AACHEN CENTER FOR ADDITIVE MANUFACTURING

Discover3DPrinting @Automechanika 2022

Basic AM Seminar

Lukas Bauch | 14.09.2022

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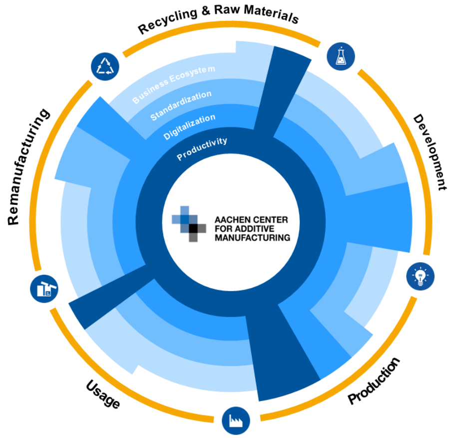
The ACAM Offers Services in the Areas of Consulting, Engineering, Research and Education with a Focus on the Additive Manufacturing Industry

Your presenter

Lukas Bauch

- Consultant for ACAM Aachen Center for Additive Manufacturing GmbH
- Research Associate at the Digital Additive Production Chair (DAP) of RWTH Aachen University

Perspective and focus



Community

BUSINESS Members

BASIC Members

COOPERATION Members

Key figures

- One-stop-shop for additive manufacturing covering the entire process chain
- Pooling of resources of RWTH Aachen Campus and facilitating industry’s access to the Additive Manufacturing expertise of leading scientific and research institutions
- Over 100 researchers engaged in topics around the AM product life cycle and industry structure
- Delivery of approx. 40 industry project in consulting, engineering and research

Heritage
At the Time of Charlemagne, Aachen was the Capital of Europe

Image Source: DAP RWTH Aachen University

Heritage
The Cradle of Metal AM

The cradle of metal AM

The world's most vivid and multifaceted AM ecosystem

1995 – **First Hybrid Machine Tool**

1997 – **Basic Patent for SLM**

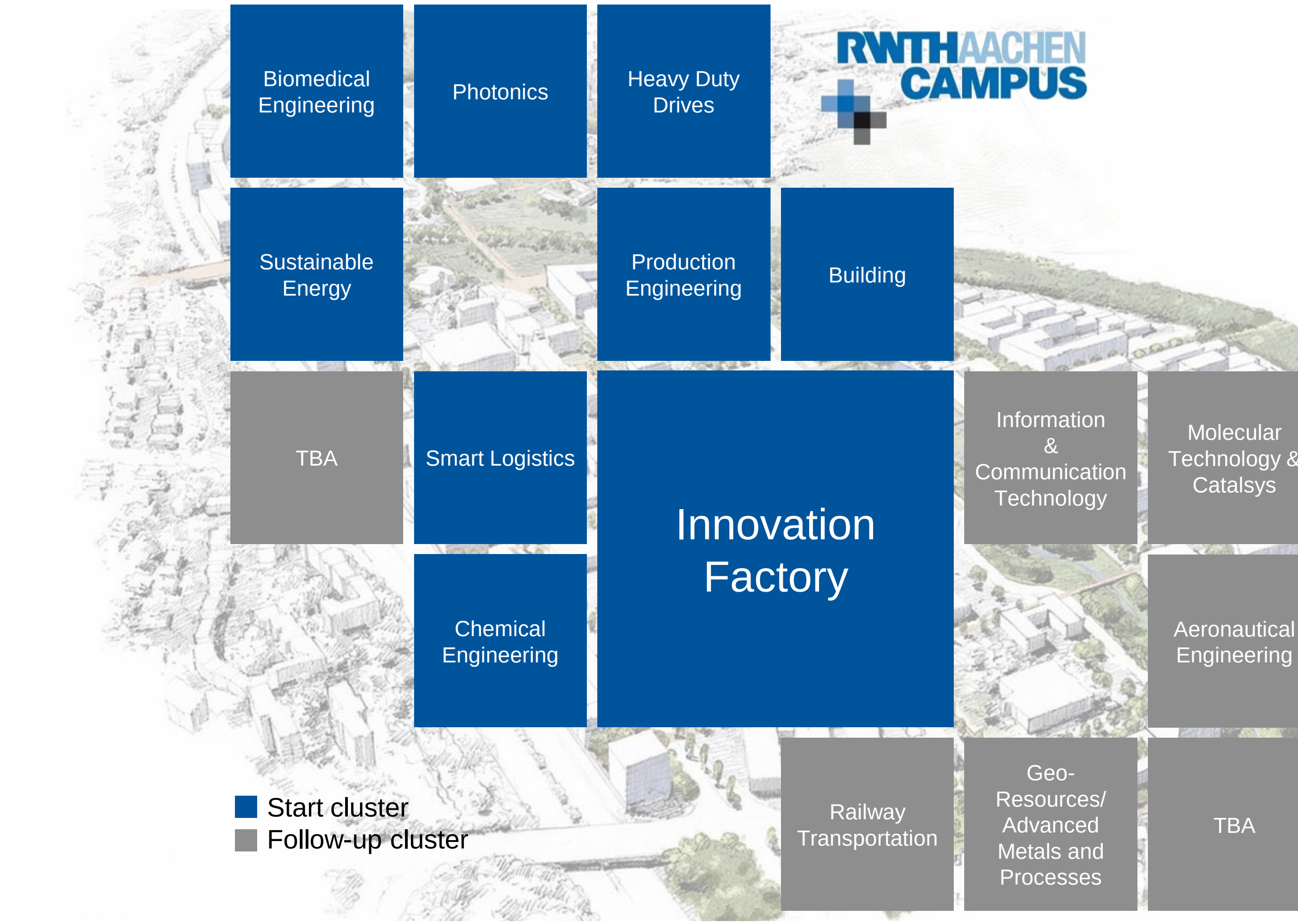
2001 – **First Tool Insert**

2008 – **First Implant**

2015 – **Foundation of ACAM**

Image Source: DAP RWTH Aachen University, Fraunhofer ILT, Campus GmbH

RWTH Aachen Campus:
16 Research Clusters Are Developing



Cluster Smart Logistic

Cluster Heavy Duty Drives

Cluster Photonics

Cluster Sustainable Energy

Cluster Production Engineering

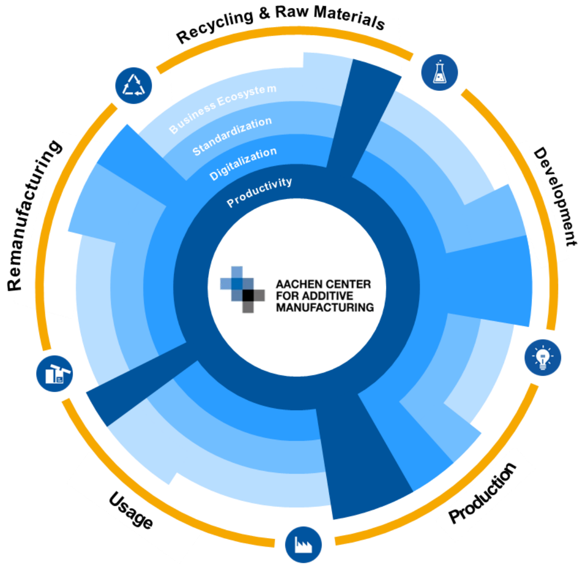
Cluster Bio-Medical Engineering

Cluster Chemical Engineering

Community
The Aachen Center for Additive Manufacturing

Navigating AM complexity

Creating opportunities by leading-edge **R&D**, professional **training and education**, and agile **engineering** and **consulting** services



- Dedicating **3,000 m²** lab space to AM research
- Connecting **100+ researchers** in the field of AM

Leading-Edge Research in Additive Manufacturing

The ACAM is your one stop shop for Additive Manufacturing research, education, engineering and consulting.

Community
Our Member Network

BUSINESS Members

oerlikon | TOYOTA | GMH GRUPPE | ZOLLERN | GRÄNGES | MTDG Manufacturing Technology Deployment Group, Inc.

BASIC Members

Materials Magic Hitachi Metals | PROTIQ A Phoenix Contact Company | TÜV SÜD | DAIDO STEEL | SCHAEFFLER | LMT TOOLS | NISSAN

SCHÄFER | toolcraft | AMEXCI | APPLIED MATERIALS | aalberts | DENSO Crafting the Core | kurtz ersa

MESSER | voestalpine ONE STEP AHEAD. | Danfoss | GE Additive | OTTO FUCHS | Linde | THE AVIATION AM CENTRE

OWL Additive Manufacturing | Hydro | AddUp | VDM Metals | GEA engineering for a better world | AUBERT&DUVAL

COOPERATION Members

Efficient Elements | LUNOVU Integrated Laser Solutions | ACUNITY | stratasys | ENABLE3D

IXUN Lasertechnik GmbH | formnext | 3YOURMIND | AMGTA

Consulting
Enabling Manufacturing Companies

Market & Customer Analysis

Product & Service Program

Intelligent Collaboration & Innovation Networks

Increase customer value (external)

Competitive Strategy

Increase productivity (internal)

Lean, Process- & Project management

Supplier Analysis & Screening

Industry 4.0 & Digital Transformation

Structural & Process Organization

Internal Support Processes

Inquiry-To-Order

Order-To-Delivery

Sustain and Retain

Demand Generation & Part Identification

Engineering, Design, Software Tool Chain

Production Planning & Scheduling

Layout Planning

Life-Cycle Assessment & Re-X Chains

Calculation & Pricing

Technology Assessment

Process Chain Design

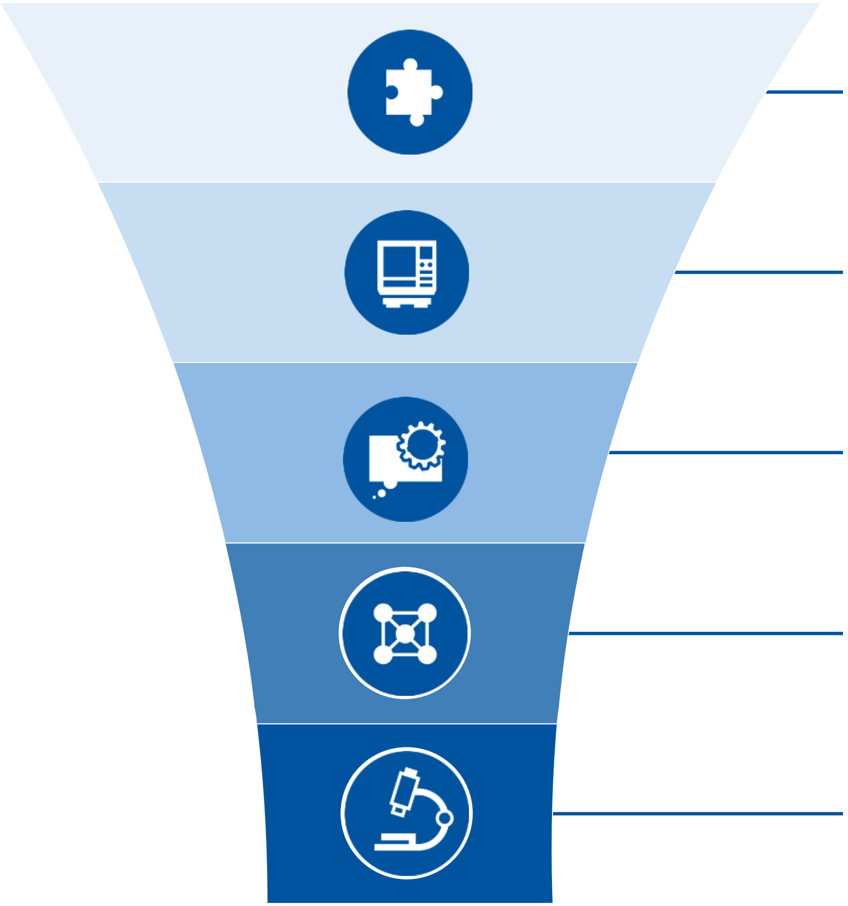
Material Flow & Automation

Certification & Auditing

Market & Customer | Top-Level Business Processes | Support Processes

Research & Development
The Future of Additive Manufacturing

Driving Additive Manufacturing Forward



- Methods and Models for AM Application & Implementation
- Developing Machines and Tools for AM and Post-Processes
- Creation of Process Principles
- Designing of Materials for AM
- Understanding the Physical Phenomena

