Roadmap for Additive Manufacturing in Aerospace

March 2015

Peter Rosker
Area Sales Manager
EOS: Technology and Market Leader for Design-Driven, Integrated 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: Global Presence

**EOS worldwide installed base**

**1,600+ Systems**
- 40% Metal systems
- 60% Polymer systems
- 310 customers with more than 1 system

**EOS global footprint**
- Customers in 53 countries
- EOS Sales & Service offices in 11 countries, distribution partners in 22 countries
- More than 541 employees worldwide (75% Germany, 25% International)
- Strong patent portfolio: „More than 650 active patents in more than 100 patent families“
- R&D spendings of approx. 14% of Sales

Source: EOS. Installed base (includes purchased and rented systems) and staff figures as per 11/2014.
EOS: A Success Story

Source: EOS. Figures for EOS Group, for financial years ending 30 September. Number of Employees: Headcounts.
“Enterprise 3D Printing” – 2014
we are on the “Slope of Enlightenment”

“The Manufacturing Technology that will change the World”
The Economist, 2011

Source: Gartner (July 2013)

Computerworld, 2013
We see big OEMs to start setting up production

Example General Electric Aviation

- 19 fuel nozzles to be installed on every CFM LEAP engine (more than 4.500 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
„Enterprise 3D Printing“ – 2015 we are on the “Slope of Enlightenment”

Source: Gartner (July 2013)
Strong focus on engine and interior market

Focus markets – Aerospace

Jet Engine
- AM is established at jet engines
- High temperature super alloys
- Different applications

Interior
- Already used in several aircrafts
- Low weight solutions
- Cost reduction
- Customizing/VIP

UAV
- High value through AM
- Most UAV's already containing AM parts
- Fast growing market
- Test bench for new technology

Worldwide use
Metal & Plastics applications
Service provider business
The EOS product portfolio consists of four Polymer Laser Sintering systems...

**FORMIGA P110**
- Compact system for RP applications and small series
- Usable build size (in mm) 200x250x330
- Laser 1x 30W (CO₂)

**EOS P 396**
- Productive, modular polymer laser sintering system
- Usable build size (in mm) 340x340x600
- Laser 1x 70W (CO₂)

**EOS P 760**
- With greatest build volume for plastic parts
- Usable build size (in mm) 700x380x580
- Laser 2x 50W (CO₂)

**EOS P 800**
- For high-performance polymer components
- Usable build size (in mm) 700x380x560
- Laser 2x 50W (CO₂)
... and four Direct Metal Laser Sintering (DMLS) systems of varying sizes and applications

<table>
<thead>
<tr>
<th>EOSINT M 270 Dental</th>
<th>EOSINT M 280</th>
<th>EOS M 290</th>
<th>EOS M 400</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Custom solution</strong> for production of dental copings and bridges</td>
<td><strong>World’s leading DMLS sytem for production applications</strong></td>
<td><strong>Highly productive modular system for serial production</strong></td>
<td><strong>Industrial Production of High-Quality Large Metal Parts</strong></td>
</tr>
<tr>
<td>Usable build size (in mm) 250x250x215</td>
<td>Usable build size (in mm) 250x250x320</td>
<td>Usable build size (in mm) 250x250x325</td>
<td>Usable build size (in mm) 400x400x400</td>
</tr>
<tr>
<td>Laser 1x 200W (Yb-fibre)</td>
<td>Laser 1x 200W/400W (Yb-fibre)</td>
<td>Laser 1x 400W (Yb-fibre)</td>
<td>Laser 1x 1000W (Yb-fibre)</td>
</tr>
</tbody>
</table>

Production scale

**SMALL SERIES**

**FLEXIBLE**

**LARGE SERIES**
For the gripper, weight has been reduced by 80% whilst keeping handling properties.

Example Kuhn-Stoff: new gripper design

Lightweight gripper

Application
- Hole gripper for part handling
- **Weight** of gripper: 19g
- **Handles** up to 12kg parts
- Integrated pneumatic membrane to apply gripping force

Advantages
- About **80% weight reduction** compared to conventional gripper
- Printed in one shot - no final assembly
- Geometry fully flexible and scalable
- Tested to >5 mio. cycles

Source: Kuhn-Stoff, EOS
In a second step, the entire handling device has been redesigned generating significant value

