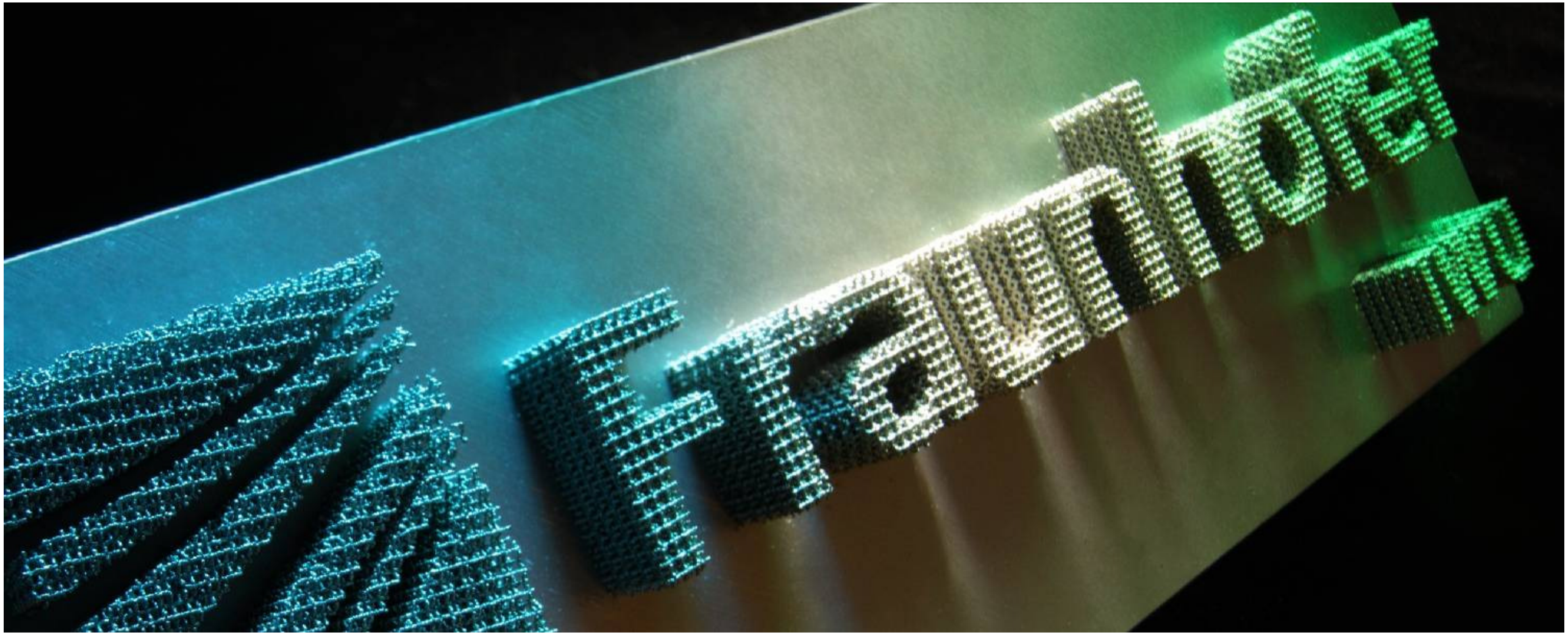
MATERIAL EFFICIENCY
POTENTIALS OF INNOVATIVE PRODUCTION METHODS

Dr.-Ing. Bernhard Mueller

Spokesman, Fraunhofer Additive Manufacturing Alliance



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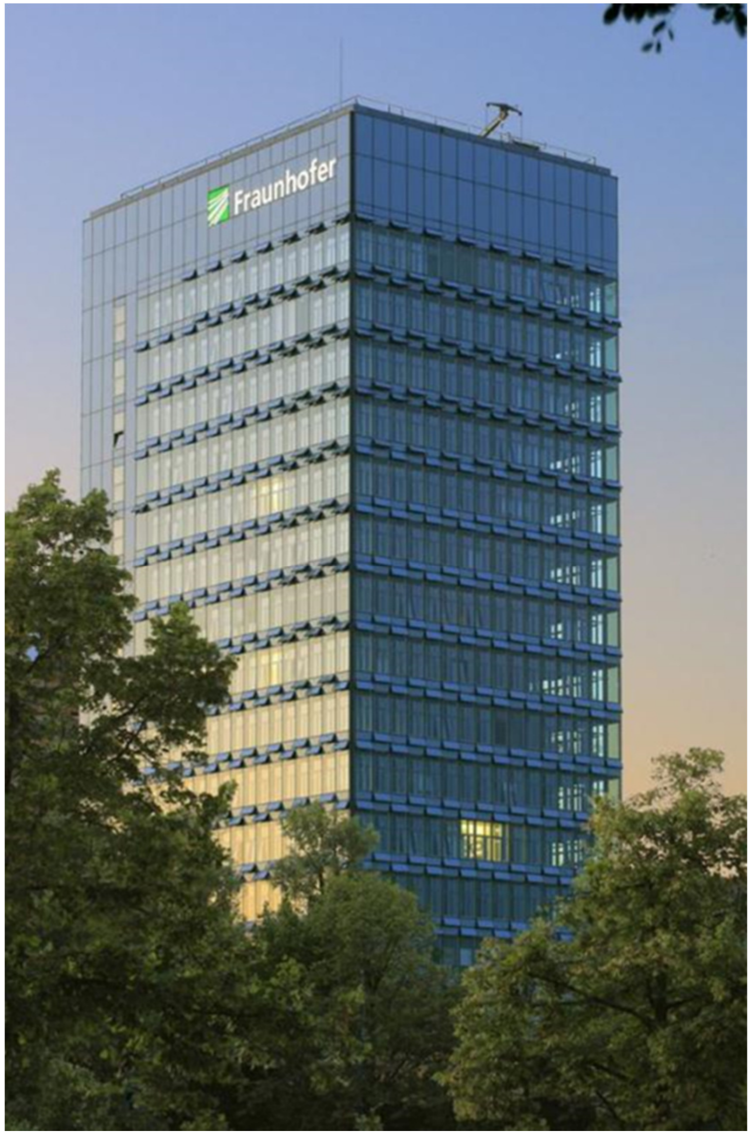
The Fraunhofer-Gesellschaft



