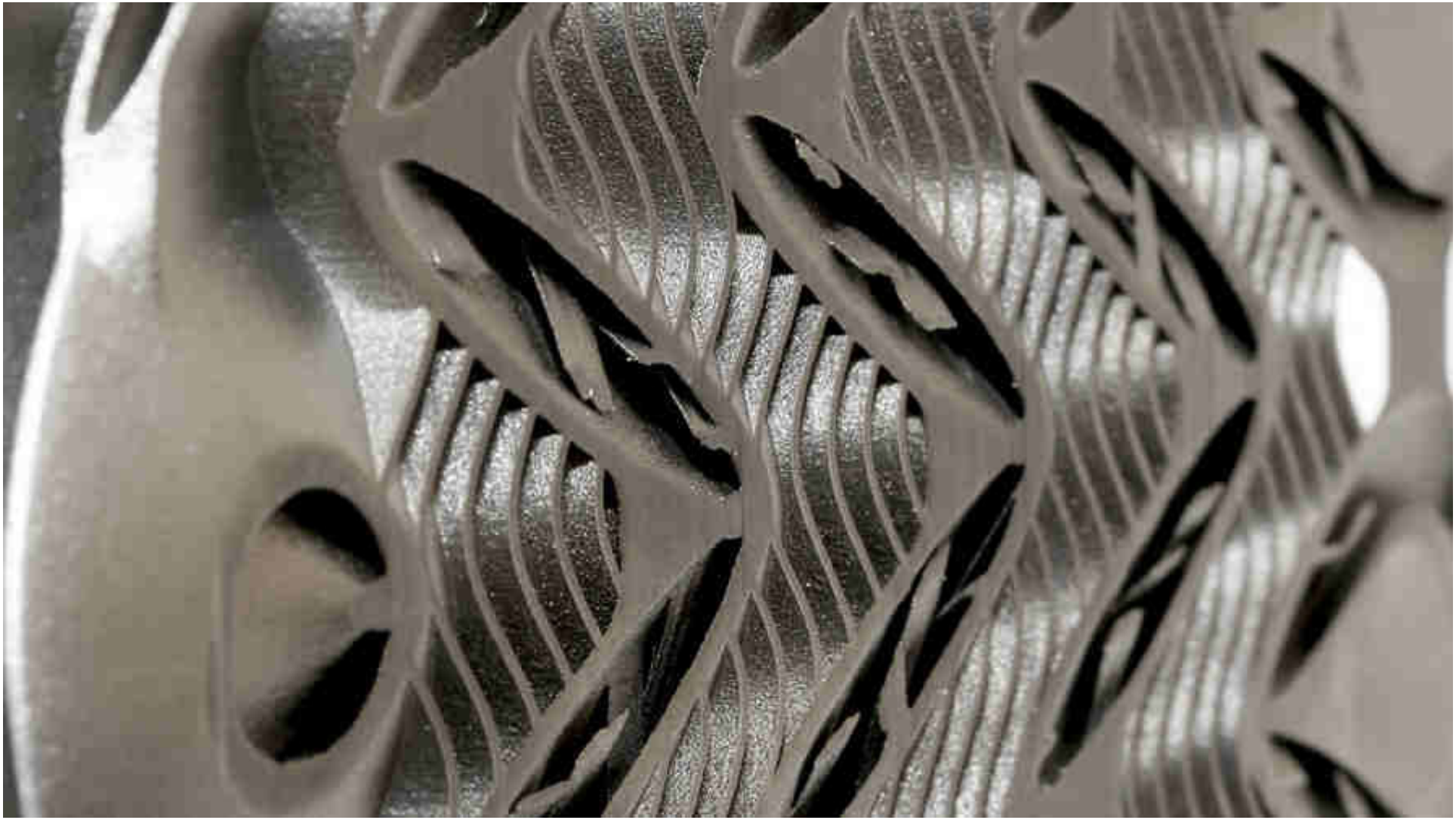

# “freedom of design” consente funzionalità totalmente nuove

## Freedom of Design

- Scambiatori di calore di nuova concezione
- Forme diverse possono essere costruite tramite l’assemblaggio di sotto elementi
- Recupero condensa integrato nella struttura delle superfici di scambio

**Advantages**

- Componenti compatti e geometria scalabile
- Significativo miglioramento nel trasferimento di calore
- Riduzione peso di oltre 80%



Source: Within, 3T, EOS

# EOS GP1 (inox 17-4) e componentistica meccanica di precisione

Tempi di produzione del singolo componente per lavorazione completa di poche ore.

Benefici:

✓ Pareti sottili (anche inferiori a spessori di 1 mm) in acciaio inox alimentare

✓ Forature a distribuzione qualsiasi create durante la lavorazione medesima lungo superfici 3D

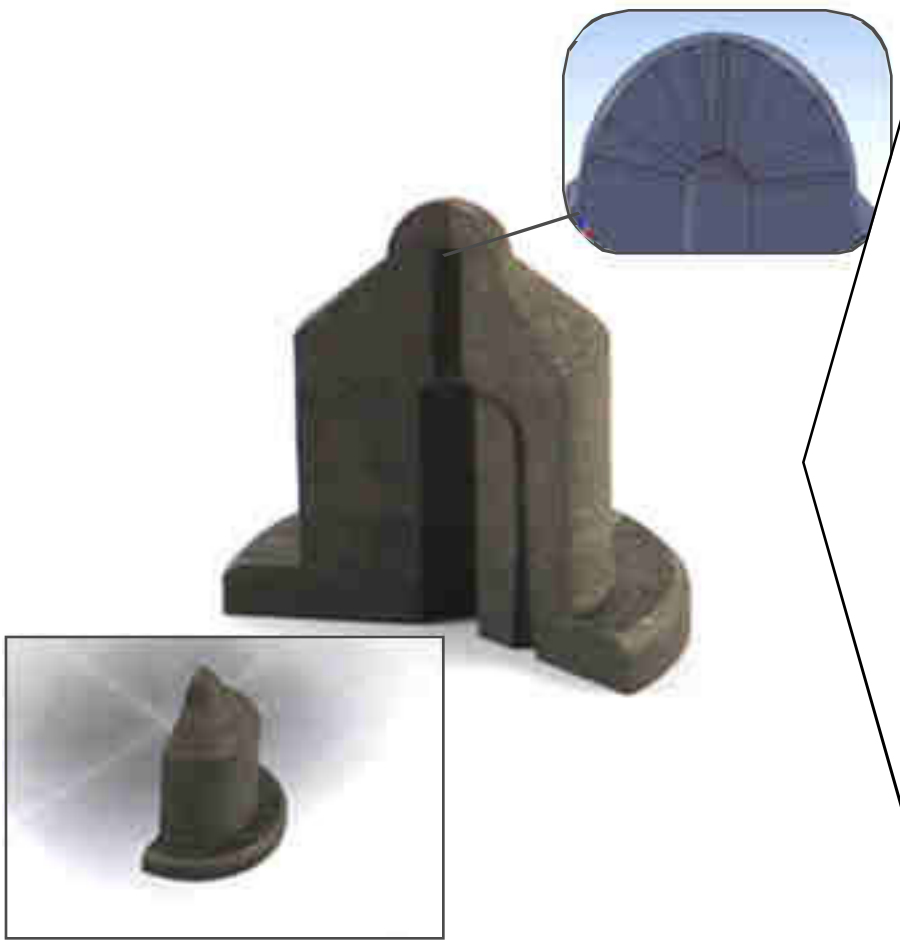
Componente per impianti di impacchettamento di prodotti alimentari in EOS GP1

# Laser sintered injection nozzles enables to distribute fuel more equally in the combustion chamber

"Multiply"

e-Manufacturing Solutions

## Technology example "fuel injection nozzle"



Injection nozzle, back view

Source: EOS

### Fuel injection nozzle

Application Features

- Up to 76 small channels for equal fuel distribution in the combustion chamber at an aperture angle of 150°

Product details:

- Weight: 5g
- Dimensions (x,y,z): 15, 12, 15 mm
- Diameter injection channel: 100µm narrowing down to 20µm on the outlet

Advantages

- Channels can be sintered in any shape
- Channels arranged closely nearby (not possible with eroding)

# Festo ha progettato un manipolo pronto ad operare immediatamente su oggetti “delicati”.

## Esempio Festo


## Bionic handling assistant

**Applicazione**

- Manipolo bionico; autoadattivo rispetto alla geometria dell’oggetto.
- Movimenti realizzati da membrane pneumatiche integrate nel manipolo medesimo

**Vantaggi**

- Manipolo per oggetti “delicati” da movimentare in alta sicurezza
- Peso ridotto al massimo
- Alta flessibilità di manipolazione. Facilità di costruire terminali (fingers) personalizzati
- Bassi costi di produzione: nessun assemblaggio richiesto

Source: Festo, Fraunhofer IPA, EOS

# EOS Additive Manufacturing
# Lifestyle Products Applications

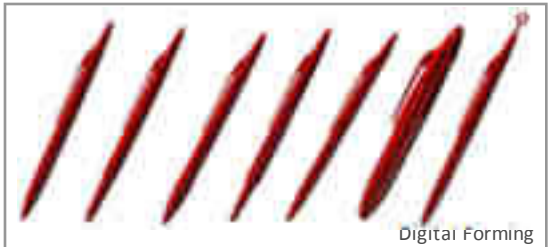
## Jewellery

Cooksongold

- **Challenge:** Develop DMLS suitable for gold
- **Solution:** New technology capable of series production offering a high degree of design flexibility

- **Optimised:** Specially built laser optics and raw material
- **Sustainable:** Less raw material required
- **Creative:** Completely new possibilities for designers

## Accessories & Gadgets



Digital Forming

- **Challenge:** Individualisation of products requires a dedicated software as well as a flexible manufacturing technology
- **Solution:** DigitalForming 's UCODO software combined with EOS Additive Manufacturing

- **Optimised**: 3D files can be customised within the design rules of AM technology
- **Economic:** e-Manufacturing provides the possibility of producing small batch sizes
- **Creative:** UCODO opens up new ways for mass-customised products

## Footwear & Sports

Ross Barber shoes

- **Challenge:** Produce high-fashion men footwear with a complex design
- **Solution:** EOS plastic laser-sintering of sole and cushioning structure

- **Freedom of Design**: 8 unique designs with organic structure
- **Optimised:** Innovative AM technology (sole production) combined with traditional craftsmanship (leather shoe uppers)
- **Economic:** Design could only be manufactured with EOS technology

Sources Images (left to right): Cooksongold (Heimerle + Meule Group), Digital Forming, Ross Barber

# Componenti per calzature

**Prototipi, elementi stile e parti funzionali finali**

Source: Sia Mahdavi (Within), Kerrie Luft

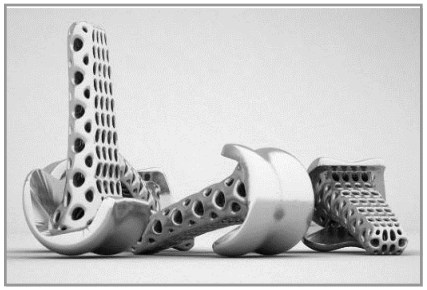
# Additive Manufacturing (AM) Application Examples For Medical

## Dental Applications

Dental restorations

- Soluzioni per corone, ponti, scheletrati e Toronto. Processi e materiali certificati. Registrazione presso Ministero della sanità come componente impiantabile
- Impianti con soluzioni di una migliore osteointegrazione
- Qualità più consistente, minori errori

## Orthopedic Devices and Implants



Finger implants

- Dispositivi ed impianti progettati per trattamenti specifici
- Superfici e miglior osteointegrazione garantiscono costi di opsedalizzazione inferiori. La riduzione degli errori e dei rischi induce miglior benefici sia per pazienti sia per I medici grazie a coperture assicurative più basse.

## Surgical Instruments

MicroTargeting™ platform

- Strumentari:
- Standard, a perdere oppure configurati sul paziente

## Medical Devices

Washing Rotor

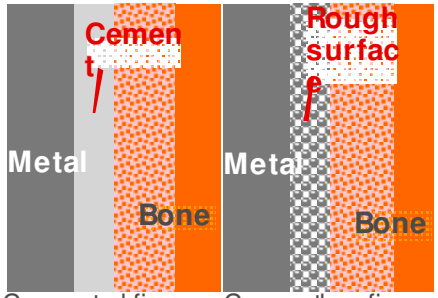
- AM è ideale per la costruzione di piccole serie di oggetti a geometria complessa.
- Possibili integrazioni funzionali con conseguente riduzione die costi di assemblaggio.

Sources Images (left to right): EOS, WITHIN Labs, FHC Inc., Hettich

# Why are customers interested in lattice structures for medical implants?

## Cementless fixation

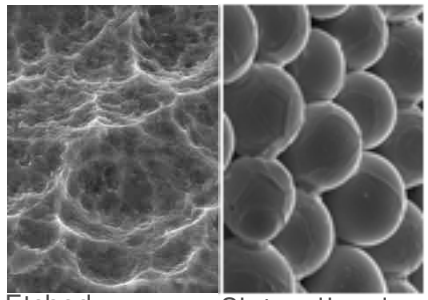
- There are two methods to secure the fixation of a permanent prosthesis to the bone:
  - Cemented fixation uses a fast-curing bone cement (PMMA) to hold the prosthesis in place
  - **Cementless fixation** relies on bone growing into the surface of the implant for fixation



Cemented fix. Cementless fix.

## Rough surface topography

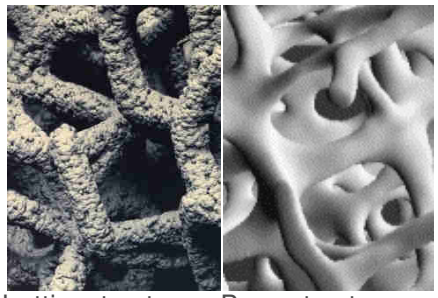
- Cementless fixation requires a **"rough" surface topography** that allows new bone to grow into the surface of the implant
- Conventionally, such implant surfaces are either textured (by etching, blasting, …) or have a porous coating (by plasma spray, sintered beads, …)


Etched Sintered beads

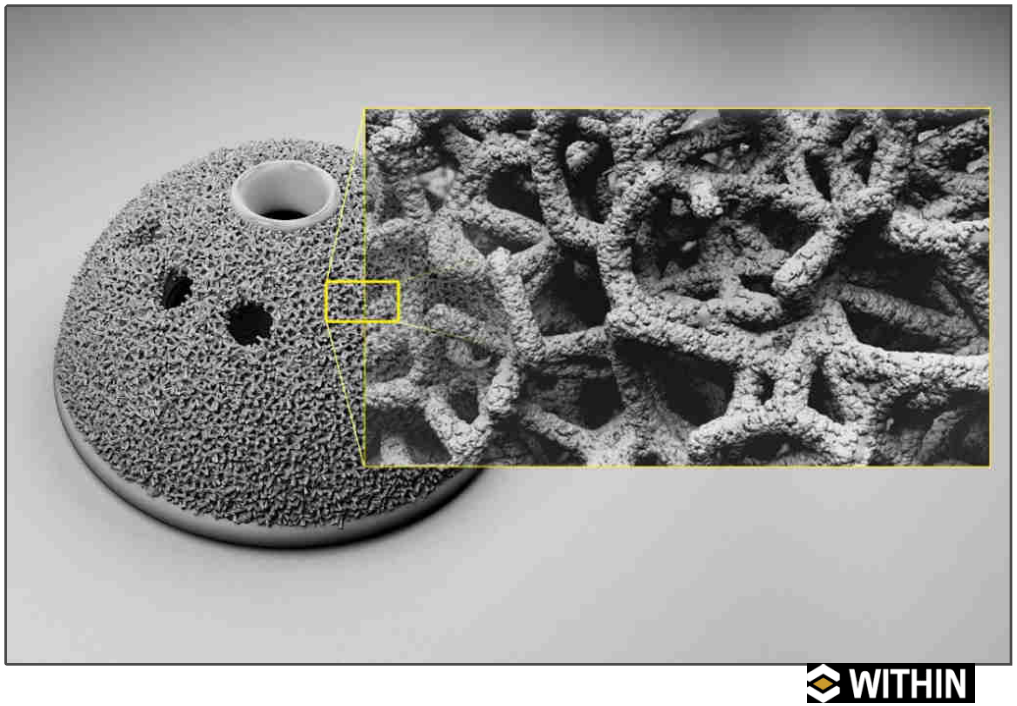
## Lattice structures

Advantages of lattice structures

- Trabecular lattice structure **resembles bone structure** and results in **improved bone-implant integration**
- Solid part and lattice structure built in one step, **no additional process step** needed


Lattice structure Bone structure

# Strutture ibride con superfici trabecolarei ottimizzate per osteointegrazione




## Within Medical Software

- **Facile da usare**
  - Applicazione di strutture porose a qualsiasi superficie
  - Controllo della rugosità superficiale
  - Dimensione dei pori controllabile

Contact at Within Technologies Ltd:

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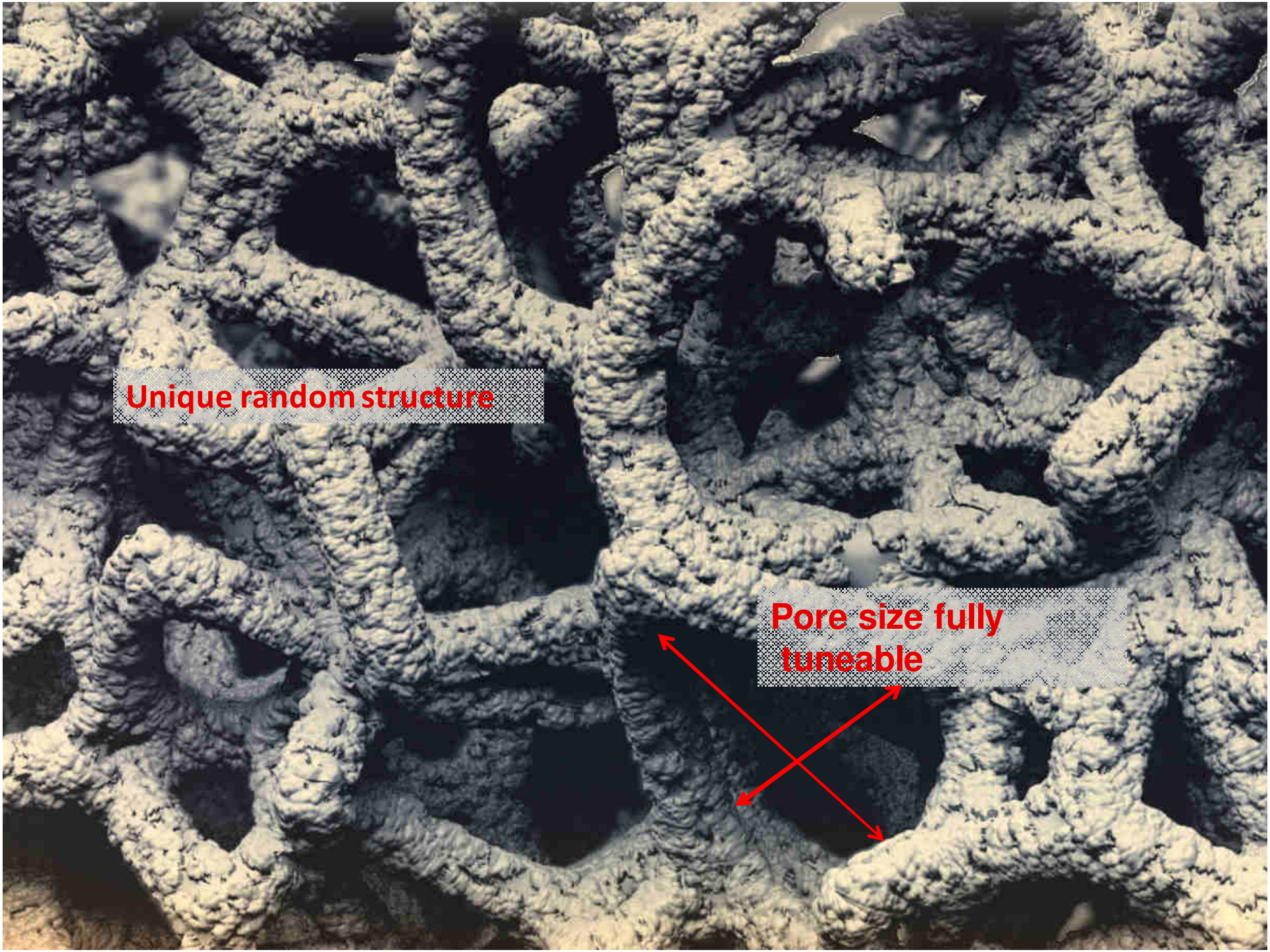
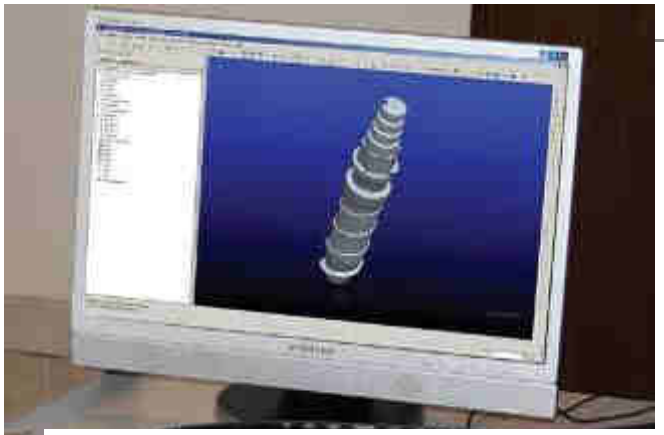
+1 570 239 4912 (US)
kaveh@withinlab.com

**Free download and training:** http://withinlab.com/medical/

Source: WITHIN, EOS


Unique random structure
Pore size fully tuneable

# Applicazioni dentali: vite per implantologia in titanio. Linea di prodotto TiXos di Leader Italia



- Costruzione diretta dalla progettazione CAD.
- Componente inerentemente decontaminato perché fabbricato senza contatti con utensili oppure olii minerali in atmosfera inerte.
- Possibilità di generare strutture ibride ed isoelastiche a densità variabile grazie all'esatto controllo della potenza del fascio laser.
- Rugosità superficiale e caratteristiche della superficie di interfaccia per la ricrescita ossea precise e ripetibili, senza la necessità di applicare rivestimenti specifici

NOVAXATEAM

Dettagli ed ulteriore bibliografia

www.leaderitalia.it

# Dispositivi in plastica monouso per applicazioni biomedicali

Dime chirurgiche monouso progettate sull'anatomia specifica del paziente: protesi ginocchio.