Example Wittmann / Kuhn-Stoff: Redesigned handling device

**Application details**

- Handling device to remove injection molding parts out of the tool during operation
- **Three parts** application:
  - Four laser sintered lightweight **hole grippers**
  - **Base plate** for stability and integrated air distribution
  - **Axis module** for 90° turning operations (embedded mechanics)
- Fully integrated application based on standard PA 2200 plastic material

Source: Wittmann, Kuhn-Stoff, EOS
The application perfectly answers today’s Handling & Robotics challenges

Example Wittmann / Kuhn-Stoff: Advantages compared to conventional solution

- **Flexibility**
  - Base plate generates lightweight stiffness and at the same time allows integrated air channels
  - Three components vs. 21, leading to less list positions and logistics effort

- **Cost per part**
  - CAPEX reduction
    - -50% gripper cost reduction
    - -86% less weight leading to smaller robot size
  - OPEX reduction
    - Lightweight and smaller build height (-60mm) resulting in shorter cycle times of injection molding machine

- **Time-to-market**
  - Laser sintered gripper to be produced “overnight”
  - Reduction of manufacturing time by 17 days
  - Fast reaction possible for spare parts or product design changes

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Source: Wittmann, Kuhn-Stoff, EOS
AM drivers in Aerospace

- Geometric freedom for improved structural optimisation
- Weight reduction
- Improved environmental performance
- Reduced material waste

**Supply Chain Shift – Direct to Part**

From → To
LEAP 56 Next Generation Fuel Nozzles

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

Turbomeca introduces additive manufacturing production capability for engine components


Serial production of parts fuel injector nozzles:
- Arrano test and production engines
- Ardiden 3 combustor swirlers

Benefits:
- One single piece of material
- Advanced injection and cooling functions

Turbomeca is a world-leading helicopter engine manufacturer.

Source: Turbomeca press release 05.01.2015

Production facility in Bordes, France
Our technology activities are seamlessly linked to our strategy resulting in various challenges

EOS: Strategy basis and resulting challenges

**Balanced triangle**

- Process
  - Part quality
  - Process robustness
  - Industrialization

- System
  - In dependency to each other

- Material
  - Effects

**Hurdles to overcome**

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

**Industrialization**
- Automation
- Quality assurance
- Easy-to-Service
- Productivity

**Part Quality**
- Mechanical properties
- Dimensional accuracy
- Surface quality
- Density
EOS Part Property Management: Solutions

- **Plug&Print EOS Standard**
  - Part quality defined by EOS
  - e-Manufacturing according to EOS-defined Part Property Profiles (PPP)

- **Plug&Print EOS Custom**
  - Part quality defined by customer
  - Customized solution based on your specification enabling unique part quality of your application(s)

- **Edit&Print**
  - Part quality defined flexibly
  - Application development starting from a well-proven baseline

For further information, see separate PPM presentation
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 (Strecken-/Flächenenergie)
- Temporal behavior of light (e.g. post glowing of splashes)
- Metallurgical properties
- Mechanical properties
- Dimensional conformance

### Melt Pool
- Energy input
- Homogeneity of melt pool
- Metallurgical properties
- Mechanical properties
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)

Step I: Flip-Book of a good job
Step II and III allow software-based image recognition, error identification and closed-loop control.

Image recognition algorithms for the specific conditions and needs of the DMLS process.

Allocation of detected failure to specific layer and part.

Closed-loop control of recoating quality.

Control of exposure quality through advanced edge detection algorithms.

Full integration in EOS software including user-friendly graphical user interface.

*In development, subject to change.*
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 allows a holistic part quality assessment – layer by layer, part by part

Layer wise reconstruction of 3D information on part quality

Monitoring of:
- Exposure process
- Recoating process
- Process conditions

2D information layer by layer → 3D Information on complete part

Typical errors:
- Cracks
- Voids
- Segregation
- Inclusions
- Powder

Source: MTU
 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

* In development, subject to change
Optical Tomography is very close to industrial market readiness and exclusive to EOS systems

6 steps to Industrial In-Process Monitoring

- Hardware + Raw data
- Process understanding and failure types
- Correlation between raw data and failure types (part quality)
- Defining failure classes (ok/nok)
- Parameterization of detection algorithms
- Automating and integration in EOS SW
EOS offers eM Validation Package to support validation of AM process chain

- **FAT – Factory Acceptance**
  - Single system qualification
  - Testing of parts, assembly, functions, safety, calibration, including test reports.