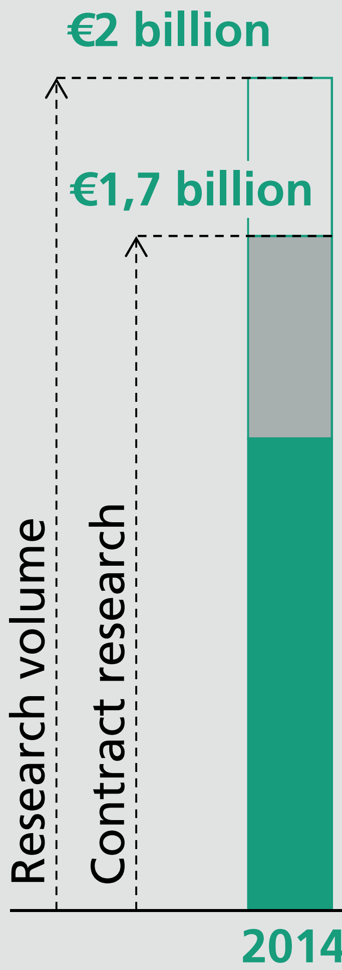
- Promotes and conducts applied research
- In an international context
- To benefit private and public enterprise
- Is an asset to society as a whole
- Our Customers
  - Industry
  - Service Sector
  - Public Administration

The Fraunhofer-Gesellschaft at a Glance

Applied research for immediate utility of economy and benefit of society

More than
24 000 staff

66 Institutes and
research units



roughly **30%** are contributed by the German federal and *Länder* governments

roughly **70%** are generated through contract research on behalf of industry and publicly funded research projects

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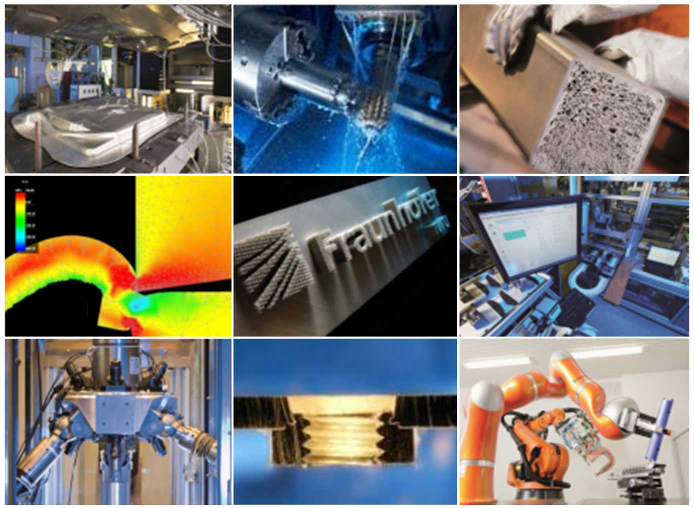
The Fraunhofer IWU

Profile

- Founded in 1991
- About 620 employees
- €41,5 million annual budget
- Locations in Chemnitz, Dresden, Augsburg and Zittau

Research under the heading "Resource-efficient Production"



- Scientific fields
  - Mechatronics and lightweight structures
  - Machine tools, production systems and machining
  - Forming technology and joining

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Fraunhofer Alliances

The Fraunhofer Alliances facilitate customer access to the services and research results of the Fraunhofer-Gesellschaft. Common points of contact for groups of institutes active in related fields provide expert advice on complex issues and coordinate the development of appropriate solutions.

- **Adaptronics (IWU)**
- **Additive Manufacturing (IWU)**
- AdvanCer
- Ambient Assisted Living
- **AutoMOBILE Production (IWU)**
- Battery
- Building Innovation
- Big Data
- Cloud Computing
- Cleaning Technology
- Digital Cinema
- Embedded Systems
- Energy
- Food Chain Management
- **Lightweight Structures (IWU)**
- Nanotechnology
- Photokatalysis
- Polymer Surfaces
- **Simulation (IWU)**
- Space
- Traffic and Transportation
- Water Systems (SysWasser)
- **Vision (IWU)**

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Fraunhofer Additive Manufacturing Alliance

- Objectives
  - Collaborating closely with national and international partners
  - Developing new rapid strategies, concepts, technologies and processes
  - Enhancing performance and competitiveness of SME

- Business areas
  - Engineering
  - Technologies
  - Materials
  - Quality

Central office

Fraunhofer IWU

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The Fraunhofer-Gesellschaft
Lighthouse projects

THERANOS — Intelligent implants that combine diagnosis with therapy

CELL-FREE BIOPRODUCTION — Synthesis of customized proteins on an industrial scale

ELECTRO-MOBILITY II — Transfer of various research findings into market-relevant products

