e-Manufacturing Solutions

EOS GmbH
Electro Optical Systems

CAE Molding Solution Alliance Conference 2014

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Agenda

e-Manufacturing Solutions

- Company
- Basic Concepts
- Applications
- New Technology
- China Service Provider

Company

EOS: Technology and Market Leader for Design-Driven, Integrated e-Manufacturing Solutions

e-Manufacturing Solutions

- **Family-owned**, founded in 1989,
- Headquartered in Krailling near **Munich, Germany**
- **Integrated solution provider for Additive Manufacturing**
- **Solution portfolio:** Additive Manufacturing (AM) systems, materials (plastics and metals), software and services
- **Complete end-to-end solutions:** from part design and data generation to part building and post-processing
- **EOS enables competitive advantages for a variety of industries**, such as medical, aerospace, tooling, industry, lifestyle products and automotive
- EOS is committed to: **Innovation – Quality – Sustainability**

EOS Management

Christian Kirner | Dr. Tobias Abeln | Dr. Hans J. Langer | Dr. Adrian Keppler

EOS Headquarters in Krailling, Germany

EOS: Global Presence

e-Manufacturing Solutions

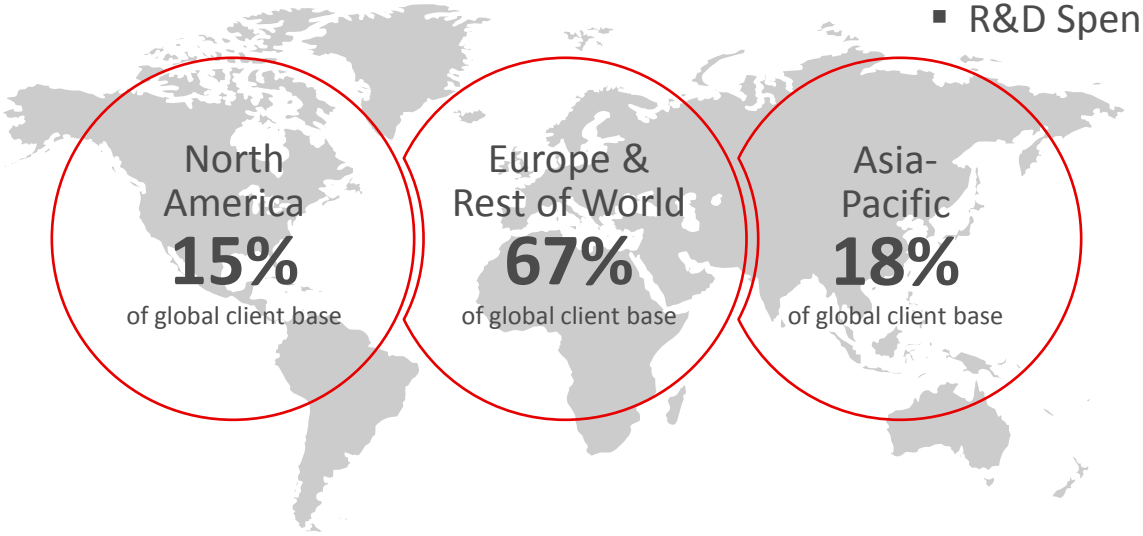
EOS worldwide installed base

1,330 Systems

- ⅓ Metal systems
- ⅔ Polymer systems
- 266 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 500 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.

EOS: A Success Story

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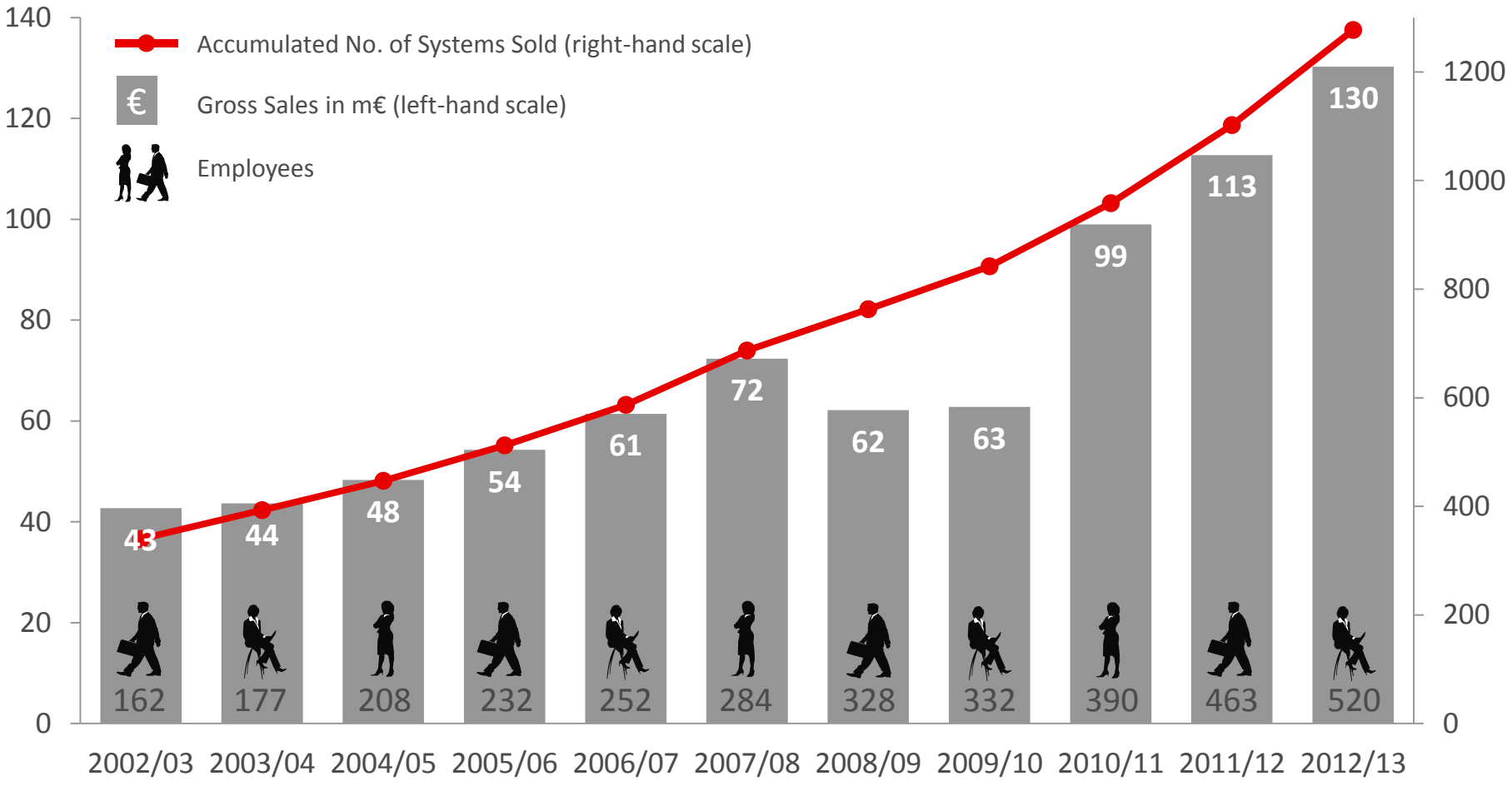

Source: EOS. Figures for EOS Group, for financial years ending 30 September. Number of Employees: Headcounts.

EOS: Awards & Achievements

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Innovation Leader

- EOS holds more than **700 active patents** in nearly **100 patent families**
- **"Top 100 – the Most Innovative Medium-Sized Companies"** award (2006, 2007, 2008, 2012, 2013)
  Top Innovator of the Year 2013

Attractive Employer

- **"Bavaria's Best 50"** award (2008 and 2011)
- **"Great Place to Work"** employer award (2008)

Top Innovator of the Year 2013 in the category of companies with more than 250 employees.