Requisiti applicativi::

- Biocompatibilità (ISO 10993 ed USP6)
- Sterilizzabilità
- Geometria progettata a CAD da dati CT

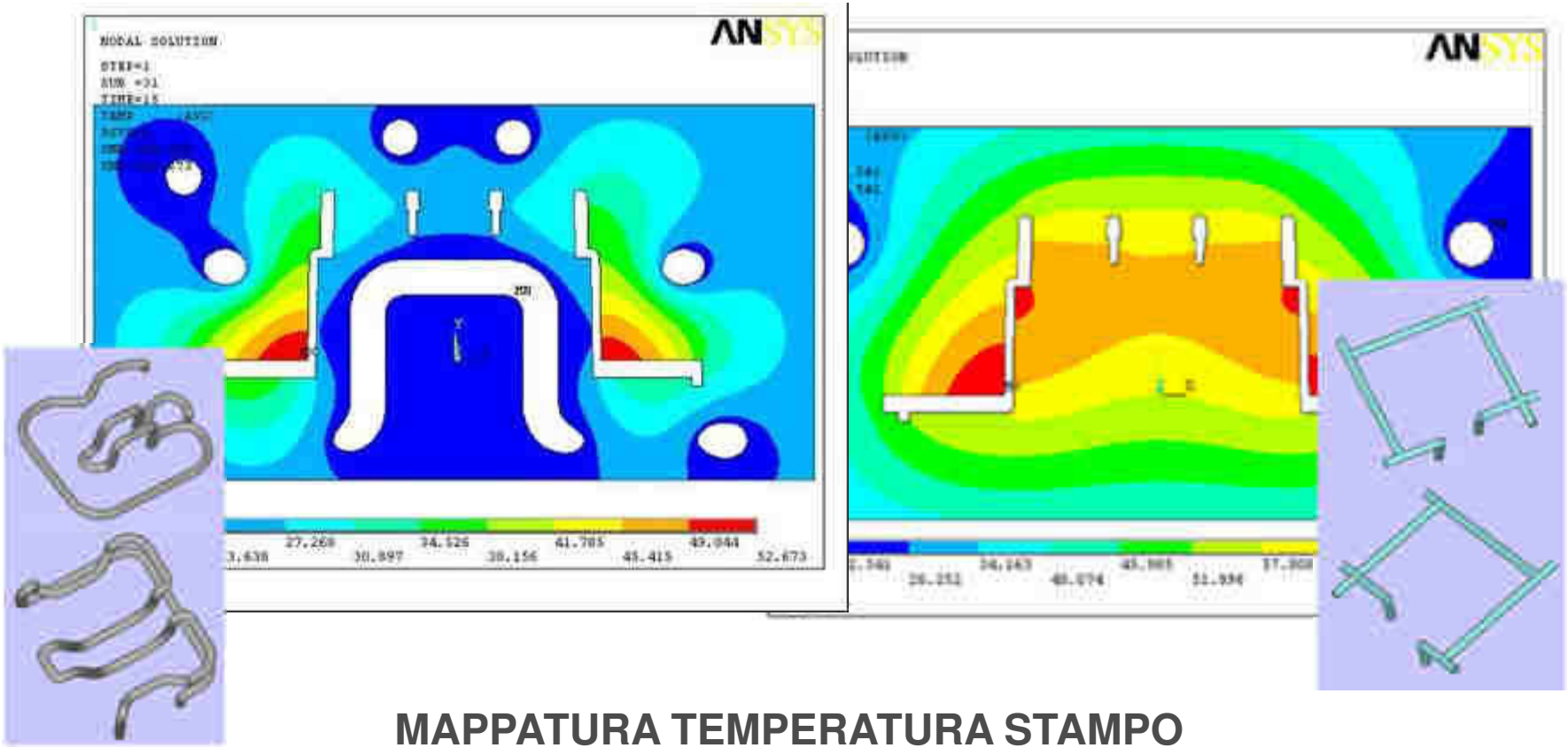
Dima. Linea VISIONAIRE

# Confronto fra i due approcci

DMLS; raffreddamenti conformali

Ciclo N°10 @ t= 15s; Punto a più alta T: 52.6 °C

Raffreddamenti tradizionali per foratura Ciclo N°10 @ t= 15s; Punto a più alta T: 75.5 °C




**MAPPATURA TEMPERATURA STAMPO**

# Complex cooling channels for improved productivity in injection moulding

## Innovative cooling bushing concept improves productivity

### Challenge

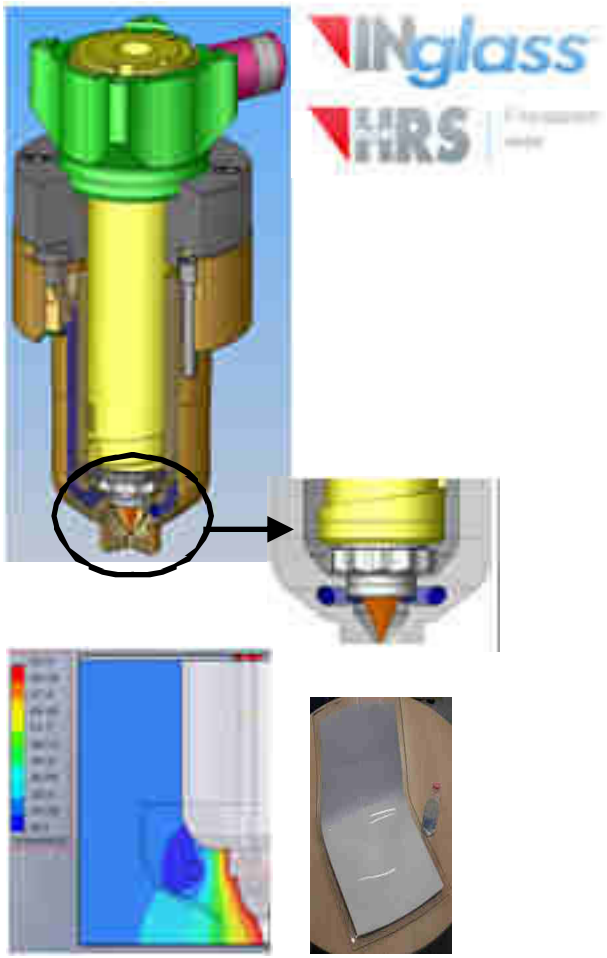
- Improve quality of the part with **innovative concept for gate bushing**

### Solution

- **Eliminate burning defects** on the injection point due to shear heating effect on the gate

### Benefits

- No burning defects on the injection gate
- **Cycle time reduction** from 128 down to 110 s.



# EOS Portfolio
# Additive Manufacturing of Polymers


| | Design | System Set-up & Production | Production Monitoring | Removal & Cleaning |
|---|---|---|---|---|
| **EOS Hardware** | | **Systems**<br>EOS FORMIGAP 110<br>EOSINT P 760<br>EOSINT P 395<br>EOS P 396<br>EOS P 800<br>**Periphery**<br>EOS IPCM / IPCM P plus<br>EOS Unpacking/Sieving station*<br>Cooldown Station P7 | EOS OLPC | |
| **EOS Materials** | | PA 2200<br>PrimePart® PLUS<br>PA 2202 black<br>PA 3200 GF<br>Alumide®<br>CarbonMide®<br>PA 1101<br>PA 2201<br>PA 2105<br>PA 2210 FR<br>PrimePart® FR<br>PrimePart® ST<br>EOS PrimeCast® 101<br>EOS PEEK HP3 | | |
| **EOS Parameters** | | ParameterEditor<br>**ParameterSets**<br>**PPPs:** TopQuality (60µm), Performance (100µm), Balance (120µm), Speed (150µm), Top Speed (180µm)<br>**OEPs:** (60µm), 100µm, 120µm, 150µm | | |
| **EOS Software** | EOS RP Tools<br>EOS PSW | EOS PSW | EOSTATE | |
| **Partner Solutions** | Materialise Streamics<br>Materialise Magics | Materialise Streamics | Materialise Streamics | EOS Blasting Cabinet<br>Normfinish |

*For P1, P3, P7

# Polymer System Portfolio Overview

## FORMIGA P 110

**Build size & volume (usable)**
- Width 200 mm
- Depth 250 mm
- Height 330 mm
- Volume = 16.5l per built

**Focus on…**
- High detail resolution
- Robust process
- Better usability and cleaning effort

## EOS P 396

**Build size & volume (usable)**
- Width 340 mm
- Depth 340 mm
- Height 600 mm
- Volume = 69.4l per built

**Focus on…**
- Manufacturing speed
- Mechanical and dimensional homogeneity across built volume → EOSAME feature
- System design improvements

## EOSINT P 760

**Build size & volume (usable)**
- Width 700 mm
- Depth 380 mm
- Height 580 mm
- Volume = 154.3l per built

**Focus on…**
- Possible large part sizes
- High-volume production
- Extensive portfolio of periphery for maximum system productivity

## EOSINT P 800

**Build size & volume (usable)**
- Width 700 mm
- Depth 380 mm
- Height 560 mm
- Volume = 149l per built

**Focus on…**
- Processing of ultra-high-temperature materials like EOS PEEK HP3, melting point of 372°C
- cost-effective production solutions (e.g. built size reduction possible)

# EOS Periphery for Polymer Production: Integrated Process Chain Management

## IPCM P plus

**Available**
- All EOS Polymer Systems can be integrated

**Benefits**
- **e-Manufacturing:** IPCM P plus ensures constant and repeatable powder quality throughout the entire production process
- **Reduced cost per part:** Precise dosing and in-situ powder qualification make material savings possible
- **Improved quality assurance:** Powder batches can be traced, thus meeting the requirements of quality-focused industries
- **Environmentally friendly:** Humidification of powder in Mixing & Qualification Station through in-line control; no energy-intensive and costly external solutions needed
- **Easy installation and minimum risk of powder contamination:** Powder remains in protected environment at all time
- **Modular approach provides highest capacity and expandability:** Each additional system requires only one extra Docking Station (and one Multibox to maintain ease of handling)

**Features**
- Dosing, refreshing, homogenization, and conditioning (humidification) of powder material
- Enables traceability of powder batches
- Transport to and conveying into the system
- Sealed, contamination-free storage of the refreshed powder

# EOS Polymer Materials

| Composition | Trade name | Colour of parts | Main feature | Typical applications |
|---|---|---|---|---|
| Polyamide 12 | **PA 2200** | white | • Multipurpose material<br>• Balanced property profile | • Functional parts |
| | **PrimePart® PLUS** (PA 2221) | natural | • Economic multipurpose material<br>• Balanced property profile<br>• Certificates available (Biocompatibility, Food contact) | • Functional parts |
| | **PA 2202 black** | anthracite black | • Balanced property profile<br>• Pigmented throughoutd | • Functional parts in anthracite black colour |
| Polyamide 12, glass bead filled | **PA 3200 GF** | whitish | • High stiffness<br>• Wear resistance<br>• Improved temperature performance | • Stiff housings<br>• Parts with requirements on wear and abrasion<br>• Parts used under elevated thermal conditions |
| Polyamide 12, aluminium filled | **Alumide®** | metallic grey | • Easy post-processing, good machinability<br>• High temperature performance<br>• Thermal conductivity (limited)<br>• High stiffness | • Applications with metal-like look<br>• Parts which need machining<br>• Parts with thermal loads |
| Polyamide 12, carbon fibre reinforced | **CarbonMide®** | anthracite black | • Extreme strength and stiffness<br>• Thermal and electrical conductivity (limited)<br>• Best strength/weight-ratio | • Light and stiff functional parts<br>• Metal replacement |
| Polyamide 11 | **PA 1101** | natural | • Very high ductility / elongation at break<br>• 100% from renewable sources (castor/ricinus oil)<br>• Acceptable tensile strength | • Functional parts which need impact resistance<br>• Parts with functional elements (film hinges) |
| **For special applications** | | | | |
| Polyamide 12 | **PA 2201** | natural | • Multipurpose material<br>• Material certificates available (Food contact) | • Medical, food |
| | **PA 2105** | light beige | • Highest dimensional accuracy<br>• High surface quality and detail resolution | • Dental |
| Polyamide 12, flame retardant | **PA 2210 FR** | white | • Economic flame-retardant material<br>• Halogen-free | • Aerospace<br>• Electric & Electronic |
| | **PrimePart® FR** (PA 2241 FR) | white | • Economic flame-retardant material<br>• Material certificates available (flammability) | • Aerospace |
| TPE-A Polyetheramide-Block-Copolymer | **PrimePart® ST** (PEBA 2301) | white | • Rubber-like flexibility (Shore D ≈ 35)<br>• No infiltration necessary | • Damping devices, bumpers / cushions, gaskets / gasket seals, shoe sole elements |
| Polystyrene | **PrimeCast® 101** | grey | • High dimensional accuracy<br>• Low residual ash-content | • Patterns for investment casting<br>• Master patterns for vacuum casting |
| Polyaryletherketone | **EOS PEEK HP3** | beige-brown | • High performance material<br>• Excellent temperature performance, strength, stiffness and chemical resistance<br>• Excellent wear resistance. Inherently flame retardant<br>• Biocompatibility and sterilizability | • Metal replacement<br>• Aerospace<br>• Automotive and motorsports. Electric & Electronic<br>• Medical<br>• Industrial |

# EOS Portfolio
# Additive Manufacturing of Metals

| | Design | System Set-up & Production | Production Monitoring | Removal &Cleaning |
|---|---|---|---|---|
| **EOS Hardware** | | **Systems**<br>EOSINT M 280 200W/400W<br>EOSINT M 270 Dental<br>EOS M 400<br>**Periphery**<br>EOS IPCM M<br>EOS Comfort Powder Module | EOSTATE Laser Measurement | |
| **EOS Materials** | | EOS MaragingSteel MS1<br>EOS StainlessSteel GP1<br>EOS StainlessSteel PH1<br>EOS StainlessSteel 316L<br>EOS NickelAlloy IN718<br>EOS NickelAlloy IN625<br>EOS NickelAlloy HX<br>EOS Titanium Ti64<br>EOS CobaltChrome MP1<br>EOS CobaltChrome SP2<br>EOS Aluminium AlSi10Mg<br>EOS Titanium Ti64ELI | | |
| **EOS Parameters** | | ParameterEditor<br>**ParameterSets**<br>Surface, Performance, Speed | | |
| **EOS Software** | EOS RP Tools<br>EOS PSW<br>EOSPRINT | | EOSTATE Base<br>EOSTATE LaserMonitoring<br>EOSTATE PowderBed | |
| **Partner Solutions** | Materialise Magics | EROWA Alignment System | | IEPCO Shot Peening |

# EOS Systems for the Additive Manufacturing of Metal Parts

**EOSINT M 270 Dental:** High-Performance DMLS for Dental Copings & Bridges

**Usable build size**
- Width 250 mm
- Depth 250 mm
- Height 215 mm

**Laser**
- Yb-fibre laser
- 200 W

**Technical data**
- Precision optics: F-theta-lens, high-speed scanner
- Scan speed: up to 7.0 m/s

**EOSINT M 280:** Mid-Sized System for Additive Manufacturing of Metal Parts

**Usable build size**
- Width 250 mm
- Depth 250 mm
- Height 320 mm

**Laser**
- Yb-fibre laser
- 200 W or 400 W

**Technical data**
- Precision optics: F-theta-lens, high-speed scanner
- Scan speed: up to 7.0 m/s

**EOS M 290:** For High-Quality Metal Parts – with Enhanced Quality Management

**Usable build size**
- Width 250mm
- Depth 250 mm
- Height 325 mm

**Laser**
- Yb-fibre laser
- 400 W

**Technical data**
- Recirculating Filter System
- Monitoring of machine and process parameters

**EOS M 400:** For Industrial Production of High-Quality Large Metal Parts

**Usable build size**
- Width 400 mm
- Depth 400 mm
- Height 400 mm

**Laser**
- Yb-fibre laser
- 1,000 W

**Technical data**
- Precision optics: F-theta-lens
- Scan speed: up to 7.0 m/s

# EOS Metal Materials

| Material Group | Brand name | Material type | Typical applications |
|---|---|---|---|
| Maraging Steel | **EOS MaragingSteel MS1** | 18 Mar 300 / 1.2709 | Injection moulding series tooling; engineering parts |
| Stainless Steel | **EOS StainlessSteel GP1** | Stainless steel 17-4 / 1.4542 | Functional prototypes and series parts; engineering and medical |
| | **EOS StainlessSteel PH1** | Hardenable stainless 15-5 / 1.4540 | Functional prototypes and series parts; engineering and medical |
| | **EOS StainlessSteel 316L** | Stainless steel 1.4404 | Functional prototypes and series parts; lifestyle, aerospace, medical |
| Nickel Alloy | **EOS NickelAlloy IN718** | Inconel™ 718, UNS N07718, AMS 5662, W.Nr 2.4668 etc. | Functional prototypes and series parts; high temperature turbine parts etc. |
| | **EOS NickelAlloy IN625** | Inconel™ 625, UNS N06625, AMS 5666F, W.Nr 2.4856 etc. | Functional prototypes and series parts; high temperature turbine parts etc. |
| | **EOS NickelAlloy HX** | UNS N06002 | Severe thermal conditions and high risk of oxidation, e.g. combustion chambers, |
| Cobalt Chrome | **EOS CobaltChrome MP1** | CoCrMo superalloy, UNS R31538, ASTM F75 etc. | Functional prototypes and series parts; engineering, medical, dental |
| | **EOS CobaltChrome SP2** | CoCrMo superalloy | Dental restorations (series production) |
| Titanium | **EOS Titanium Ti64** | Ti6Al4V light alloy | Functional prototypes and series parts; aerospace, motor sport etc. |
| | **EOS Titanium Ti64ELI** | Ti6Al4V ELI (grade 23) | Medical Implants |
| Aluminium | **EOS Aluminium AlSi10Mg** | AlSi10Mg light alloy | Functional prototypes and series parts; engineering, automotive etc. |

# EOS Pursues a Platform-based DMLS Strategy – from R&D to Production

**Large scale Production Platform**

- Manufacture application in production environment

**Focus on production**

- Semi-automated processes
- Modular concept
- Single field with 1kW laser
- Multi-field with 200/400W lasers*
- XL build chamber (400x400x400mm)

**Scale up for production**

**R&D / small scale Production Platform**

- Develop & qualify applications
- Freeze system settings for production
- Produce small scale volumes

**Focus on flexibility**

- Designed for flexible material exchanges
- 200 / 400 W laser
- Build chamber (250x250x325mm)

**Adapt to application**

**Application specific** [1)]

- Derive application-specific system, e.g. PRECIOUS M 080

**Focus on application**

- Adapted system to match requirements of specific applications [1)]
- Dedicated materials and parameters (e.g. gold)

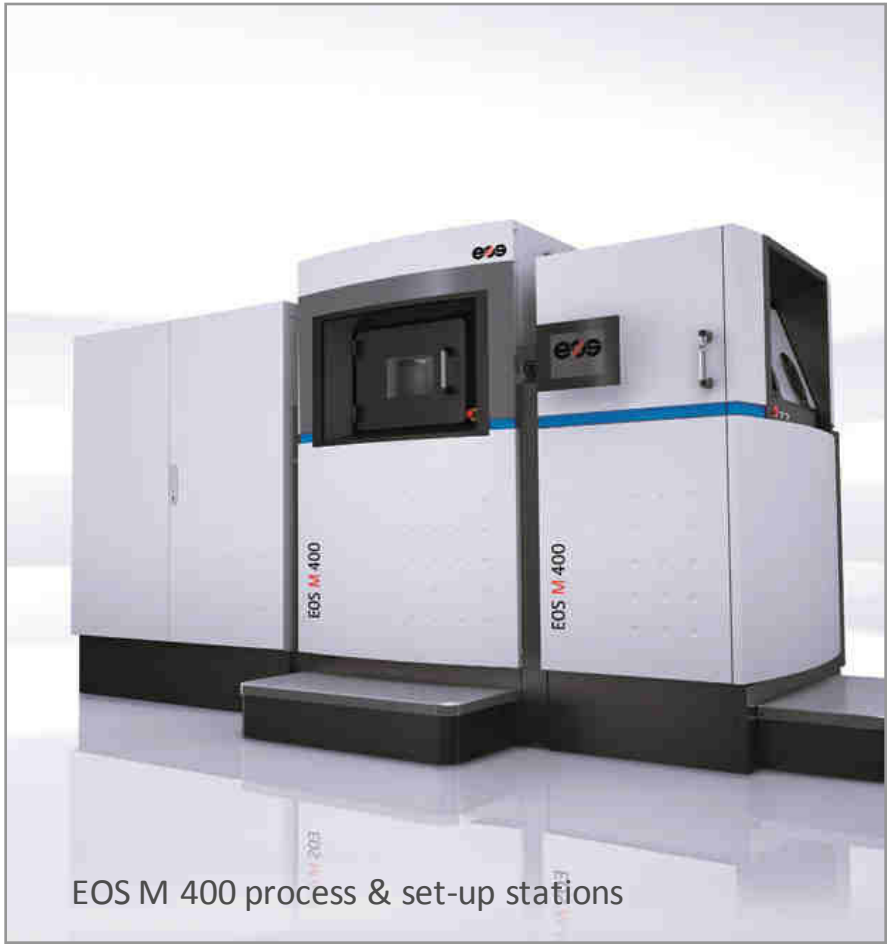
1) Requires dedicated business case * In development, subject to technical changes

