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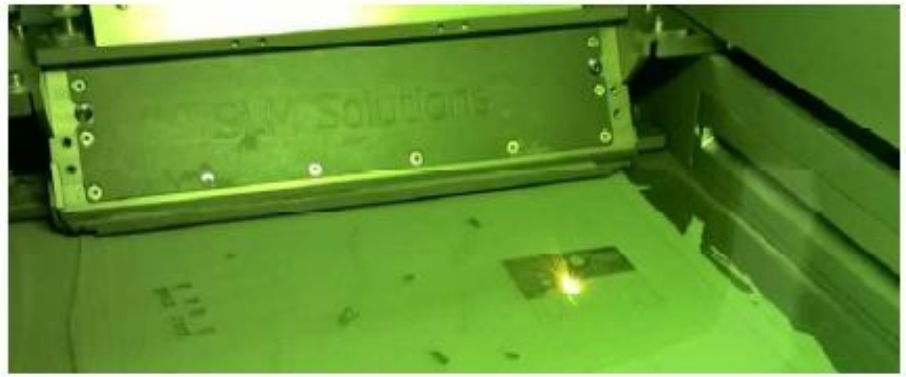
FUTURE MANUFACTURING TECHNOLOGIES
Tulevaisuuden tuotantoteknologiat

ELME STUDIO

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# Metal 3D AM

## A Technology Overview:
# Industrial Solutions

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**Postdoctoral Resercher**

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Leverage from the EU 2014–2020

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# In Cooperation

European Union
European Regional Development Fund

CASR
Centre for Advanced Steels Research

POHJOIS-POHJANMAA
Council of Oulu Region

Interreg
Nord
European Regional Development Fund

EUROPEAN UNION

# Approximated market development


**Sales on machines increased 80% between 2017-2018** (Worhlers report 2019)

# Metal 3D Printing research


- **Equipment: SLM Solutions 280 HL 2.0**
  - Build envelope 280 x 280 x 365 mm³ - 700W laser
  - Materials: Al-Alloys, Co-Alloys, Ni-Alloys, Ti-Alloys, Tool Steel and Stainless Steel
- **Research focus areas:**
  - Materials, design and manufacturing
  - Printing process and mechanical properties of 3D printed materials
    - Static and dynamic strength
    - Corrosion resistance – Stress, spot and fatigue corrosion,
  - AM in combination with other manufacturing methods
  - Cost effective post-processing process in the AM production
- **Commissioned research**
  - 3D printing in commercial products and prototypes
  - Design and prototyping
  - Material testing
  - Feasibility studies
- **Funding**
  - M3Lab – project (ERDF – Council of Oulu region)
  - C3TS – project (ERDF – Interreg Nord)
  - Hybridi – project (ERDF – Council of Oulu region)

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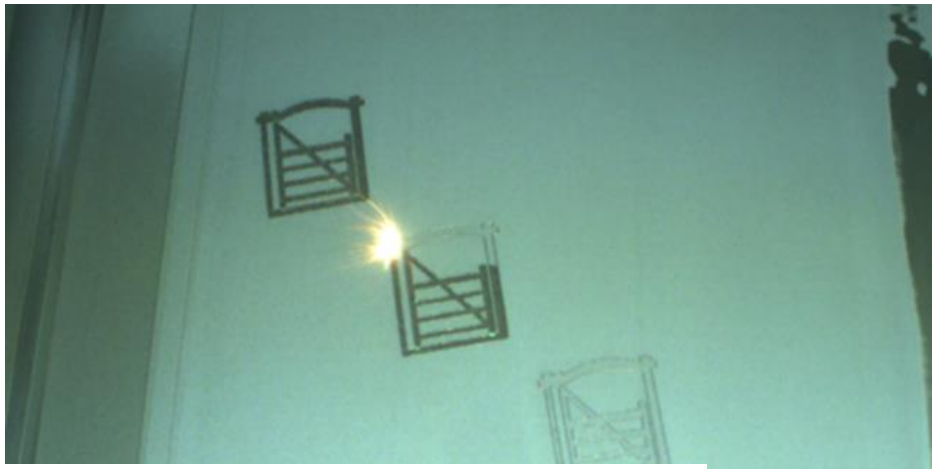
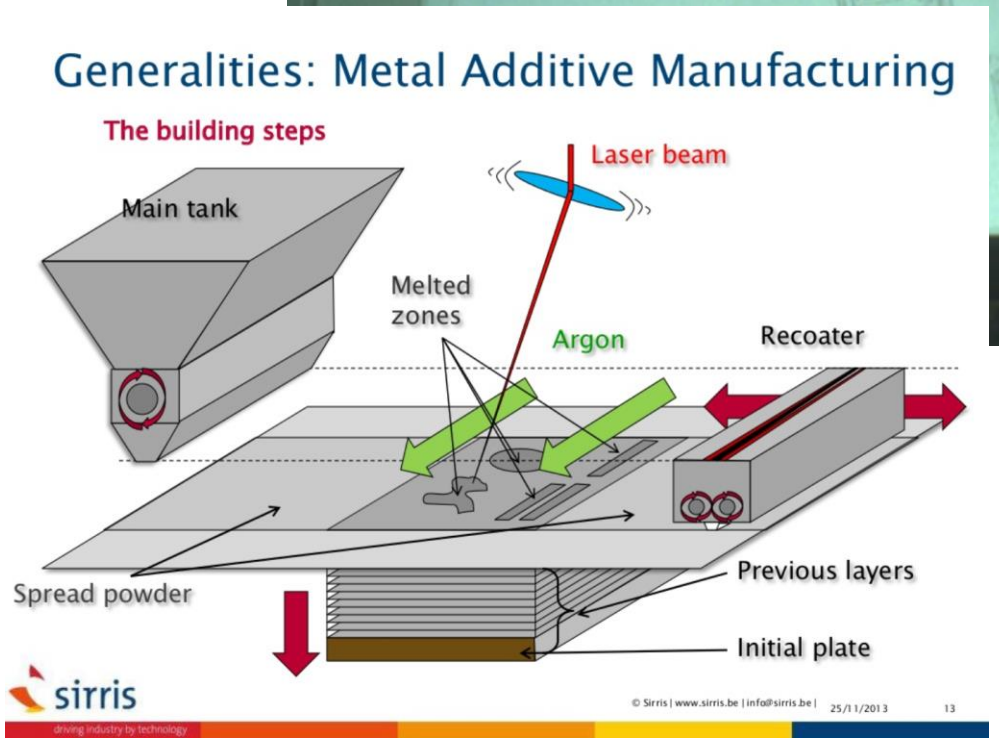





https://www.slideshare.net/carstenengel/selective-laser-melting-versus-electron-beam-melting


https://www.3dprintingmedia.network/slm-solutions-presents-upgraded-slm-280-2-0-3d-printer-tire-technology-exhibition/

- Powder Bed Fusion
  - Laser Powder Bed Fusion
    - Selective Laser Melting
    - Selective Laser Sintering
  - (Selective) Electron-Beam Melting
- Direct Energy Deposition
  - Direct Laser Deposition
  - Electron-Beam Deposition