EOS: A Global Organisation

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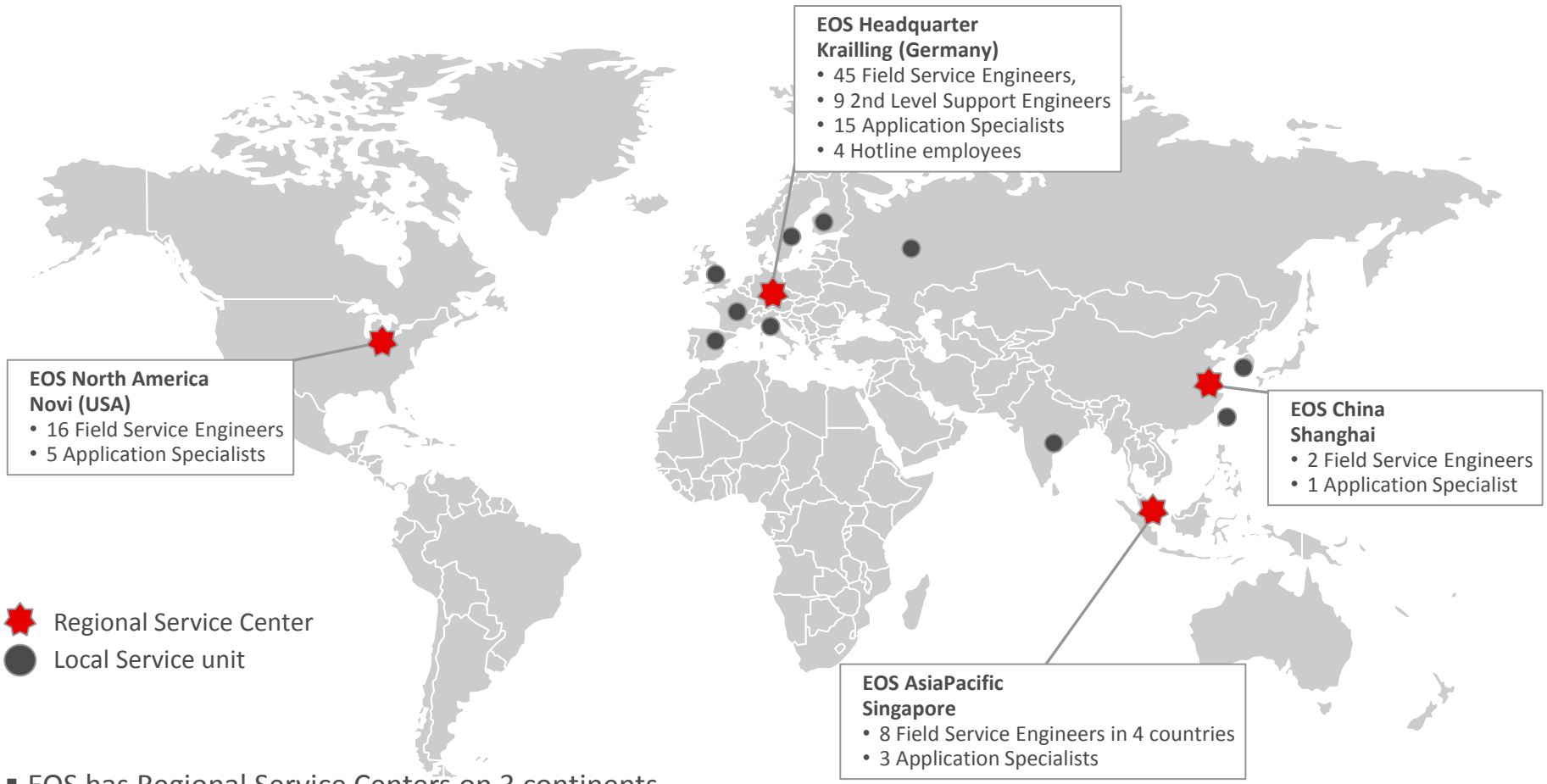

- EOS has Regional Service Centers on 3 continents
- A growing number of local Service units with own Field Service Engineers and depots ensures customer vicinity in key regions
- Application Engineers consult on customer specific application challenges.

Customers from Numerous Industries Rely on EOS Technology

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OEMs

Service Providers

Sample customers.

Basic Concepts

3D Printing / Additive Manufacturing

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Different Types of Technology

- **Selective Laser Sintering (SLS)**
  - Ex. EOS
- **Selective Laser Melting (SLM)**
  - Ex. EOS
- **Stereo lithography (SLA)**
  - Ex. 3D Systems
- **Fused Deposition Modeling (FDM)**
  - Ex. Stratasys (Objet)

OTHERS:

- Polyjet
- DLP
- LOM
- EBM
- LENS
- Other 3D Printing

Additive manufacturing (**AM**) also known as *3D printing,* is defined by ASTM as the "process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies, such as traditional machining. Synonyms include *additive fabrication*, *additive processes*, *additive techniques*, *additive layer manufacturing*, *layer manufacturing*, and *freeform fabrication*".

Freedom of Design

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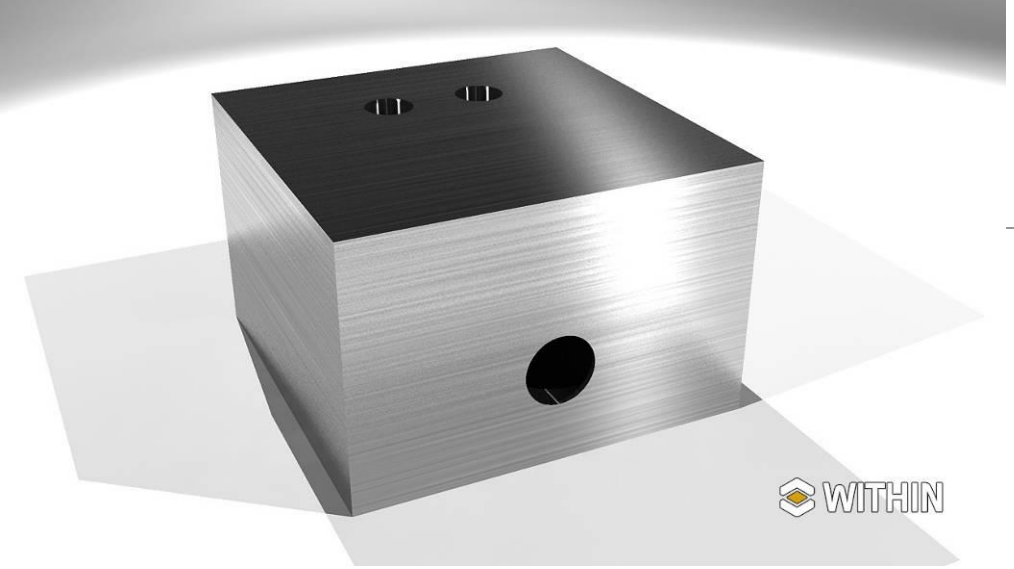
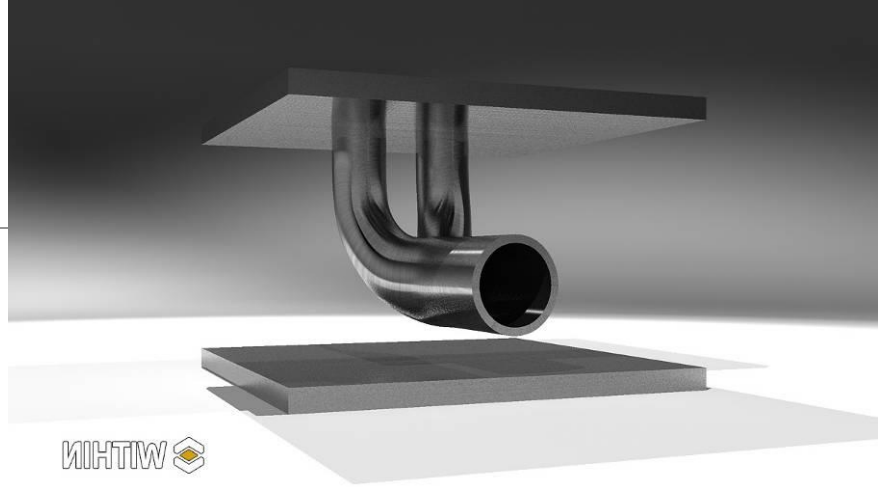
自由成型
打破传统加工制造工艺的限制