# EOS M 400 – an industrial DMLS platform

## Main Features

- Modular platform for easy integration of future innovations
- Build volume of 400 x 400 x 400 mm³
- Laser power of 1000 W
- 2 recoater blades and bi-directional recoating
- Material dosing from above
- Exchangeable frame for easier job handling
- Intuitive user interface
- Efficient workflow before and during build
- Enhanced EOSTATE Monitoring & Reporting

DMLS for e-Manufacturing of a new class of products



EOS M 400 process & set-up stations

# Depending on the Application, EOS will offer a Single or Multi-Field Manufacturing Solution

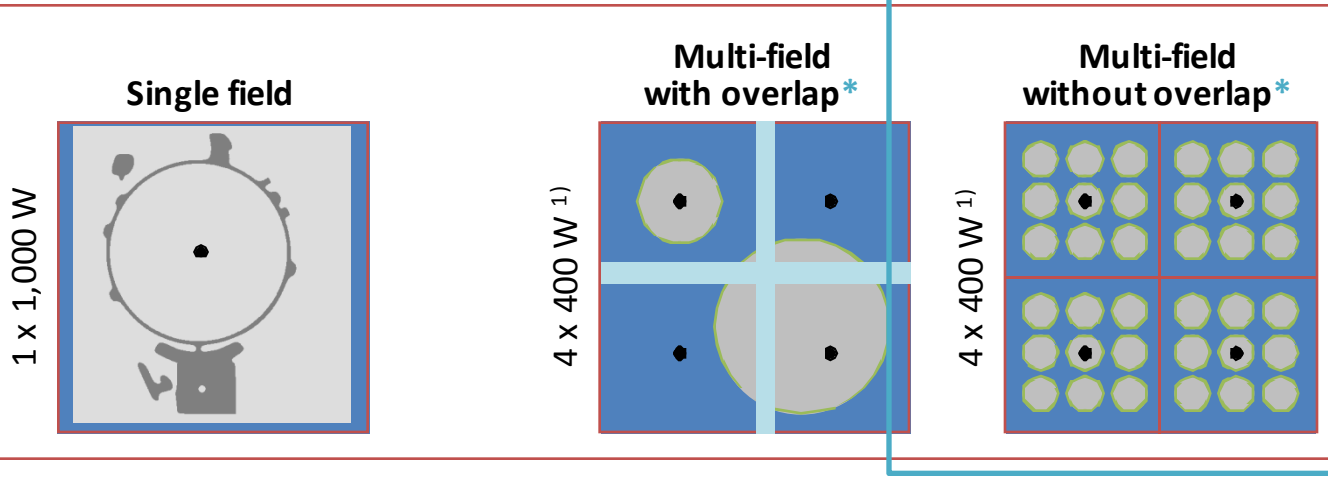
**Focus on speed**

- Big & bulky parts
- Surface roughness allowed
- Functional surfaces typically finished

Application-specific approach

**Focus on accuracy**

- Rather small parts
- High resolution required
- Direct similarity to M 280




1) Laser power can be adapted for similarity purposes (e.g. 200 W) * In development, subject to technical changes

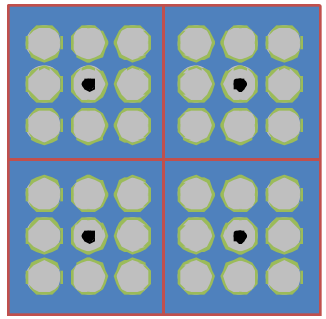
# Peek into the Lab – EOS M 400-4*

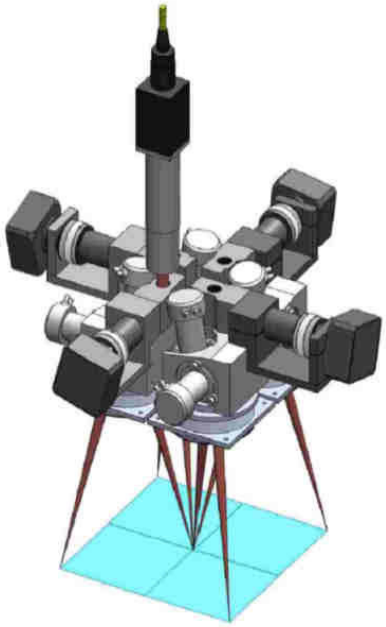
**Preliminary Information***

- Multi-head optics
  → 4x 200 or 400 W lasers
- Proven DMLS quality known from EOSINT M 280
  → Productivity can increase by a factor of 2-4 depending on the part
- Same Materials & Processes as EOSINT M 280 ensures the legacy of qualified production processes

Increased productivity for e-Manufacturing that has been qualified on EOSINT M 280

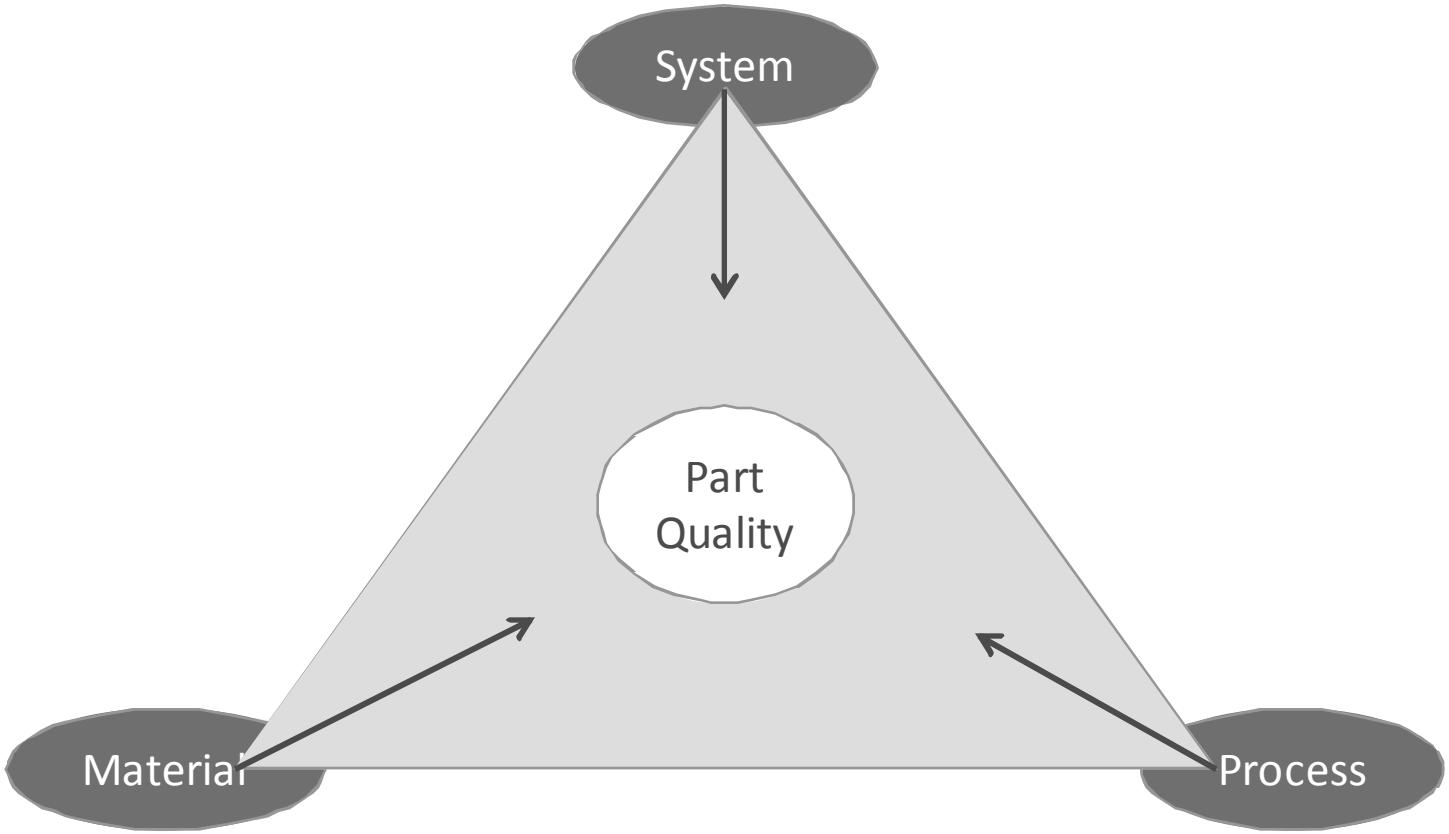
Multi-head optics





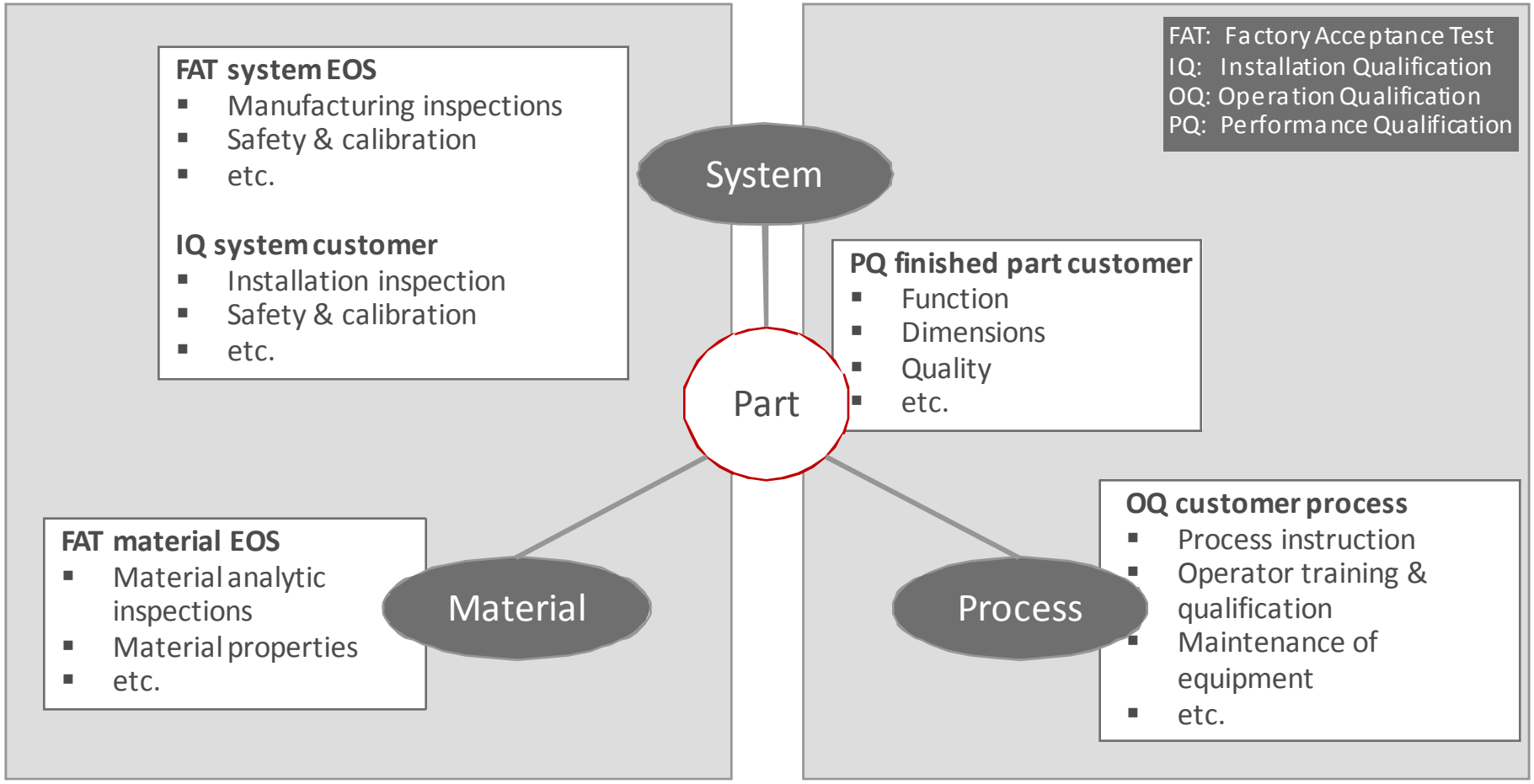
* In development, subject to change

# Quality output in EOS solutions results from a combination of factors




With EOS Qualification Support Services, the influencing factors of the laser sinter triangle are addressed ⇨ see following page

# EOS QUALITY MANAGEMENT SERVICES: From Delivery to Validation




For FAT and IQ, EOS delivers standard or customised protocols.

For OQ and PQ, customer develops protocols and can use EOS Consulting.

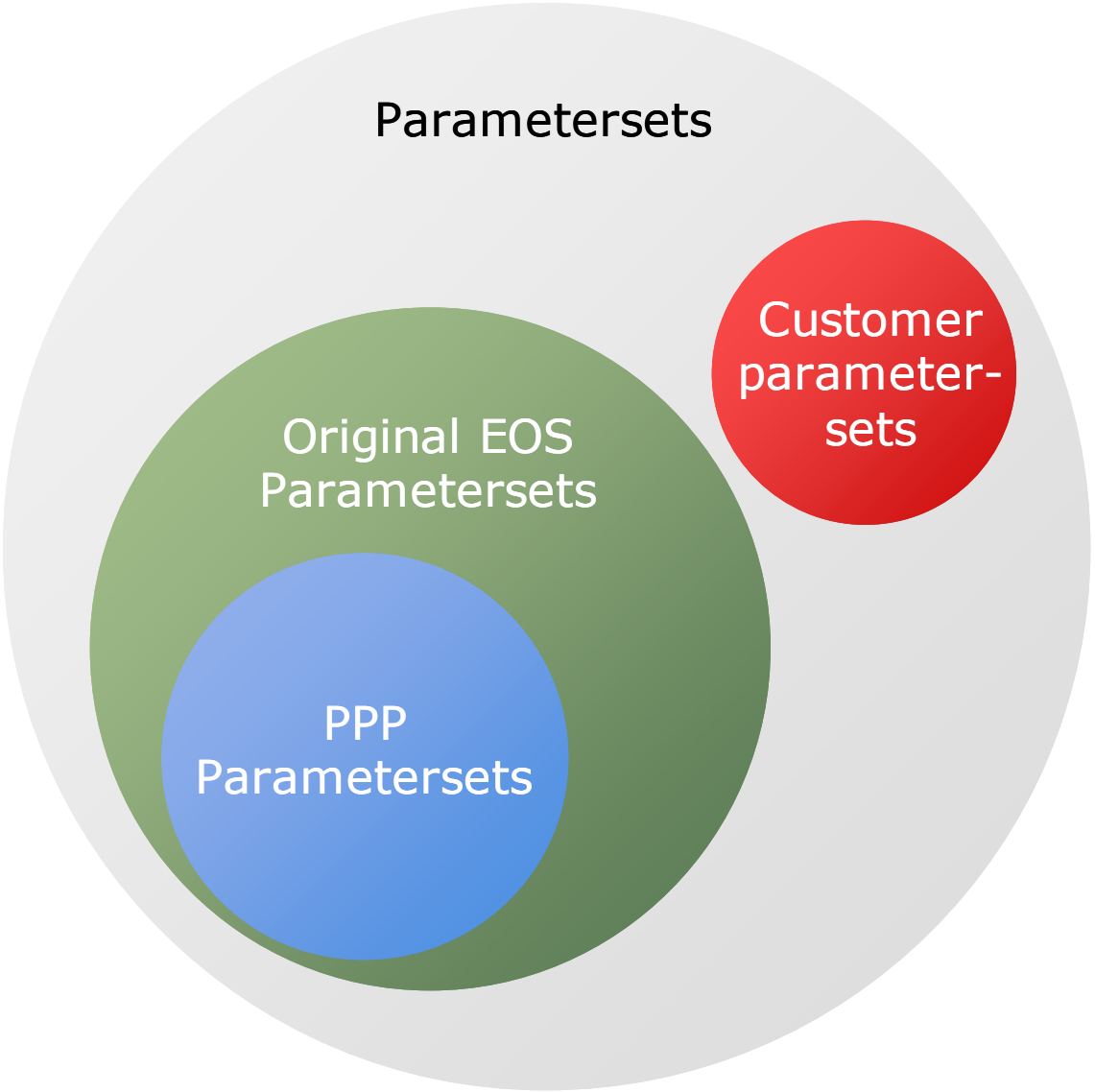
# Variants of FAT and IQ Support Service

| | FAT / IQ EOS Standard | FAT / IQ Extended | FAT / IQ Customised |
|---|---|---|---|
| **Feasibility study (Pre-validation)** | -- | Assessment of customer acceptance criteria | Feasibility study for customer specific part |
| **Qualification Consulting** | -- | ▪ Def. test scope + method<br>▪ Acceptance criteria | ▪ Def. test scope + method<br>▪ Acceptance criteria |
| **Application Consulting** | -- | -- | (If required for specific part) |
| **Test scope + method** | EOS standard | Customer specific | ▪ Customer specific<br>▪ Adjusted to spec. part |
| **Sample part production** | EOS standard | EOS standard | Customer specific part |
| **Documentation** | EOS standard | Extended documentation | Customized documentation |

**The EOS Standard solution is a well proven process.**
**However, for specific requests, we are prepared to customise our offer.**

# CONTROLLO PROCESSO E SUE VARIABILI

# Parametersets




**Part Property Profiles** specify material & process properties

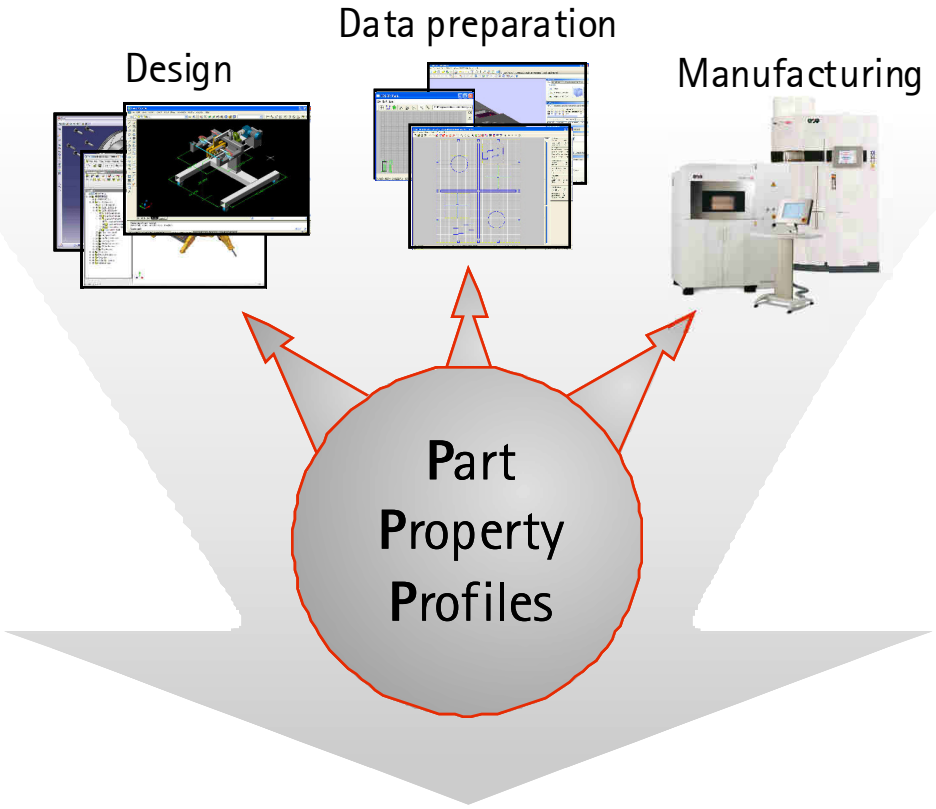
Parametersets realise them.

**Original EOS Parametersets (OEP)** = parametersets released by EOS

**Part Property Profile Parametersets** = qualified material- & process properties

**Customer parametersets** = parametersets developed by customer.

# Overview Part Property Management




**Standardized material and process properties**

- Normally designers plan the material- & process properties during design.
- EOS offers these standardised properties as Part Property Profiles (PPP).