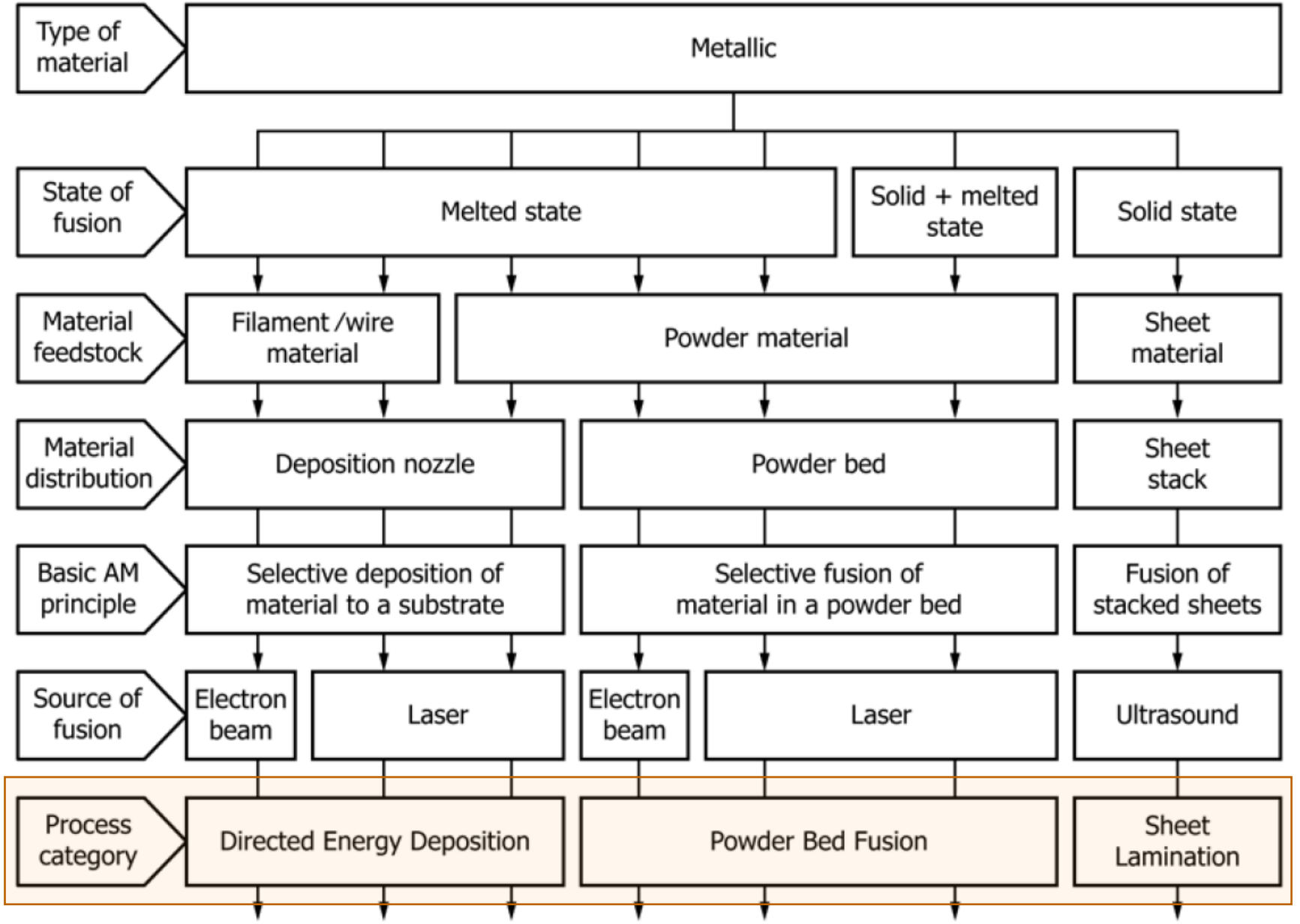
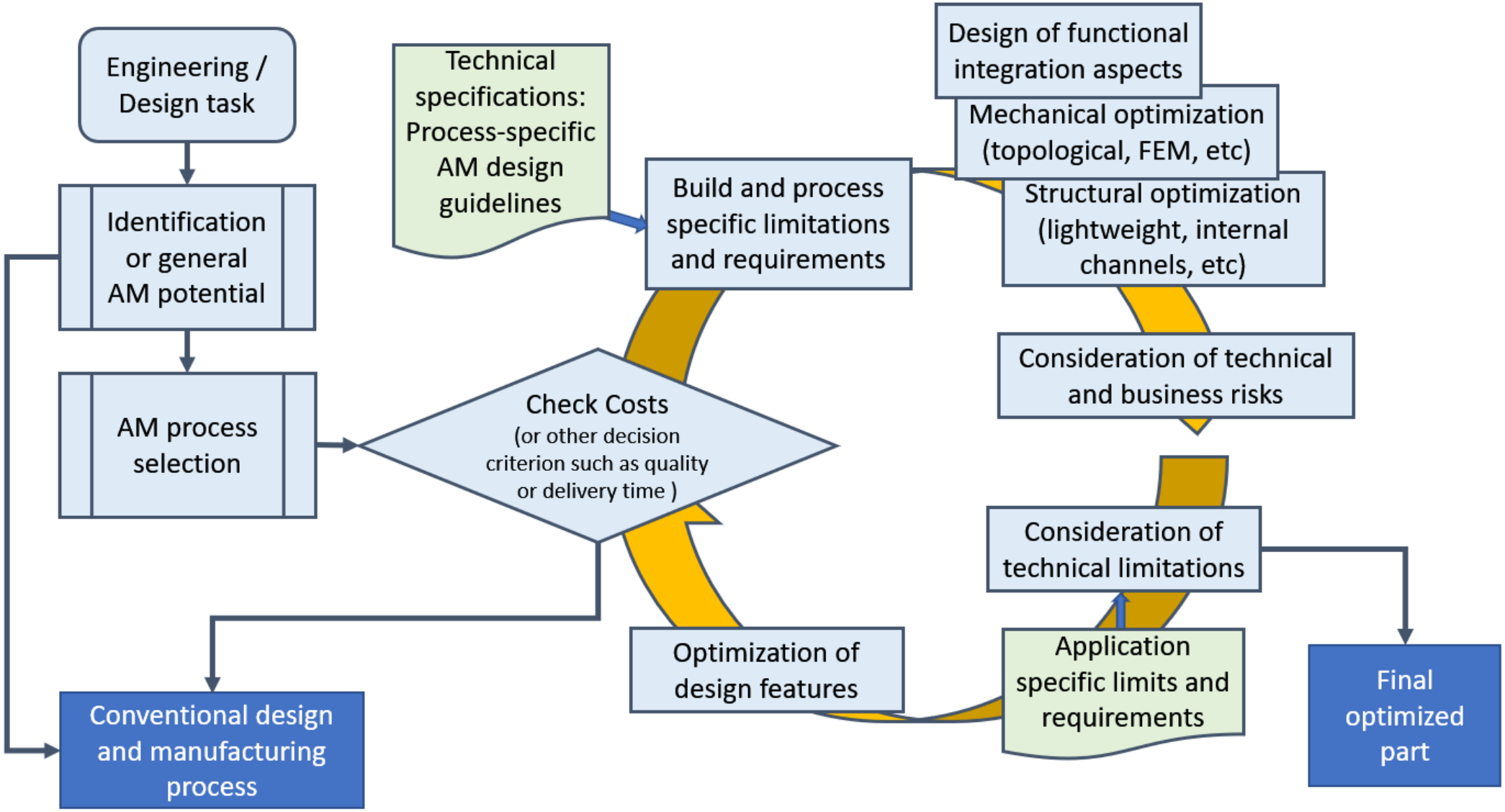