制造为导向的设计

设计为导向的制造

Source: EOS


WITHIN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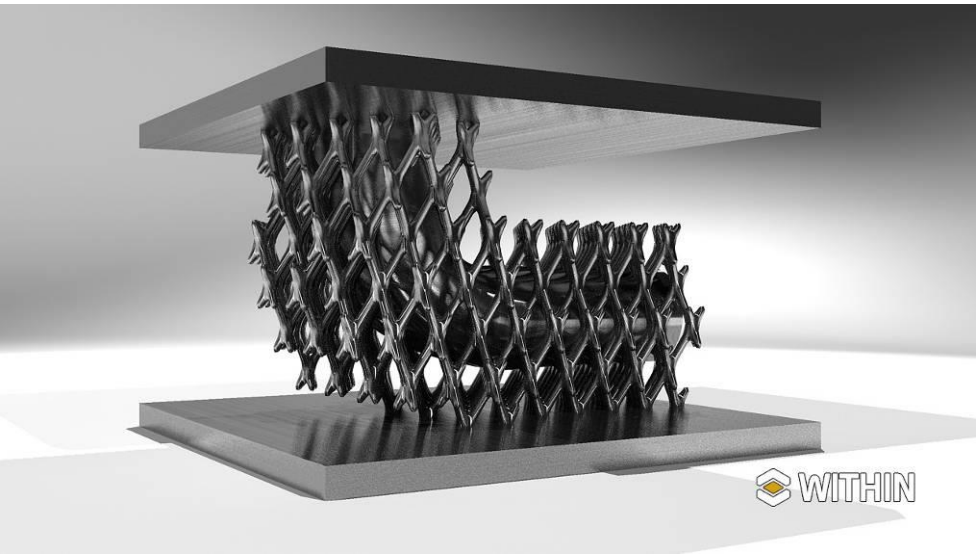
WITHIN


WITHIN

从打样进入生产

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快速原型

RP

- 成型速度
- 精度
- 材料特性
- 稳定度

快速制造

RM

Source: EOS

Direct Part Manufacturing

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23 laser-sintered parts produced with FORMIGA P110

Powder funnel

Control switch housing

Fine adjustment unit

Pyrometer housing

Pictures not to scale

Source: HP

订制化及小批量生产

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大规模
标准化生产

- 产品个别变化不影响生产
- 产品变化透过设计软件完成
  – 数字化生产

结合订制与批量化生产

Source: EOS

Medical – Orthopedic Implants

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Batch of finger implants in
EOS CobaltChrome MP1

Replacement knee joint in
EOS CobaltChrome MP1

Spinal implants in
EOS Titanium Ti64

project partners: Stryker Orthopaedics and Protocast

Source: EOS, Stryker Orthopaedics and Protocast

Applications

Industry Applications

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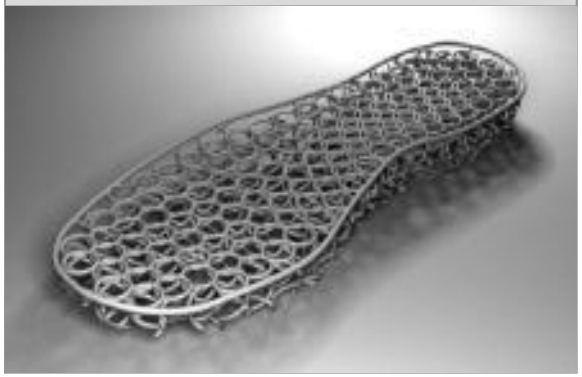
Aerospace

Medical

Industry

Lifestyle



Automotive

Tooling

Sources (upper, left to right): Morris Technologies; M. Kandler, Frauenhofer IPA; Festo; (bottom l. to r.): WITHIN Labs/EOS; EOS; BKL

Automotive

Automotive Prototyping

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Bumper incl. fixture

Requirement:

- Prototypes which resist the high demands of the Jaguar-profile

Solution:

- Laser-sintering on EOSINT P

Result:

- Testparts identical with series parts
- Reduction of development times
- Cost savings
- Higher tool adaption for series production

Laser-sintered prototyp produced in polyamid, painted afterwards, for assembly tests of key components e.g. exhaust pipes

Project partner: JAGUAR

Source: JAGUAR CARS, EOS

Automotive

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Essential material properties

General material data

- Average grain size: 60 µm
- Bulk density: 0.59 - 0.62 g/cm^3
- Density of laser-sintered part*: 1.23 - 1.28 g/cm^3

Mechanical properties

- Tensile modulus: 3200 ± 200 N/mm^2
- Tensile strength: 48 ± 3 N/mm^2
- Elongation at break: 6 ± 3 %
- Ball indent. hardness: 98 N/mm^2

Thermal properties

- Melting point: 172 - 180 °C

* EOS-method

Air intake unit

Fully functional prototype for development purposes

Project partner: Mann + Hummel

Source: EOS

Automotive Weight Reduction

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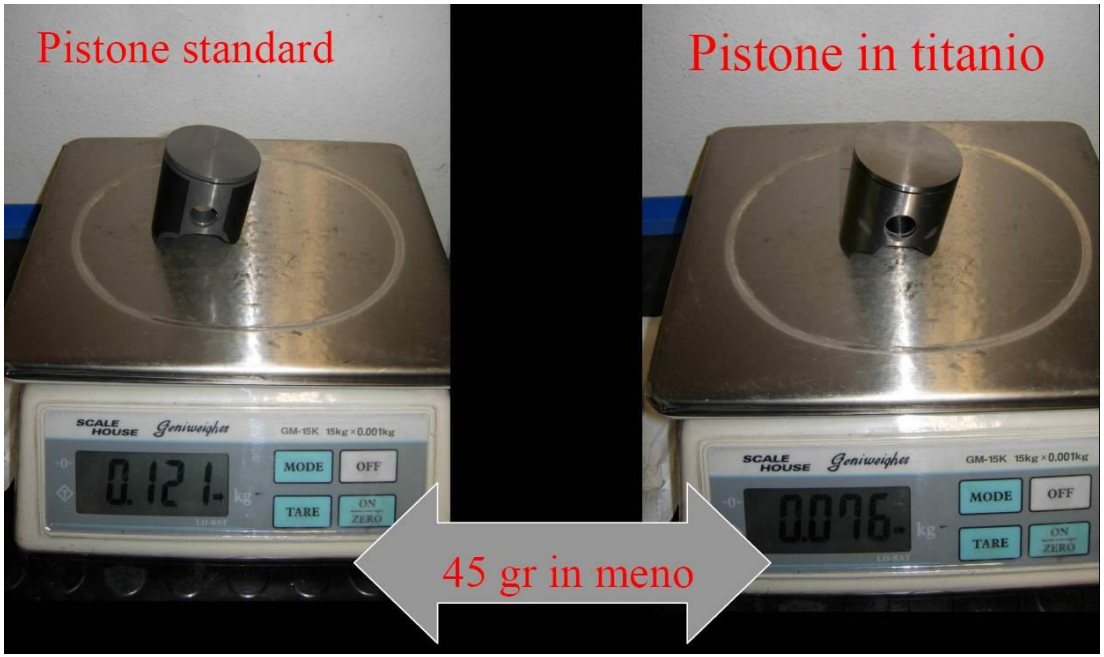
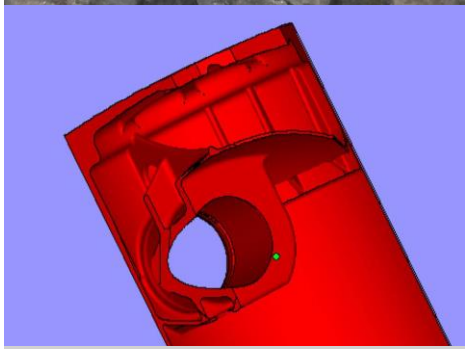
27% weight saving