- **IQ - Installation Qualification**
  - Single system qualification during installation
  - Testing of installation, functions, safety, calibration, including test reports.

- **OQ – Operational Qualification**
  - Repeating qualification of the customer production process
  - Testing of operating conditions, process steps, production instructions, operator qualification, machine conditions, maintenance, statistical variations, including test reporting.

- **PQ – Performance Qualification**
  - Repeating qualification of the finished customer part
  - Testing of the finished parts on functions, dimensions, surface quality part properties, statistical variations, including test reports.
# Completed Validation Projects

<table>
<thead>
<tr>
<th>AVIO Prop, Italy</th>
<th>Turbomeca, France</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 M280 FQ+IQ Qualification completed 05.2012</td>
<td>1 M280 FQ+IQ Qualification completed 06.2012</td>
</tr>
<tr>
<td>Corporate QA Avio involved</td>
<td>Pre Acceptance @EOS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MTU Aerospace, Germany</th>
<th>A.B.Dental, Israel</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 M280 FQ+IQ Qualifications completed 10.2014</td>
<td>1 M280 IQ+OQ Qualification completed 08.2012</td>
</tr>
<tr>
<td>Pre Acceptance @EOS</td>
<td>3rd party validation service Bio Chem used</td>
</tr>
<tr>
<td>Aerospace Authority involved</td>
<td></td>
</tr>
<tr>
<td>New optical scanner test standard</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALPHAFORM, Germany</th>
<th>RUETSCHI, Switzerland</th>
</tr>
</thead>
<tbody>
<tr>
<td>IQ M280 completed 05.2013</td>
<td>IQ M280 completed 06.2013</td>
</tr>
</tbody>
</table>
Enhancement of the Benchmark in Additive Manufacturing of Metal Parts

**EOS M 290**

**NEW** Recirculating Filter System
- Automated removal of condensate cake
- Longer filter lifetime for lower operating costs

**NEW** EOSYSTEM machine software with improved user interface for intuitive, efficient and stable operation

**NEW**EOSPRINT Desktop Software for faster job preparation enables machine to concentrate on building

**NEW** Enhanced Monitoring
- Comprehensive monitoring of machine and process parameters
- Prepared for integration of further monitoring features and products

Same Materials & Processes as EOSINT M 280
→ Process similarity to EOSINT M 280 has been shown which helps ensure legacy
**EOS M 400**

**Highlights**

1. **Modular Platform**
   - Smooth handling of platform, parts and powder between stations
   - Easy integration of future innovations
2. **Qualification & e-Manufacturing of new DMLS applications**
   - Larger parts and batches
   - Higher build rates
3. **Usability designed for e-Manufacturing**
   - Intuitive user interface
   - Efficient workflow before and during build
   - Enhance EOSTATE Monitoring & Reporting

**DMLS for e-Manufacturing of a new class of products**
The EOS M400-4 system is designed for integration into a series production environment.

The EOS M400-4

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
BestInClass has developed an effective surface finishing process

Post processing: Micro machining process (MMP) and application examples

**Micro machining process**
- Surface finishing process
- Mechanical, physical and catalyst technology

**Benefits**
- Access to shape and dimensional details
- No surfaces destruction through abrasives
- Preservation of the surface micro-structure
- Enhanced surfaces performance (lifetime, corrosion, friction)