FIG. A1.2 Overview of single-step AM processing principles for metallic materials



ISO/ASTM 52900:2015(E)

# Choosing AM method, validation and designing process by standard ISO/ASTM 52910:20

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# ISO/ASTM 52900:2015(E)

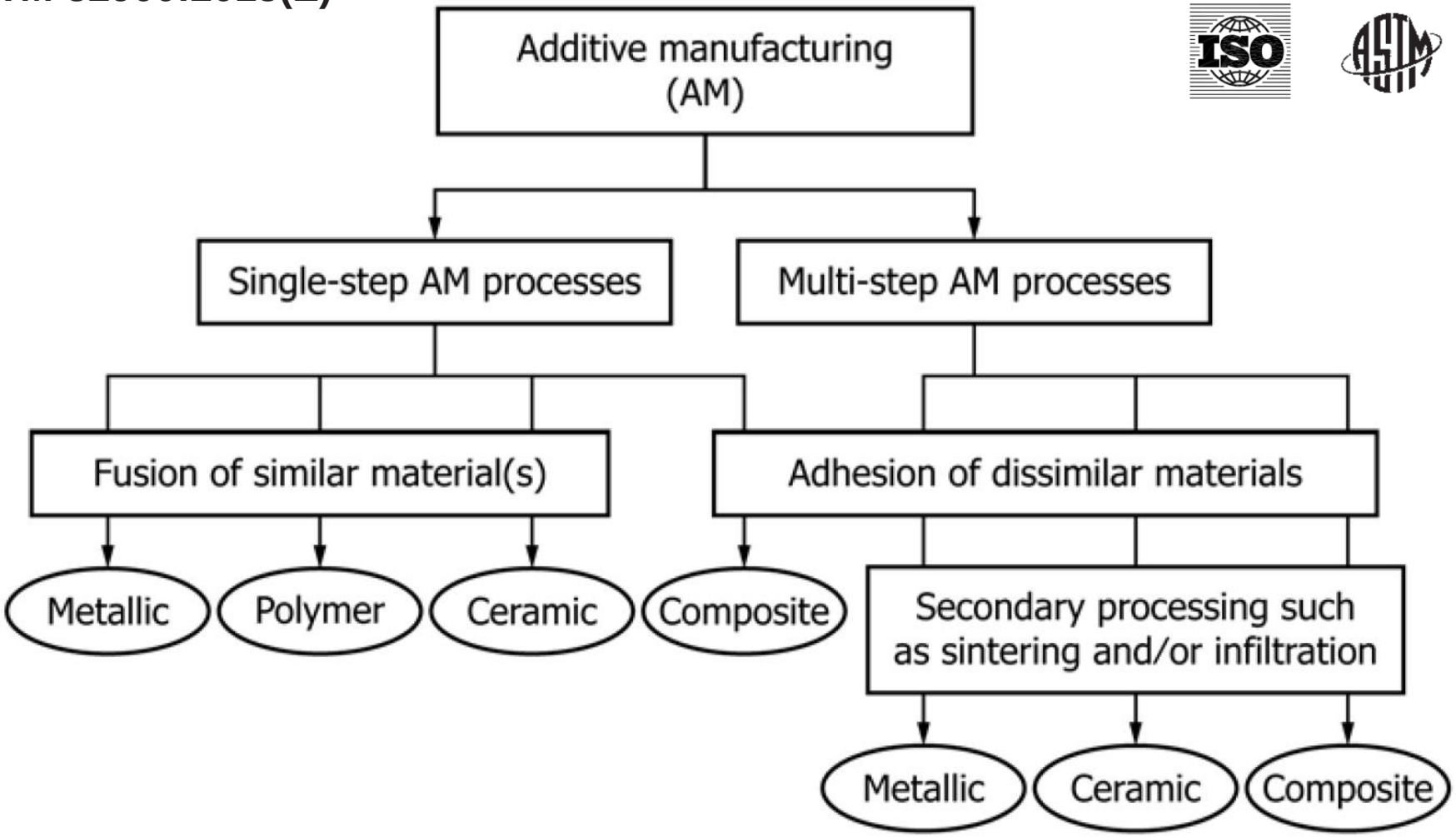
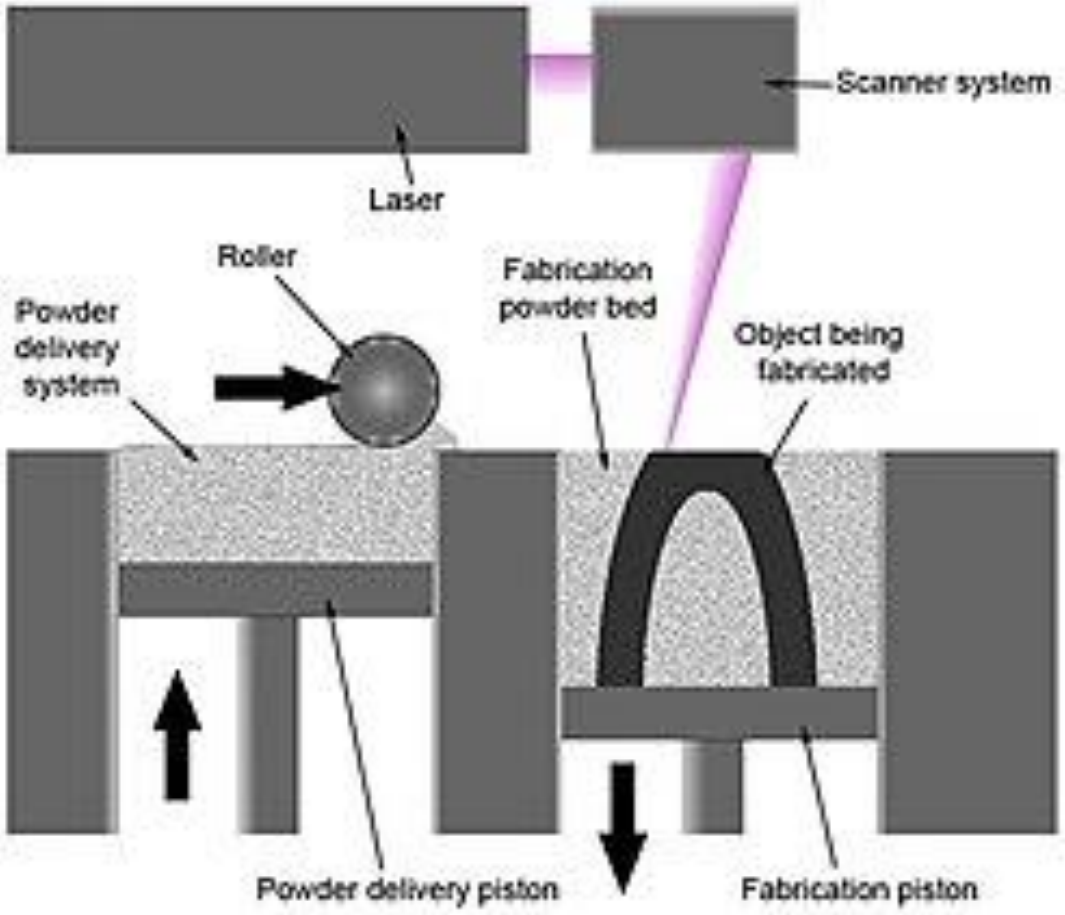
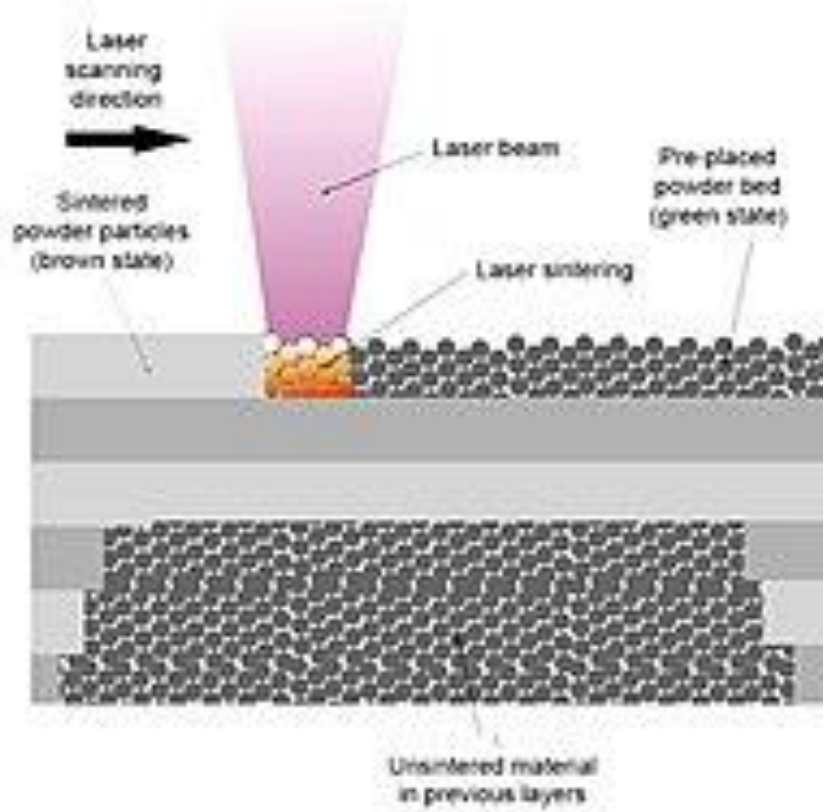