Laser-sintered piston with integrated conformal oil/water cooling channels

Source: Pro2

Volkswagen used EOSINT M with StainlessSteel GP1 for one-off production for a concept car

Project summary

- Requirement:
  - one-off production of a gear shifter knob for a concept car
  - complex geometry for eye-catching hollow look
  - aesthetically match other metal trim components
- Solution:
  - DirectPart® on EOSINT M 270 with EOS StainlessSteel GP1
- Result:
  - great attention at Los Angeles Auto Show 2006
  - possibility of economic production of customized or limited edition shifter knobs

Volkswagen's GX3 concept vehicle

Designer shifter knob in EOS StainlessSteel GP1.

Project partner: Volkswagen N.A.

Source: EOS, Volkswagen N.A.

Tooling

EOS Additive Manufacturing Tooling Applications

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Smarter design of conformal cooling channels:
Cost savings, cycle time reduction, increased performance, scrap rate reduction

Injection Molding

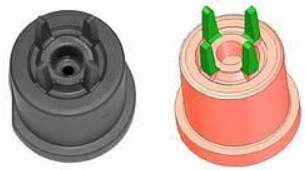
Salcomp tool insert and injection-moulding part

- **Challenge:** Enable precision cooling for production of mobile phone plastic parts
- **Solution:** Improved cooling design. Manufacture of core inserts using EOS technology

Result

- Production increased by 56,000 units/month
- Rejection rate reduced from 2% to 1.4%
- Annual cost savings of approx. 20,000 euros

Repairing



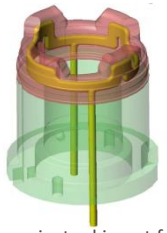
Ecoparts tool insert

- **Challenge:** Repair a partially damaged tool insert
- **Solution:** Generation of a new reference surface; Positioning of part in EOS machine. On-top construction of missing parts

Result

- Save costs of a complete new insert construction
- Reduction of lead time: partial construction instead of complete construction

Die Casting



Innomia tool insert for die casting

- **Challenge:** Build a tool insert for a die casting application
- **Solution:** Cooling system optimisation; insert built via DMLS on EOSINT M 270 in EOS MaragingSteel MS1

Result

- Significant cycle time reduction
- Improved life time of inserts

Rapid Tooling

PEP (Pôle Europeen de Plasturgie) tool insert

- **Challenge:** Injection moulding tooling for 50,000 electrical component parts
- **Solution:** Redesign of inserts with conformal cooling channels; inserts built in EOS MaragingSteel MS1

Result

- Lead time and cost reduction
- Higher mould productivity
- Better thermal management

Sources images (left to right): Innomia, Ecoparts, PEP

Conformal Cooling Channel

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- **Challenge**
  - Improve cycle time for inserts used to Manufacture air collector
  - Improve quality of the inserts
  - Previous inserts made in Ampco® alloy
- **Solution**
  - Change in design with the integration of **Conformal cooling channels**
  - Insert built in EOS MaragingSteel MS1,
  - 40 µm layer thickness
- **Benefits**
  - Improvement of the quality of the inserts
  - Consistent cycle time reduction

Examples of cooling inserts for the automotive industry

Source: Innomia

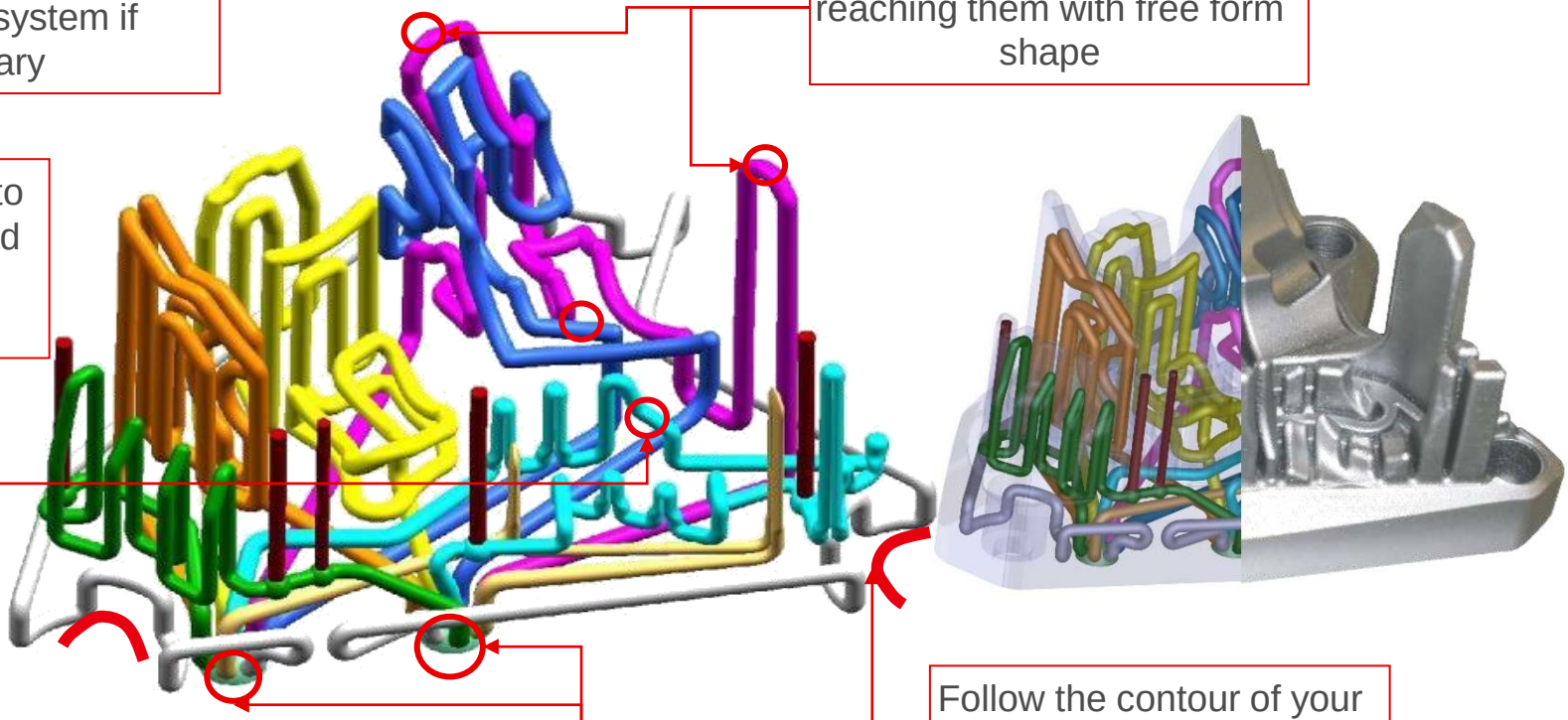
Freedom of Design

e-Manufacturing Solutions

Do not hesitate to “boost” your cooling system if necessary

Cool down critical area, reaching them with free form shape

Give preferences to smooth lines, avoid right corners



Follow the contour of your insert and keep distance to surface/wall constant

If you need to split your channels, then take care of balancing them.
Characteristics: - water input/output: Ø 10 mm
- 8 splitted channels with Ø 3 mm with “equivalent” length