Connecting Industry and Research

Consortial ACAM Projects

- Annual R&D projects from research partners exclusive for ACAM members
- Quick knowledge boost by collaboration

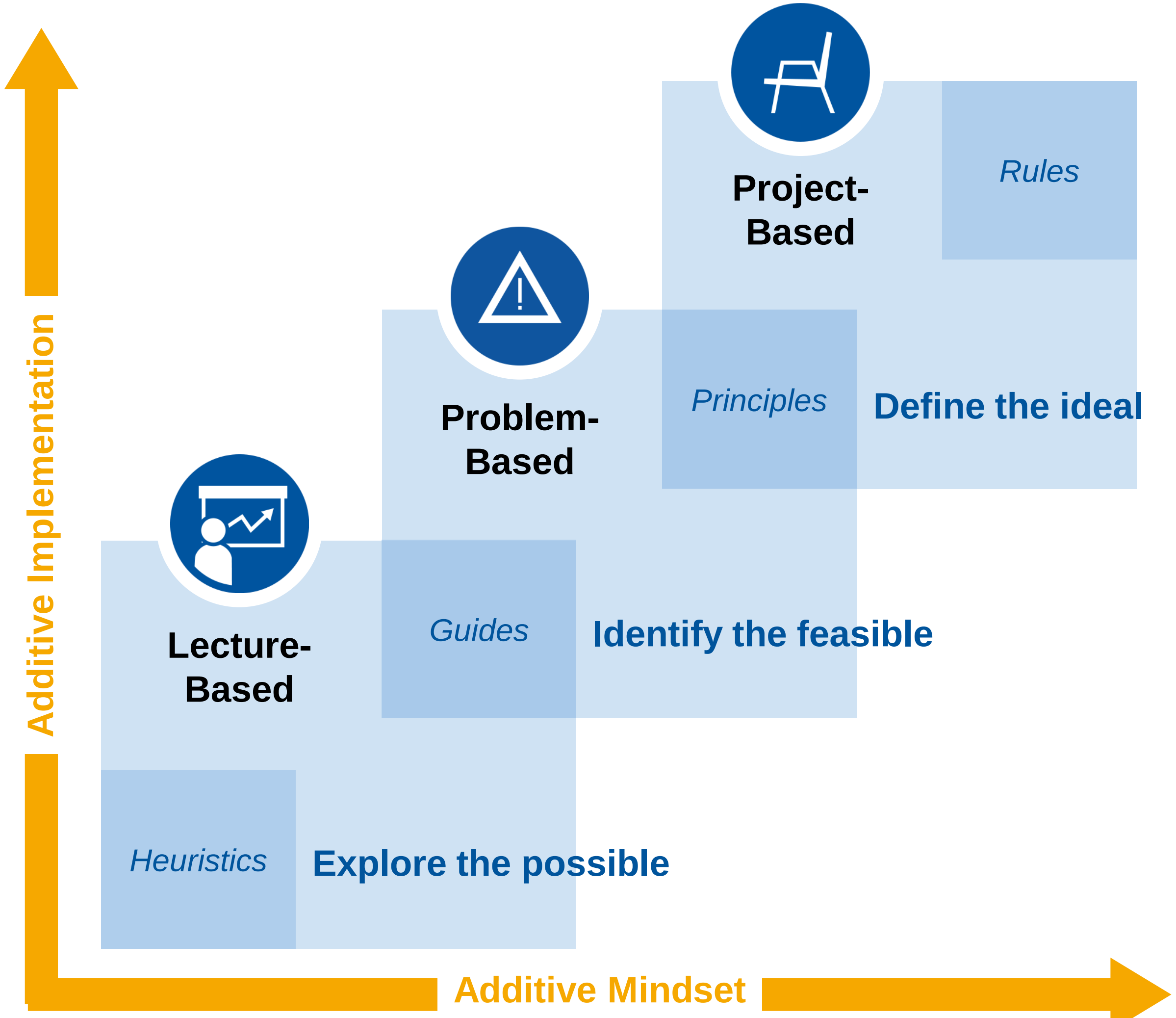
Bilateral R&D Projects

- Address contemporary challenges in R&D projects
- Overcome risks by fast results from leading-edge research

Public-funded R&D Projects

- Take part in shaping the future of Additive Manufacturing
- Benefit from public funding to reach long-term goals

Education
Implementing an Additive Mindset



Source: Schleifenbaum and Schuh et al. (2020): Structured Approach for Changing Designer's Mindset Towards Additive Manufacturing

Targeting Continuous Learning

Project-based Approach

- Starting with predefined goals
- Structuring the design process and integrating existing knowledge
- Focus on discussions about solutions

Problem-based Approach

- Starting with selected examples
- Understanding theoretical fundamentals of design problems
- Focus on the perception of problem indicators

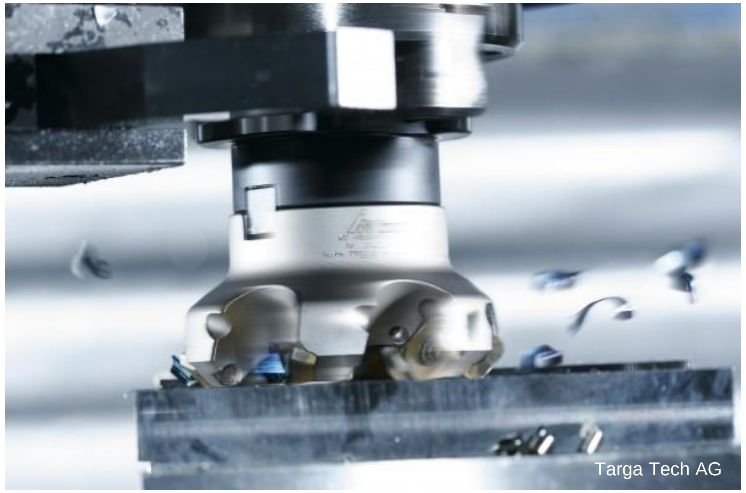
Lecture-based Approach

- Starting with heuristic information
- Summary of experiences and theoretic knowledge
- Structured lectures transporting information
- Focus on existing knowledge of audience

Basic AM Seminar – Content

Subdivision of Manufacturing Technologies

Subtractive Manufacturing



Manufacturing of geometry by removing of defined areas from workpiece

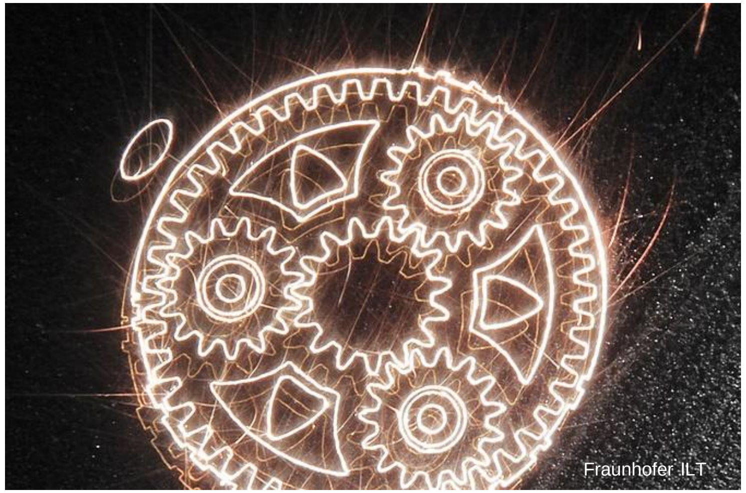
- Milling
- Turning
- …

Formative Manufacturing

Forming a given volume into geometry under the condition of constant volume

- Deep Drawing
- Molding
- …

Additive Manufacturing



Stacking of volume elements (usually in layers)

- Laser Powder Bed Fusion
- Laser Metal Deposition
- …

Additive Manufacturing – Definition

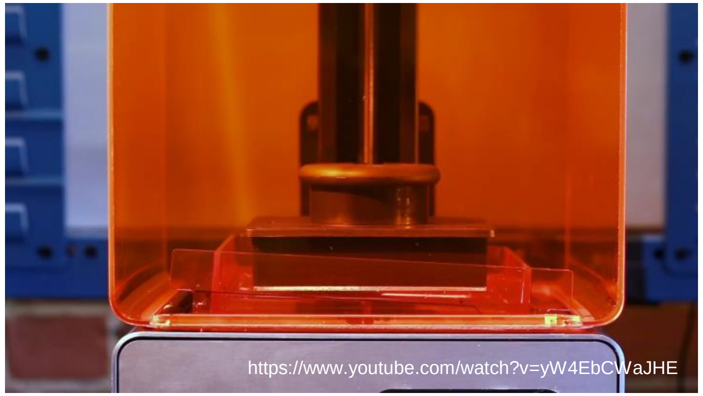
Definition (ASTM 52900)

"Additive Manufacturing (AM) is defined as the process that
- ***produces components from 3D model** data*
- *by **joining material usually layer by layer**,*
- *as opposed to subtractive and formative manufacturing methods."*

Definition (VDI 3405)

*"Manufacturing process in which the **workpiece is built up in successive layers or units**."*


https://www.youtube.com/watch?v=yKHMmKqdI68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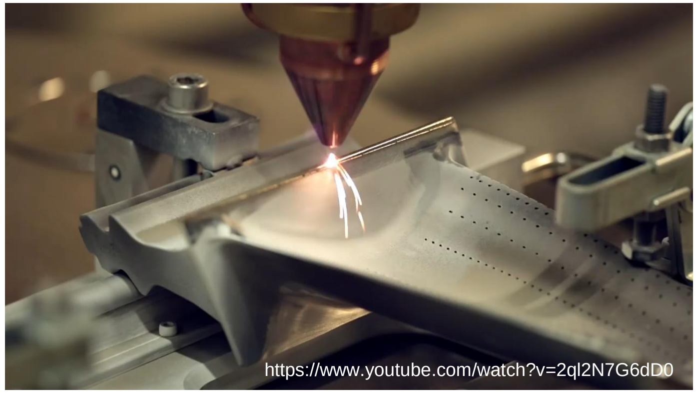
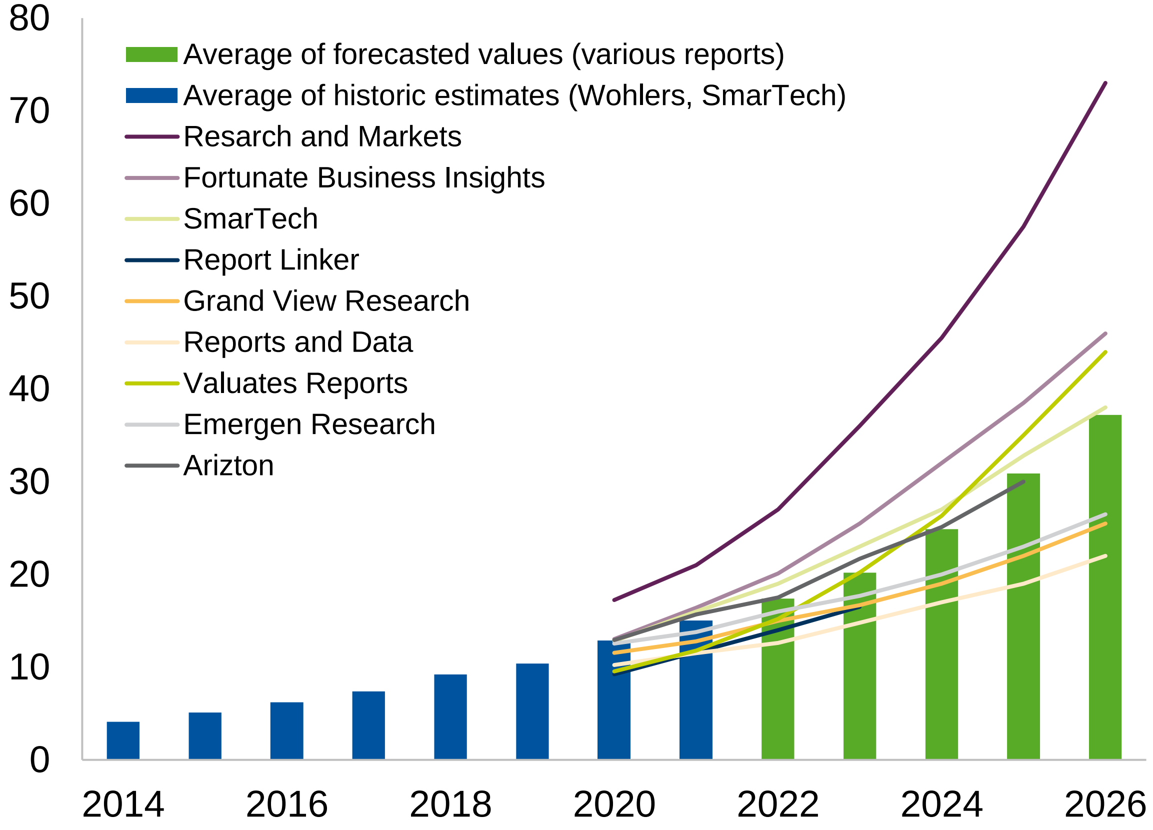

https://www.youtube.com/watch?v=2ql2N7G6dD0


https://www.youtube.com/watch?v=te9OaSZ0kf8

Positive Historic and Future Development of the AM Market

Total AM market size according to different market reports [$ billion]