FIG. A1.1 Single-step and Multi-step AM process principles

# Principle of selective laser melting



# Automatization of the AM Design Process

## Design Automation

- AM optimized CAD
- Topology optimization
- Part manufacturing orientation optimization
  - Manufacturability opt.
  - Support minimization
- General support optimization
  - Support-free design?
- Parametric models

## Work Preparation Automation

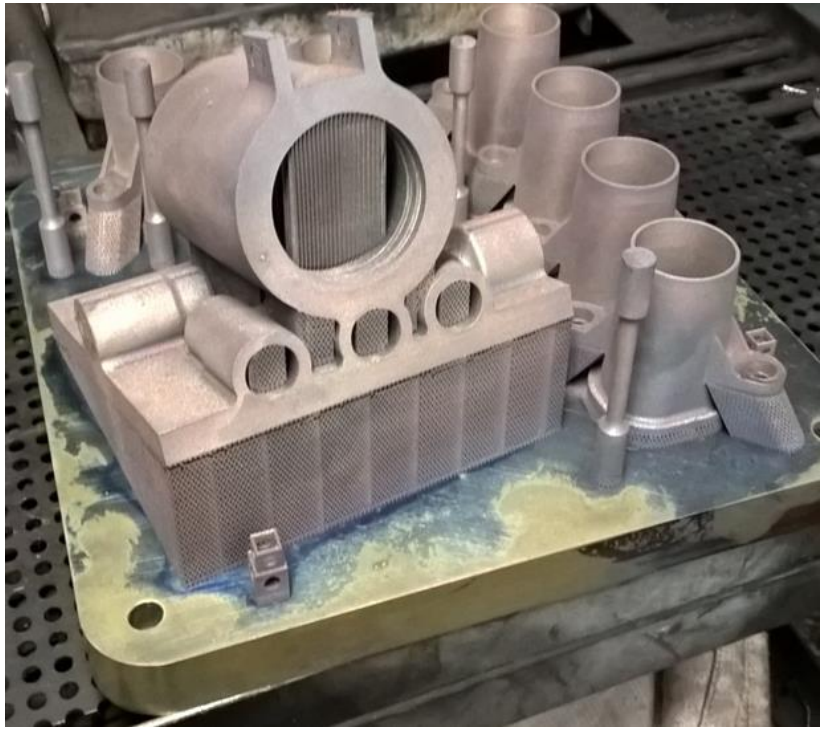
- Platform nesting optimization
- Manufacturing parameter opt.

## Post-Processing Design Automation

- Post-processing planning
  - Manufacturing features
  - Machine programming
- Management of the complete post-processing design

Iso-Junno et. al. **A Short Glance on Metal 3D AM, ICMSE-RAC 2018**

# DFAM
# Key methods



- **Topology optimization**
  - Optimization of the shape and topology
  - FEM based topology optimizers help designers to get an optimal complex geometry
- **Multiscale structure design**
  - Micro and mesoscale lattice and cellular structures for the preferred properties
- **Multi-material design**
  - Parts with multi-material or complex material distribution
- **Design for mass customization**
  - Reduction of the cost and leading time in producing customized products
- **Parts consolidation**
  - Part count reduction and improved functional performance

- **Minimization of post-processing**
- **Unified geometry with functional and manufacturing properties**

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# Designing

- Designing is the base of everything. On the other hand if one does not understand what machine makes, one can not use all its possibilities
- Models and prototypes are definitely yesterday. Fully functional industrial solutions and devices
- Trends; parts consolidation, mechanisms etc.
- Less weight, no joint surfaces, ultra high strength materials….