RARE EARTH METALS (60 Nd, 66 Dy) — Up to 50% reduction of rare earth metals needed for permanent magnets

E³-PRODUCTION — New production technology to gain maximum value with minimum resources

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Lighthouse project: E³-Production

E³-PRODUCTION

- From "maximum profit with minimal capital investment" towards "maximum value creation with minimal use of resources"

- Mission: contribution to
  - the national sustainability strategy
  - the establishment of production research skills into the E³-concept
  - strengthening the production engineering expertise inside the Fraunhofer-Gesellschaft

- Involved Fraunhofer Institutes:
  FIT, IBP, ICT, IFF, IGB, ILT, IML, IPA, IPK, IPT, IWU, UMSICHT
- Project leader: Prof. Putz , Fraunhofer IWU

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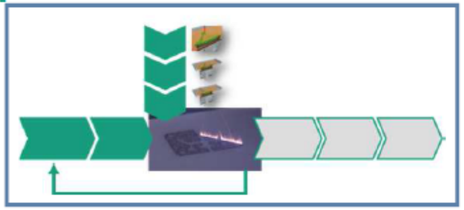
E³-Production: Approach within the project

E³-PRODUCTION

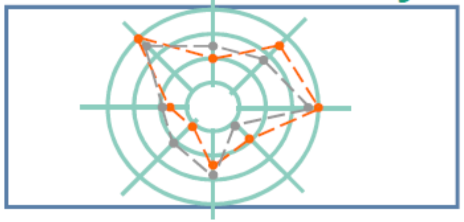
Analyze of the process chain



Key questions

- Analyze state-of-the-art process chain
- Material and geometry of the reference components
- Borderline of the scope of the balancing
- Analyze process chain with additive manufacturing

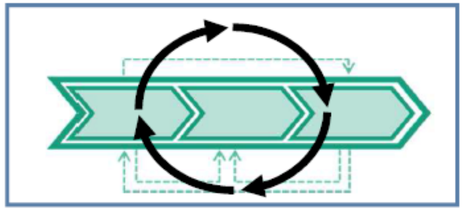
Assessment of the resource efficiency



Key questions

- Identification of relevant resources drivers
- Quantification of all necessary resources
- Assessment of resource needs of single processes

Holistic assessment



Key questions

- Development of appropriate assessment tools and methods
- Holistic assessment of resource needs

Source: Fraunhofer IPT

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E³-Production: Shorten process chains

E³-PRODUCTION

Challenges

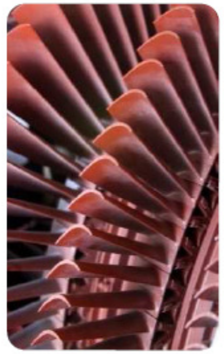
- Expansion to the whole process chain
- Quantification of the resource consumption
- Development of an evaluation methodology
- Identification of potentials for optimizing the process chain

Additive Manufacturing Process Chain

INVESTMENT CASTING OF **TIAL** WITH ADDITIVE MANUFACTURING

Design → SLS - wax model → Ceramic mold → Casting → Finishing → ...

Scope of balancing



Objectives within the project

TECHNOLOGICAL ASPECT

- Layout of additive manufacturing processes for realizing concrete reference components

METHODICAL ASPECT

- Development of a model to assess the process chain and its resource efficiency

Source: Fraunhofer IPT

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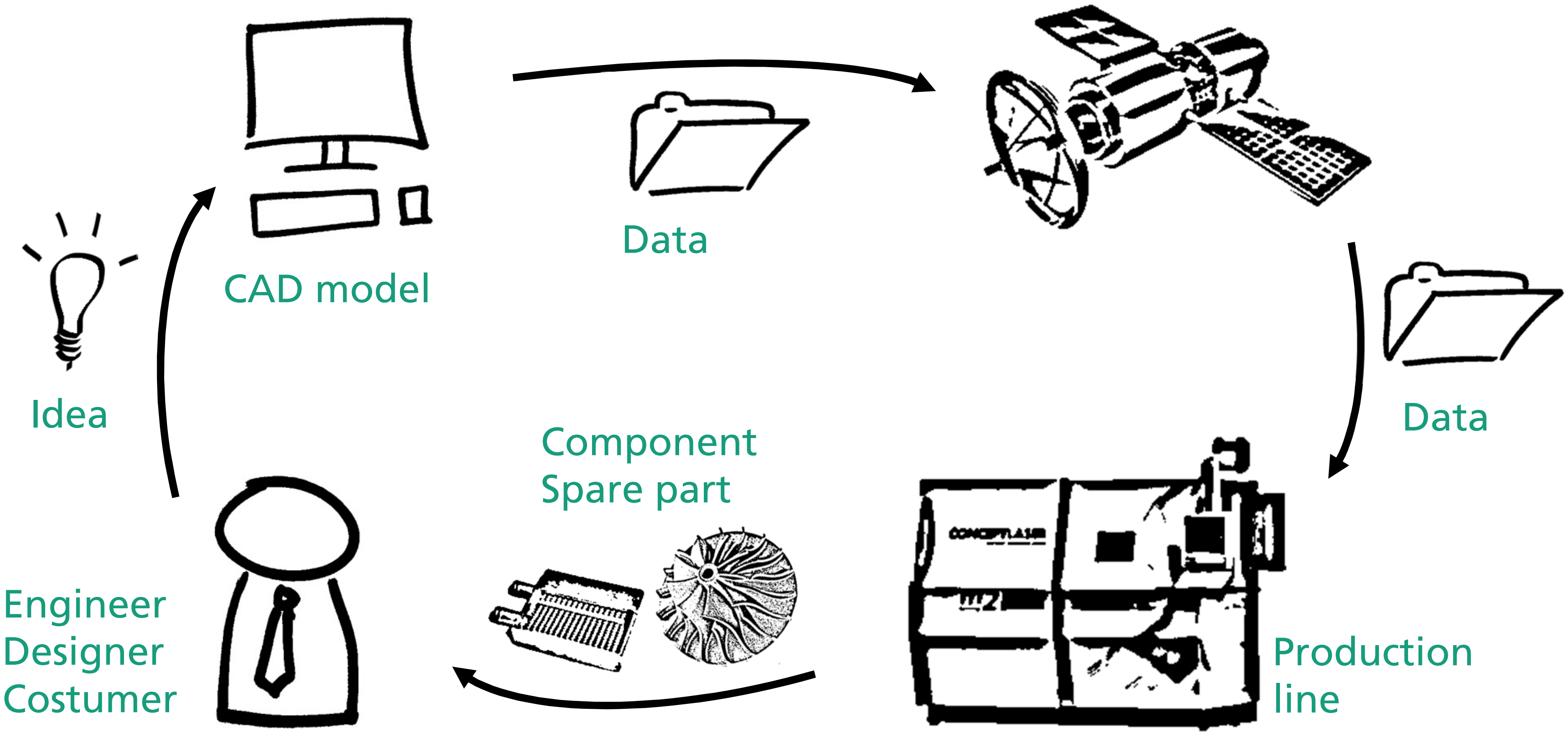
Global Trends