LBC
LaserBearbeitungsCenter GmbH

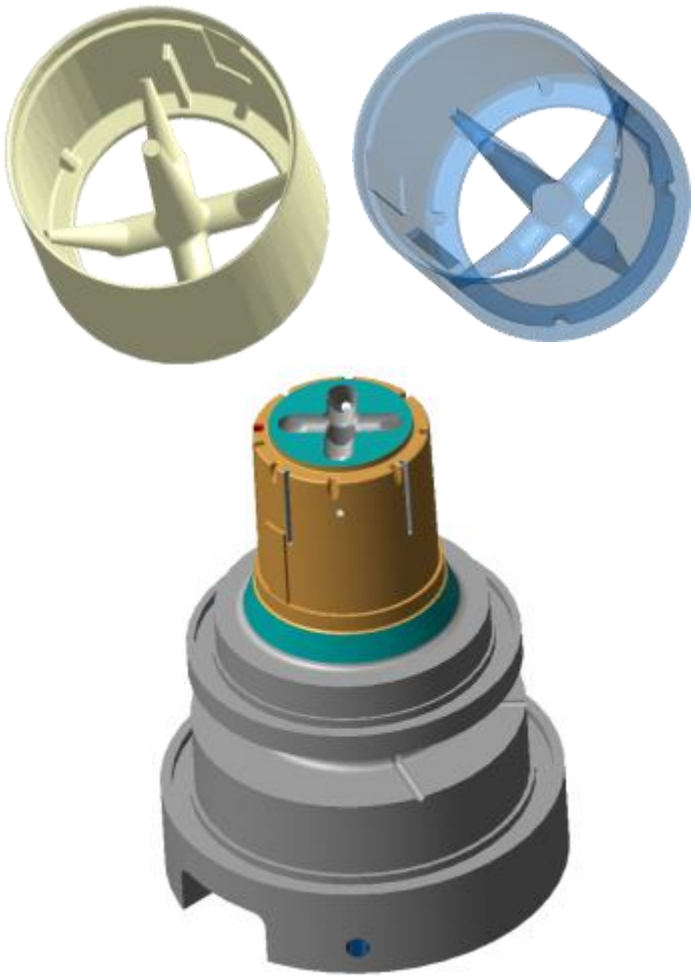
Source: LBC

Better injection moulding process with DMLS

DMLS addresses quality and cost per part challenges

Challenge

- Cost reduction for the manufacturing of an automotive plastic product (San, Luran 368 R Crystal Clear, BASF)
- 4 cavities mould, standard solution with cupper alloy inserts
- Optimize cold Runner and nozzle gate process
- Improve quality of the manufactured part



Insert and plastic part

Source: BBE Engineering; Prodintec

Better injection moulding process with DMLS

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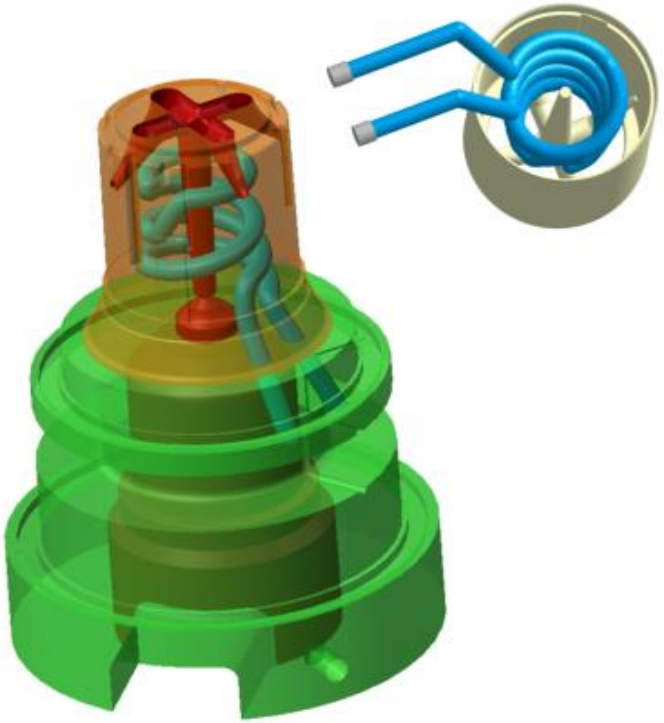
DMLS tools and hybrid design improve part quality and cycle time

Solution

- Design of conformal cooling channels
- Hybrid structure
  - Manufacture the lower part of the mold by conventional process (CNC milling)
  - Upper part built on EOS M 270
- Material: EOS MaragingSteel MS1
- Validation of results with flow, fill and cooling simulation using Moldex3D => decision for final design



conformal cooling channel; design of the DMLS insert

Better injection moulding process with DMLS

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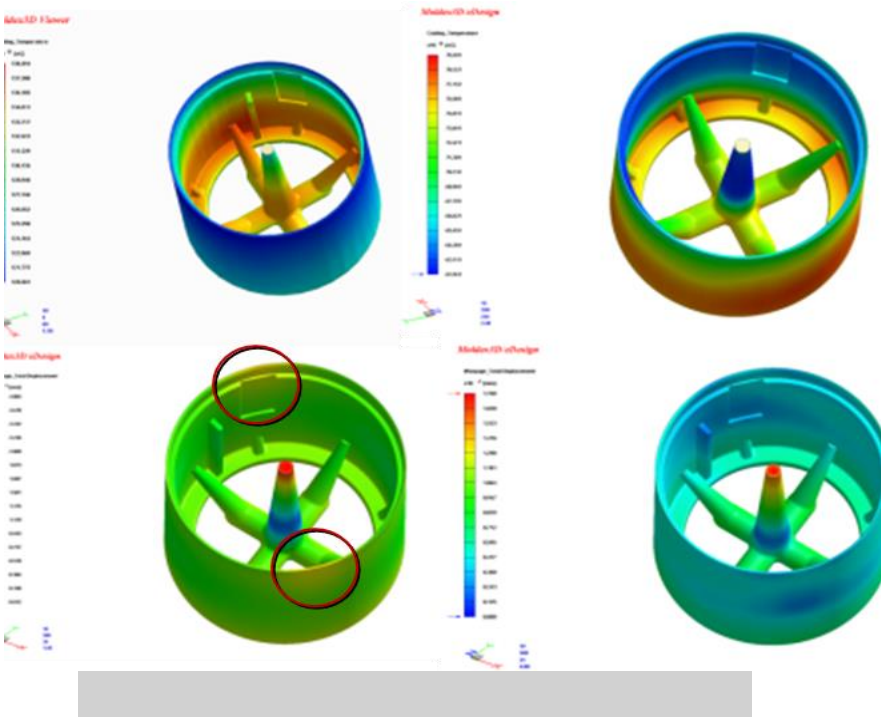
Simulation compares benefits of conformal cooling channels with conventional solution

Upper picture : temperature distribution analysis.