# Designing


- Normal regulations on designing does not apply. Almost everything is possible, corkscrew channels, inside chambers, honeycomb….
- By testing nice things can be found. On the other hand there will be a lot of disappointments and stuff. That is metal 3D AM
- Used stl files and surface models, actually triangles. The coming of real route steering like G-code is still to come
- An accurate data from full pallet of parts is 2-7 terabytes

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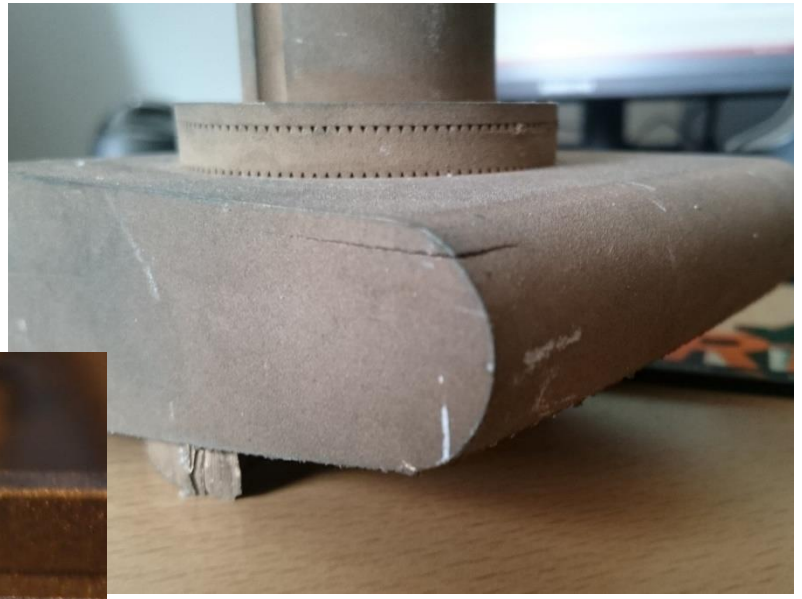
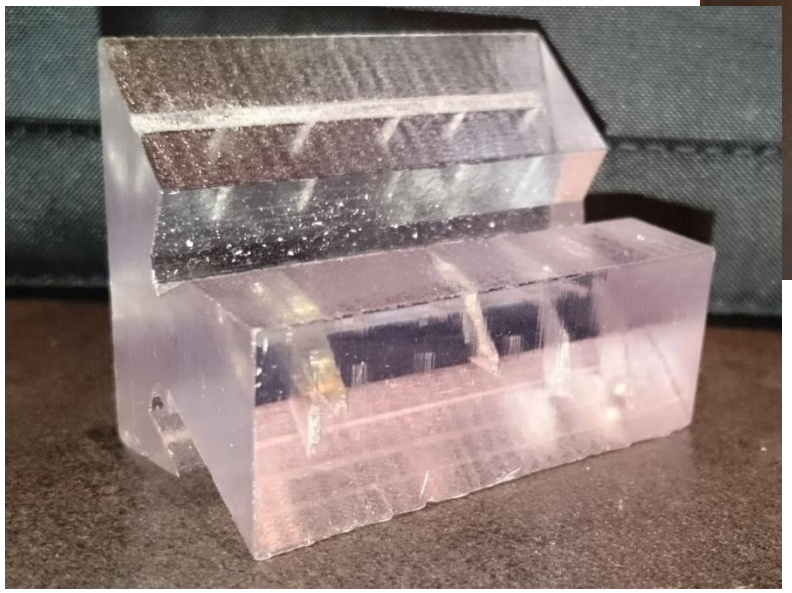
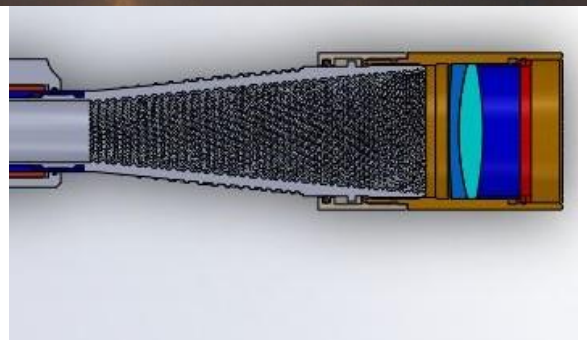
# When everything did not go as planned…