Individual, flexible and ressource efficient products

- Digitalization of value added chain



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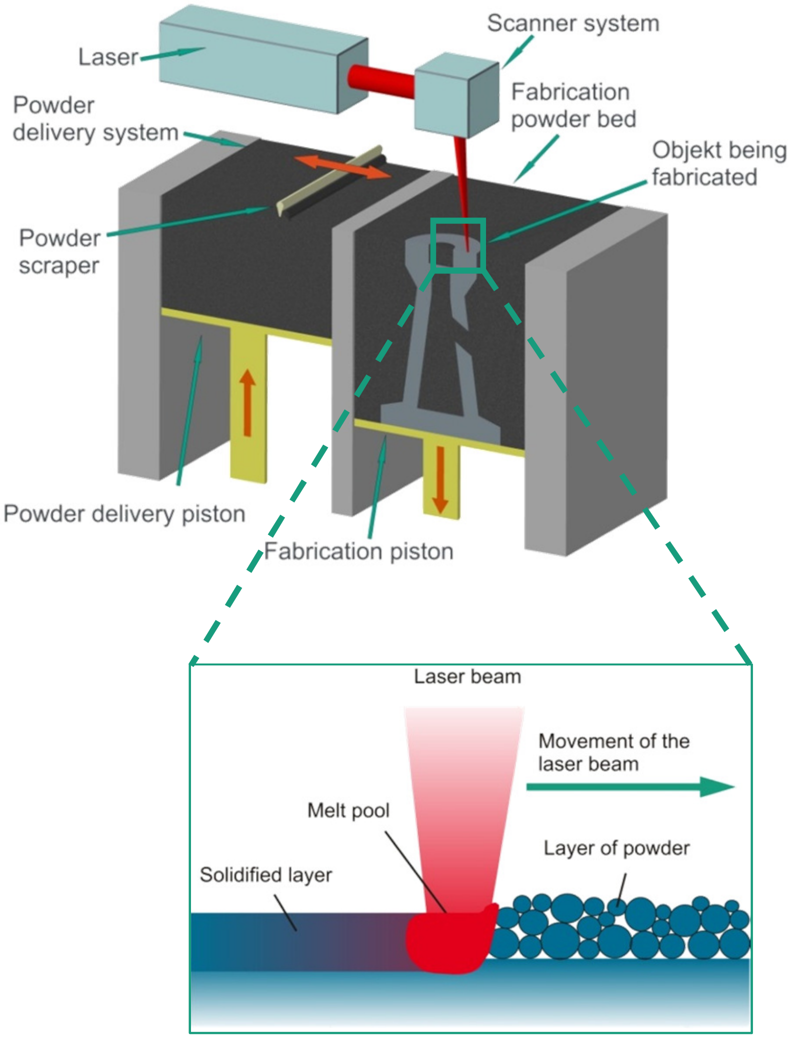
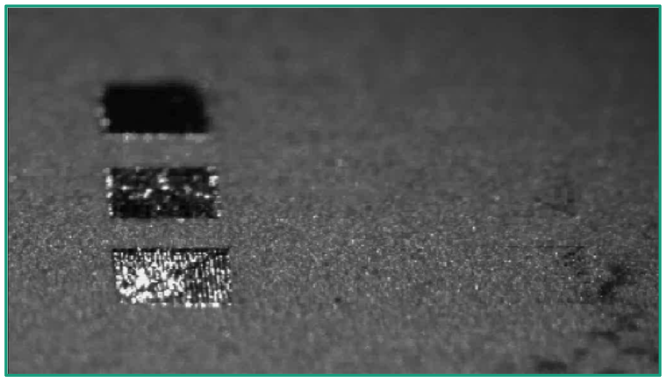
Global Trends

Key Technology: Additive Manufacturing



- Main advantages
  - Short time to product
    - no tools and NC programming
  - Freedom of shape
    - Lightweight design
    - Functional integration
  - Material diversity