- **Overall positive** forecasted and historic growth rates in all reports
- **Diverging positive forecasts** indicate a **developing** volatile and uncertain market
- **Included revenue (primary market):**
  - AM systems
  - Software
  - Materials
  - Services

Source: Hubs Additive manufacturing trend report 2021 and cited sources

Introduction to AM
Key Characteristics of Additive Manufacturing

Additive

Geometry is generated by adding material instead of removing or forming

Toolless

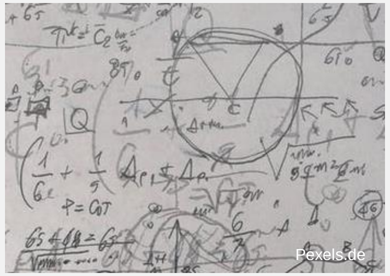
Component geometry is independent from tool

Digital

Direct manufacturing based on 3D models

Complex

Different technologies require specific expert knowledge



AM Benefits and Barriers

AM Benefits

- **Design freedom**: Complex features, lightweight, monolithic
- **Flexible design** iterations and engineering changes
- **Integration of functions**
- Economic **small quantities** and **individualization**
- **Short time** and efficiency **idea to product**
- **Short supply chain**
- **Insourcing:** Appealing for staff in industrialized countries & high degree of automation
- **Sustainability** by material reduction or efficiency in performance

AM Barriers

- **Long printing times**
- Almost **no economies of scale**
- **Low surface quality** as-built
- **Large geometrical tolerances** as-built
- **Requires** “Additive Mindset” and **skills**
- **Complex quality assurance** and **certification**
- **Health and security** measures required

AM **benefits and barriers** are **not generic –** consideration of use case, AM technology and process chain mandatory

Source: Unsplash, Pexels

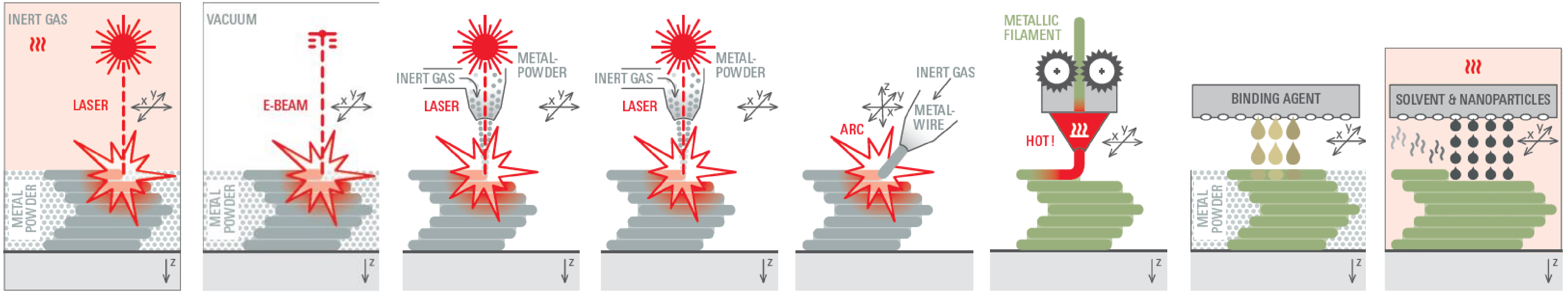
Basic AM Seminar – Content

AM Technology Overview
Segmentation of Established Metal AM Technologies

Additive Manufacturing

Metal

Powder Bed Fusion		*Direct Energy Deposition*			*Material Extrusion*	*Binder Jetting*	*Material Jetting*
Fused with laser	Fused with electron beam	Laser energy absorbed by substrate	Laser energy absorbed by powder feedstock	Fused with electric arc	With filament, green part to be sintered	Joined with bonding agent, to be sintered	Cured with heat, to be sintered
L-PBF Laser Powder Bed Fusion	**EBM** Electron Beam Melting	**LMD** Laser Metal Deposition	**EHLA** Extreme High Speed LMD	**WAAM** Wire Arc Additive Manufacturing	**Metal FDM** Metal Fused Deposition Modeling	**BJ** Binder Jetting	**NPF** Nano Particle Jetting



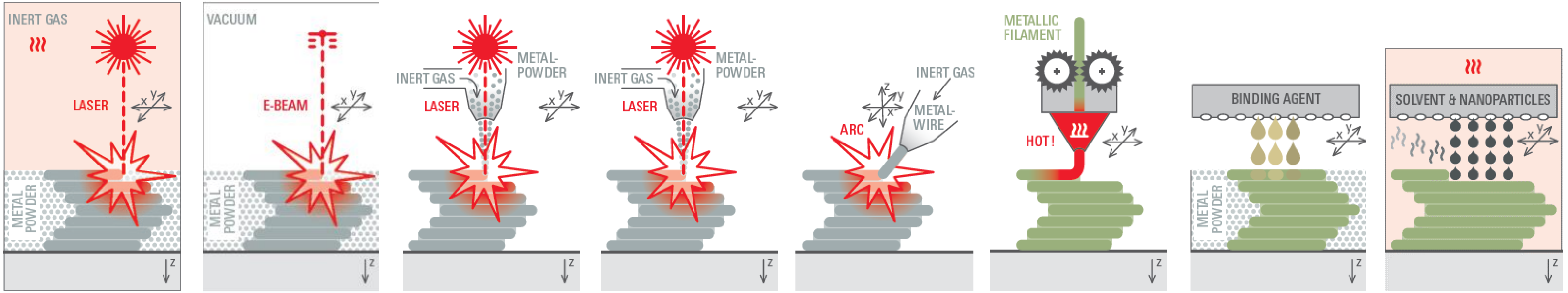
Source: Derived from Fomrnnext AM Field Guide Compact and DIN EN ISO/ASTM Terminology

AM Technology Overview
Segmentation of Established Metal AM Technologies

Additive Manufacturing

Metal

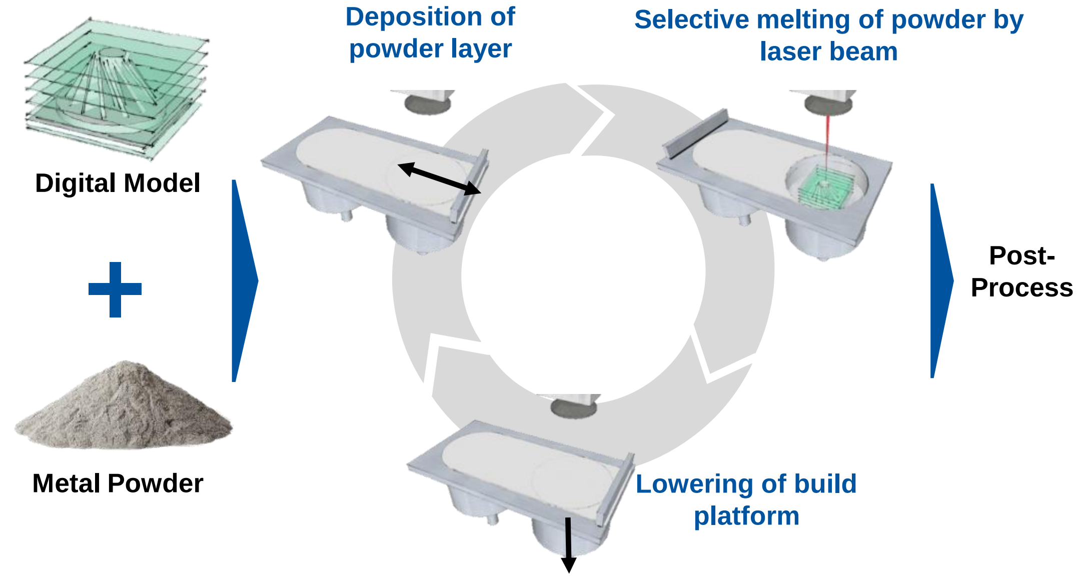
Powder Bed Fusion	Fused with laser	**L-PBF** Laser Powder Bed Fusion
Powder Bed Fusion	Fused with electron beam	**EBM** Electron Beam Melting
Direct Energy Deposition	Laser energy absorbed by substrate	**LMD** Laser Metal Deposition
Direct Energy Deposition	Laser energy absorbed by powder feedstock	**EHLA** Extreme High Speed LMD
Direct Energy Deposition	Fused with electric arc	**WAAM** Wire Arc Additive Manufacturing
Material Extrusion	With filament, green part to be sintered	**Metal FDM** Metal Fused Deposition Modeling
Binder Jetting	Joined with bonding agent, to be sintered	**BJ** Binder Jetting
Material Jetting	Cured with heat, to be sintered	**NPF** Nano Particle Jetting



Source: Derived from Fomrnnext AM Field Guide Compact and DIN EN ISO/ASTM Terminology

AM Technologies
Laser Powder Bed Fusion of Metal (LPBF)