Advantages:

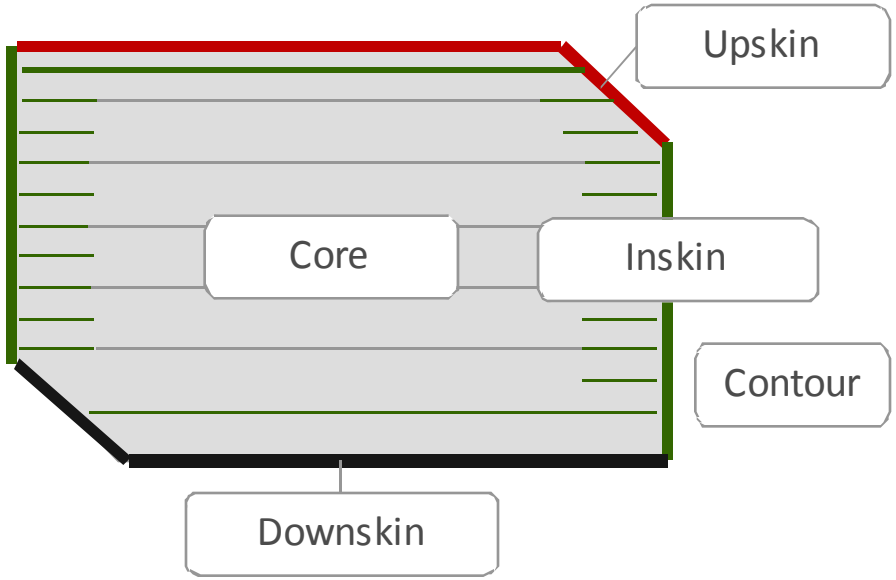
- Standardisation
- Dependability and quality
- Cost efficiency

# Adaption of Key Parameters for Every Part Area Possible

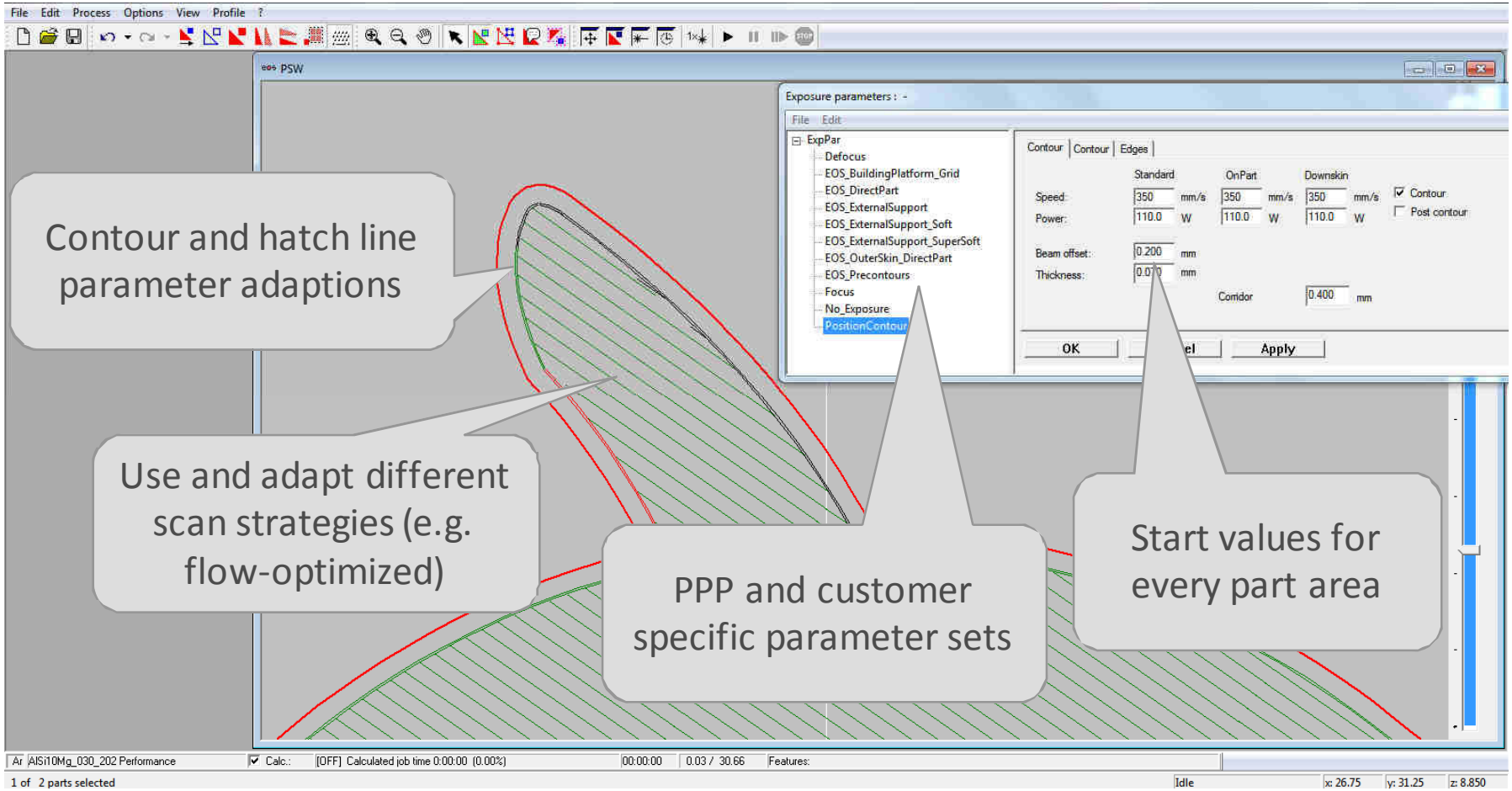
## Key Features

- Possible adaptions for every area category (see scheme on the right):
  - Laser speed
  - Laser power
  - Hatch distance
  - Offset
  - Skywriting
  - Edges
- Depending on default job: 164 – 240 possible adaptions
- Sophisticated exposure strategies
- Variable number and sequence of contour lines (Pre- or Post-Contour)

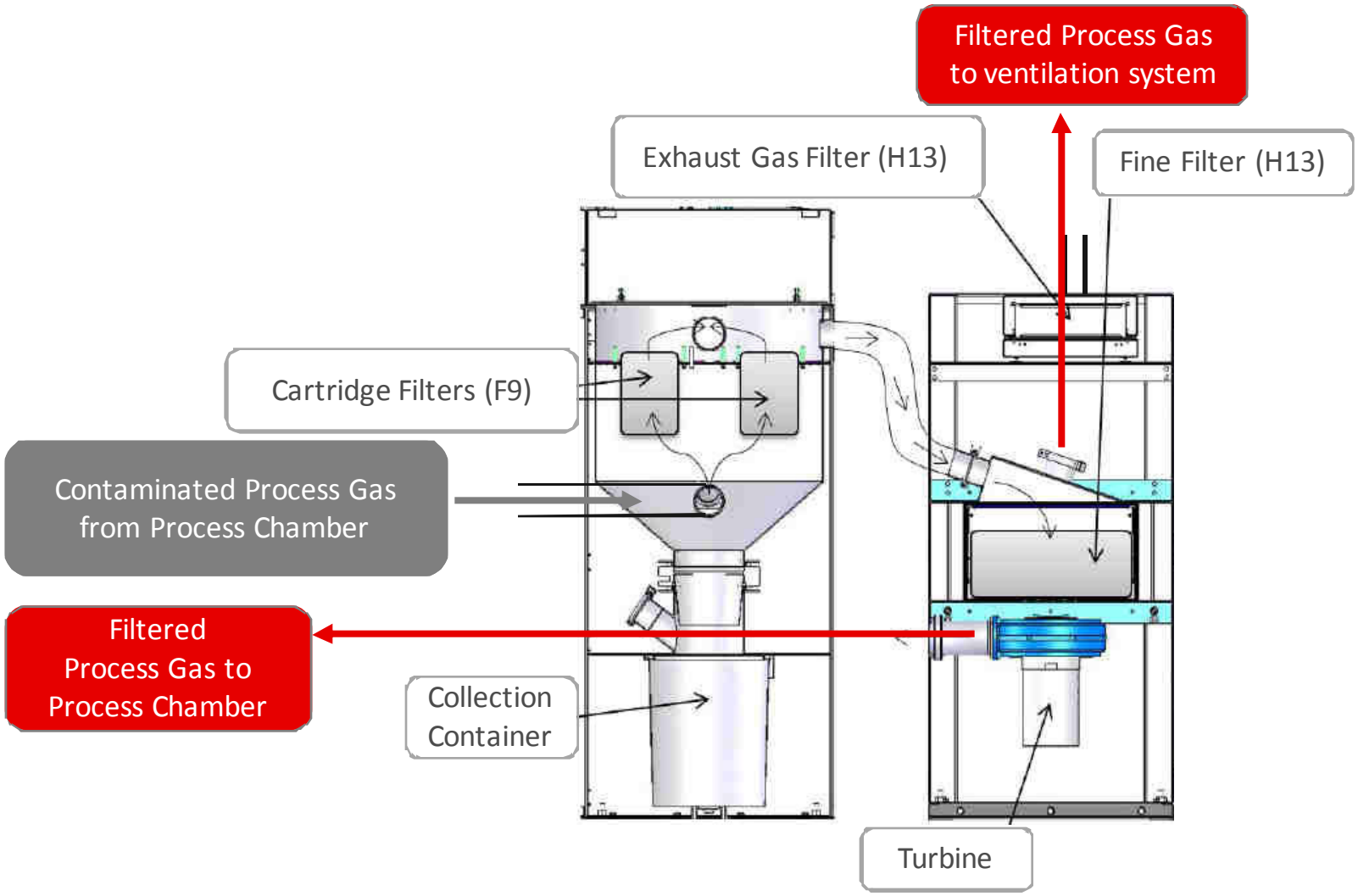
## Scheme



# Possible Parameter Adaptions with the ParameterEditor



# **NEW** Recirculating Filter System



# **NEW** Recirculating Filter System

## 2-stage Filter System …

Stage 1: Cartridge Filters (F9)

- Set of 4 filters
- Removes most of the contamination
- Automated filter cleaning: removal of powder cake from filter into collection container ensures constant filter efficiency

Stage 2: Fine and Exhaust Gas Filters (H13)

- Ensures that process gas can be safely released into onsite ventilation system and back into the process chamber
  - 99.95% of particles smaller than 1µm are filtered

## Fewer Filter Exchanges …

Lifetime Cartridge Filter:

- Approx. 1,500 laser hours (400W)
- Approx. 2,000 laser hours (200W)

Lifetime H13 Filter: approx. 3,500 laser hours

Lifetime Collection Container: approx. 400 laser hours

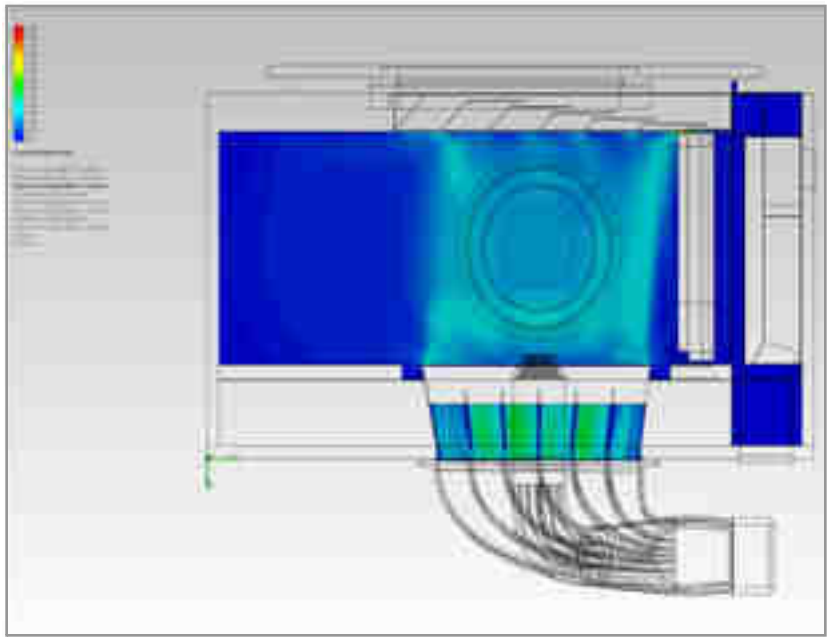
… ensures optimal process quality.

… reduces operating costs considerably*

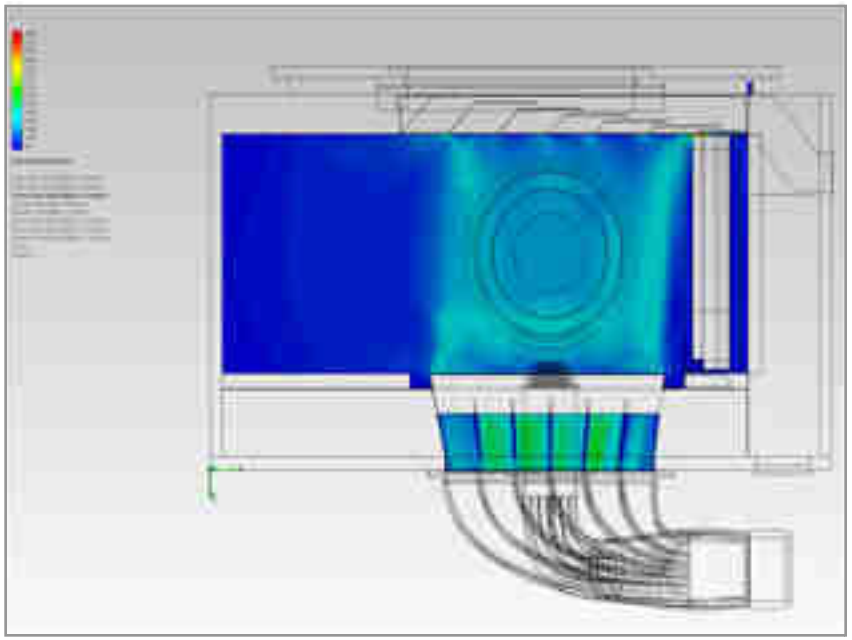
* Compared to EOSINT M 280

# Process Similarity: Comparison of Flow

EOSINT M 280



EOS M 290



Conclusion: Results are within the measurement accuracy and defined tolerances, therefore no significant effect on process result

Observation in 10mm above building platform

# Process Similarity: Comparison of Part Properties

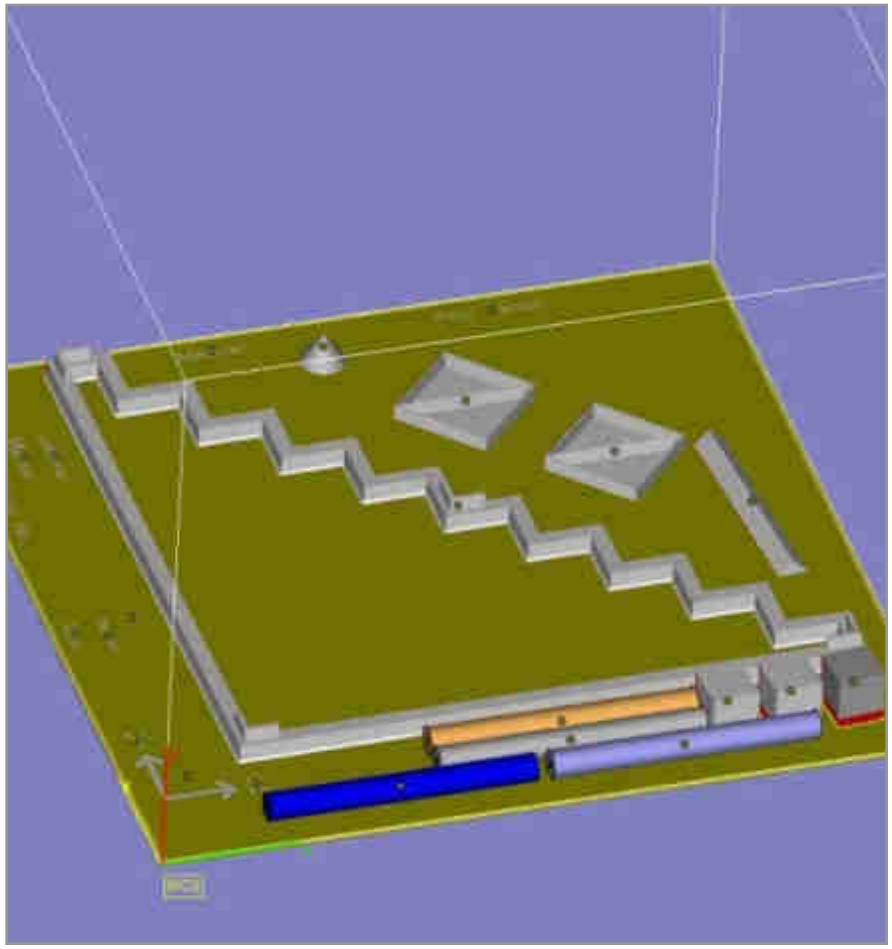
## EOS CobaltChrome MP1

Test Set-up
1. Test Job: EOS QA Job
2. ParameterSets
   a. MP1_Surface (20µm, 200W)
   b. MP1_Speed (50µm, 400W)
3. Systems: 3 EOS M 290
4. Test matrix per ParameterSet:
   3 QA Jobs on 3 different M 290 systems each

Properties analysed:
- Mechanical properties, e.g. tensile strength, yield strength, elongation at break, modulus of elasticity
- Relative Density
- Dimensional accuracy

Conclusion: Part properties are comparable as per Material Data Sheet for EOS CobaltChrome MP1

EOS QA Job



# Process Similarity: Comparison of Part Properties

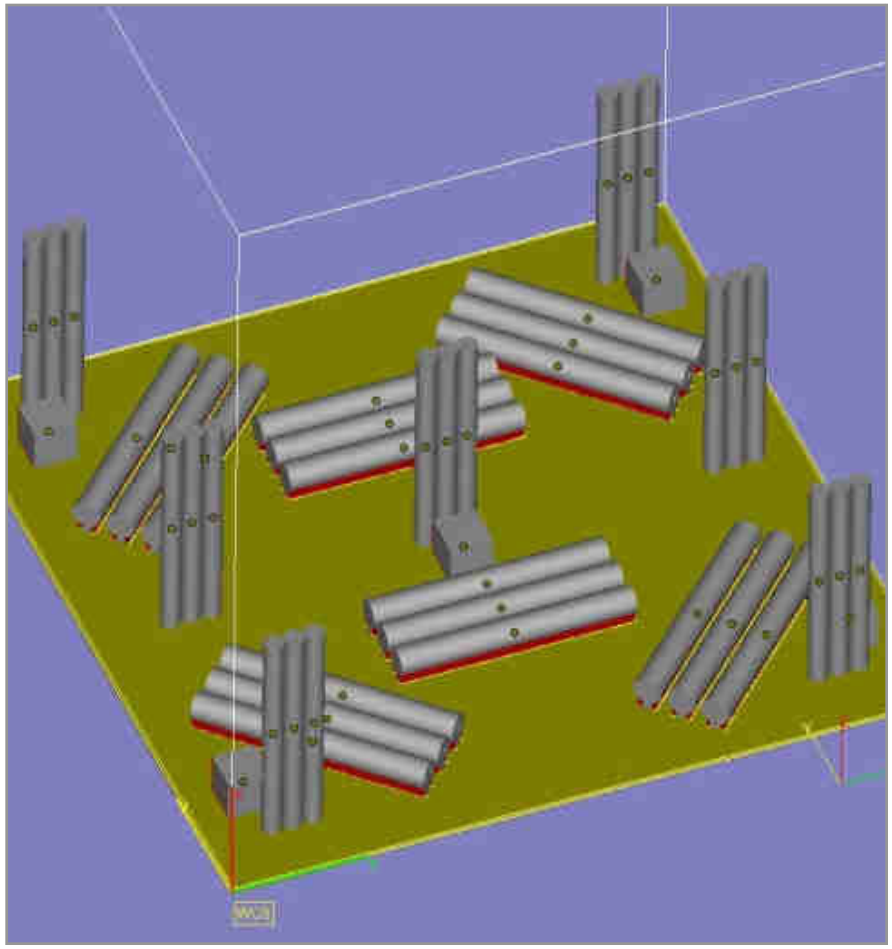
## EOS NickelAlloy IN718

Test Set-up
1. Job: EOS Verification Job
2. ParameterSet: IN718_Performance (40µm, 400W)
3. Systems: 3 EOS M 290
4. Test matrix per ParameterSet:
   1 Verification Job on 3 different M 290 systems

Properties tested/analysed:
- Mechanical properties, e.g. tensile strength, yield strength, elongation at break, modulus of elasticity
- Relative Density

Conclusion: Part properties are comparable as per EOS Material Data Sheet for EOS NickelAlloy IN718

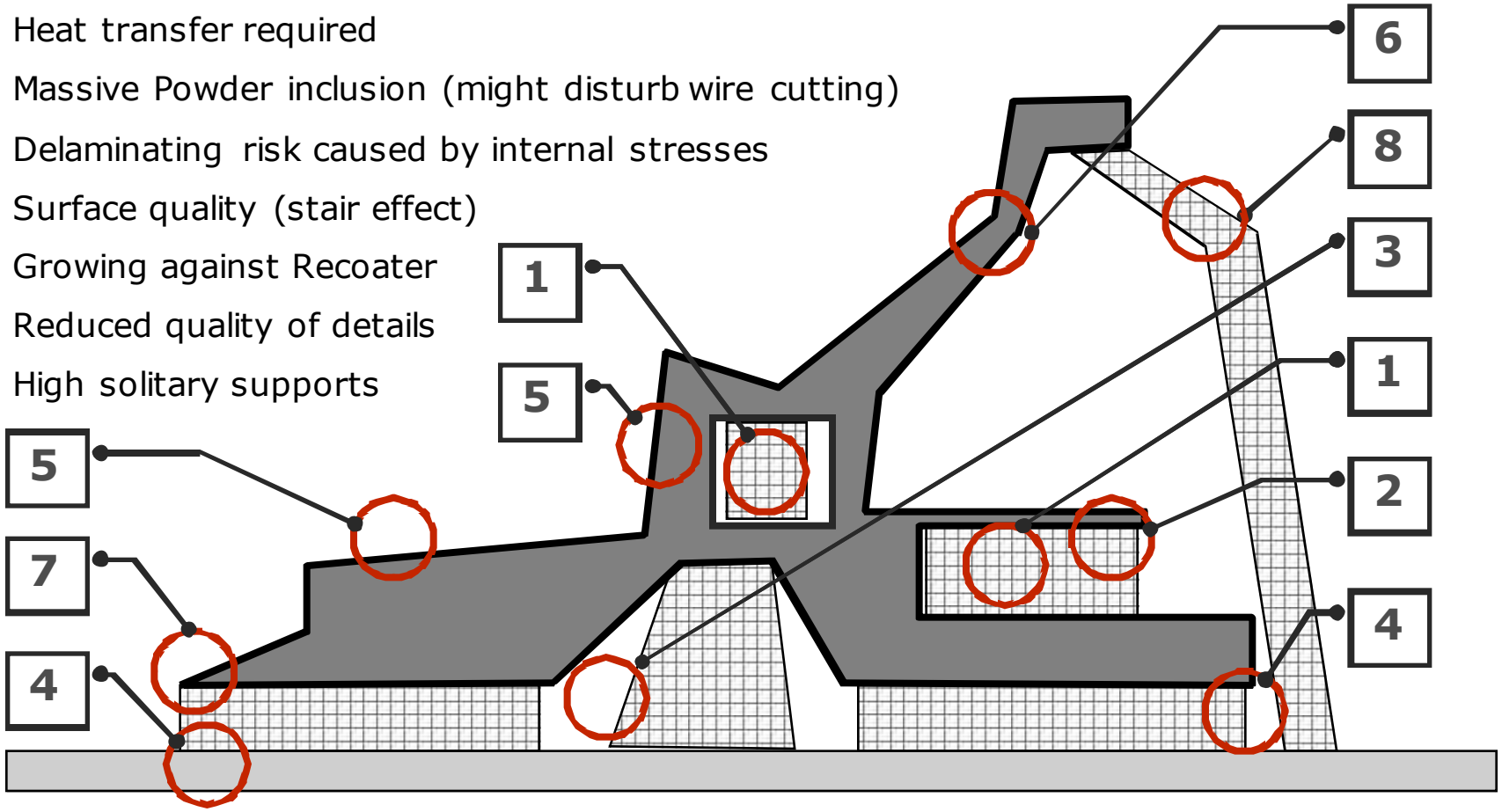
EOS Verification Job



# Exercise – Generating supports

Pitfalls for support and build techniques

1. Removability problem
2. Heat transfer required
3. Massive Powder inclusion (might disturb wire cutting)
4. Delaminating risk caused by internal stresses
5. Surface quality (stair effect)
6. Growing against Recoater
7. Reduced quality of details
8. High solitary supports