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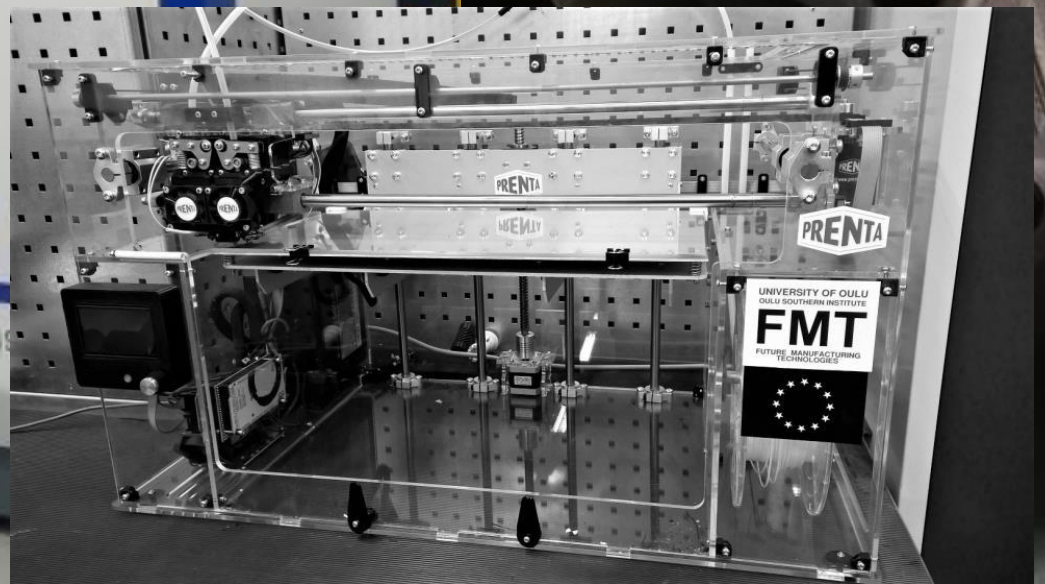
# Collapsing and bending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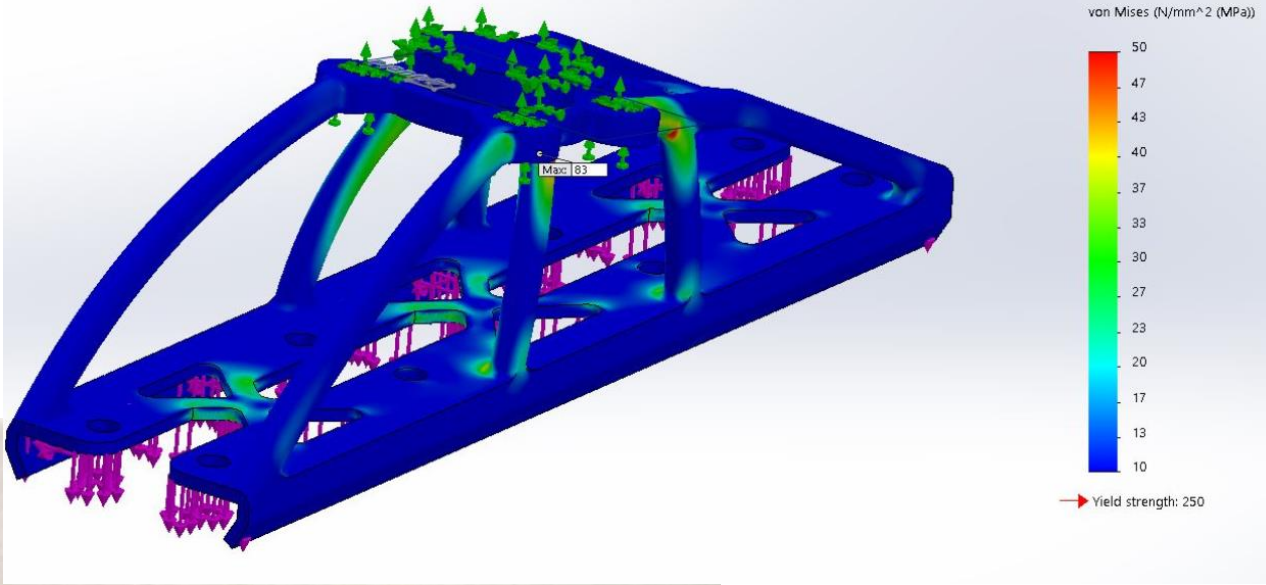
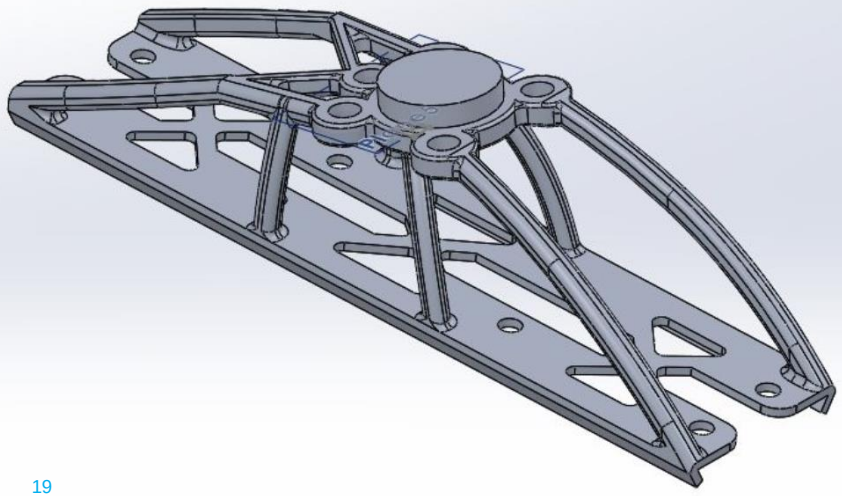
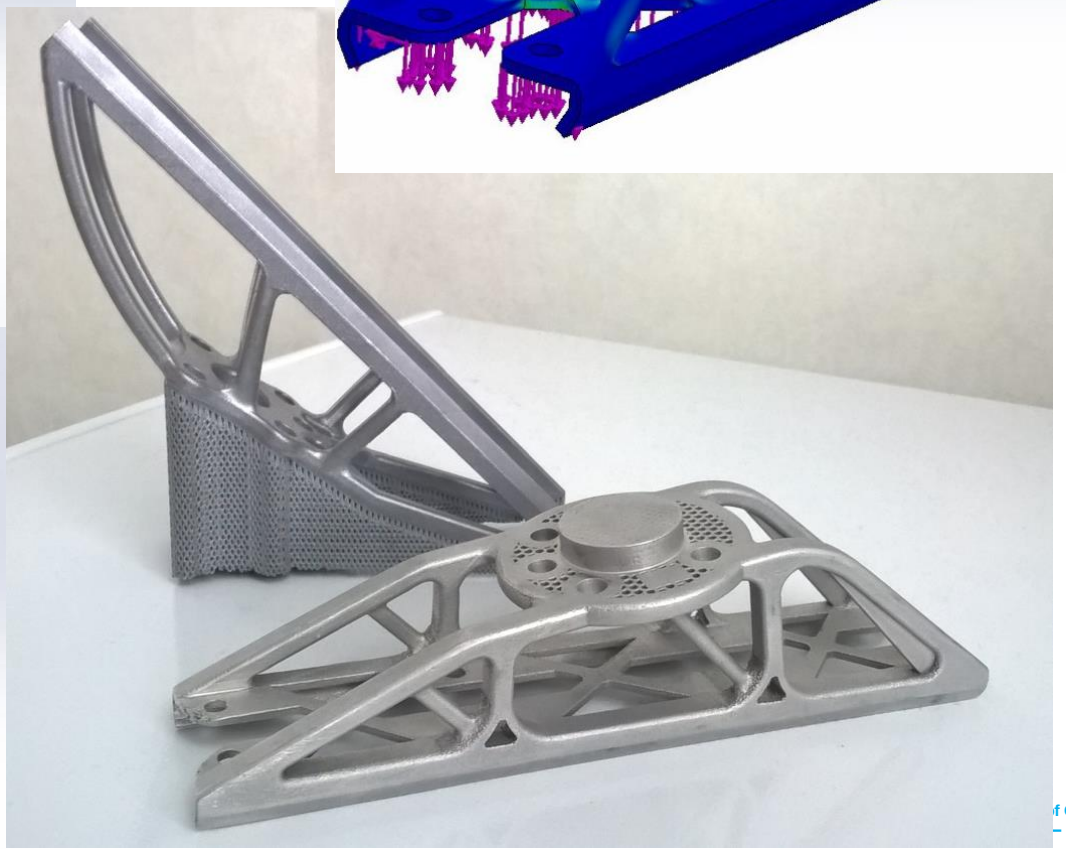
# Case Gripper

SCIART
RETHINKING DESIGN

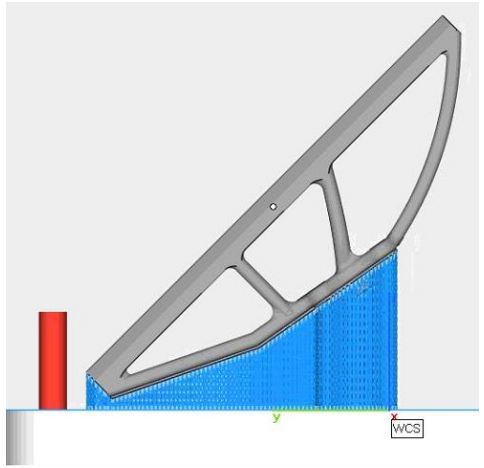
ParetoWorks



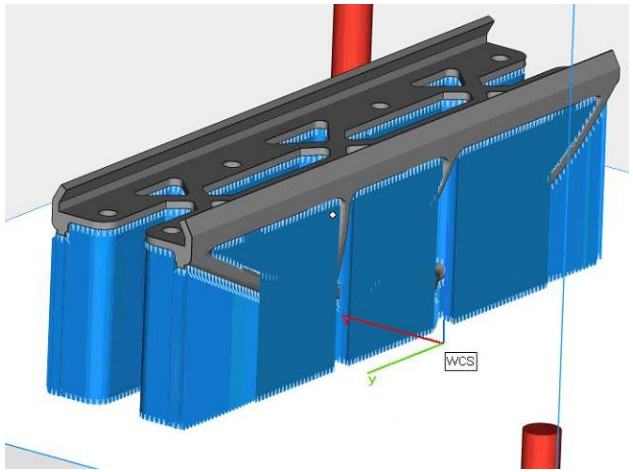





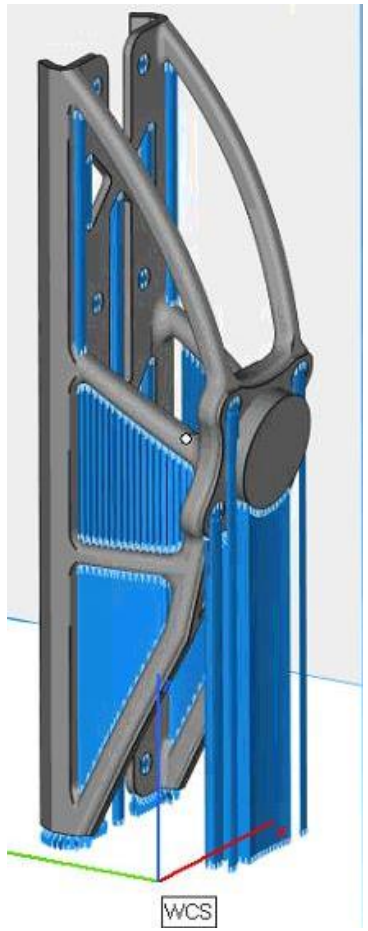
# Process – How orientation etc. effects on price