![Micro machining process examples](image)
## EOS Polymer Materials

<table>
<thead>
<tr>
<th>Composition</th>
<th>Trade name</th>
<th>Colour of parts</th>
<th>Main feature</th>
<th>Typical applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyamide 12</td>
<td>PA 2200</td>
<td>white</td>
<td>• Multipurpose material</td>
<td>• Functional parts</td>
</tr>
<tr>
<td></td>
<td>PrimePart° PLUS</td>
<td>natural</td>
<td>• Economic multipurpose material</td>
<td>• Functional parts</td>
</tr>
<tr>
<td>(PA 2221)</td>
<td>PA 2202 black</td>
<td>anthracite black</td>
<td>• Balanced property profile</td>
<td>• Functional parts in anthracite black colour</td>
</tr>
<tr>
<td>Polyamide 12, glass bead filled</td>
<td>PA 3200 GF</td>
<td>whitish</td>
<td>• High stiffness</td>
<td>• Stiff housings</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Wear resistance</td>
<td>• Parts with requirements on wear and abrasion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Improved temperature performance</td>
<td>• Parts used under elevated thermal conditions</td>
</tr>
<tr>
<td>Polyamide 12, aluminium filled</td>
<td>Alumide°</td>
<td>metallic grey</td>
<td>• Easy post-processing, good machinability</td>
<td>• Applications with metal-like look</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• High temperature performance</td>
<td>• Parts which need machining</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Thermal conductivity (limited)</td>
<td>• Parts with thermal loads</td>
</tr>
<tr>
<td>Polyamide 12, carbon fibre reinforced</td>
<td>CarbonMide°</td>
<td>anthracite black</td>
<td>• Extreme strength and stiffness</td>
<td>• Light and stiff functional parts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Thermal and electrical conductivity (limited)</td>
<td>• Metal replacement</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Best strength/weight-ratio</td>
<td></td>
</tr>
<tr>
<td>Polyamide 11</td>
<td>PA 1101</td>
<td>natural</td>
<td>• Very high ductility / elongation at break</td>
<td>• Functional parts which need impact resistance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• 100% from renewable sources (castor/ricinus oil)</td>
<td>• Parts with functional elements (film hinges)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Acceptable tensile strength</td>
<td></td>
</tr>
<tr>
<td>For special applications</td>
<td>PA 2201</td>
<td>natural</td>
<td>• Multipurpose material</td>
<td>• Medical, food</td>
</tr>
<tr>
<td></td>
<td>PA 2105</td>
<td>light beige</td>
<td>• Highest dimensional accuracy</td>
<td>• Dental</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• High surface quality and detail resolution</td>
<td></td>
</tr>
<tr>
<td>Polyamide 12, flame retardant</td>
<td>PA 2210 FR</td>
<td>white</td>
<td>• Economic flame-retardant material</td>
<td>• Aerospace</td>
</tr>
<tr>
<td></td>
<td>PrimePart° FR</td>
<td>white</td>
<td>• Halogen-free</td>
<td>• Electric &amp; Electronic</td>
</tr>
<tr>
<td>(PA 2241 FR)</td>
<td></td>
<td></td>
<td>• Economic flame-retardant material</td>
<td>• Aerospace</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Material certificates available (flammability)</td>
<td></td>
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<tr>
<td>TPE-A Polyetheramide-Block-Copolymer</td>
<td>PrimePart° ST</td>
<td>white</td>
<td>• Rubber-like flexibility (Shore D ≈ 35)</td>
<td>• Damping devices, bumpers / cushions, gaskets / gasket seals, shoe sole elements</td>
</tr>
<tr>
<td></td>
<td>(PEBA 2301)</td>
<td></td>
<td>• No infiltration necessary</td>
<td></td>
</tr>
<tr>
<td>Polystyrene</td>
<td>PrimeCast° 101</td>
<td>grey</td>
<td>• High dimensional accuracy</td>
<td>• Patterns for investment casting</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Low residual ash-content</td>
<td>• Master patterns for vacuum casting</td>
</tr>
<tr>
<td>Polaryletherketone</td>
<td>EOS PEEK HP3</td>
<td>beige-brown</td>
<td>• High performance material</td>
<td>• Metal replacement</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Excellent temperature performance, strength, stiffness and chemical resistance</td>
<td>• Aerospace</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Excellent wear resistance. Inherently flame retardant</td>
<td>• Automotive and motorsports. Electric &amp; Electronic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Biocompatibility and sterilizability</td>
<td>• Medical</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• • Industrial</td>
<td></td>
</tr>
</tbody>
</table>
EOSINT P 800 with EOS PEEK HP3

HP3 – high-temperature and performance Applications

- Material belong to the Polyaryletherketone Group
- Outstanding material data:
  - Tensile strength up to 95 MPa
  - Youngs modulus up to 4400 MPa
  - Long term usability between 180 °C and 260 °C
- Exceptional performance:
  - High chemical resistance
  - Flame retardant conform UL 94- V0
  - Biocompatibility
  - Sterilisability