# Several laser sintering competences are needed to develop a complete solution

## End-to-end laser sintering solution

**Laser sintering technology**

**Raw material development & supply**

**Laser sintering system, software development & innovation**

**End-to-end laser sintering solution**

**Design and data generation** → **Laser sintering manufacturing solution** → **Post processing**

| Design | Production | Finishing |
|---|---|---|
| ▪ Design rules and data generation<br>▪ Software interface | ▪ Application development (parameter, building strategy)<br>▪ Production | ▪ Post machining<br>▪ Finishing |

# MMP TECHNOLOGY®: Super Precision Surface Finishing

## Post processing: Micro Machining Process (MMP) for 7 main markets

### Micro machining process

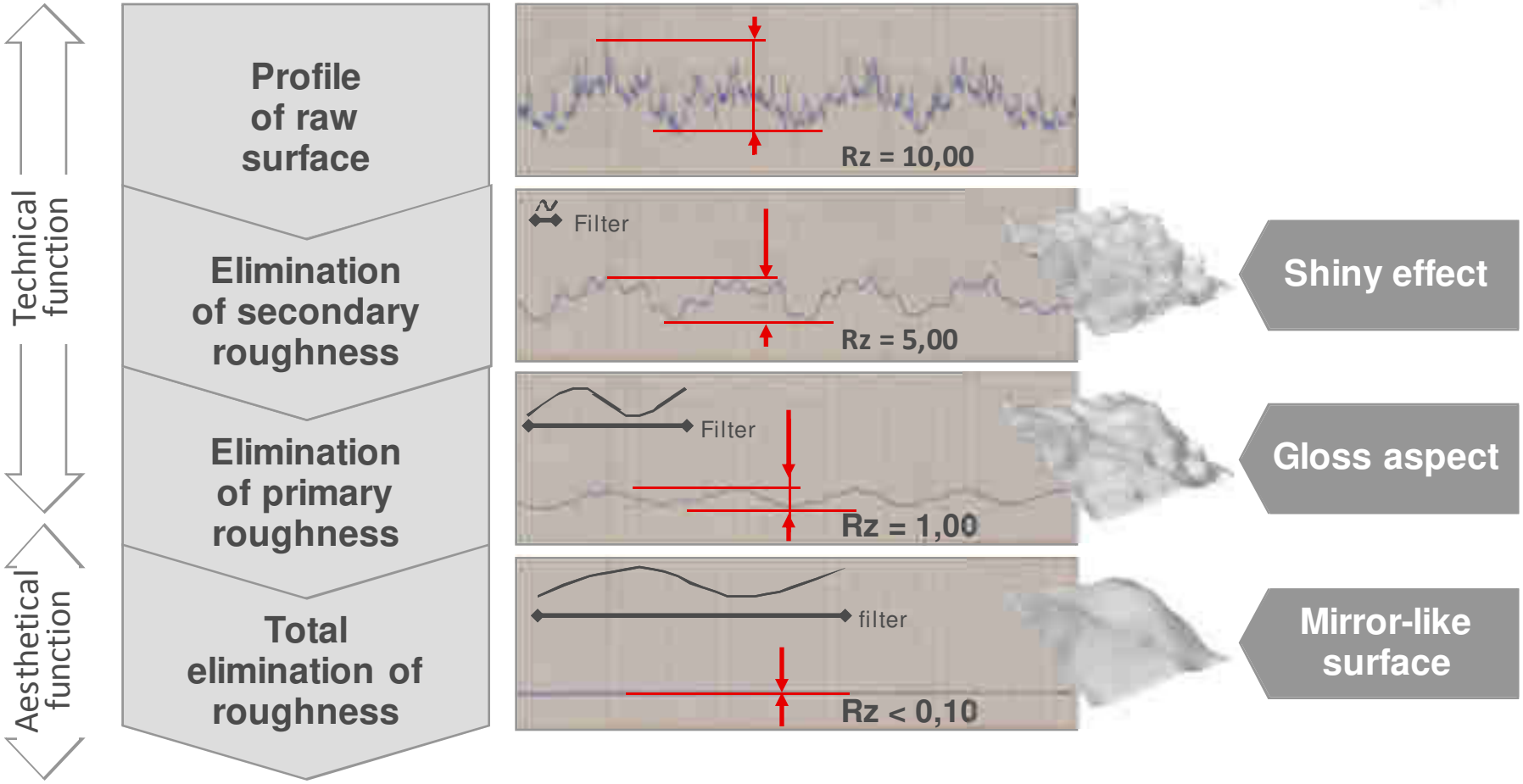
- Surface finishing process
- Mechanical, physical and catalyst technology

**Benefits**

- Access to shape and dimensional details
- Minimum material removal
- Preservation of the surface micro-structure
- Enhanced surface performance (lifetime, corrosion, friction)

# From controlled roughness to mirror-like brilliance

## Post processing: Finishing steps of MMP TECHNOLOGY®




Source: FIRST SURFACE Oberflächentechnik GmbH

# MMP TECHNOLOGY®: adapted to many materials and various manufacturing techniques

## Post processing – an example

### Materials

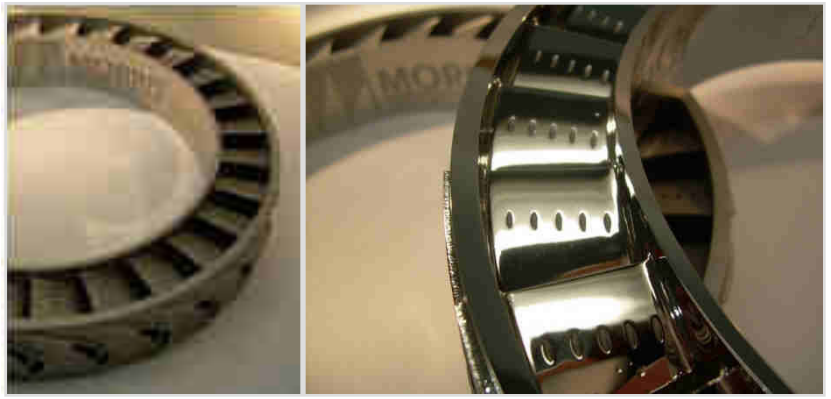
- Standard steel
- Hardened steel
- Copper
- Titanium
- Carbides – hard metal
- Coatings (PVD, CVD)
- Inconel alloys
- Precious metals
- Quartz
- Ceramics
- Plastic materials
- …

### Processes

- Milling
- Turning
- Grinding
- DMLS
- EDM
- Shot peening
- Casting
- MIM/CIM
- …

### MMP treatment

**before** **after**



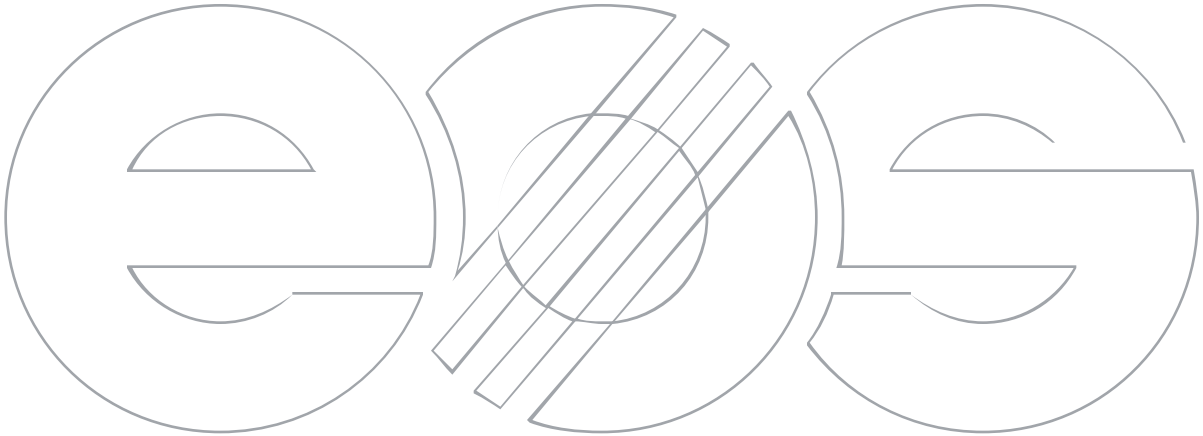
FIRST SURFACE

Oberflächentechnik GmbH

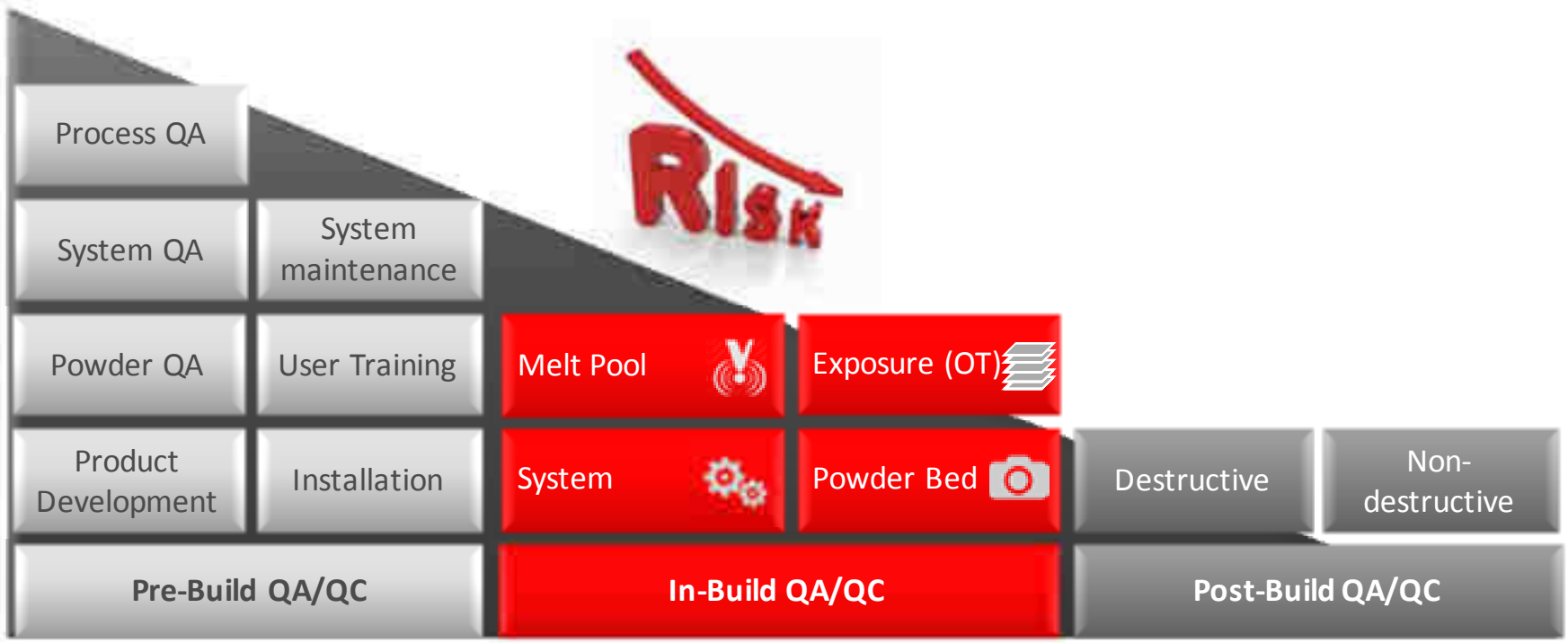
info@firstsurface.de
www.firstsurface.de

Source: FIRST SURFACE Oberflächentechnik GmbH

# EOS DMLS Monitoring



# Value Add: Risk reduction

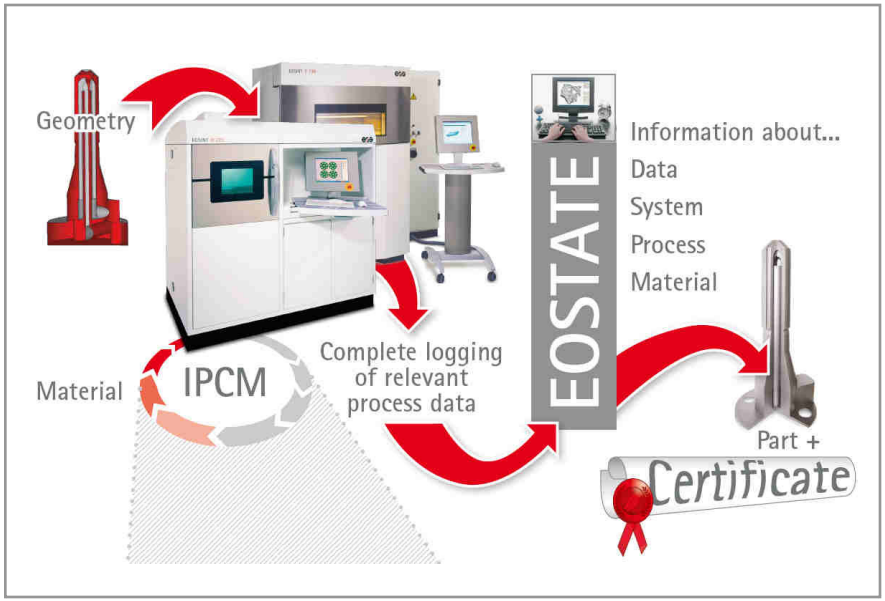



Risk reduction is a key aspect when moving DMLS towards production – together we can reduce it to a minimum.

# Integrated Quality Management System (IQMS)

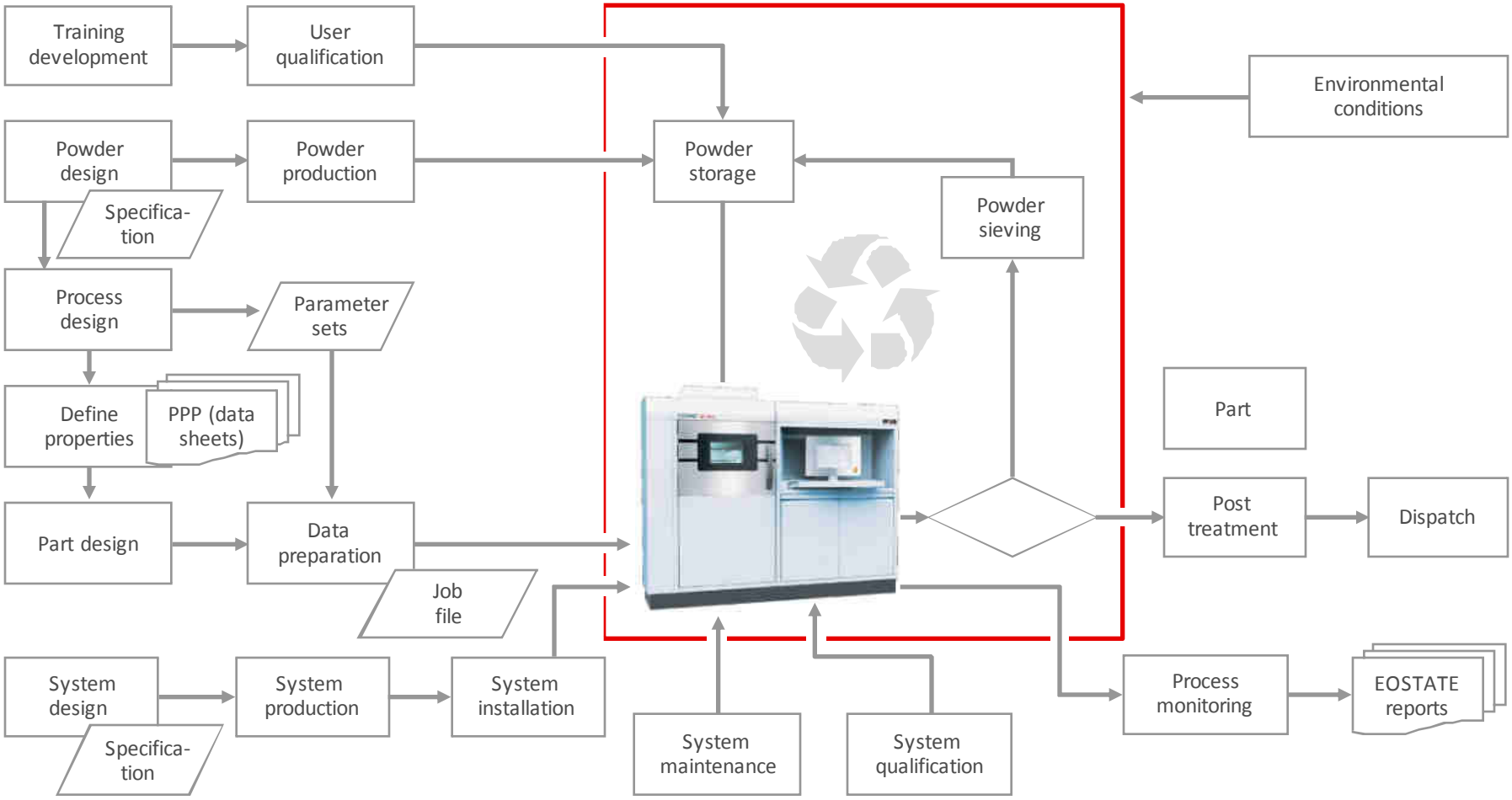
The EOS concept for fulfilling quality requirements and achieving the highest possible quality levels in e-Manufacturing using EOS products

- Including laser-sintering systems, materials, software and part data
- Including design-for-quality, monitoring and documentation of quality-relevant factors




Source: EOS

# IQMS covers everything that influences part quality



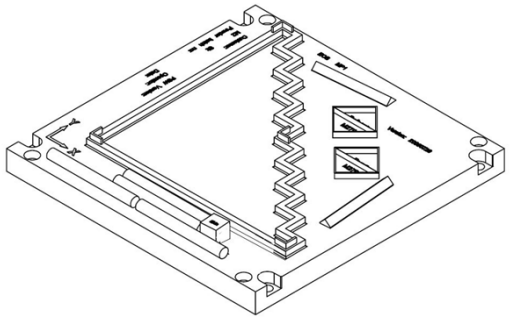

Source: EOS

# EOS has thorough quality assurance procedures for the manufacture of EOSINT machines

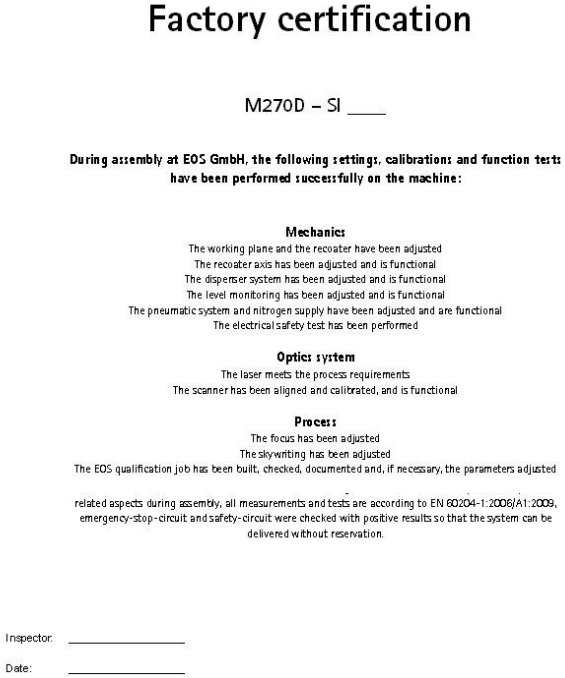
## QA of EOSINT machines

All relevant stages in the supply chain and production are subject to documented quality assurance procedures (specifications, tests, documentation etc.)

- At (sub-) suppliers via quality assurance agreements
- Within EOS via Quality Management System (ISO 9001)



QA job built on every EOSINT M machine



Factory certificate

M270D – SI ____

**During assembly at EOS GmbH, the following settings, calibrations and function tests have been performed successfully on the machine:**

**Mechanics**
The working plane and the recoater have been adjusted
The recoater axis has been adjusted and is functional
The dispenser system has been adjusted and is functional
The level monitoring has been adjusted and is functional
The pneumatic system and nitrogen supply have been adjusted and are functional
The electrical safety test has been performed

**Optics system**
The laser meets the process requirements
The scanner has been aligned and calibrated, and is functional

**Process**
The focus has been adjusted
The skywriting has been adjusted
The EOS qualification job has been built, checked, documented and, if necessary, the parameters adjusted

related aspects during assembly, all measurements and tests are according to EN 60204-1:2006/A1:2009, emergency-stop-circuit and safety-circuit were checked with positive results so that the system can be delivered without reservation.