Bottom picture: warpage analysis

Solution

- The simulation is performed for the 2 possible solution with Mouldex3D
- Temperature distribution
  - The solution with the cupper alloy shows a maximum temperature of 107°C
  - The solution with the cupper alloy shows a maximum temperature of 79°C
- Warpage analysis
  - The conventional solution shows of max 0,25mm
  - The DMLS solution shows a warpage of 0,1



BBE ENGINEERING

Moldex3D MOLDING INNOVATION

Better injection moulding process with DMLS

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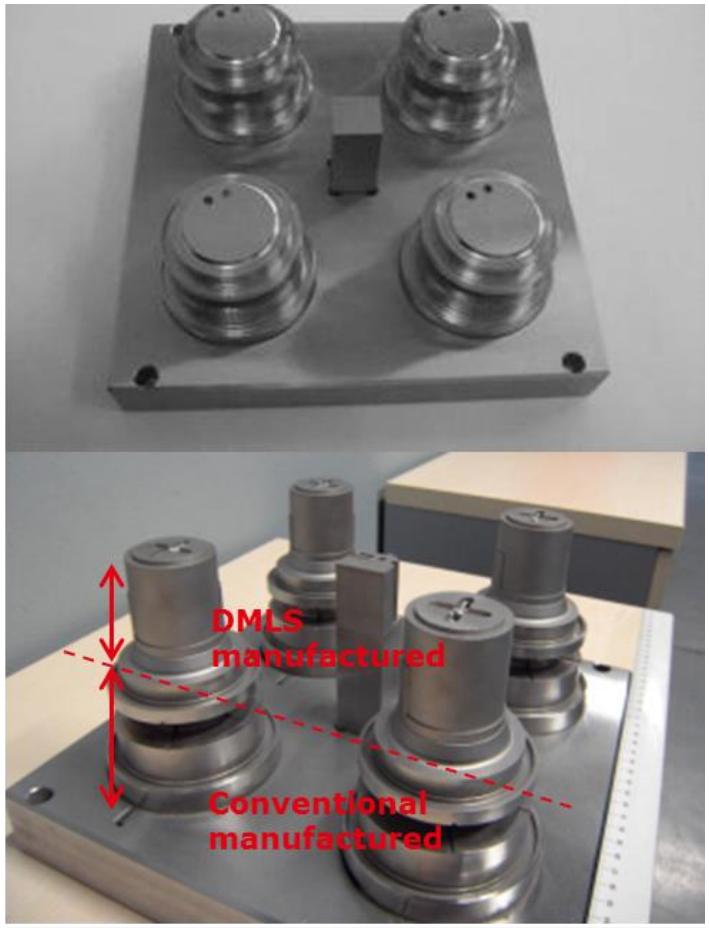
DMLS tools and hybrid design improve part quality and cycle time

Benefits

- Cooling time reduction from **24s to 7,5s => 68 %** faster cooling time
- Average ejection temperature from 95ºC to 68ºC
- Temperature gradient from **12ºC to 4ºC**
- Reduction of scrape rate **from 60% to 0%**
- Improvement of productivity up to 3 parts/min

4 cavities inserts



Proven Advantages

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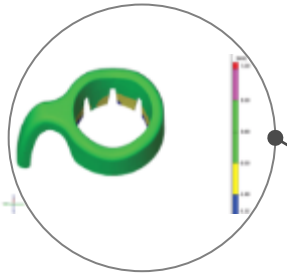
Manufacturing of sustainable plastic product with reduced cost per part

Quality



Warpage reduction

Moulded Mug holder

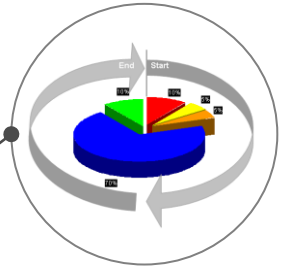
Cost saving

Cost per part reduction

Performance

Substantial productivity improvement

Cycle time



31% (from 38,9s to 26,5s)

innomia

Industry & Automation

Industrial Automation

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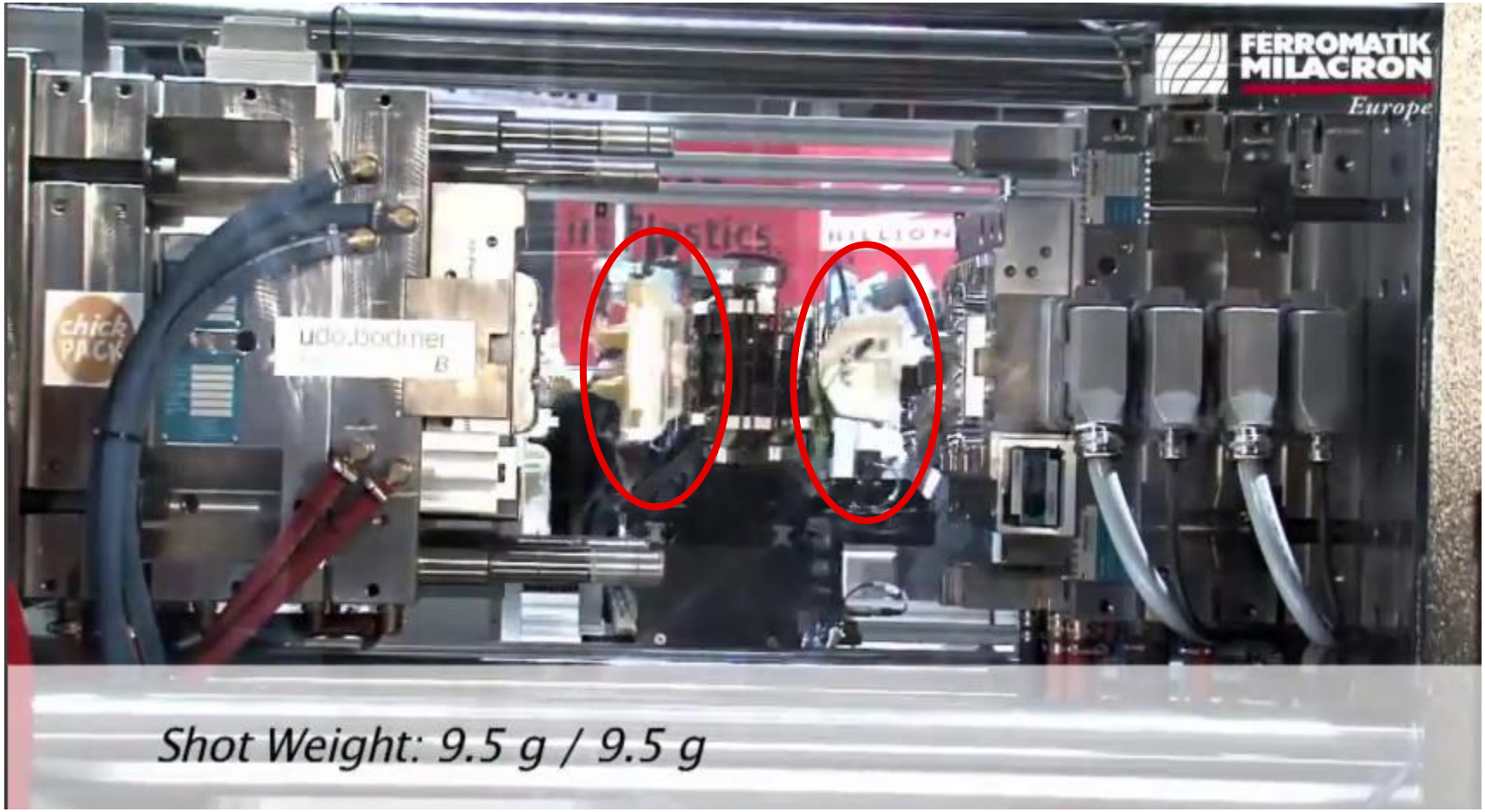

A conventional handling device was redesigned leveraging the possibilities of laser sintering

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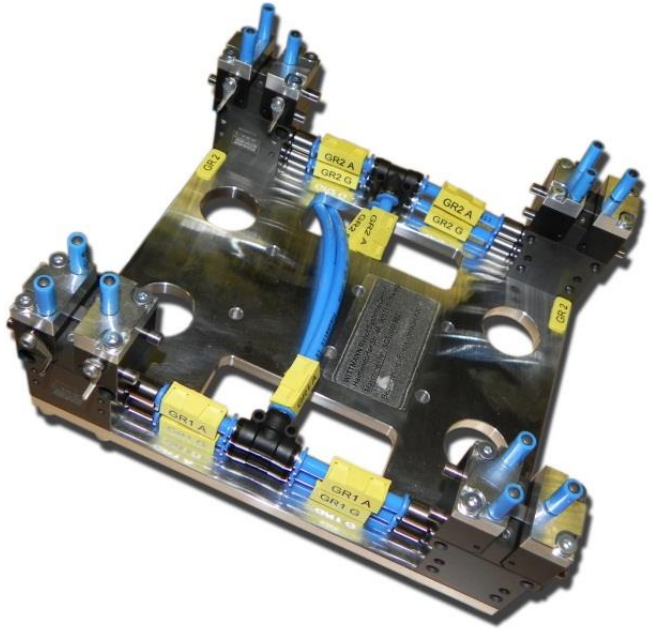
OLD design