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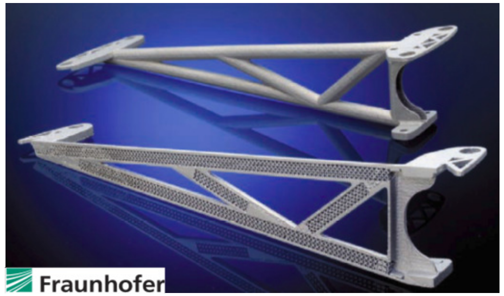
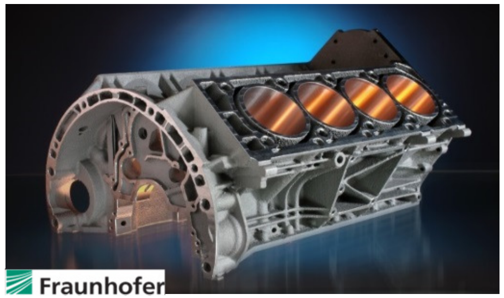
Global Trends
One Approach

AGENT3D
ADDITIV GENERATIVE FERTIGUNG

- Additive Manufacturing
  - The 3D revolution for product manufacturing in digital age

- Objectives
  - Placing industry-specific, additively manufactured products successfully on international markets
    - Cost reduction > 20%
    - Performance increase > 20%
  - Sustainable process chains and customer-supplier-relationship with complete value creation in Germany
  - Interlinking science and industry to a driver of innovation





Source: Fraunhofer IWS / AGENT-3D e. V.

Industrial Applications of AM

Aerospace

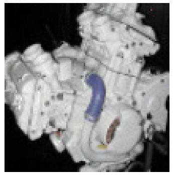
- **Fuel nozzle** for General Electric's leap flight engines
- **5x more durable, 25% lighter**

- **Thrust chamber** for aerospace rocket engine by SpaceX
- **More reliable, robust, and efficient**

- **Metal brackets** designed for AM
- Resulting in **up to 50% less weight** and less raw material input

Automotive

- Completely **3D-printed electric vehicle** based on new fiber-reinforced thermoplastics
- **Only 40 parts (200 kg)** instead of 30,000 parts (600 kg)



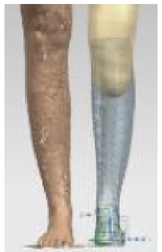
- **Prototyping** of components
- Reduction of **development time from 28 to 8 weeks** for high-performance engine

- Used for **proto-typing to reduce development time**
- **Direct production of complex parts** like air vents to reduce cost

Healthcare

- Sonova produces **hearing aids**
- Mass production of **highly customized** parts

- **Model to aid tumor surgery** printed by 3D systems
- **Reduction of surgery time and complications**



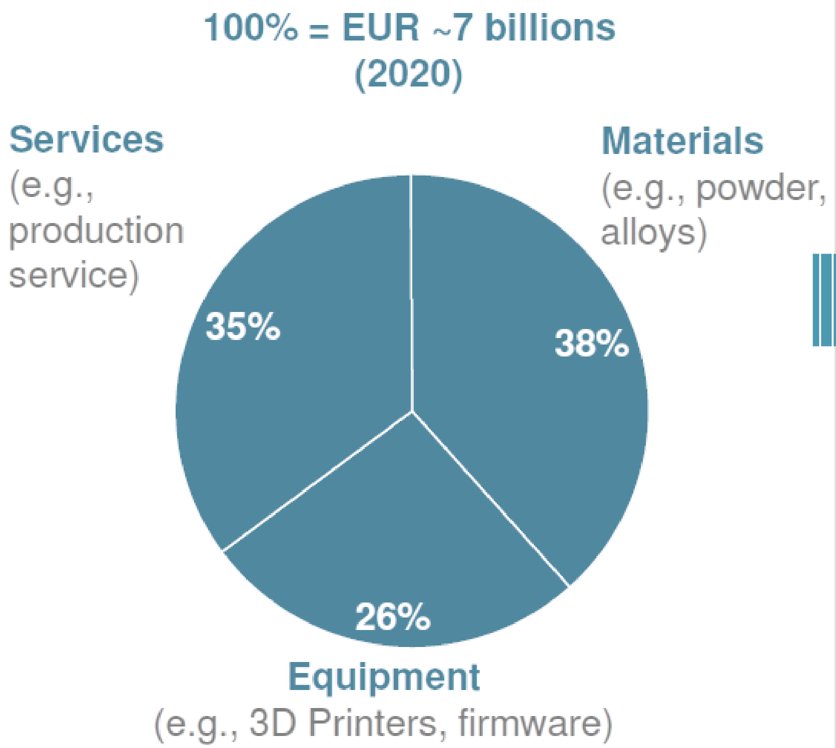
- **Artificial limbs constructed in 2 weeks** replacing lower half of left leg
- Perfect **physical fit with aesthetic components**