Process Principle

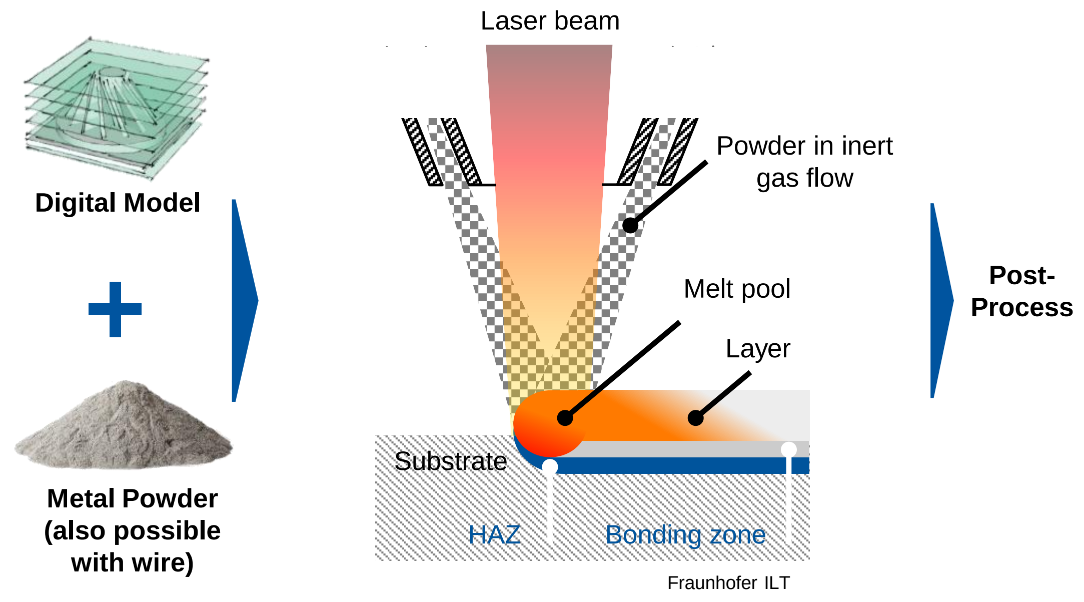


Process in Action

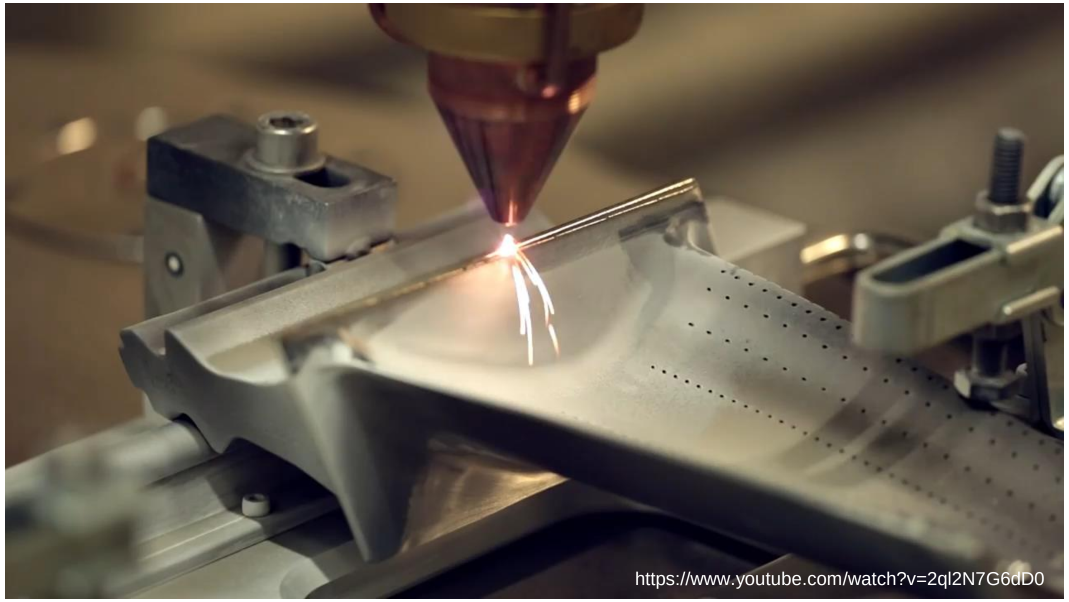
- Selective melting of metal powder layer-by-layer with one or more lasers
- Requires support structures for overhangs
- General suitability for weldable materials, comparably many alloys are qualified (e.g., steels, Ni base alloys, CoCr, copper and alloys, Ti and alloys, Al alloys, refractory metals, Mg alloys, HEA)

AM Technologies
Laser Metal Deposition (LMD)

Process Principle



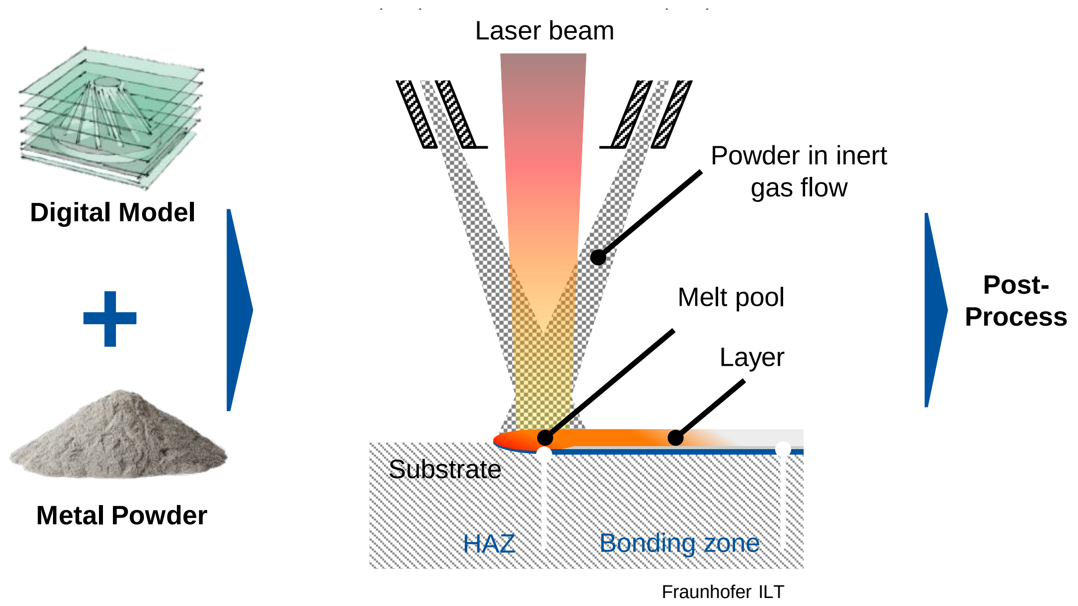
Process in Action



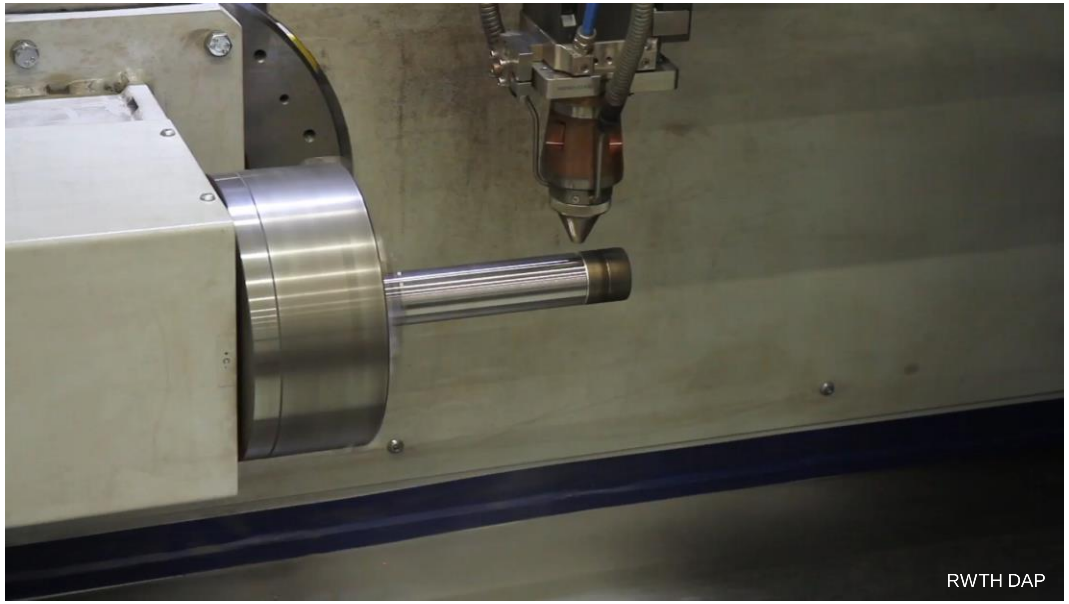
- Used for additive manufacturing, additive coating and repair (deposition on existing geometry)
- Powder is transported by an inert gas flow
- Energy for melting the metal powder is mainly deposited in the substrate, not directly in the powder
- General suitability for weldable materials, different materials qualified (e.g., steels, Ni-base alloys, Al alloys)

AM Technologies
Extreme High Speed Laser Metal Deposition (EHLA)

Process Principle



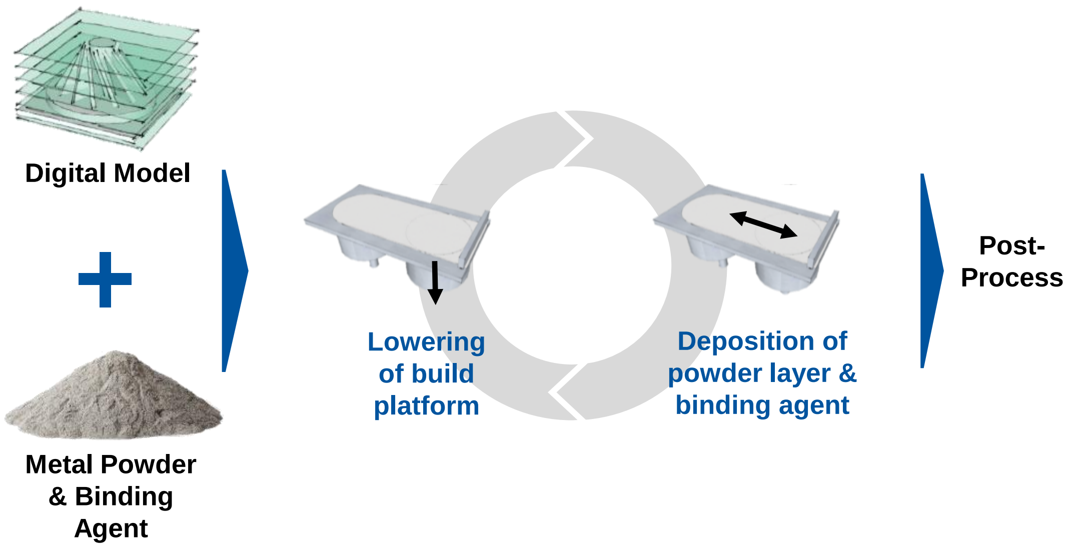
Process in Action



- Application of homogenous coatings on rotationally symmetrical parts with higher process speed than LMD
- Powder is transported by inert gas flow
- Energy is mainly deposited in the metal powder and not the substrate
- EHLA for AM of 3D parts is an emerging technology

Binder Jetting (BJ)

Process Principle



Process in Action

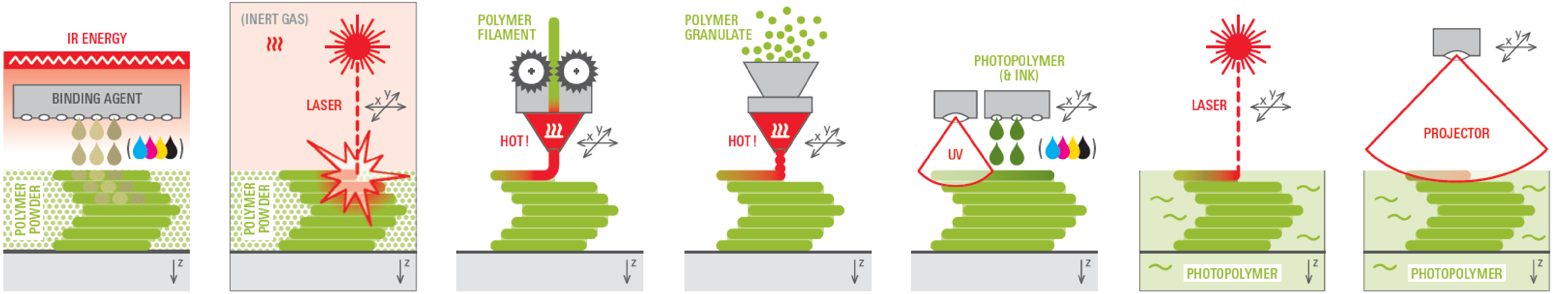
- Production of complex geometries by selective deposition of binder agent on metal powder layer by layer
- As-built part is in green state and requires further processing steps for functionality (e.g., curing, depowdering, sintering)
- Compared to LPBF lower technological maturity and less materials qualified, but potential of higher productivity

AM Technology Overview
Segmentation of Established Polymer AM Technologies

Additive Manufacturing

Polymer

Powder Bed Fusion		*Material Extrusion*		*Material Jetting*	*Photopolymerization of Resins*	
Fused with agent + energy	Fused with laser	With filament	With granulate	Cured with UV light	Cured with laser	Cured with projector
MJF Multi Jet Fusion	**SLS** Selective Laser Sintering	**FDM** Fused Deposition Modeling	**Granulate FDM**	**MJ** Material Jetting	**SLA** Stereo Lithography	**DLP** Digital Light Processing



Source: Derived from Fomrnnext AM Field Guide Compact and DIN EN ISO/ASTM Terminology