Source: EOS GmbH, FP
Aerospace Ducting

Source: EOS GmbH
Southampton University Laser Sintered Aircraft

SULSA - UAV

- Project created in about one month
- Built in five parts with ~ 3 kg weight
- Wingspan ~ 2 meters
- Flaps with hinges integrated (no fasteners or screws used)
- Snap fit techniques for easy and quick assembly
- Geodetic structures and elliptical wings

Source: 3 T RPD
Complex Metal Parts

Source: EOS GmbH
# EOS Metal Materials

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

Aircraft Interieur

Requirement:
- customer-specific light frames for 777 aircraft
- 9 light frames per 777 cabin
- good aesthetics (visible part)
- fulfilment of FAA requirements

Solution:
- DirectPart® on EOSINT M 270 with EOS StainlessSteel 17-4

Result:
- implementation of design and manufacture within 30 days
- flexible manufacturing configuration

Project partner:

Source: EOS, Boeing Commercial Aircraft

Boeing 777 with laser-sintered light frame for the cabins of a special Airlines edition
CoCr MP1 super alloy
Functional aircraft engine parts

Project summary

Challenge
- Functional prototypes for developing helicopter gas-turbine engine components.
- Capable of running in test-bed conditions, e.g. high strength at high temperature

Solution
EOSINT M 270 with EOS CobaltChrome MP1 super alloy

Result
- Can be built fully dense in 23 hours
- Can be automatically polished
- Properties fulfil requirements for running on test-bed

Source: PEP/Turbomeca/Best-in-Class, EOS
With the design freedom of EOSINT M you can integrate all sorts of functionality into products.

Weight saving internal cavities oil ways and service channels

Complex bosses

Cooled aerofoils

Flange design for weight saving and load distribution

Enclosed and perforated honeycomb structure

Integral instrumentation with curved pathways

Source: 3T RPD, Assystem
New design structures in heat exchangers increase compactness and effectiveness

Example complex components

Conceptual heat exchanger

Application
- Design study for heat exchanger
- Repeated sub-elements can be formed into almost any shape
- Self-supporting, integrated cooling fins on outside surfaces
- Turbulators inside the cooling tubes disrupt the flow of the cooled fluid
- Material: Aluminum

Advantages
- Compact and scalable design
- Maximum heat transfer

Source: Within, 3T, EOS
Door hinge build with DMLS

Challenge
- Create a "light weight" nacelle hinge

Solution
- Stress and load path proved design by EADS engineers
- Highly complex design built as "one piece" with integrated function
- Built on M270 Xt
- Material: Ti64

Benefits
- A 60% weight saving was achieved through topology optimization
- Significant cost reduction

Source: Evo Magazine and EADS IW Filton, from:
http://www.evo.co.uk/features/features/261526/3d_printing_is_this_the_future.html

Optimized A320 Nacelle Hinge – DMLS and Conventional EOS Ti64 produced on EOSINT M 270Xt at EADS IW
Supply Chain Shift – Direct to Part

From

To

Source: GE – Greg Morris - Additive Metal Applications within the Aerospace Industry
MTU Production & Technology machines

Additive Manufacturing at MTU:
- 4 Production machines (M280)
- 1 Technology machine (M280)
- 1 Technology machine (M270)

Materials:
- IN 718
- MAR-M509
- Steels
- New Superalloys
Phase 2: Substitution
Experiencing (acc. to Gartner’s hype cycle)

A lot of potential parts

Certification requirements
Test program
Process chain set-up

Still some further development to be done

First parts in production

First approval for development engines

Typical introduction of a new technology
Phase 2: Substitution
First AM production parts

Boroscope bosses for the A320NEO engine finally brought in production

- All development engines provided with AM parts
- Start of production in 2013
- Ramp-up in 2015
Typical Superalloy Components Manufacturer
UK - production with EOS AM Technology

- Delivered up to date about to 6,000 parts

Source: Materials Solutions
Production hall with CNC Technology

Source: http://www.freund-drehtechnik.de
UK - production with EOS AM Technology

Source: Materials Solutions
Additive Manufacturing – the manufacturing technology that will change the world!

www.eos.info

Thank you!
Contact

Peter Rosker
Area Sales Manager

EOS GmbH
Electro Optical Systems
Robert-Stirling-Ring 1
D-82152 Krailling (Munich) Germany

Tel: +49 89 89 336 2173
Mob.: +49 172 890 98 19
eMail: Peter.rosker@eos.info
web: www.eos.info