Source: McKinsey & Company

Additive Manufacturing
Expected economic impact

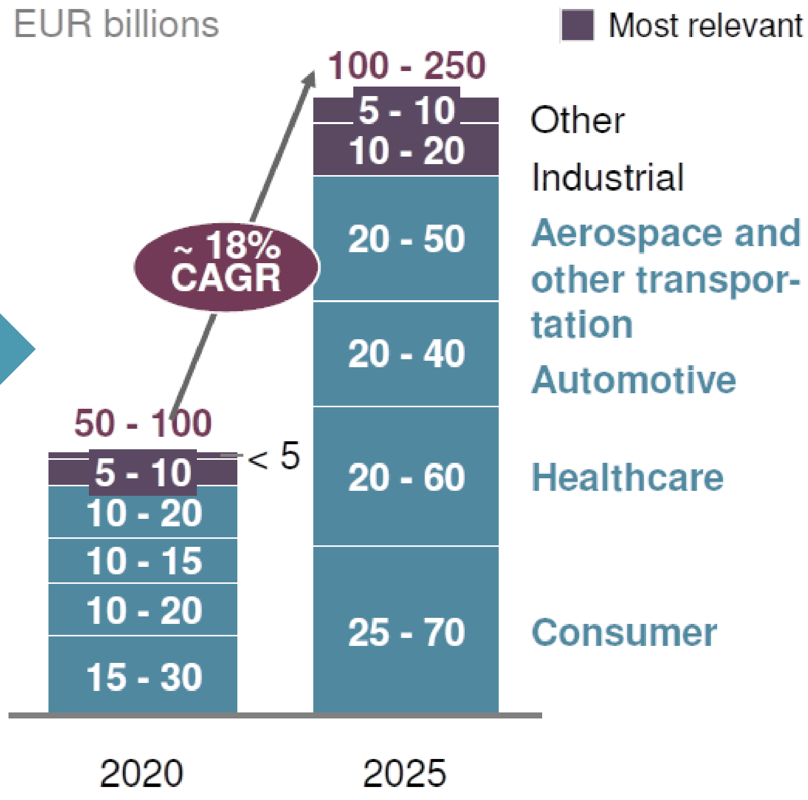
The primary AM market size is moderate …

Direct AM market
Revenues from materials, equipment, services



… but the total expected value of produced goods and services is significant

Economic impact
Value of products and services sold



Source: Wohlers Associates; IDC, Marketsandmarkets, McKinsey research and expert interviews

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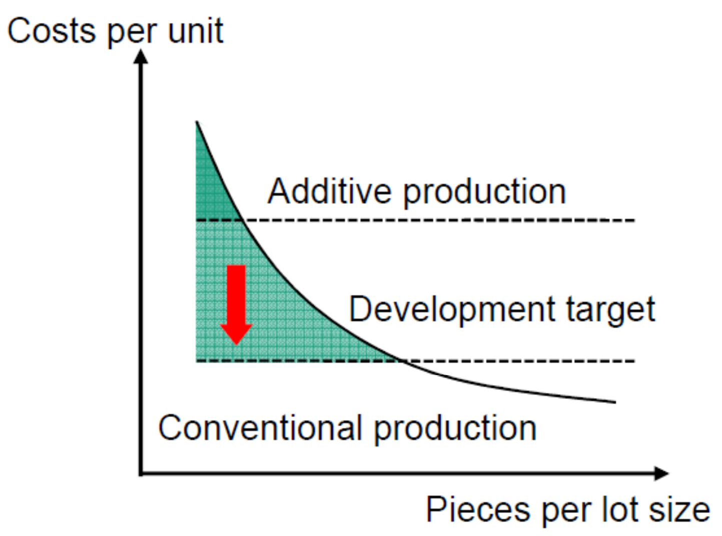
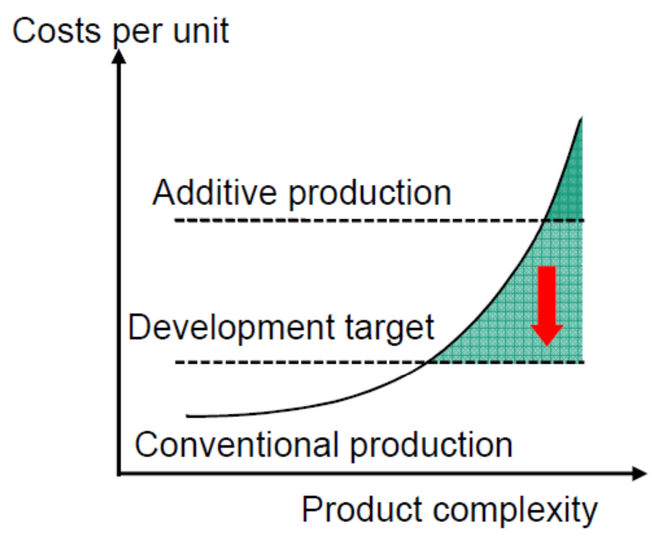
Additive Manufacturing
Unique features

Individualization



Complexity



Due to its low costs for single and small batch production AM is mainly used for prototyping

AM offers potential for manufacturing of complex and high value added parts

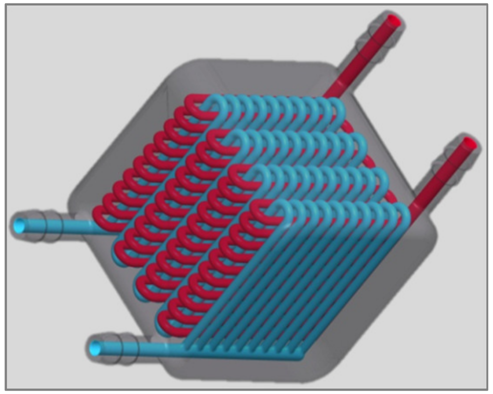
Costs for additive manufactured components are nearly independent of the number of items and the complexity!