AM Technology Overview
Segmentation of Established Polymer AM Technologies

Additive Manufacturing

Polymer

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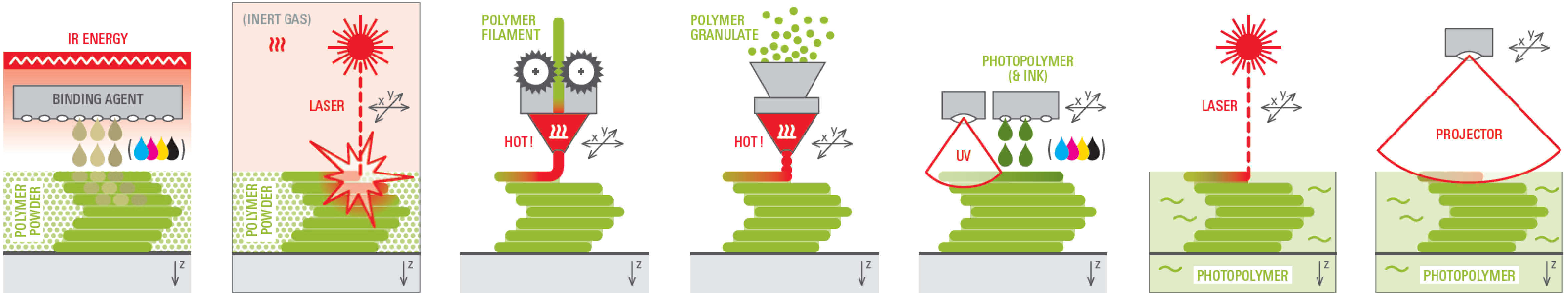
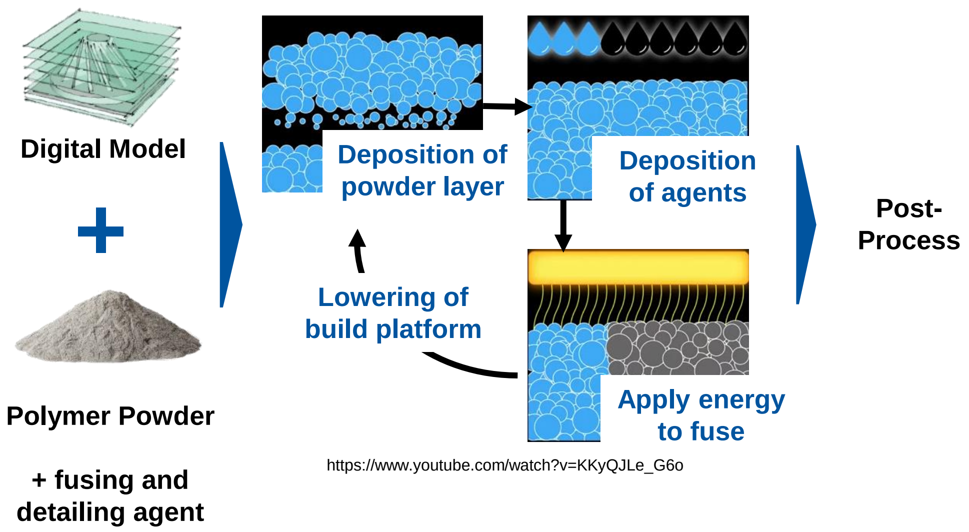


Source: Derived from Fomrnnext AM Field Guide Compact and DIN EN ISO/ASTM Terminology

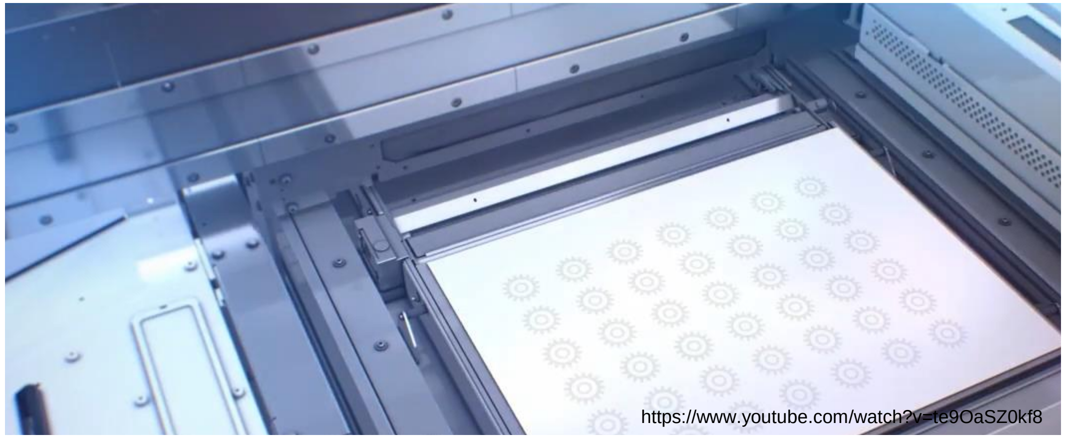
AM Technologies
Multi Jet Fusion (MJF)

Process Principle



https://www.youtube.com/watch?v=KKyQJLe_G6o

Process in Action

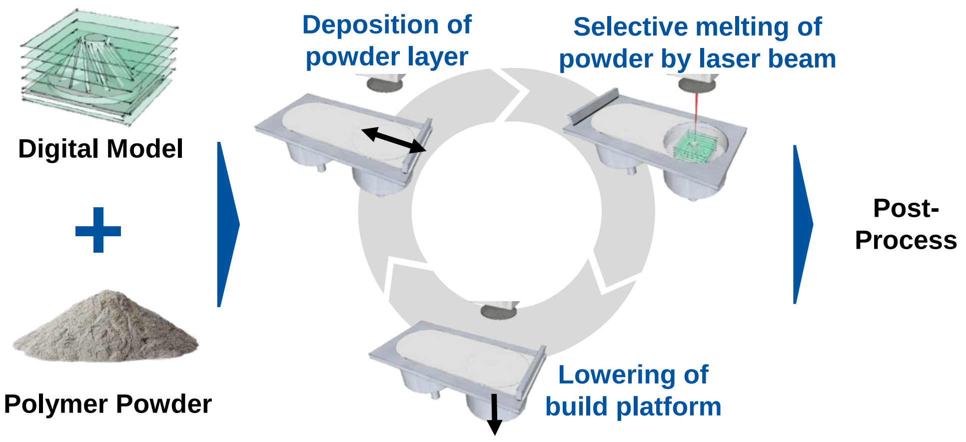


https://www.youtube.com/watch?v=te9OaSZ0kf8

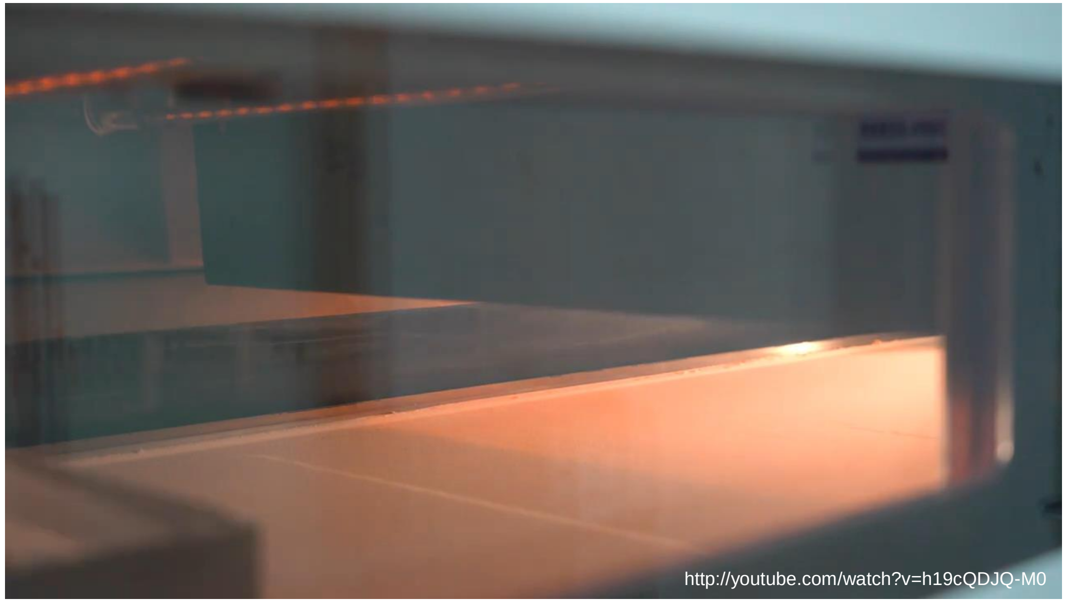
- Layer-by-layer application of material applied to powder in build chamber
- Introduction of liquid binder by inkjet print heads to bond powder particles together
- Energy input (curing) through UV lamps

AM Technologies
Selective Laser Sintering (SLS)

Process Principle



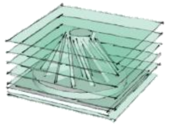
Process in Action



- Production of complex geometries by selective melting of polymer powder with one or more lasers
- As-built parts are usually white (polymer color)
- Many different materials available (e.g., PA11, PA12, TPU, PEEK, TPE, PP)

AM Technologies
Fused Deposition Modeling (FDM)

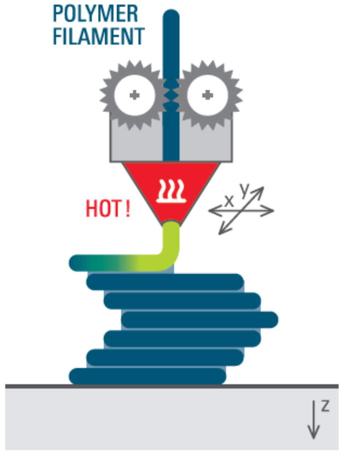
Process Principle



Digital Model

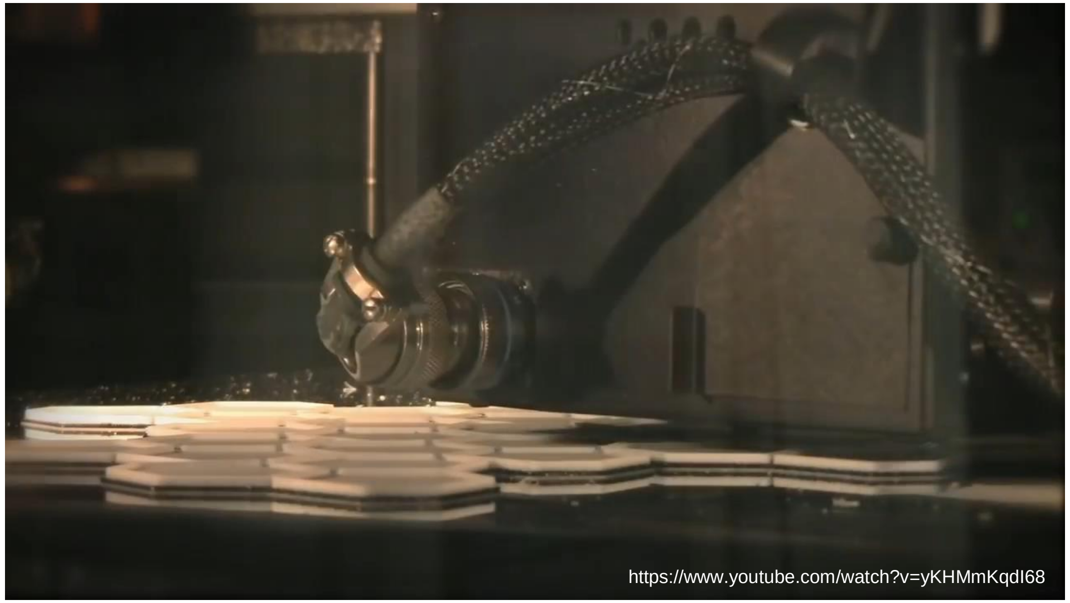
+

Thermoplastic filament



Post-Process

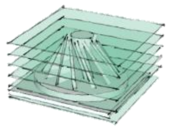
Process in Action



- Thermoplastic filament is molten and extruded through a hot nozzle
- Support structures are required for overhangs
- Use in industry, but also huge open source and DIY community
- Many materials available (e.g, PLA, ABS, PP, PA, PC, TPE, TPC, TPU, PEEK, PEKK, PPSU, PEI)

AM Technologies
Stereolithography (SLA)