45 deg (30 µm, AlSi10Mg):
Part volume 37203 [mm3]
Support volume 10875 [mm3]
Printing time: 12 h 30 min
Post-processing: easy




0 deg (30 µm, AlSi10Mg):
Part volume 37203 [mm3]
Support volume 66165 [mm3]
Printing time: 8 h
Post-processing: hard




90 deg (30 µm, AlSi10Mg):
Part volume 37203 [mm3]
Support volume 9749 [mm3]
Printing time: 15 h 30 min
Post-processing: medium

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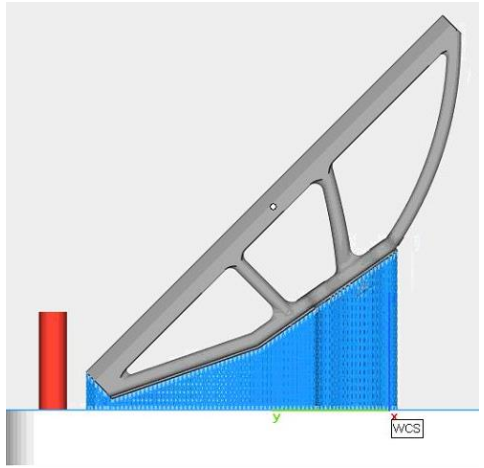
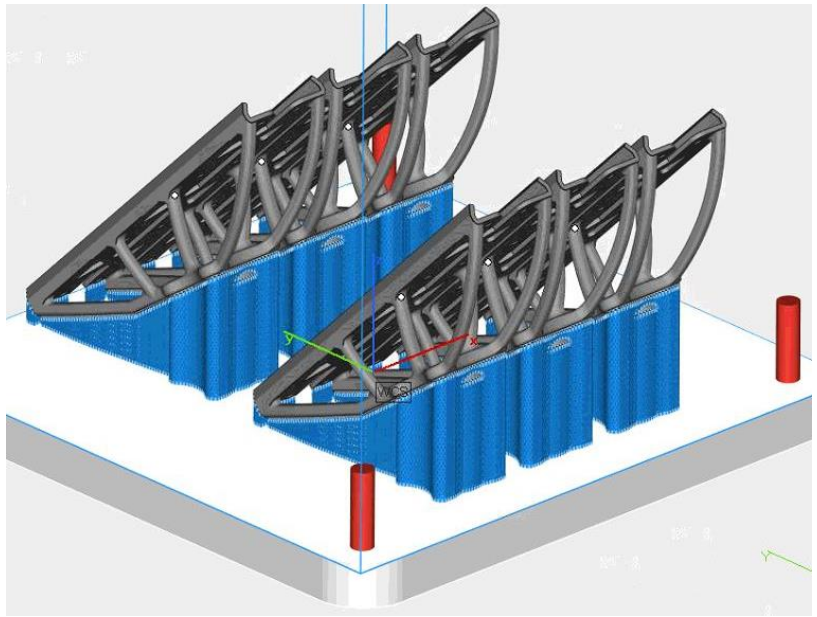
# Process – Optimize the full area of platform

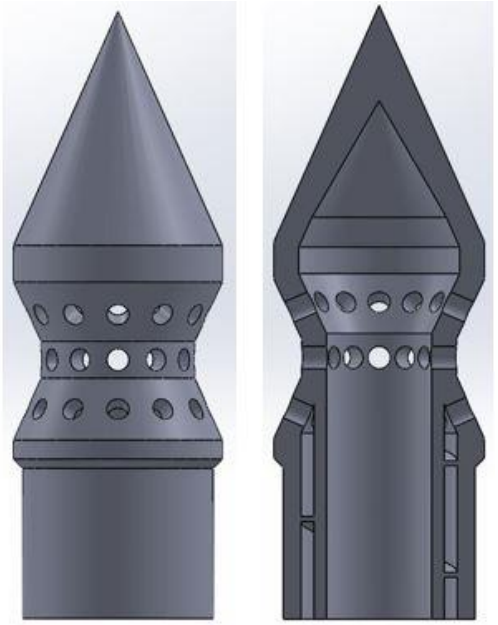


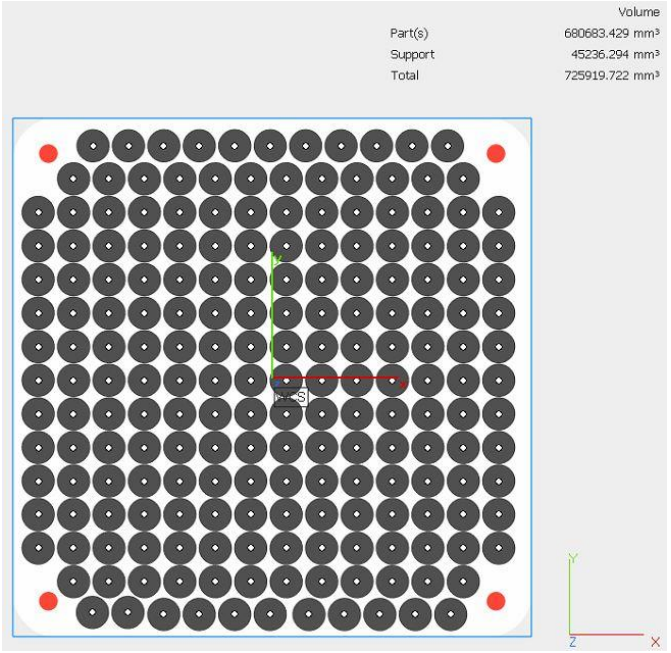

45 deg (30 µm, AlSi10Mg):
Part volume 37203 [mm3]
Support volume 10875 [mm3]
Printing time: 12 h 30 min
Printing cost/part: 1000 € + post-processing



6 kpl 45 deg (30 µm, AlSi10Mg):
Part volume 223218 [mm3]
Support volume 65250 [mm3]
Printing time: 29 h 30 min
Printing cost/part: 393 € + post-processing