NEW design

- Weight reduction 86%
- Cost reduction 50%
- Lead time reduced from 21 days to 4 days

Source: Wittmann, Kuhn-Stoff, EOS

New Technology

EOS is focusing on Part Quality, Process Robustness and Industrialization

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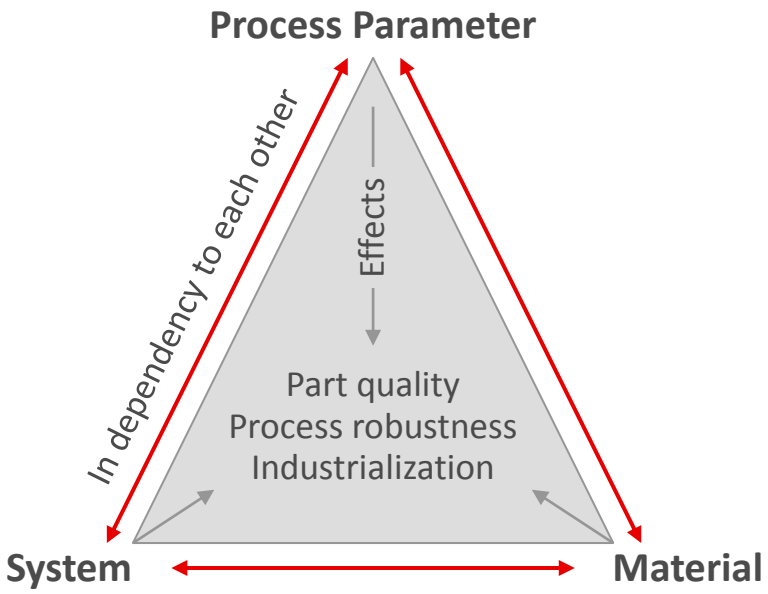
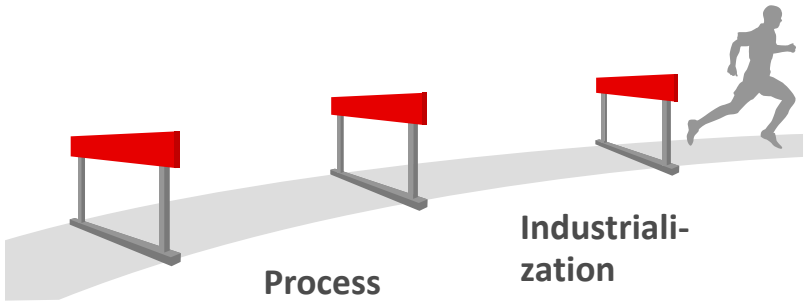
EOS Technology Focus

Balanced triangle



Hurdles to overcome



Part Quality
- Mechanical properties
- Dimensional accuracy
- Surface quality
- Density

Process Robustness
- Build platform
- Several jobs
- Several machines
- Several suppliers

Industriali-zation
- Automation
- Quality assurance
- Easy-to-Service
- Productivity / reduced cost-per-part

EOS Polymer Laser Sintering Systems

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FORMIGA P 110: Compact system for RP applications and small series

Usable build size
- Width 200 mm
- Depth 250 mm
- Height 330 mm

Laser
- CO_2 laser
- Nominal power 30 W
- Wave length 10.6 µm
- Laser spot size ~0,4 mm

Layer thickness
- 0.12 mm
- 0.10 mm
- 0.06 mm

EOS P 396: Productive, modular polymer laser sintering system

Usable build size
- Width 340 mm
- Depth 340 mm
- Height 600 mm

Laser
- CO_2 laser
- Nominal power 70 W
- Wave length 10.6 µm

Layer thickness
- PA 2200: 0.06 mm; 0.10 mm; 0.12 mm; 0.15 mm; 0.18 mm
- All other materials according to compatibility matrix

EOSINT P 760: With greatest built volume for plastic parts

Usable build size
- Width 700 mm
- Depth 380 mm
- Height 580 mm

Laser
- 2 CO_2 lasers
- Total nominal power: 100 W
- Wave length 10.6 µm

Layer thickness
- PA 2200: 0.06 mm; 0.10 mm; 0.12 mm; 0.15 mm; 0.18 mm
- All other materials according to compatibility matrix

EOSINT P 800: For high-performance plastic components

Usable build size
- Width 700 mm
- Depth 380 mm
- Height 560 mm

Laser
- 2 CO_2 lasers
- Total nominal power: 100 W
- Wave length 10.6 µm

Layer thickness
- Standard: 0.12 mm

EOS Polymer Materials

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

EOS Direct Metal Laser Sintering (DMLS) Systems

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EOSINT M 280: Leading-edge DMLS system for the Additive Manufacturing of metal parts

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

EOSINT M 270 Dental: High-performance DMLS for production of dental copings and bridges

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

EOS M 400: System for the Industrial Production of High-Quality Large Metal Parts

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 M 400

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System Features

Build Chamber

- **400x400x400mm** (including build platform) with optimized flow
- Smooth surfaces for easy cleaning
- **Single 1 kW laser** for higher buildrates

Material Dosing

- Feeding from above with inert gas injection to prevent agglomeration
- Recoating from both sides for reduction of non-productive time

Recirculating Filter System

- Automated removal of condensate cake
- Longer filter lifetime for lower operating costs

EOS M 400

NEW User Interface on system enables….

Intuitive

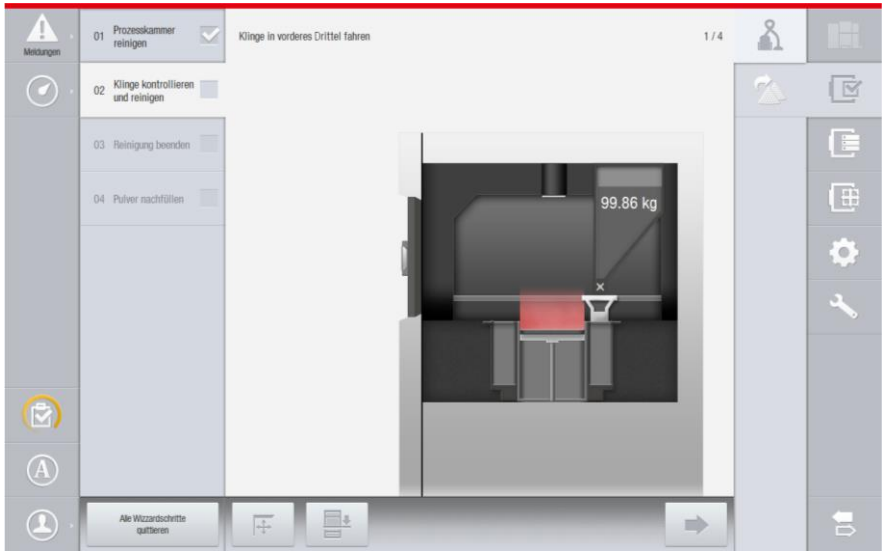
- Simplified user interface with touch screen, developed with usability experts based on customer input
- Automatic creation of process conditions. Remaining time until job start is calculated
- Customizable dashboard for full transparency of system conditions