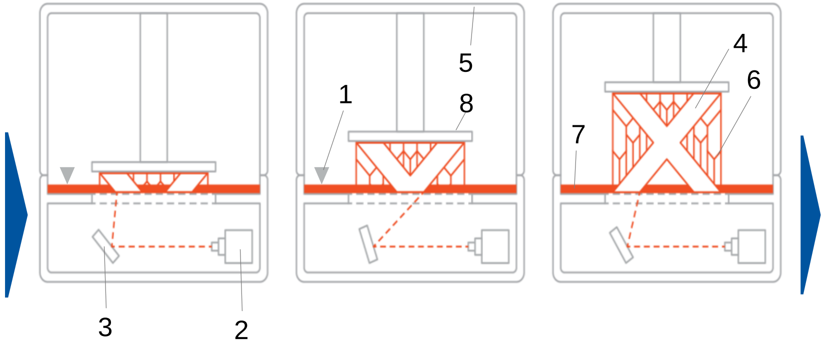
Process Principle



Digital Model

+

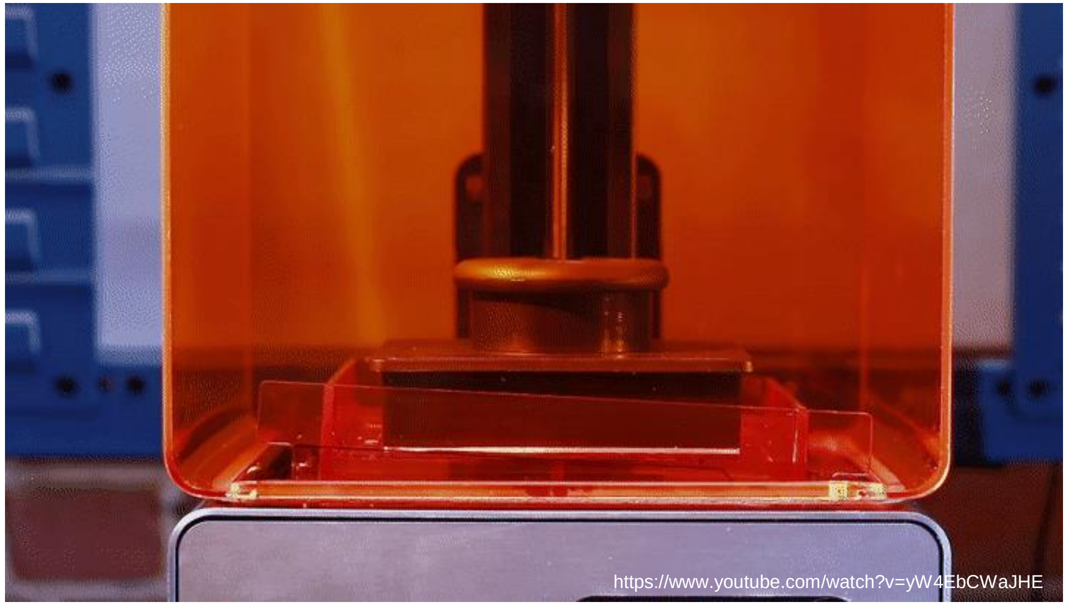
Photo-reactive resin



1. Surface of polymer bath
2. Laser
3. X-Y-scanner
4. Generated part
5. Housing
6. Support structure
7. Polymer batch
8. Build platform

Post-Process

Process in Action

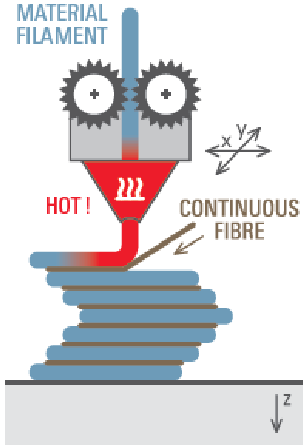


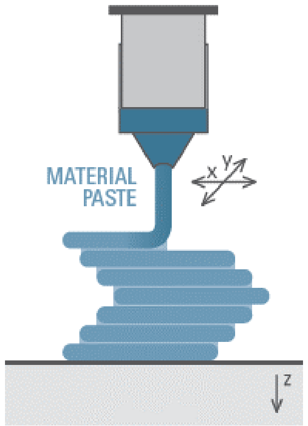
- Polymerization of photo-reactive resin by selective scanning with a UV laser beam (usually through transparent container from below)
- Requires support structures for overhangs
- Wide range of photo-reactive resins with different optical, thermal and mechanical properties

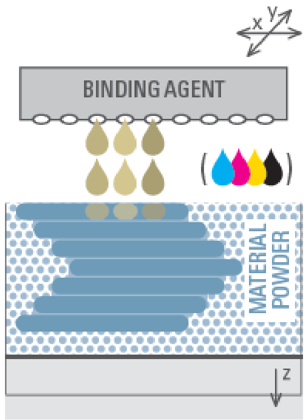
AM Technology Overview
Segmentation of Other AM Technologies

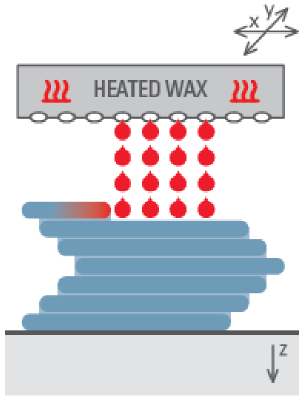
Additive Manufacturing

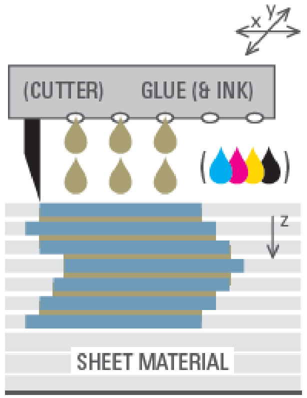
Reinforced polymer fibers	Any material paste	Sand or gypsum	Wax	Composite or paper
Material Extrusion		***Binder Jetting***	***Material Jetting***	***Sheet Lamination***
Material extrusion of **composite**	Paste extrusion of **any material**	Joined **sand or gypsum** with bonding agent,	Selective application of **wax** droplets	Cured with projector
CFF Continuous Filament Fabrication	**PEM** Paste Extrusion Modeling	**BJ** Binder Jetting	**DOD** Drop on Demand	**SDL / LOM** Selective Deposition Lamination / Laminated Object Manufacturing











Source: Derived from Fomrnnext AM Field Guide Compact and DIN EN ISO/ASTM Terminology

Basic AM Seminar – Content

AM Application Examples

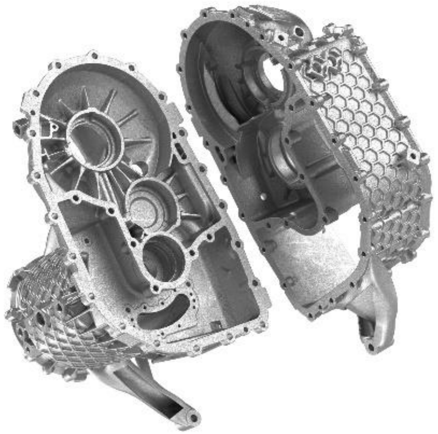
Functional Prototype – AM Housing for Fully Integrated E-Drive Module

Characteristics

- Prototype of a fully integrated e-drive housing for a small series production
- Passed quality and stress tests without problems
- Material: Aluminum
- AM Technology: LPBF

Utilized AM Benefits

- Design freedom: Complex features, lightweight (-10%), monolithic
- Integration of functions
- Economic small quantities
- Short time and efficiency from idea to product
- Part consolidation to avoid assembly steps



Source: RWTH WZL, Porsche AG, SLM Solutions, https://newsroom.porsche.com/en/2020/innovation/porsche-protoype-small-production-electric-drive-housing-3d-printer-23235.html

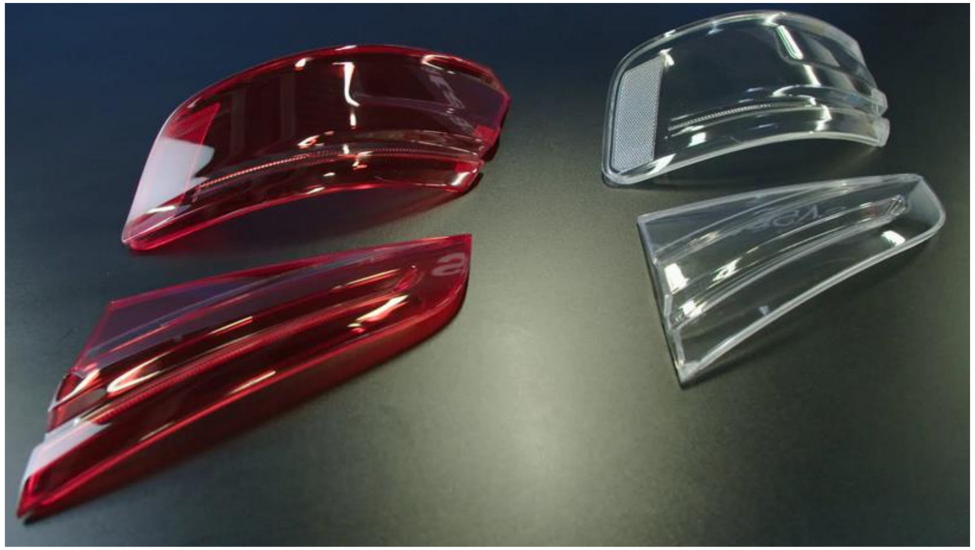
AM Application Examples
Design Prototype – Tail Light Covers

Characteristics

- True-to-color and transparency prototypes of tail light covers
- Reduction of prototyping lead times by up to 50%
- Acceleration of design verification process
- AM technology: PolyJet

Utilized AM Benefits

- Economic small quantities
- Short time and efficiency from idea to product
- Flexible design iterations and engineering changes



Source: RWTH WZL, Audi AG

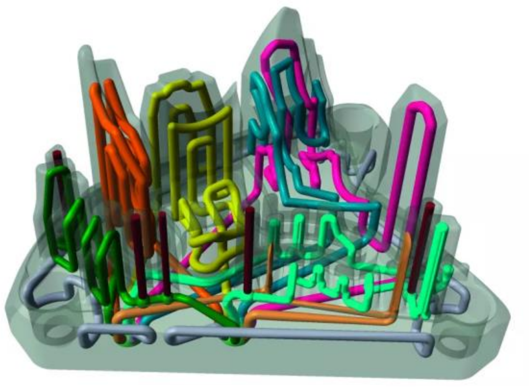
AM Application Examples
Molding Tools and Tool-inserts with Internal Cooling Channels

Characteristics

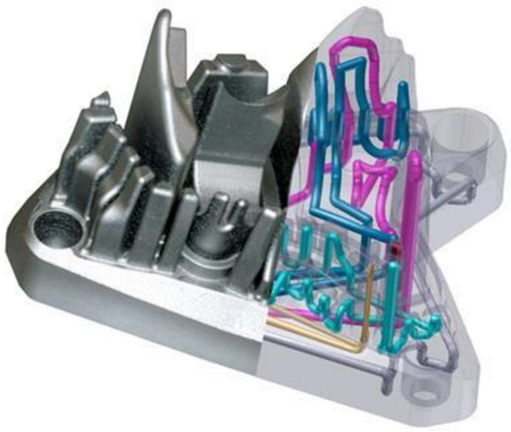
- Internal cooling channels enable faster cooling to reduce cycle times and improve quality
- Impossible to produce with conventional manufacturing
- AM technology: LPBF

Utilized AM Benefits

- Integration of functions
- Economic small quantities
- Short time and efficiency from idea to product
- Economic and ecologic sustainability though performance improvement in use



https://www.plastverarbeiter.de/werkzeuge-formen/werkzeugfertigung-2-0.html



https://www.renishaw.com/en/industrial-applications-of-renishaw-metal-additive-manufacturing-technology--15256

- Cooling phase: -11%
- Tool life: +80%

(compared to conventional)

https://www.voestalpine.com/

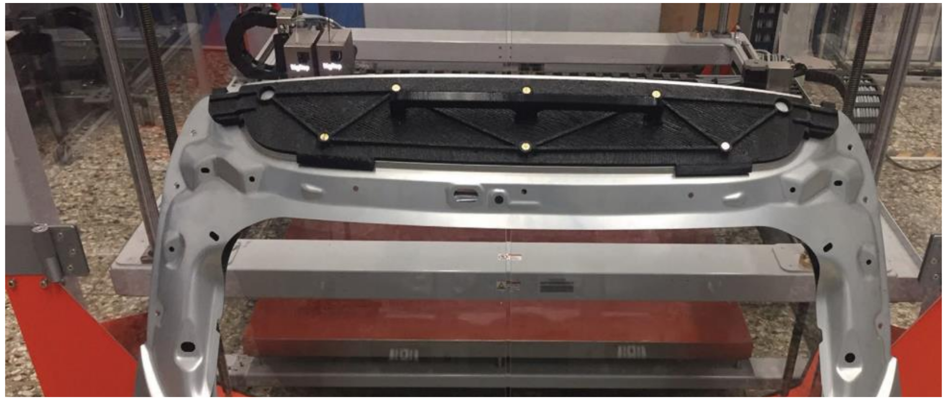
Assembly and Manufacturing Aids by Ford

Characteristics

- Frame for measuring gaps in assembly e.g. between body and the door of a vehicle
- Aids for manual positioning of badges
- Welding fixture
- AM technology: FDM (large format)