Source: Fraunhofer ILT

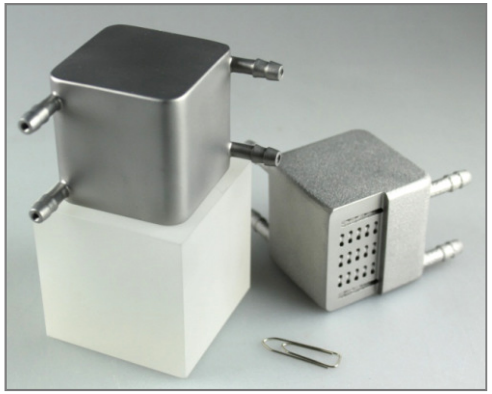
Trends and Examples
Engineering / Component development

- Trends
  - Extreme lightweight design, downsizing / miniaturization
  - (Mass) Customization / individualization
  - Integral part design / functional integration
  - Full-strength materials from all technically relevant metal alloy groups

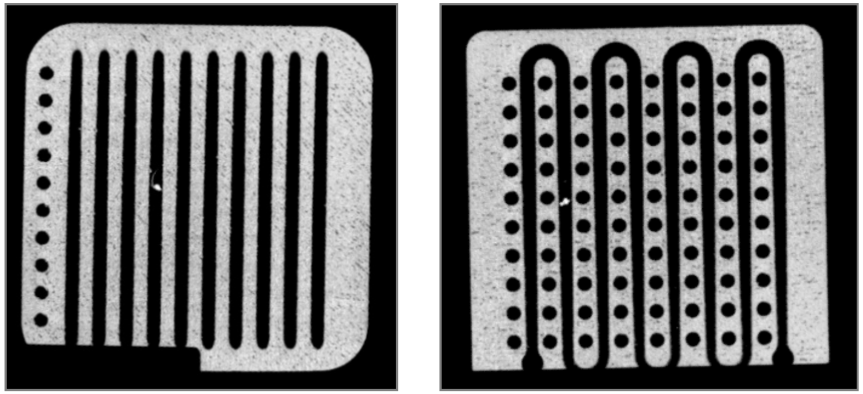
- Example: Innovative heat exchanger



3D CAD model



Additively manufactured parts



Evaluation / inspection by µCT scan

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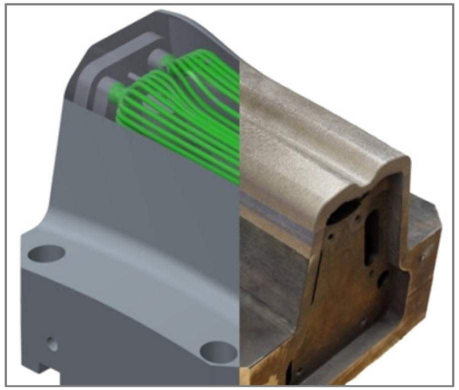
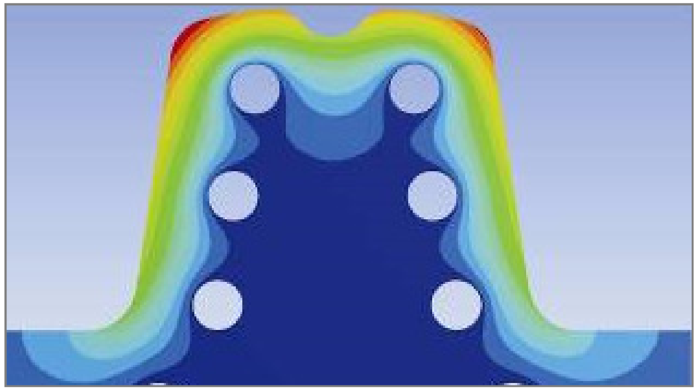
Trends and Examples
Production tooling

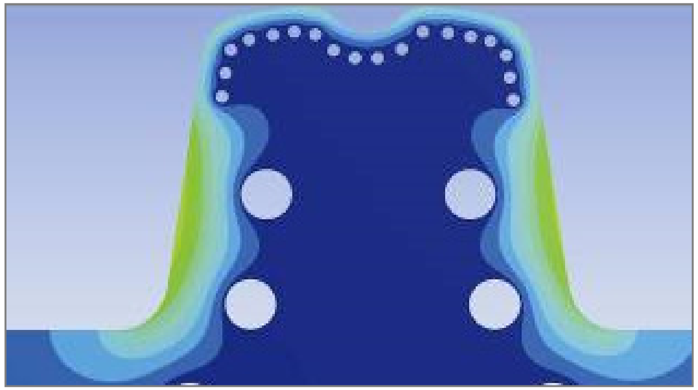
- Trends
  - Highly efficient, real-time cooling / thermal management
  - Integration of sensors in dies and moulds
  - Load case oriented and structured design of tooling
- Example: Tooling for hot sheet metal forming
  - forming press locking time reduced by 50 % → total cycle time reduced by 20% → energy consumption in typical car body production (reference plant) reduced by 245 MWh (equals 146 t CO_2)



Press hardening tooling segment



Conventionally drilled cooling bores



conformal cooling channels (design for AM)

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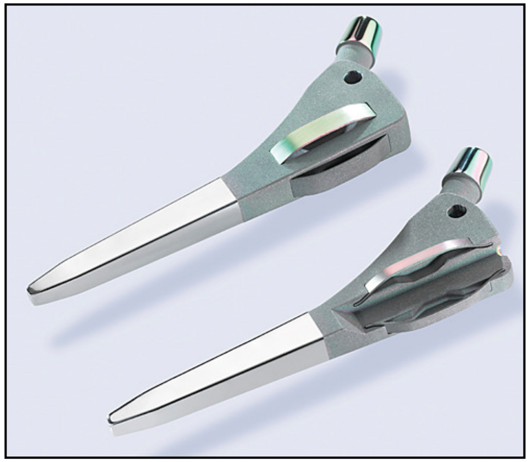
Trends and Examples
Medical engineering