Efficiency

- Task-based layout on touch screen for faster operation and bundling of associated steps
- Wizard guidance to support operator's learning curve
- Automated sequence of tasks possible

Stability

- Reduction of risk of wrong operation in production environment



… Improved Usability – Intuitive Interface

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

e-Manufacturing Solutions

Focus on speed

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

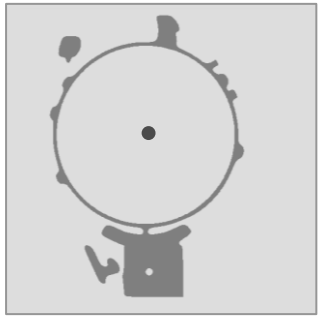
Application-specific approach

Focus on accuracy

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

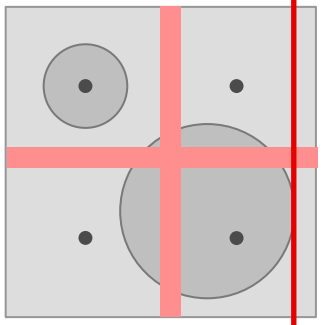
Single field

1 x 1,000 W



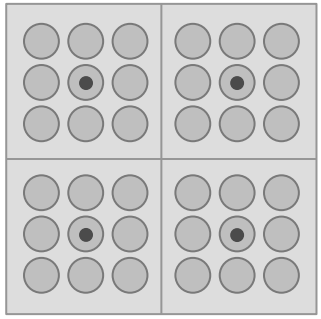
Multi-field with overlap*

4 x 400 W [1)]



Multi-field without overlap*

4 x 400 W [1)]



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

NEW EOSTATE PowderBed

Recoating & Exposure monitoring

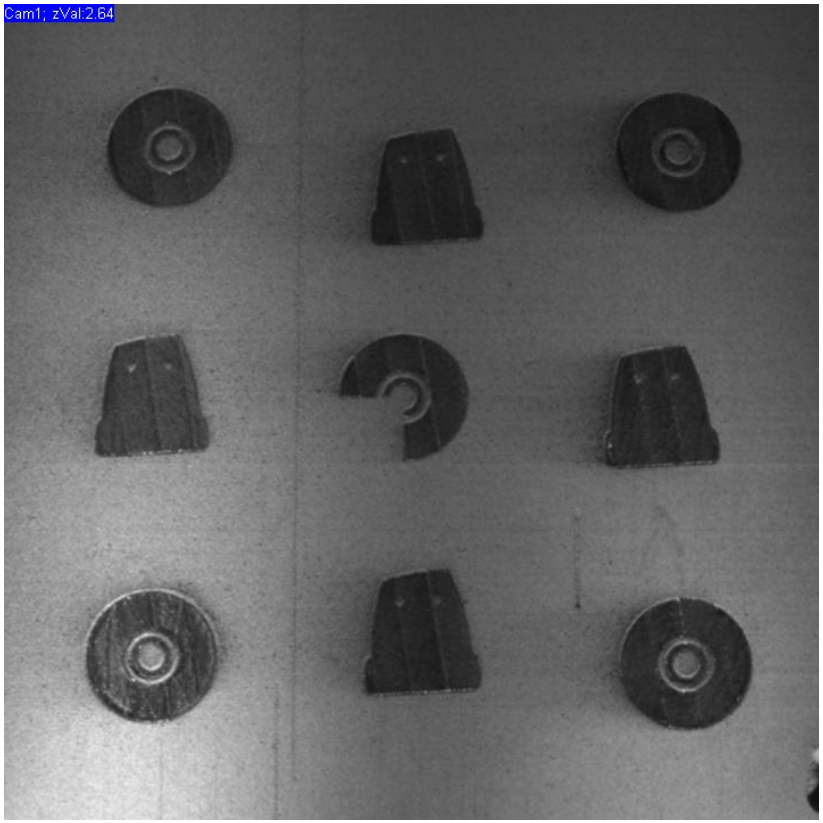
Taking Fotos

- 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

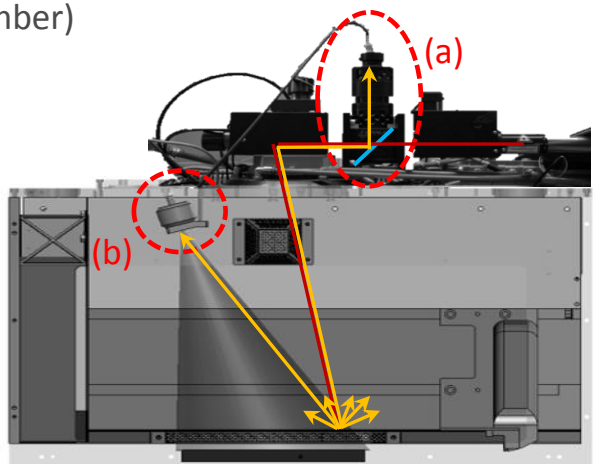
Step I: Flip-Book of a good job



Peek into the Lab – EOSTATE MeltPool*

Principle of operation

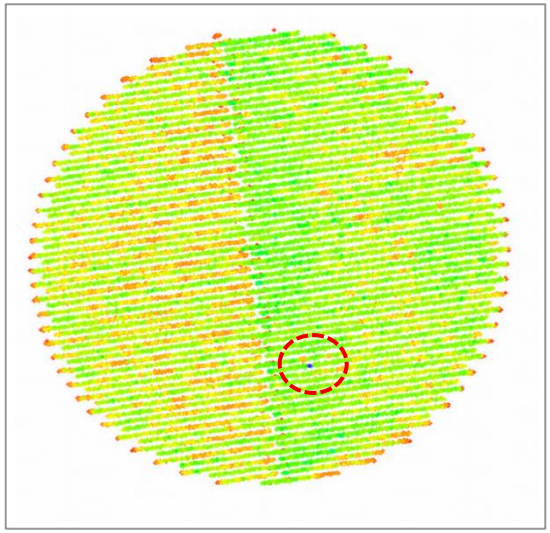
- Capturing **light emissions from DMLS process** with **photodiode-based sensors**
  a) „On-Axis“ configuration (= through the scanner)
  b) „Off-Axis“ configuration (= diode inside process chamber)



- Sensing **light intensity** and **signal dynamics**, which are among the **most relevant indicators** for process behavior
- Correlation of **sensor data** with **scanner position** and **laser power** signal

Current Development

- **Cooperation** with experienced industry partner leveraging synergies of **EOS process know-how** and partner’s expertise in **industrial monitoring**
- Deepening **know how about correlations** of monitoring data, process characteristics and part quality
- Further development of **algorithms for automated data analysis** and **visualization**
- Implementation in **user-friendly** software



Mapping of data of a tensile bar

*** In development, subject to change**

EOS Metal Materials

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Material Group	Trade 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
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	Parts with severe thermal conditions and high risk of oxidation, e.g. combustion chambers, burner components, fans, roller hearths and support members in industrial furnaces
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.
Aluminium	**EOS Aluminium AlSi10Mg**	AlSi10Mg light alloy	Functional prototypes and series parts; engineering, automotive etc.

EOS Service Provider Near YOU!

Business Model

e-Manufacturing Solutions

Consumer

Manufacturer

GE, BMW, Johnson & Johnson, Electrolux

Service/Web Platform

Materials Solutions – Rapid development to meet environmental challenges

3T

MORRIS TECHNOLOGIES

Materialise – innovators you can count on

shapeways

Technology Supplier

EOS

Source: EOS

China Service Provider Network

e-Manufacturing Solutions

Weifang M280 x 1

Tsingdao M280 x 1

Xi'an M280 x 5

Chengdu M270 x 1

Wuxi M280 x 3

Shanghai M280 x 2

Hangzhou M280 x 1

Huanan M280 x 1?

e-Manufacturing Solutions

Thank you for your attention!