Utilized AM Benefits

- Lightweight design and materials
- Part consolidation to avoid assembly steps
- Economic small quantities
- Short time and efficiency from idea to product (e.g., 8-10 weeks to 2-3 days for seal gap frame)
- Flexible design iterations & engineering changes



Source: https://bigrep.com/ebooks/ford-upscales-their-in-house-tooling-with-bigrep-3d-printers/

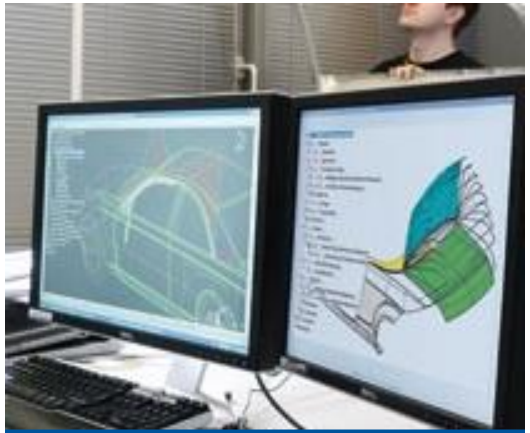
AM Application Examples
Fixture Interfaces – Rapid Production with AM for Assembly & Production

Characteristics

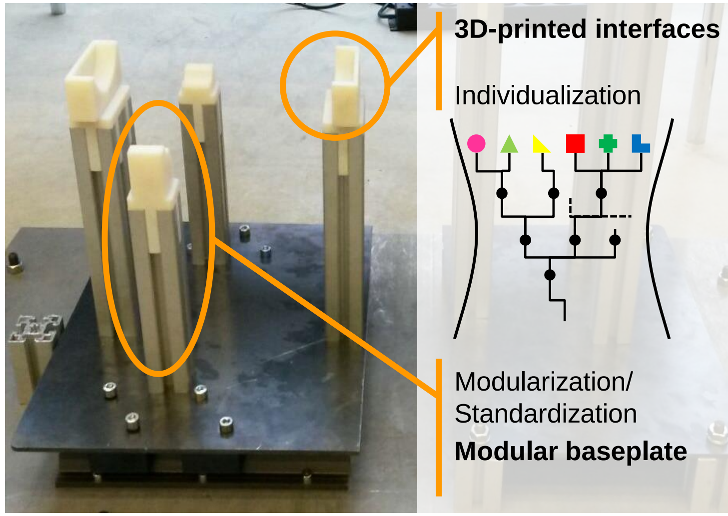
- Use of rule-based algorithms for the fast design of printed interfaces for fixtures
- Increased production speed of fixtures
- Fast set-up, clamping and fixing
- AM Technology: Polyjet

Utilized AM Benefits

- Economic small quantities
- Short time and efficiency from idea to product
- Integration of functions



Rule-based algorithms and construction kit approach



ANLAUF FABRIK

Adaptive City Mobility

Gefördert durch:

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

Source: Research Project ACM2, RWTH PEM, https://www.anlauffabrik-aachen.de/adaptive-city-mobility/

AM Application Examples
Series Part - BMW i8 Roadster Roof Mount

Characteristics

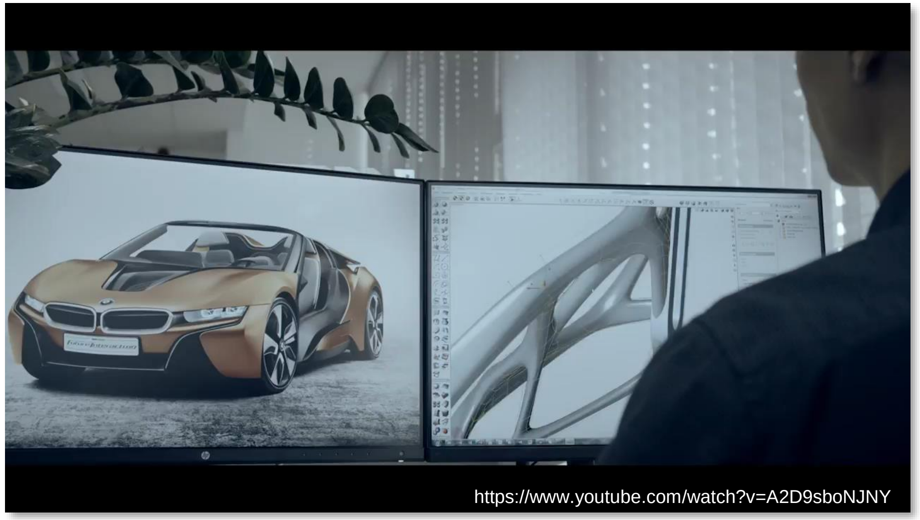
- Stiff part that holds the convertible roof of the BMW i8 roadster
- Small series end-use part
- AM Technology: Laser Powder Bed Fusion
- Material: Aluminum alloy (AlSi10Mg)


https://www.3dnatives.com/de/altair-enlighten-award-2018-220820181/#!


https://www.press.bmwgroup.com

Utilized AM Benefits

- Algorithmic design (topology optimization)
- Flexible design iterations
- Lightweight design and material (44% weight reduction)
- Economic and ecologic sustainability through material efficiency


https://www.youtube.com/watch?v=A2D9sboNJNY


https://www.youtube.com/watch?v=A2D9sboNJNY

AM Application Examples
Series Part - Coating of Brake Disks using EHLA by HPL WECODUR

Characteristics

- Additive coating of brake disks
- Up to 90 % reduction in brake disc-related particulate emissions
- Corrosion-free, also in recuperation mode
- Longer usage time with only low additional cost for coating

Utilized AM Benefits

- Economic and ecologic sustainability though performance improvement in use
- Economic and ecologic sustainability through material efficiency
- Integration of functions

www.wecodur.de/portfolio/anwendungen

https://dap-aachen.de/project/ehla

https://www.wecodur.de/portfolio/technologie/

Source: HPL Technologies, WECODUR

AM Application Examples
Series Part - Porsche Car Seats Produced by Oechsler

Characteristics

- AM lattice structure is integrated in bodyform full shell seat
- Planned: Individualization to customers body scan and retrofit of existing Porsche cars
- AM technology: MJF

Utilized AM Benefits

- Lightweight design
- Functional integration for seating and climate comfort
- Sustainability by recyclable material
- Part consolidation to avoid assembly steps
- Economic small quantities

https://www.oechsler.com/downloads/use-cases/seating-experience-20/

Source: https://www.oechsler.com/downloads/use-cases/seating-experience-20/

AM Application Examples

Restauration - Window Winders and Door Handles for the Elvis BMW 507

Characteristics

- Obsolete parts for old timer restauration (years 1956-1959)
- 3D scan of original part and afterwards reproduction with AM
- AM Technology: Laser Powder Bed Fusion

Utilized AM Benefits

- Economic small quantities and individual products
- Short time and efficiency from idea to product

https://3dprinting.com/news/elvis-bmw-restored-with-am/

https://www.press.bmwgroup.com/

https://www.press.bmwgroup.com/

https://3dprinting.com/news/elvis-bmw-restored-with-am/

https://www.press.bmwgroup.com/

Source: https://3dprinting.com/news/elvis-bmw-restored-with-am/, https://3dprinting.com/news/elvis-bmw-restored-with-am/

AM Application Examples
Customized Parts - 3D Models for FDM of by Customers of Ford Maverick

Characteristics

- 3D models for further personalization by user are available by OEM
- 3D models fit in matching mound slides
- E.g. cup holders, bottle holders, trays

Utilized AM Benefits

- Integration of functions
- Economic small quantities and individual products
- Short time and efficiency from idea to product

Source: https://3dprinting.com/news/elvis-bmw-restored-with-am/, https://3dprinting.com/news/elvis-bmw-restored-with-am/

Basic AM Seminar – Content

Successful Adaption of AM
Benefits Through an "Additive Mindset"

Comparing Apples with Oranges…

***Successful AM adaption** requires **consideration of AM differences**. Without change of expectations, AM turns out as a poor substitute for established processes.*

…Additive Manufacturing is different

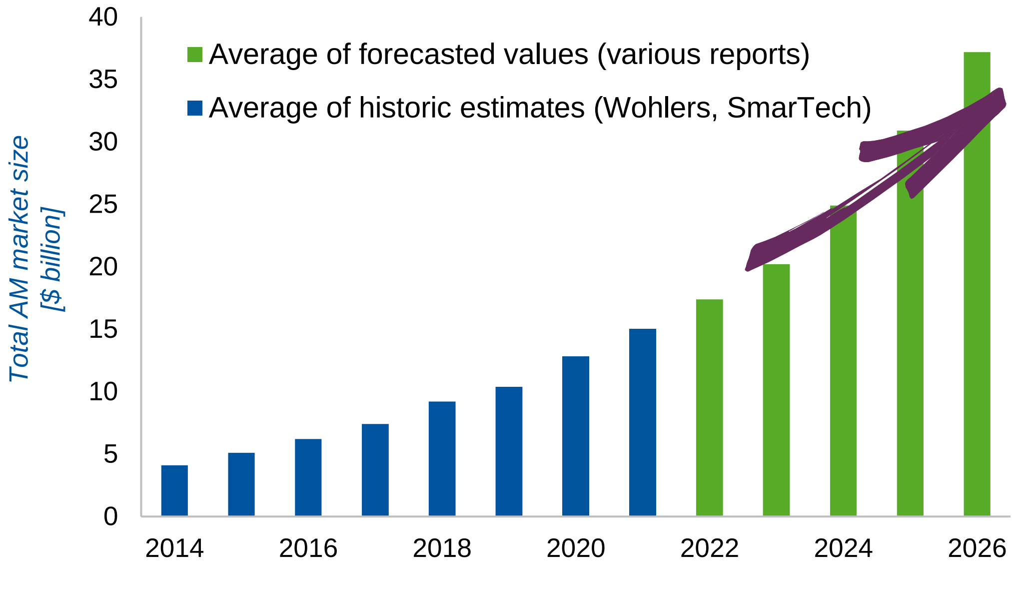
- **Different cost structure:** High upfront investment costs and high material prices, but not driven by economies of scale
- **Financial return** and **technological feasibility** must be considered in **identification of parts with positive business case**
- Enables **new business models** such as mass customization or digital warehousing
- **Products and required expertise** along the product life cycle are different (e.g. Design for Additive Manufacturing)
- Some AM technologies require complex **health & security measures**

Source: Effectory, TCT

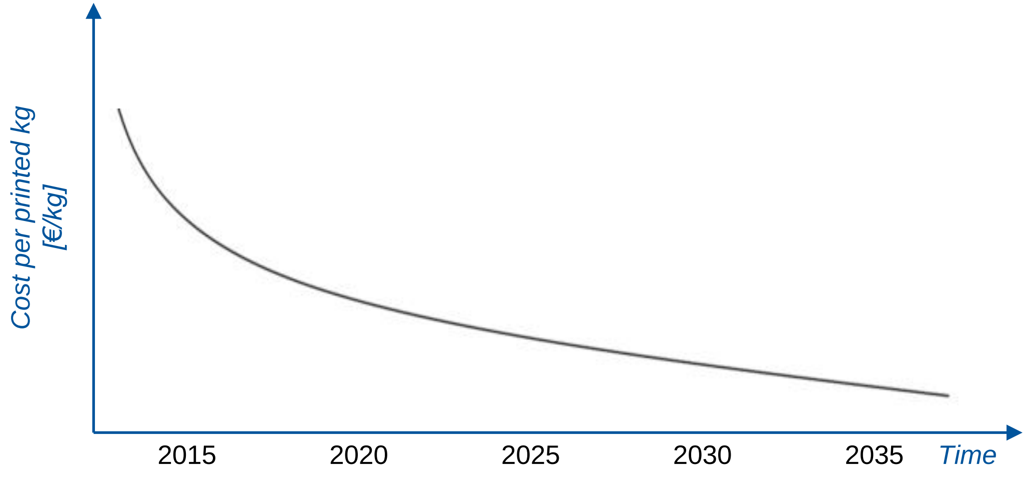
Basic AM Seminar – Content

Future Perspective of AM
What Does the Future Hold for Additive Manufacturing?