Inspector: _____

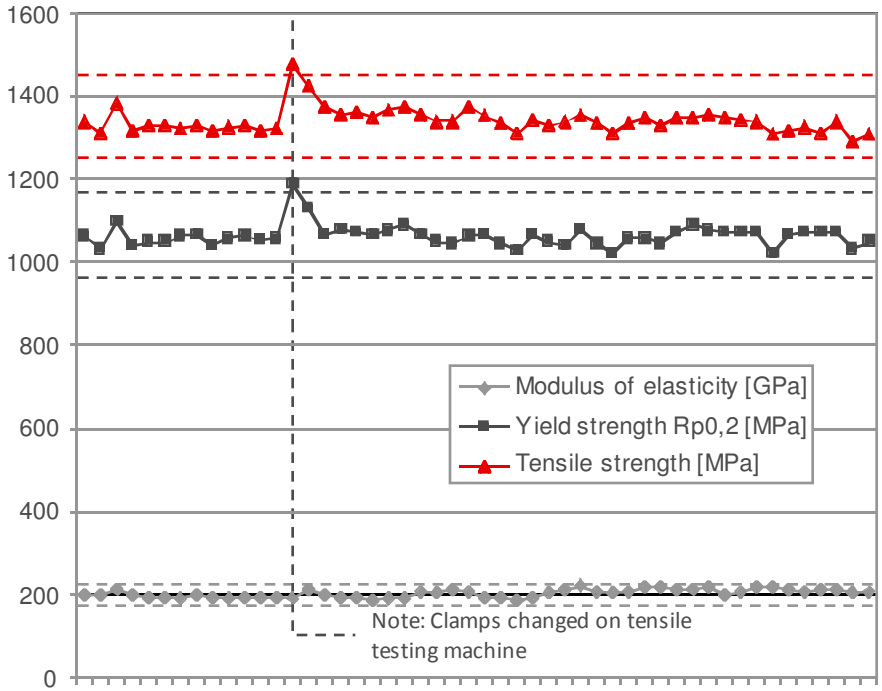
Date: _____

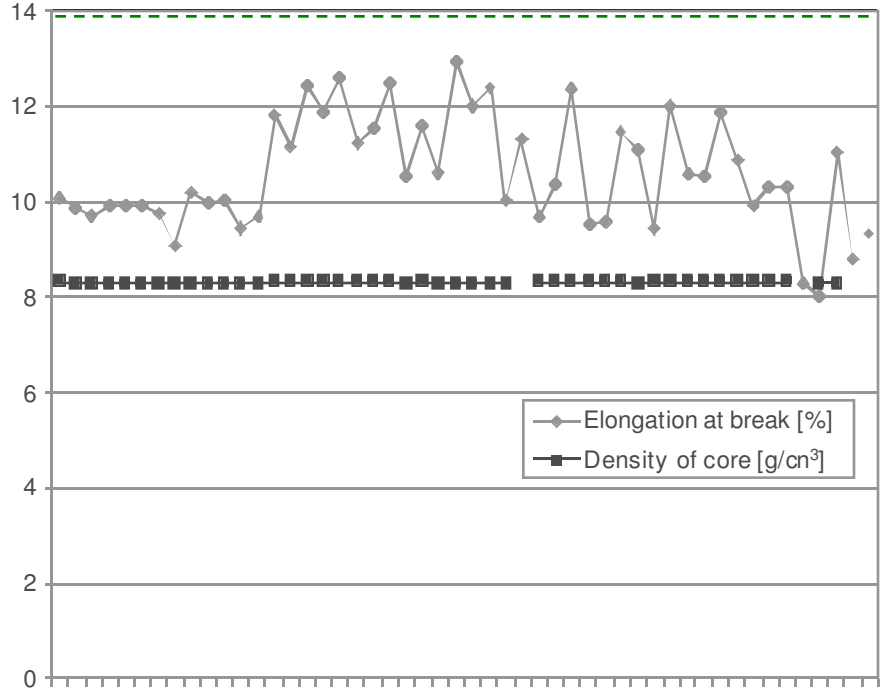
Factory certificate, issued for every EOSINT M machine

Source: EOS

# EOS builds and analyses test parts on every EOSINT M system during quality assurance

## Examples of statistics with EOS CobaltChrome MP1



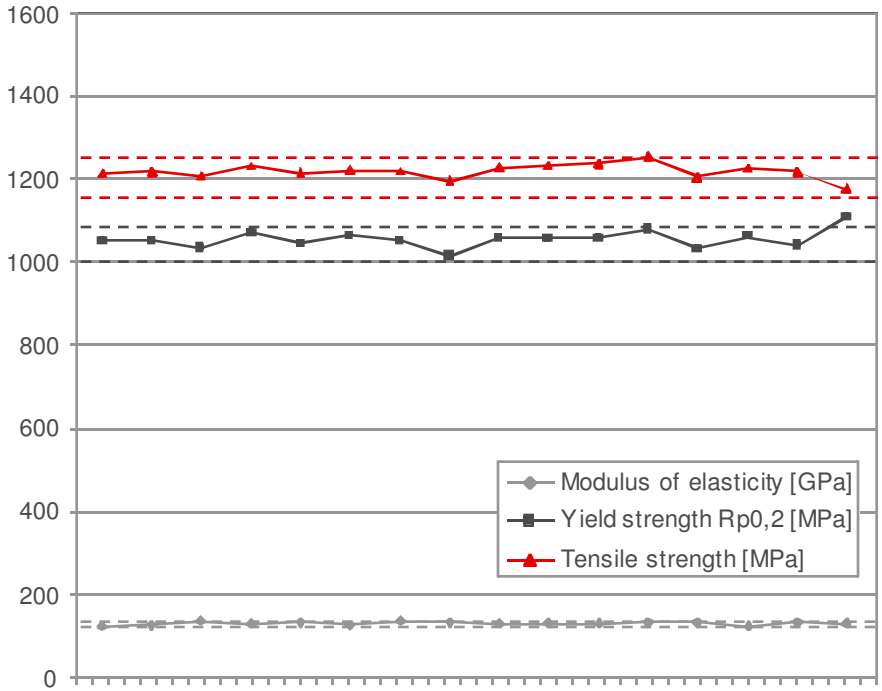

Properties of EOS CobaltChrome MP1 parts built on 44 consecutively produced EOSINT M 270 systems

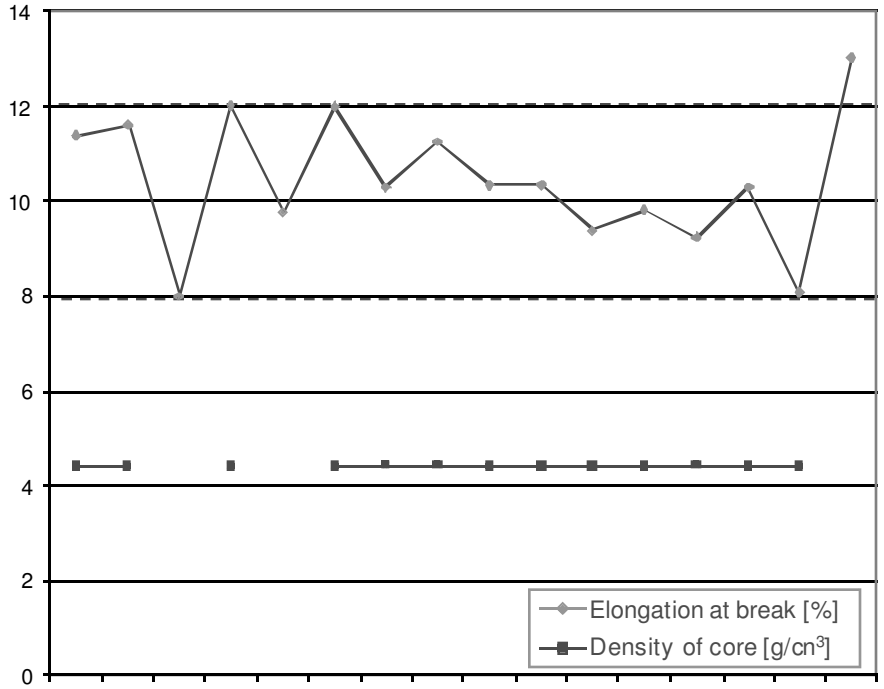
Tensile testing according to ISO 6892-1:2009 (B) Annex D, horizontal specimens

Note: Dotted lines show typical range specified in material data sheet
Source: EOS

# EOS builds and analyses test parts on every EOSINT M system during quality assurance

## Examples of statistics with EOS Titanium Ti64



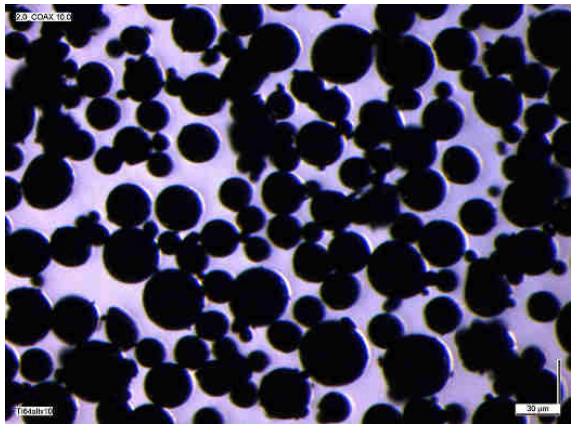

Properties of EOS Titanium Ti64 parts built on 16 consecutively produced EOSINT M 270 systems

Tensile testing according to ISO 6892-1:2009 (B) Annex D, horizontal specimens

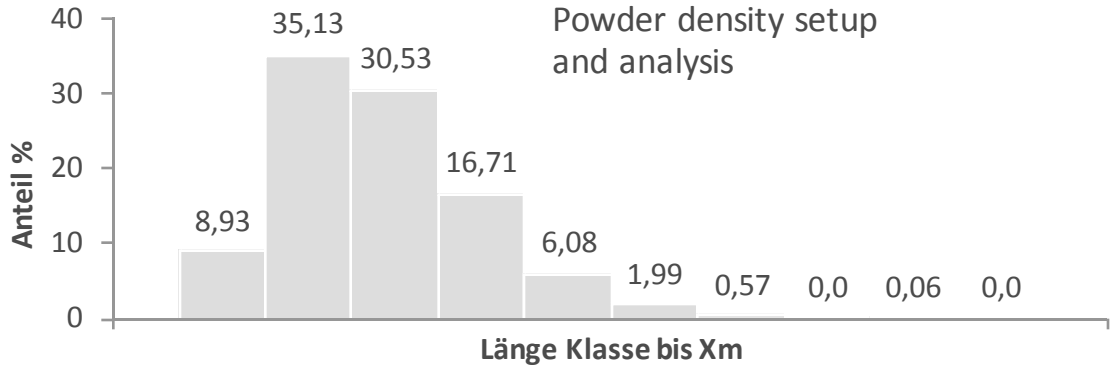
Note: Dotted lines show typical range specified in material data sheet
Source: EOS

# EOS applies thorough quality assurance in materials and process development

## Powder characterization



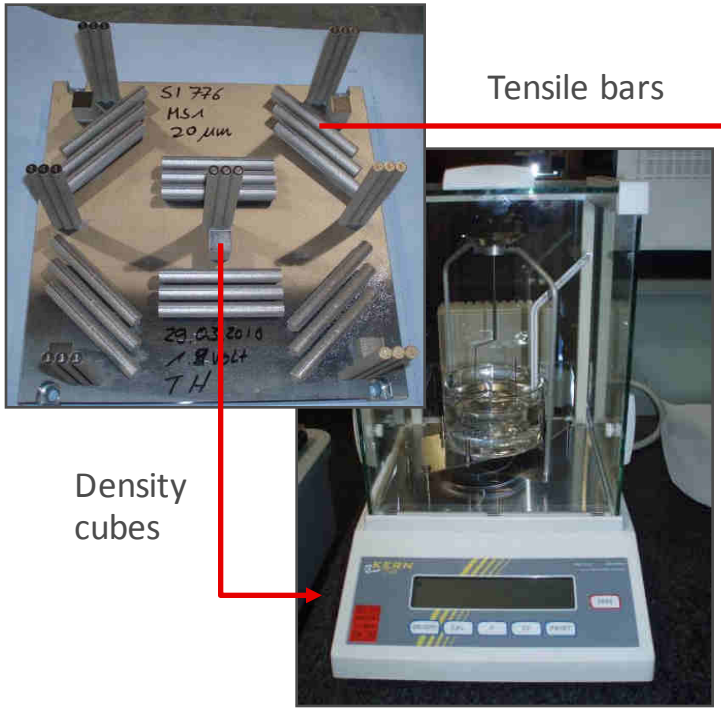
DIN ISO 3923-2 "Metallic powders – Determination of apparent density – Part 2: Scott volumeter method"



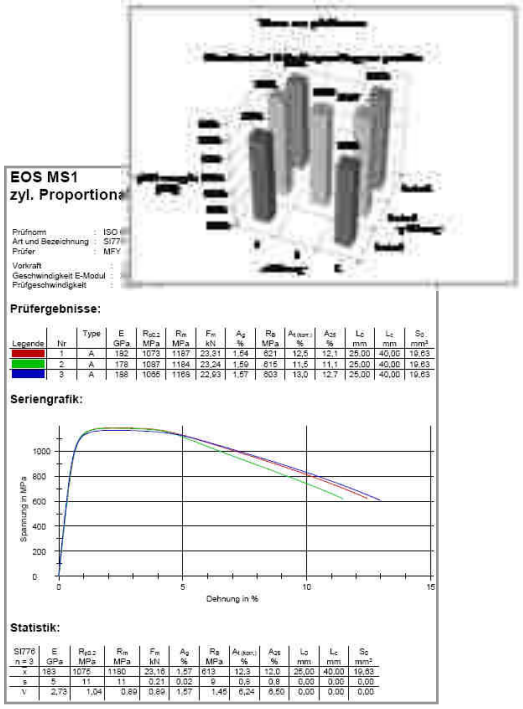

Source: EOS

# EOS applies thorough quality assurance in materials and process development

## Measurement of density and mechanical properties




EN ISO 3369 "Impermeable sintered metal materials and hardmetals – determination of density"


Zwick/Roell Z050, max. force 50kN, force accuracy according to ISO 7500-1, extensometer accuracy according to ISO 9513

Source: EOS

# EOS verifies the Part Property Profiles resulting from each parameter set

## Material data

- The Part Property Profiles are published as material data sheets
- Various data are measured and published, depending on the application, e.g.
  - Mechanical and thermal properties
  - Horizontal and vertical build orientations
  - As-built and heat treated
  - Room temperature and elevated temperature

**Mechanical properties of parts at 20 °C ( 68°F )**

| | As built | Stress relieved [5] |
|---|---|---|
| Tensile strength [6] | | |
| - in horizontal direction (XY) | 1350 ± 100 MPa<br>196 ± 15 ksi | 1100 ± 100 MPa<br>160 ± 15 ksi |
| - in vertical direction (Z) | 1200 ± 150 MPa<br>174 ± 22 ksi | 1100 ± 100 MPa<br>160 ± 15 ksi |
| Yield strength (Rp 0.2 %) [6] | | |
| - in horizontal direction (XY) | 1060 ± 100 MPa<br>154 ± 15 ksi | 600 ± 50 MPa<br>87 ± 7 ksi |
| - in vertical direction (Z) | 800 ± 100 MPa<br>116 ± 15 ksi | 600 ± 50 MPa<br>87 ± 7 ksi |
| Elongation at break [6] | | |
| - in horizontal direction (XY) | (11 ± 3 ) % | min. 20 % |
| - in vertical direction (Z) | (24 ± 4 ) % | min. 20 % |
| Modulus of elasticity [6] | | |
| - in horizontal direction (XY) | 200 ± 20 GPa<br>29 ± 3 Msi | 200 ± 20 GPa<br>29 ± 3 Msi |
| - in vertical direction (Z) | 190 ± 20 GPa<br>28 ± 3 Msi | 200 ± 20 GPa<br>29 ± 3 Msi |
| Fatigue life [7] | | |
| - max. stress to reach 10 million cycles | approx. 560 MPa, 81 ksi | |
| - max. stress to reach 1 million cycles | approx. 660 MPa, 96 ksi | |
| Hardness [8] | approx. 35 - 45 HRC | |

[5] High temperature stress relieved, 6 hours at 1150 °C (2100 °F) under inert argon atmosphere

[6] Tensile testing according to ISO 6892-1:2009 (B) Annex D, proportional test pieces, diameter of the neck area 5mm ( 0.2 inch), original gauge length 25mm (1 inch).

[7] Testing according to ASTM E466:1996, using vertical samples, as built, under 250 MPa ( 36.3 ksi ) stress amplitude and 44 Hz testing frequency

[8] Rockwell C (HRC) hardness measurement according to EN ISO 6508-1 on polished surface. Note that measured hardness can vary significantly depending on how the specimen has been prepared.

Extract from EOS CobaltChrome MP1 material data sheet

Source: EOS

# The modular EOS monitoring solution covers the key factors to ensure highest product quality

## System Monitoring

- Monitoring and controlling all system settings and process parameters
- Ensuring optimal machine and process conditions as a prerequisite for highest part quality

## Powder Bed

- Recoating quality
- Exposure quality

- Metallurgical properties
- Dimensional conformance

## Exposure (OT)

- Energy input (Streckenergie)
- Temporal behavior of light (e.g. post glowing of splashes)

- Metallurgical properties
- Mechanical properties
- Dimensional conformance (indirect)

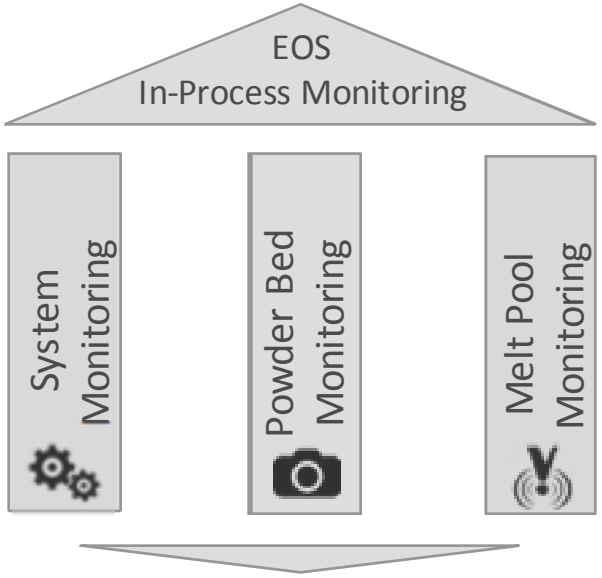
## Melt Pool

- Energy input
- Homogeneity of melt pool

- Metallurgical properties
- Mechanical properties

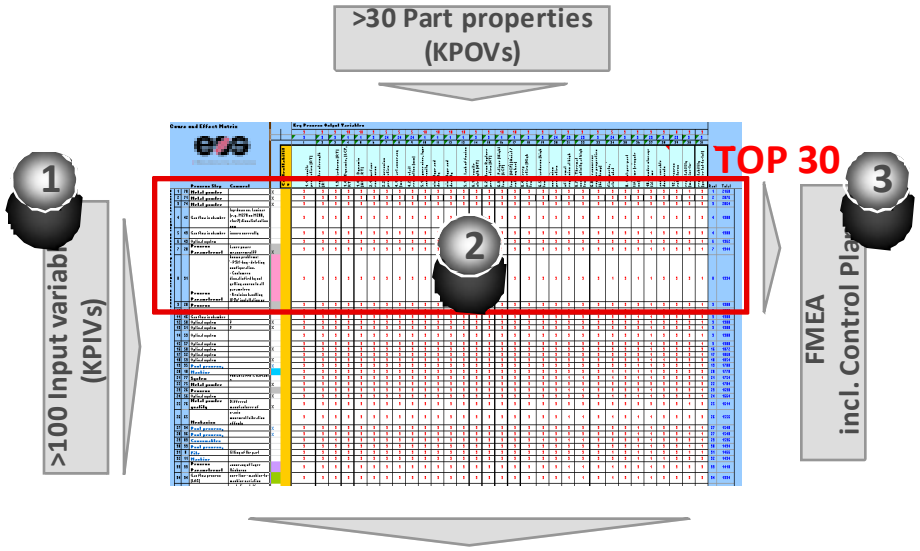
# EOS in-process monitoring is based on 3 complementary elements and is continuously verified by a structured quality analysis

## EOS In-Process Monitoring




- A Process documentation
- B Failure detection and process control
- C Cutting costs in post-process quality assurance
- D Further process understanding for process R&D

## Process FMEA – from technology understanding to process monitoring




1. Understanding and list of input variables & effect on part properties
2. Ranking of factors based on expert assessment
3. FMEA on most critical variables and control plan (minimizing the occurrence and maximizing the detection probability of failures)

EOS Pre-, In- and Post-Process Monitoring

# The EOS 3-way monitoring approach covers the key factors to ensure highest product quality

| | System Monitoring | Powder Bed Monitoring | Melt Pool Monitoring |
|---|---|---|---|
| Input Variables | ▪ System settings<br>▪ Process parameters<br>▪ System periphery settings | ▪ Recoating quality (reference)<br>▪ Exposure quality (reference)<br>▪ Failure classes | ▪ Energy intensity<br>▪ Good/ Bad process (reference)<br>▪ Classes of defects |
| Process Indicators | ▪ Moving axis<br>▪ Laser power<br>▪ Process atmosphere<br>▪ Process temperature<br>▪ Filter system | ▪ Missing powder and particles or grooves in powder bed<br>▪ Exposure localization (comparing layer data and images of processed and unprocessed material) | ▪ Homogeneity and temporal behavior of melt pool<br>▪ Influence of laser power, hatch distance and scan speed<br>▪ Influence of flow profile in process chamber (exposure strategy and splashy process) |
| Part Properties | ▪ Prerequisite for good part quality | ▪ Indication for metallurgical soundness<br>▪ Dimensional conformance (part accuracy and detail resolution) | ▪ Correlation to metallurgical properties (pores, lack of fusion,…)<br>▪ Correlation to surface quality<br>▪ Indication for mechanical properties |