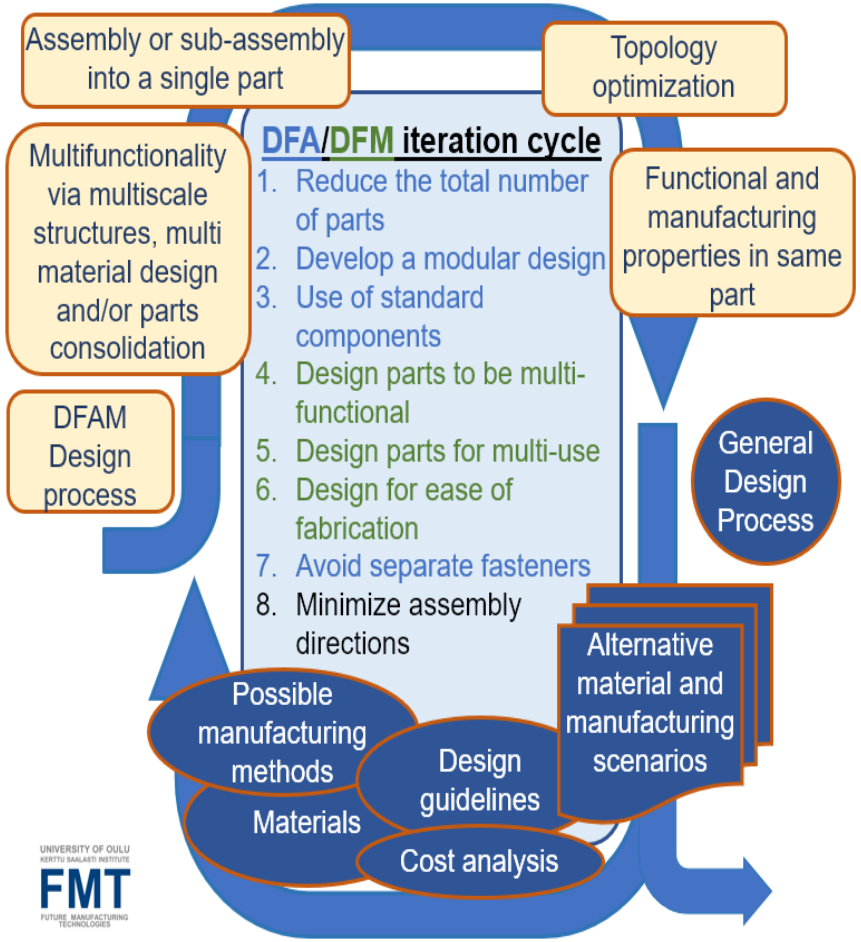
# What is the cost ?





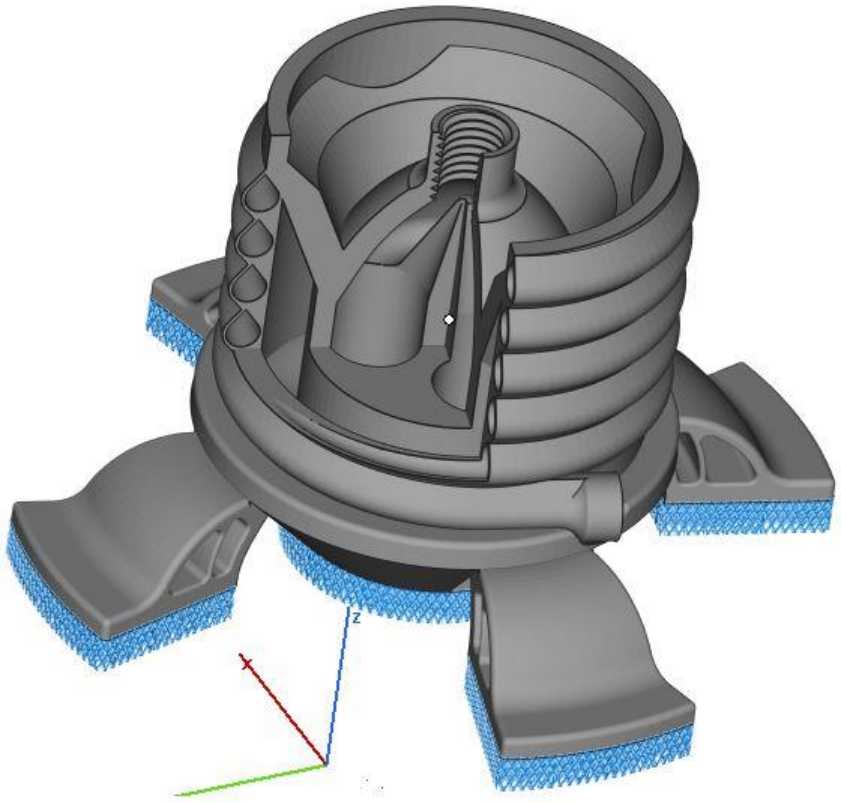

- 200 pieces of firemans nozzle (SLM280HL single 700W laser)
- 725919 mm3 total
  - Supports 45236 mm3 (about 6 %)
- Total manufacturing time 133 h
- Approximated costs
  - Machine time 133 h * 50 €/h = 6650 €
  - Materials 573.5 €
  - Manhours 8*75 €/h = 600 €
- Tulostusvaiheen kustannukset/osa 13873.5 € / 200 = 39,1 €/osa
- Postprocessing around 30 €/piece (Heattreatment, Finishing, Turnining the 0-ring groowe)
- Total costs 69.1 €/piece

# AM Design Guidelines




1. **Requirements**
2. **Manufacturing method and material**
   1. Guidelines for SLM, FFF, etc.
   2. Material specific guidelines and restrictions
3. **Optimization of geometry**
   1. Topology optimization
   2. Taking into account the special features of the manufacturing process
      - Part orientation, support structures, tolerances, geometric feature min/max sizes, residual stress, etc
   3. Minimizing post-processing
   4. Industrial design

# Process – Summary



- **If one can make parts with conventional manufacturing method, like milling and turning, it is allmost impossible to make it profitable with metal 3D AM**
- **DFAM = Design for Additive Manufacturing. Made parts should be design for this method**
- **Profitable metal 3D AM parts are:**
  - Such that use the possibilities of metal 3D AM
  - Structurally has such features that can not made with any other manufacturing method
  - Think parts consolidation and mechanisms
  - Use nesting on platform, maximize the area
  - The harder is to mill or the turn, the better for this method

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# *Thank you for your kind attention!*


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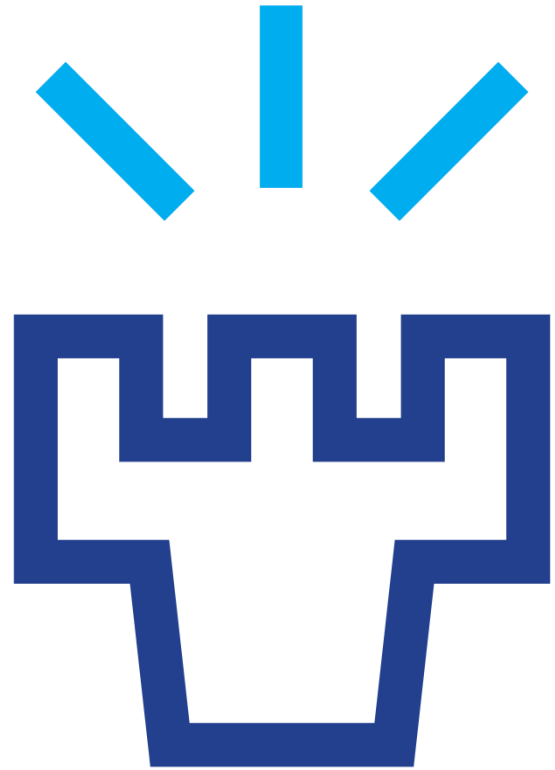

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