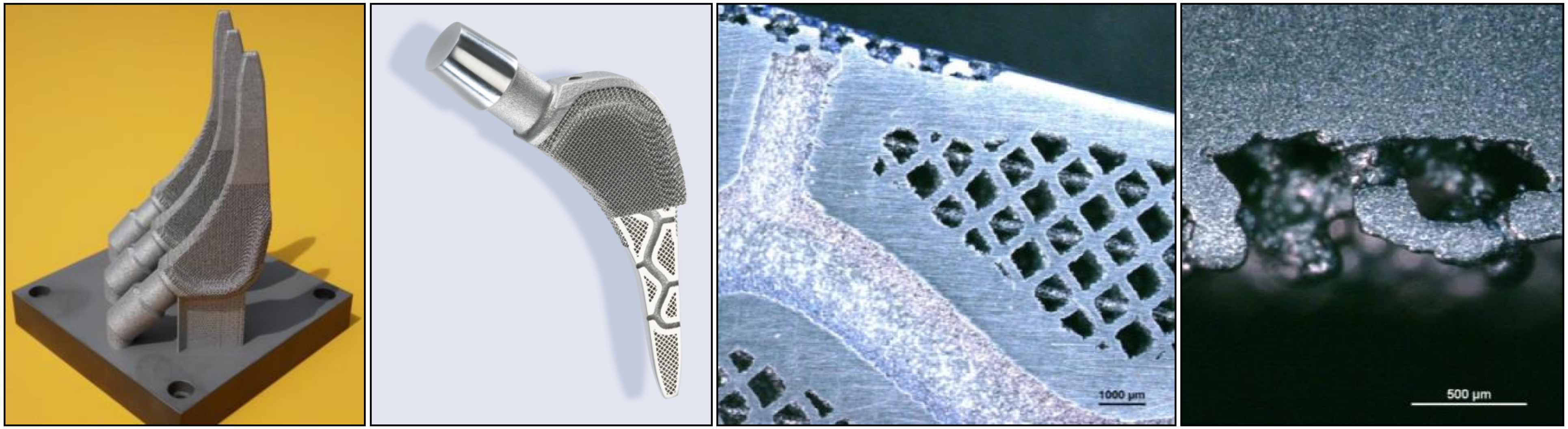
- Trends
  - Customized, patient-specific implants
    - Based on medical imaging data like CT or MRI
    - Tool-free manufacturing in medically approved materials
  - Functional integration in implants

- Example: AktiLoc – Implant with integrated shape memory actuators
  - Homogeneous and stable fixation of cement-less hip stems
  - Increase the primary stability by an optimal force distribution at the bone-implant interface using Shape Memory Alloy (SMA) elements



Trends and Examples
Medical engineering

- Example: MUGETO® – Implant with functional channels and cavities
  - additively manufactured by Laser Beam Melting in titanium TiAl6V4 ELI
  - macro-porous surface structures → osseo-integration
  - inner cellular structures → stiffness adaption to bone
  - channels and cavities → drug depot, endoscopic inspection, filling gaps, …



Additive Manufacturing
Necessary adoption steps for wide use in production

Challenges for AM	Necessary Steps	Fraunhofer contribution
Missing technical standards	Standardisation	Contributing to ISO activities, e.g. through the Association of German Engineers VDI
Reproducibility	Quality control systems / in-situ feedback control systems	Various R&D activities together with the German Laser Beam Melting machine manufacturers
Costs	Gained productivity	Development of High Power Laser Beam Melting Machines (1 kW Laser) and novel scanning strategies
Education with regard to AM design	Widely spread teaching of AM principles at universities / colleges	Implementing AM principles in lectures at Fraunhofer-linked universities
Material variety (e. g. carbon steel, copper, ceramics)	Material and process development	R&D activities with regard to processability of more material types and alloys

Additive Manufacturing
A Fraunhofer perspective

- So far
  - AM technologies are prepared for industrial use
  - There is a large variety of different technologies – picking the right one is crucial to succeed
  - Additive Manufacturing will not replace other technologies:
    - it is a complementary manufacturing method
    - it is able to extend the possibilities and add value to products
  - A profitable use of AM, most often depends on a different way of thinking:
    - This may affect product design as well as the overall production process
  - Development will be more a continuous evolution than a disruptive revolution
  - Fraunhofer is active in many fields of AM and looking forward to cooperation with industries willing to adopt AM technology

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Fraunhofer Direct Digital Manufacturing Conference DDMC
Berlin (Germany), March 16 and 17, 2016

- SCOPE: Encouraging dialogue!
- Range of topics:
  - Product Development
  - Technologies
  - Material
  - Quality
  - Innovative and visionary approaches
- Keynotes:
  - Prof. Boris Chichkov, Laser Zentrum Hannover
  - Dr. Richard Bibb, Loughborough University
  - Dr. Tommaso Ghidini, ESA
  - Dr. Martin Hillebrecht, EDAG
  - RA Prof. Dr. L. Grosskopf LL.M.Eur., Uni Bremen
  - Wouter Gerber, Aerosud (Pty) Ltd, Südafrika
- More information: www.ddmc-fraunhofer.de

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