# **NEW** EOSTATE Base – System Monitoring

## Monitoring sensors

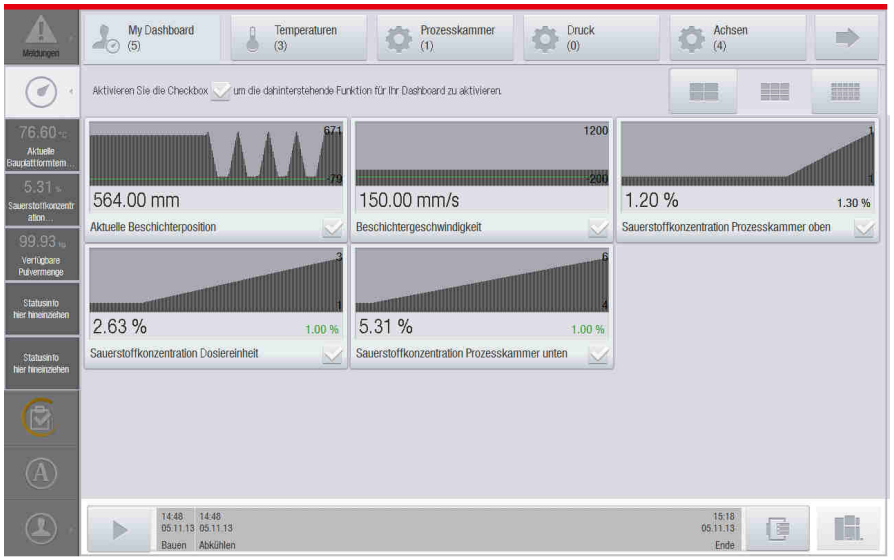
### Machine conditions

- Laser status
- Scanner status (Automatic self calibration, 'Home In')
- Cooling system status
- Electrical power surveillance incl. power outage protection
- **NEW** Build platform position measurement (layer thickness) via glass scale
- Dispenser system measurement
- Collector platform position measurement
- **NEW** Recirculation filter system: operating pressure (Set Point and real value)
- **NEW** Recirculating filter system: filter clogging ,flow rate
- Process chamber overpressure

### Process conditions

- Laser power monitoring
- Build platform temperature
- Process chamber atmosphere: oxygen-level
- **NEW** Process chamber atmosphere: temperature
- **NEW** Process chamber atmosphere: humidity
- **NEW** Ambient atmosphere: humidity temperature
- Recoater speed

## **NEW** Graph of current job shown on touchscreen




Optimal and stable machine and process conditions are a prerequisite for highest part quality

# EOSTATE LaserMeasurement

## Laser Measurement Kit

- Primes Pocket Monitor with laser sintered bracket
- Pre-defined measurement period
- Recommendation: Measurement before and after a build job

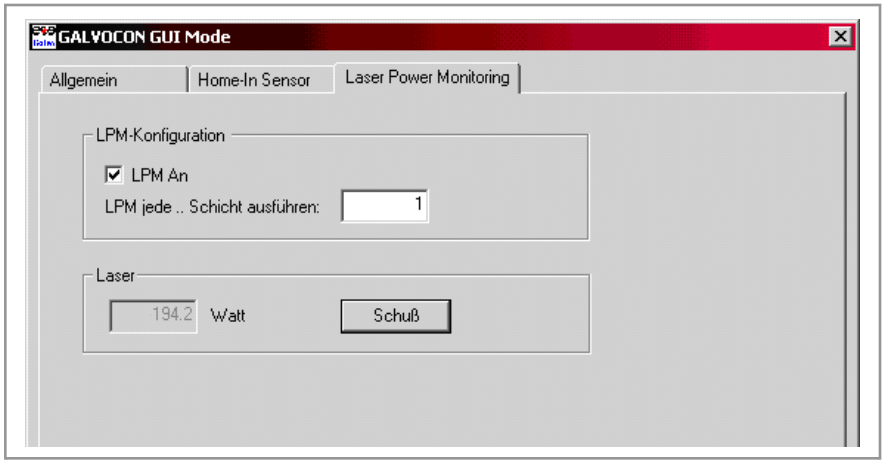
## Benefits

- Quick and easy to place Pocket Monitor in bracket
- Quick and easy to position bracket on recoater arm
- Simple and easy to use meter
- For use with EOSINT M 270 and EOSINT M 280

# EOSTATE LaserMonitoring

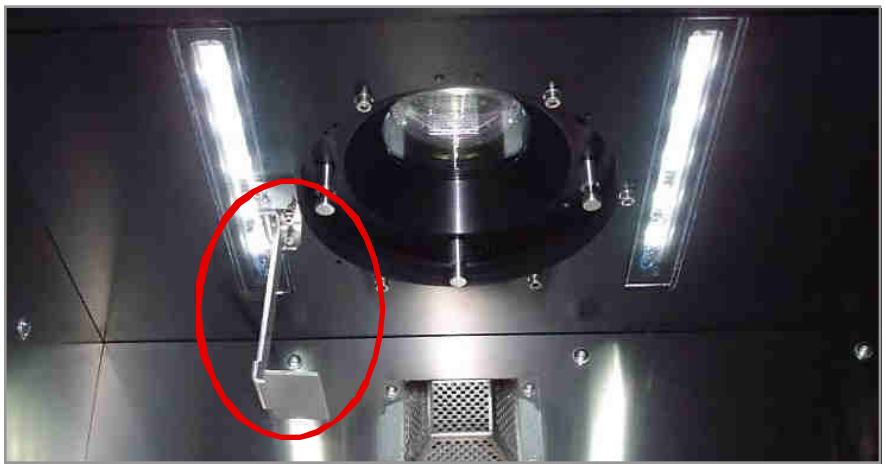
## Laser Monitoring Kit

- Online laser power monitoring during the job
- Operator can define measurement interval in PSW
- Laser exposes a defined test exposure on a beam trap inside the process chamber




## Benefits

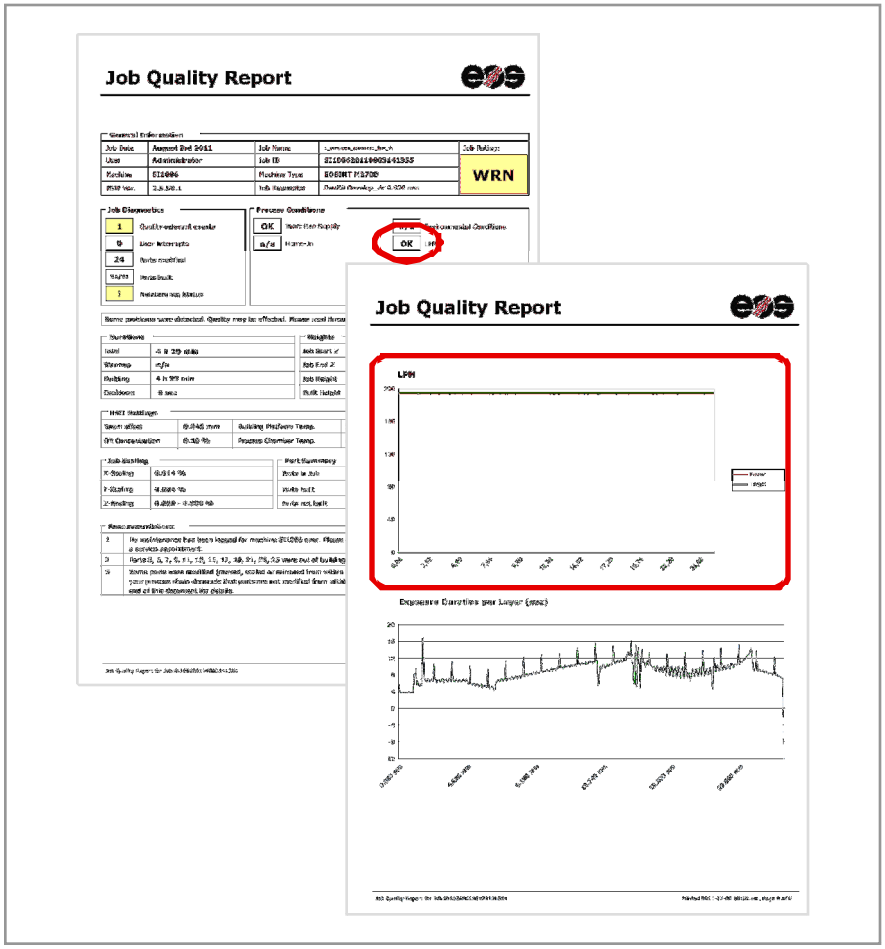
- Flexible setting of measurement frequency to suit your QA needs
- Monitoring at source (laser) to ensure that specified laser power is maintained
- Error message in case of deviation during job
- Job is not interrupted



# EOSTATE LaserMonitoring

## Laser Monitoring Reporting

- EOSTATE 1.2 Quality Assurance Module in Job Report

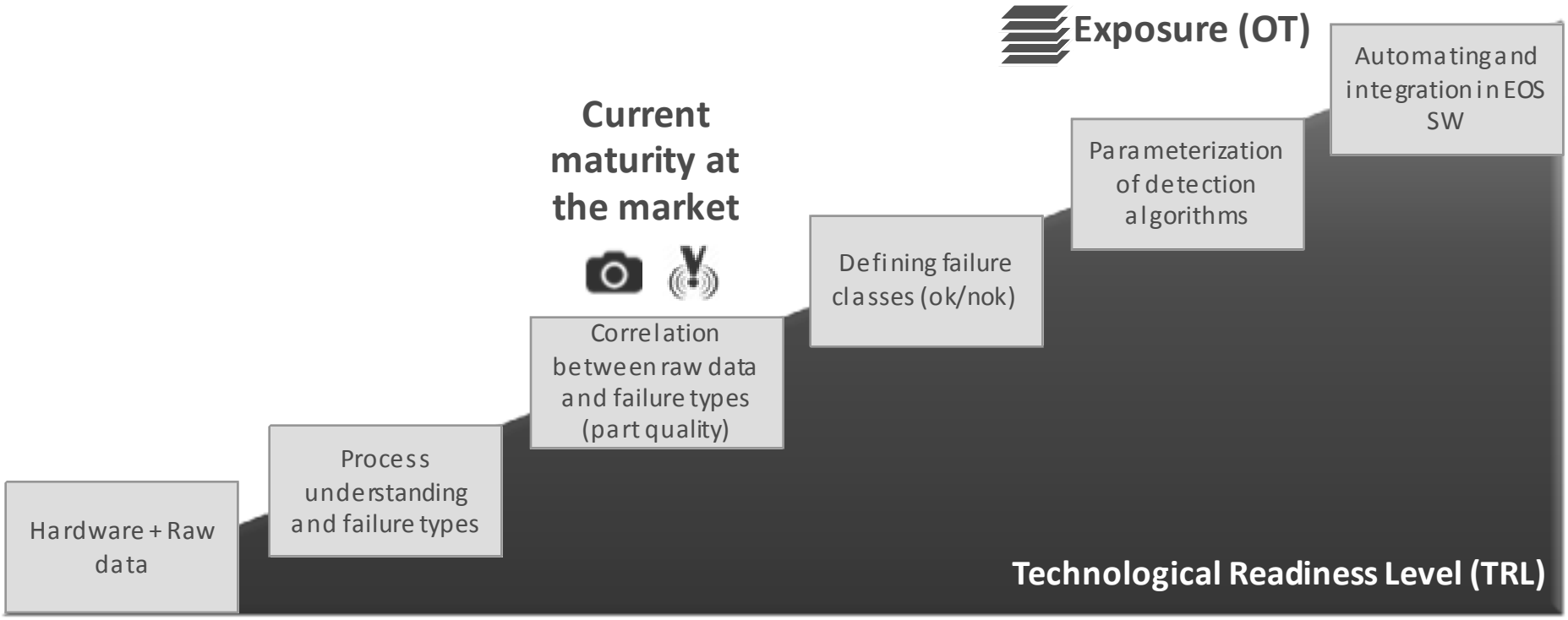



## Benefit

- Quality Assurance documentation

# Optical Tomography is very close to industrial market readiness and exclusive to EOS systems

## 6 steps to Industrial In-Process Monitoring



# **NEW** EOSTATE PowderBed – 1/2

## Recoating & Exposure monitoring

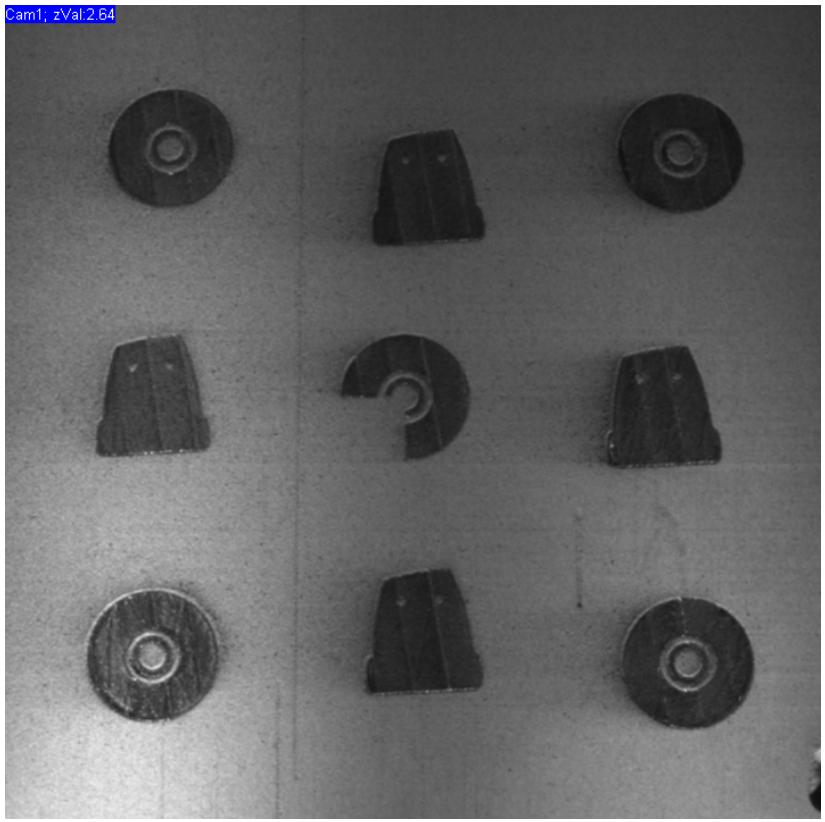
### Taking Fotos

- Camera integrated in ceiling of process chamber in the immediate vicinity of the optics (off-axis)
- Illumination has been optimized with regard to image recognition
- 2 pictures of entire build area per layer, one after exposure and one after recoating
- Less is more, e.g. 1.3 Megapixel standard industrial camera, less data for image recognition in realtime and realtime calculation

### Viewing Fotos

- Touchscreen: most recently taken image + flip through past layers of current job
- EOSTATE plug-in on desktop PC: all images + flip through layers of selected job + flipbook (AVI export)
- Recoater speed

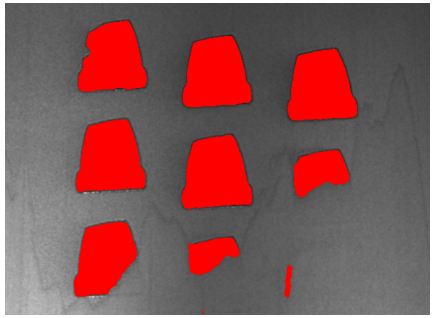
## Step I: Flip-Book of a good job

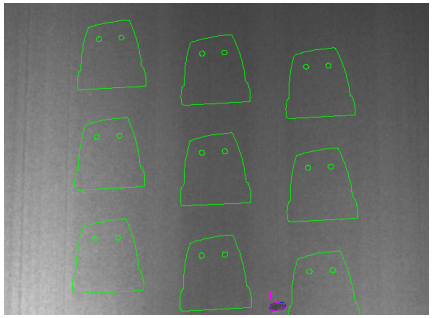
# **NEW** EOSTATE PowderBed – 2/2

## EOSTATE PowderBed – Step II & III

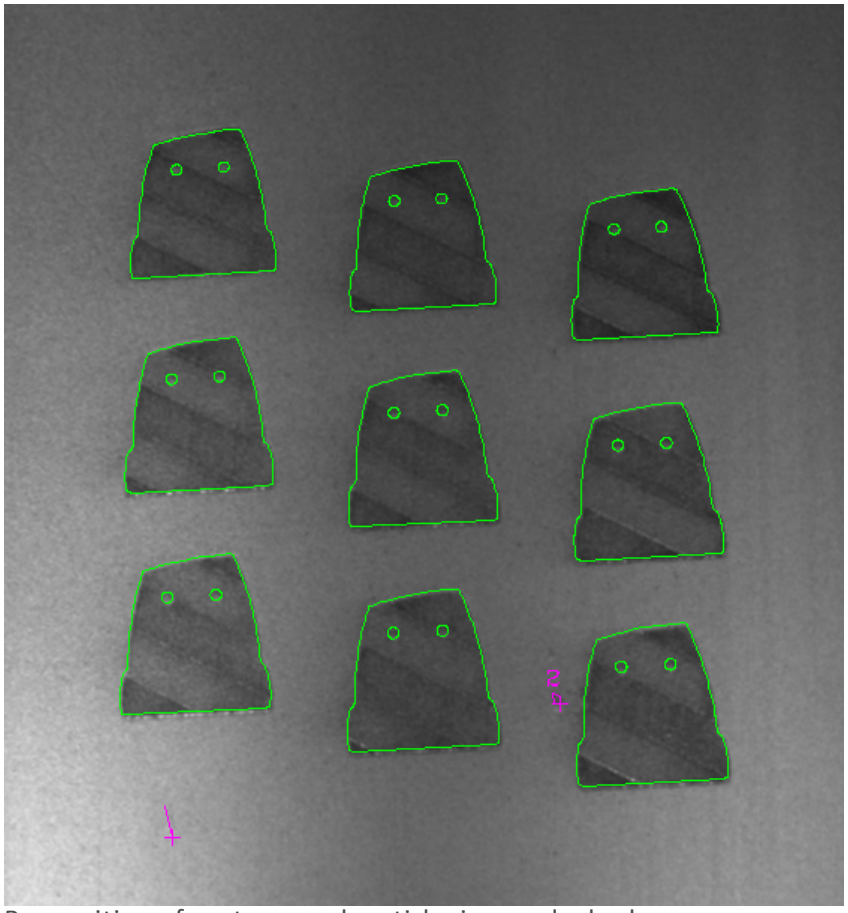
- Step II and III allow software-based **image recognition**, **error identification** and **closed-loop control**
- Test software and image recognition algorithms have been developed, according to **specific conditions** and needs of the **DMLS process**
- Control of **exposure quality** through advanced **edge detection** algorithms
- Automatic **assurance of recoating quality**
- **Allocation** of detected failure to specific layer an part number
- Next step: Full **integration** in EOS software architecture and **user-friendly GUI**



Recognize insufficient recoating



Repeat recoating until OK



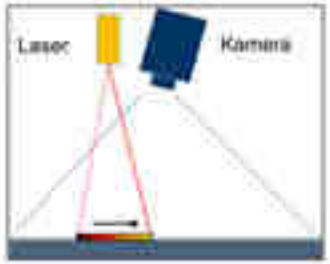
Recognition of contours and particles in powder bed

# **FUTURE** EOSTATE Exposure (OT technology)

## Technological principle

Langzeitbelichtung
Stadtverkehr

→ Verkehrsmenge




Helligkeit im Foto enstpricht
Strahlungsleistung x Zeit

→ Maß für Energieeintrag /
Streckenenergie

Langzeitbelichtung
Generative Fertigung

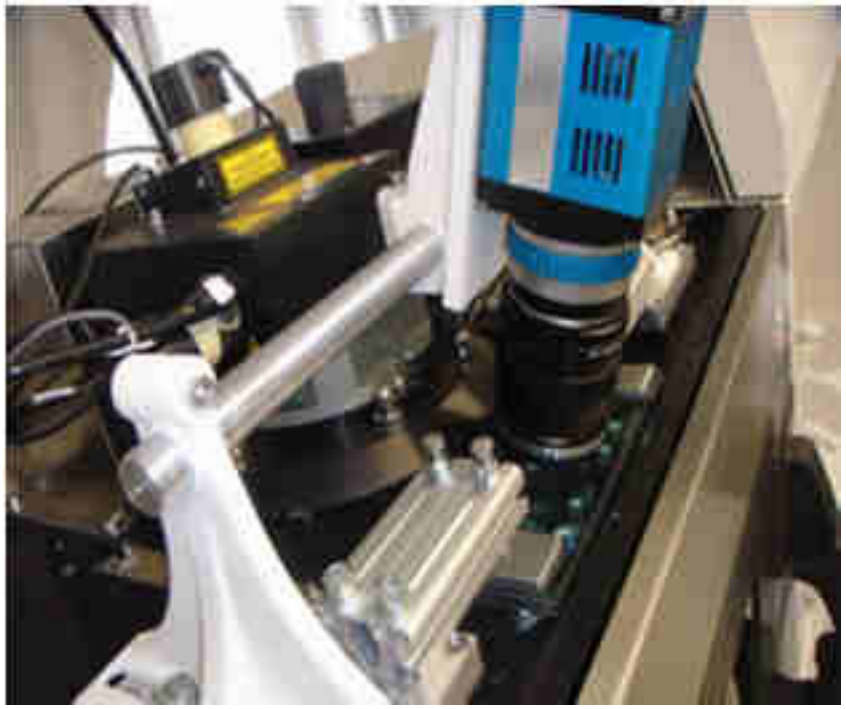
→ Wärmemenge

- Looking at entire platform
- Monitoring emitted light of **melt pool plus periphery** with camera
- "Quasi long-time" exposure to process light
- Analyzing and comparing to good process reference
- Defined failure types
- Statistical correlation to part quality allows conclusion on part quality