Expected market development



Prognosis of cost development



- *Increase of machine productivity*
- *Decrease of material prices*
- *Higher technology readiness level*
- *Higher degree of automation*

The AM market is predicted continuous strong growth and costs for AM parts are expected to decrease.
Current barriers of AM are addressed in industry and ongoing research and development.

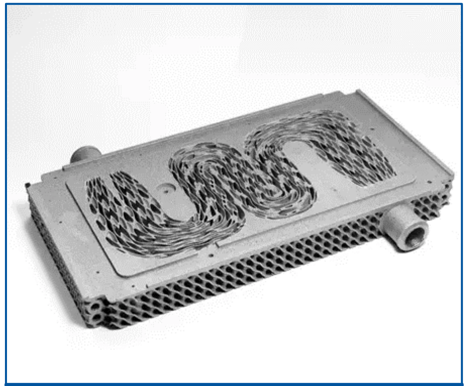
Source: Audi AG, Hubs, Wohlers, SmarTech, Metal-AM

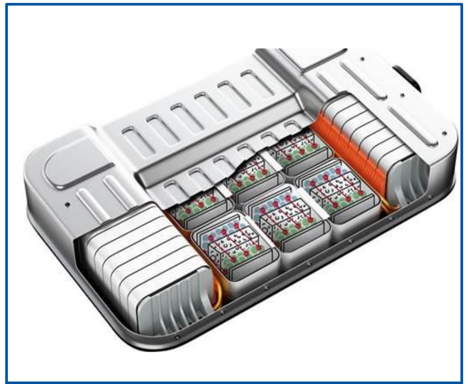
Future Perspectives of AM
Potential Automotive Applications Focusing on Electric Vehicles


Brackets


Connectors


Drive Housing


Heat Exchangers


Battery Electrodes


Stator Windings


Structural Components


Aesthetic Components

Source: https://www.additivemanufacturing.media/kc/am-for-ev#template4

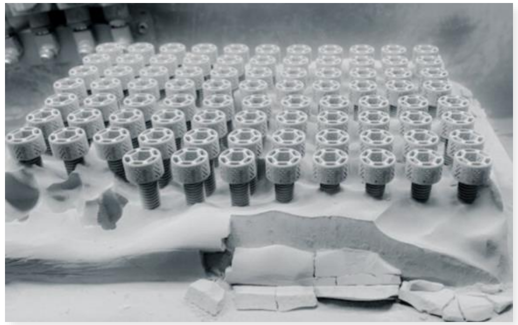
Future Perspective of AM
Emerging AM Technologies – Metal Binder Jetting for Mass Production

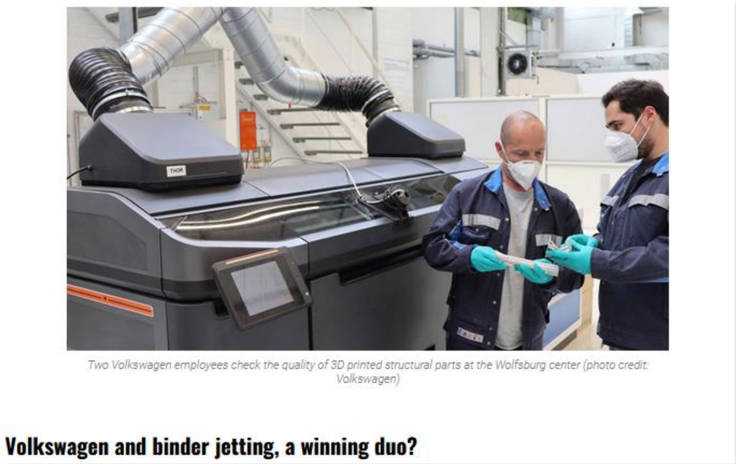
Expectations in productivity

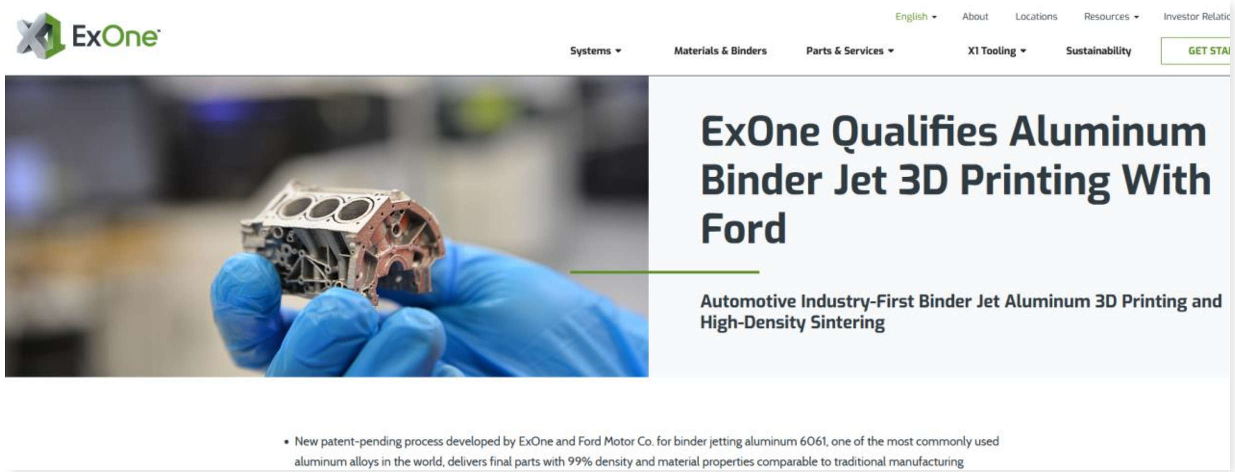
- More parts per build job due to 3D nesting compared to 2D nesting with LPBF
- Faster printing speed especially with high filling degree

Barriers for realization

- Additional process steps: Debinding & Sintering
- Automation, e.g., removal of green parts from powder cake
- Comparably low technology maturity compared to LPBF







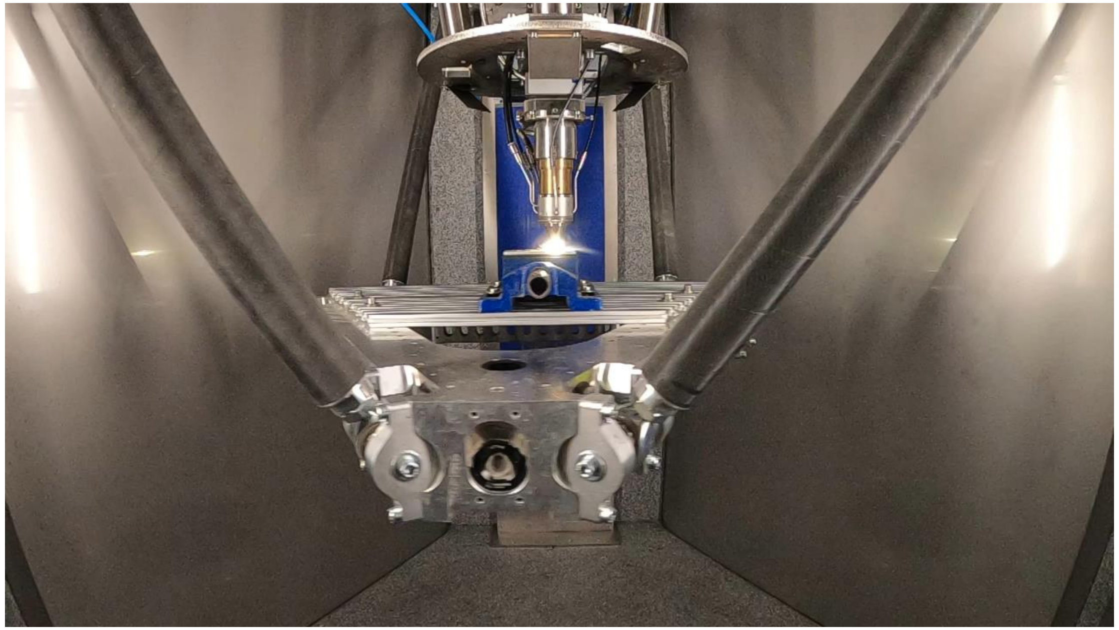
Source: ExOne, 3Dnatives, AFMG

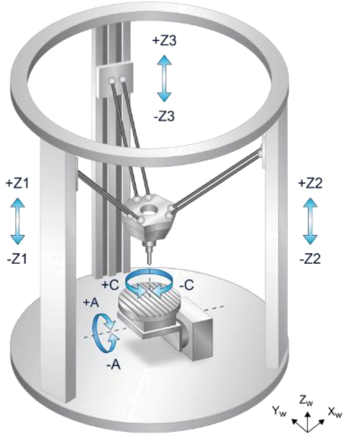
Future Perspective of AM

Emerging AM Technologies – EHLA for Non-Rotational Symmetric Parts

Characteristics of the Ponticon 3D EHLA Process

- Additive coating and manufacturing of components
- Non-rotationally symmetric components possible
- Complex surfaces can be coated locally
- Wide variety of materials
- Develop and process new types of alloys





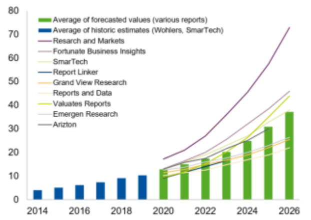
Tripod Kinematics

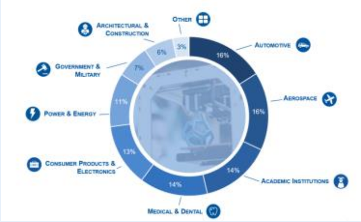
Source: Courtesy of Ponticon

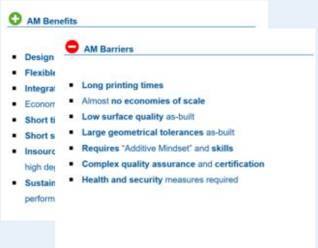
Basic AM Seminar – Content

Basic AM Seminar
Summary

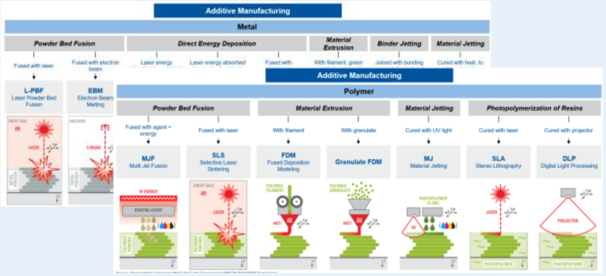
Introduction to Additive Manufacturing







Overview of AM Technologies



- High variety of established and emerging AM technologies
- Varying technology readiness
- Technology-specific characteristics, advantages and disadvantages
- Material choice according to application

Future Perspective

- Expected continuous market growth
- Cost decrease due to increased technology readiness level, productivity and industrialization
- Technological and economical challenges are addressed through industry and R&D

Successful Adaption of AM

Successful AM adaption *requires* ***consideration of AM differences****. Without change of expectations, AM turns out as a poor substitute for established processes.*

AM Application Examples

- Various applications along the product lifecycle
- Differentiation in rapid prototyping, rapid tooling and AM of end use parts
- Taking advantage of different AM benefits according to application

Outlook

From…

Via…

Education

Additive mindset

Product analysis

Use case development

To…

Cost savings

Differentiation

Resilient supply chains

Customer satisfaction

Sustainability

Product innovation

The strong market growth of AM continues holding immense potential for most industries.
Successful implementation requires understanding of AM characteristics and strategic business model development.

Get in touch!

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Get in touch with our experts and become a part of Europe‘s most vivid AM and engineering ecosystem!