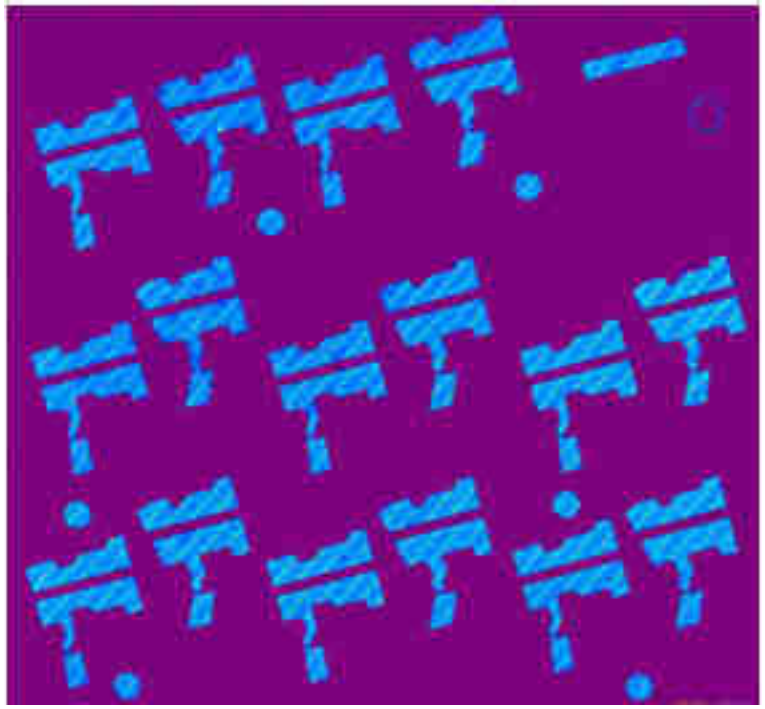
Source: MTU

# Optical Tomography is camera-based monitoring technology, designed and approved for serial production

## Camera based optical tomography



Optical tomography system allows for 100% monitoring of all layers



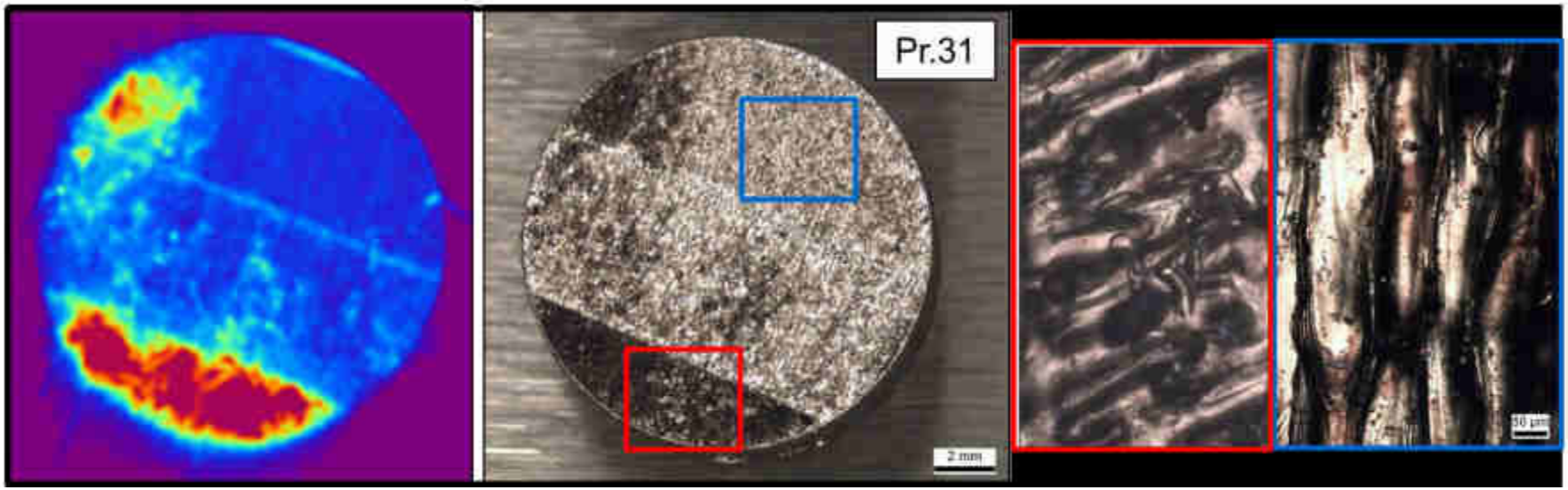
Optical tomography monitoring of serial production

Source: MTU

# EOSTATE Exposure detects process phenomena and failure types – in the process and in the part

## Layer information and microscope inspection of the same layer

OT-inspection | Overview | Detailed view



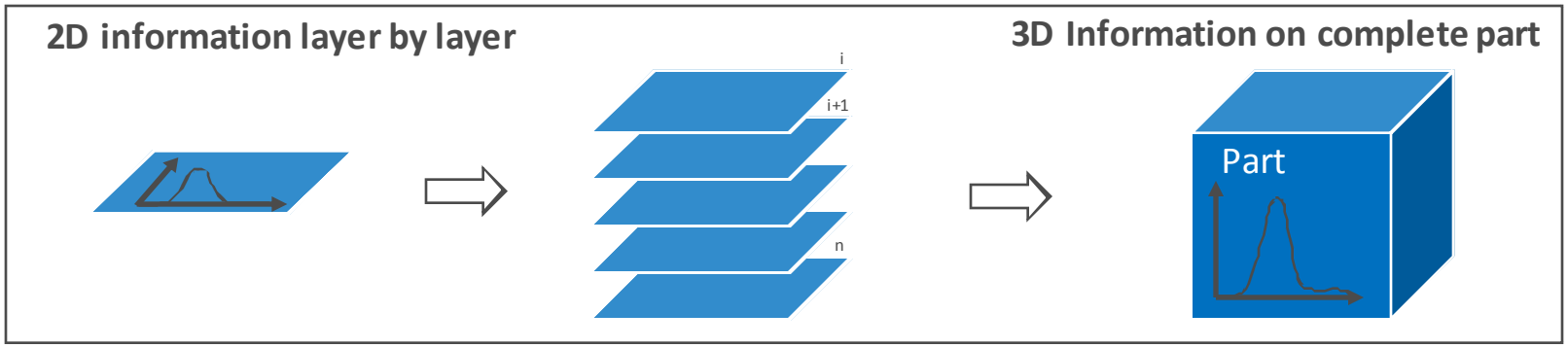

Source: MTU

# EOSTATE Exposure allows a holistic part quality assessment – layer by layer, part by part

## Layer wise reconstruction of 3D information on part quality

**Monitoring of:**

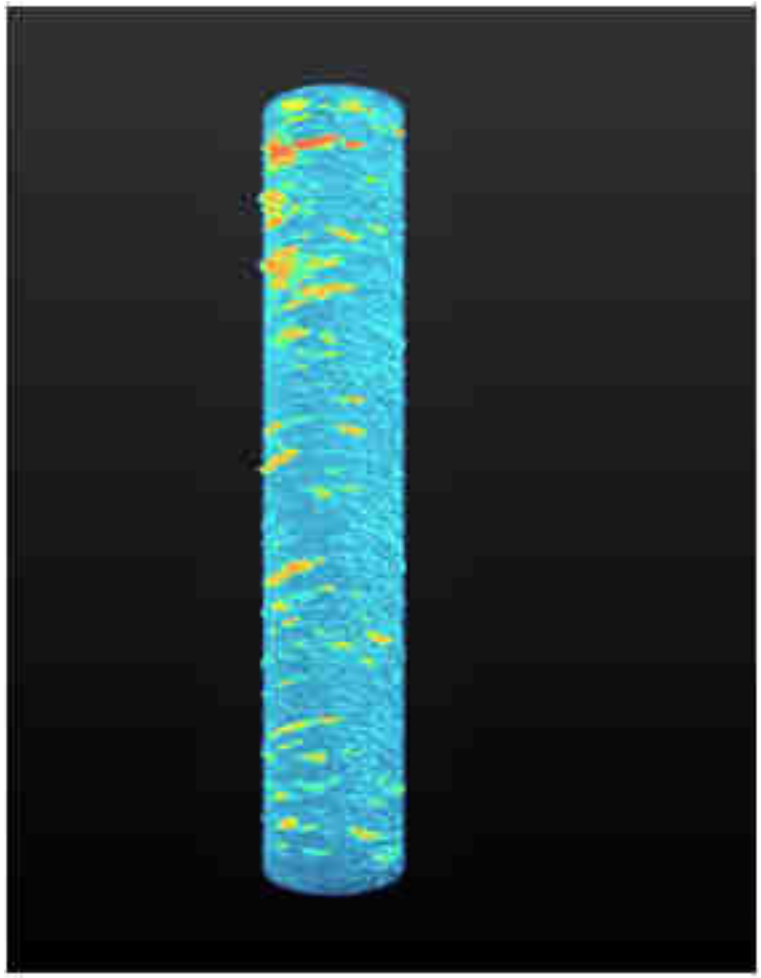
- Process conditions
- Recoating process
- Exposure process

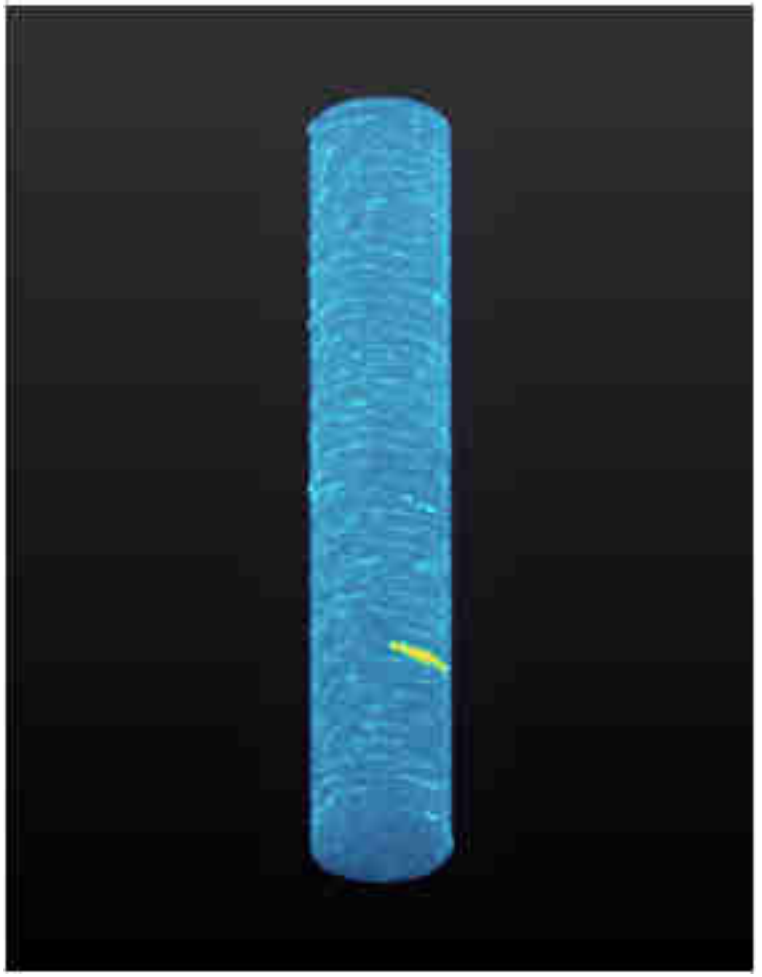



**Typical errors:**


Source: MTU

# Animated visualization with failure indication

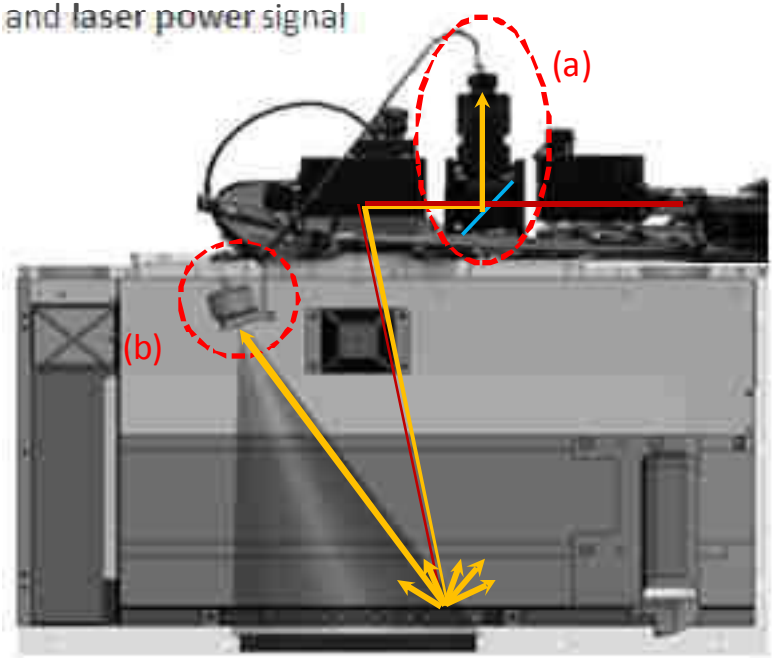




# **FUTURE** EOSTATE MeltPool – 1/2

## Principle of operation

- Capturing **light emissions from DMLS process** with **photodiode-based sensors**
  a) „On-Axis“ configuration (= through the scanner)
  b) „Off-Axis“ configuration (= diode inside process chamber)
- Correlation of **sensor data** with **scanner position** and **laser power** signal



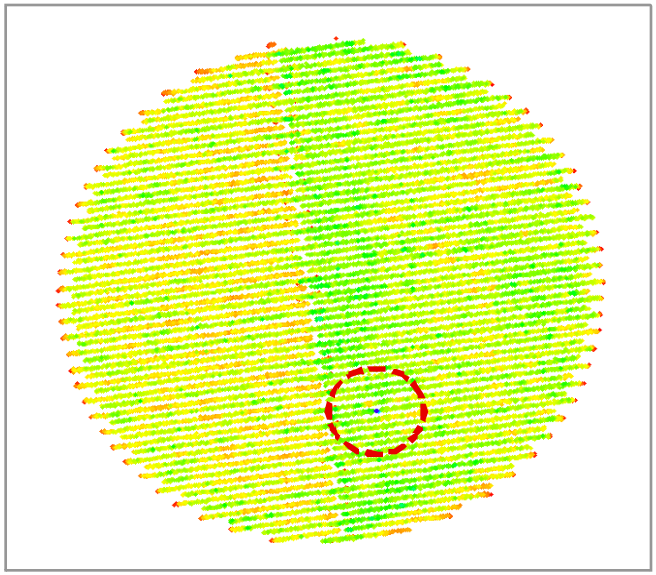

## Benefits

- Sensing **light intensity** and **signal dynamics**, which are among the **most relevant indicators** for process behavior
- Photodiodes offer **high temporal resolution** adequate to the extreme dynamics of DMLS process
- **Partnership with experienced industry partner** established, co-development ongoing
- Leveraging synergies of **EOS process know-how** and partner’s industrial **monitoring and data handling** expertise
- Advanced melt pool monitoring fosters deeper **process understanding**
- Very promising candidate for **automatic quality surveillance**
- Future potential for **closed-loop control**

# **FUTURE** EOSTATE MeltPool – 2/2

## Current development status

- R&D systems mounted on several EOS machines
- Development of algorithms for **data analysis** and **visualization**
- Tests program comprises **parameter variation**, **provoked errors and standard processes**



Mapping of data of a tensile bar
(Pseudo-color visualization)

## R&D – next steps


- Further **elaboration of algorithms**
- Deepening **know how about correlations** of monitoring data, process characteristics and part quality
- Implementation in **user-friendly software**, data reduction, graphical data presentation

# Monitoring is only the first element

## … of three, which are essential for holistic Quality Control / Quality Assurance

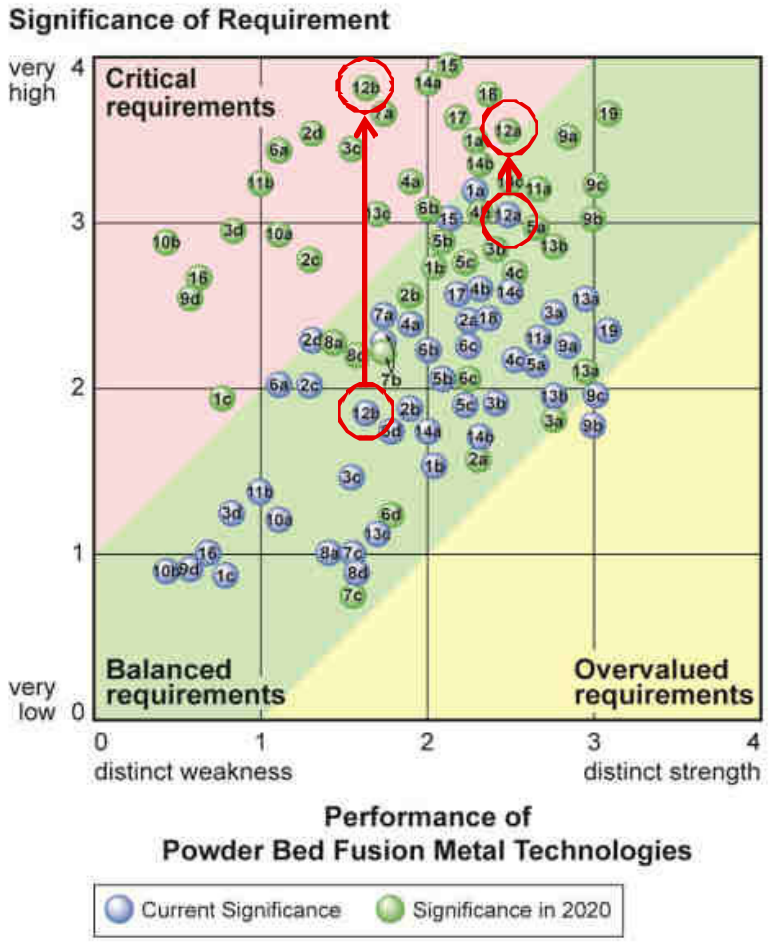

| | MONITOR | ANALYSE & INTERPRET | ACT |
|---|---|---|---|
| PURPOSE | Value(s) from measuring device(s), state of a system | Comparison of theoretical and actual value(s) and interpretation thereof to detect errors and/or trends | Intervention to prevent and/or repair errors |
| DOCUMENT | Raw Data recorded, e.g. in Database | Results recorded, e.g. in QA documentation, error message(s) | Confirmation of action recorded, e.g. in QA documentation |

# In-build QC is one of the most critical requirements in the future

## Significance-performance portfolio for Powder Bed Fusion Metal Technologies

HEINZ NIXDORF INSTITUTE
University of Paderborn
Product Engineering
Prof. Dr.-Ing. Jürgen Gausemeier

DMRC




1. **Build chamber volume (V in m³)**
1a) V < 1 m³
1b) 1 m³ ≤ V ≤ 8 m³
1c) V > 8 m³
2. **Build-up rates (production speed at highest quality in cm³/h)**
2a) 1 - 10 cm³/h
2b) 11 - 40 cm³/h
2c) 41 - 100 cm³/h
2d) > 100 cm³/h
3. **Minimal surface quality of parts with highest quality (measured by its average surface finish $R_a$)**
3a) $R_a$ ≥ 10 µm
3b) 5 µm ≤ $R_a$ < 10 µm
3b) 1 µm ≤ $R_a$ < 5 µm
3d) $R_a$ < 1µm
4. **Dimensional accuracy (average deviation in µm)**
4a) <±50 µm
4b) ±50 - 100 µm
4c) > ±100 µm
5. **Layer thickness (in mm)**
5a) < 0,05 mm
5b) 0,05 - 0,099 mm
5c) 0,1 - 2 mm
6. **Machine incidental acquisition costs (in % p.a. referring to machine acquisition costs)**
6a) < 4% p.a.
6b) 5 - 10% p.a.
6c) 11 - 15% p.a.
6d) > 15% p.a.
7. **Maintenance costs (in % p.a. referring to machine acquisition costs)**
7a) < 10% p.a.
7b) 10% - 20% p.a.
7c) >20% p.a.
8. **Processability of materials with AM-machines**
8a) Magnesium
8d) Shape memory alloys (SMA)

9. **Availability of new material properties**
9a) Fire resistance
9b) Thermal conductivity
9c) Electrical conductivity
9d) Self-healing properties
10. **Flexible / hybrid material processing**
10a) Processing different types of material by one machine (sequential processing of e.g. plastics and metals)
10b) Processing different types of material within one job (simultaneous multimaterial processing of e.g. plastics and metals)
11. **Possibility to build up on existing structures**
11a) Building up on flat surface
11b) Building up on 3D surface
12. **Quality control in production processes**
12a) Conduct quality control after job completion
12b) Conduct quality control on-line (during job)
13. **Process integration**
13a) Partial integration (e.g. powder management system)
13b) Automated integration of AM-machines into production line
13c) Highly integrated AM-machine (machine as production line)
14. **Certification**
14a) Ensure continuous certification in the aircraft production (usability of parts in aviation)
14b) Ensure continuous certification in the automotive production (usability of parts in traffic)
14c) Ensure continuous certification in the manufacturing equipment (usability of parts in manufacturing equipment)
15. **High Process stability**
16. **Integration of electronic circuits into additively manufactured parts**
17. **Provision of design rules**
18. **Availability of a database containing properties of additively processed materials** (e.g. thermal characteristics, tensile strength etc.)
19. **Recyclability of materials**