MANUELA

WEBINAR: Introduction to Additive Manufacturing (AM) using metal to Aerospace sector

Lars Nyborg, Emmanuel Onillon, Eduard Hryha, Paul Häyhänen, Karolina Kazmierczak

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement n° 820774.

Agenda

Time	Topic
09.00 – 09.05	Introduction – Karolina Kazmierczak / Paul Häyhänen (Chalmers Industriteknik)
09.05 – 09.25	Additive Manufacturing possibilities in MANUELA project – Lars Nyborg (Chalmers)
09.25 – 09.35	Presentation of Use Cases from the Aerospace sector – RUAG and Qioptiq – Emmanuel Onillon (CSEM)
09.35 – 09.50	Benefits of AM, Unique Selling Points – Eduard Hryha (Chalmers)
09.50 – 10.00	Info about Open Call (MANUELA) – Paul Häyhänen (Chalmers Industriteknik)
10.00 – 10.30	Discussion, questions, open points – All

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Introduction

- Aim:
  - To introduce AM possibilities for the aerospace industry through the EU project MANUELA
  - MANUELA - Additive Manufacturing using Metal Pilot Line – offerings for companies via “Open Call”

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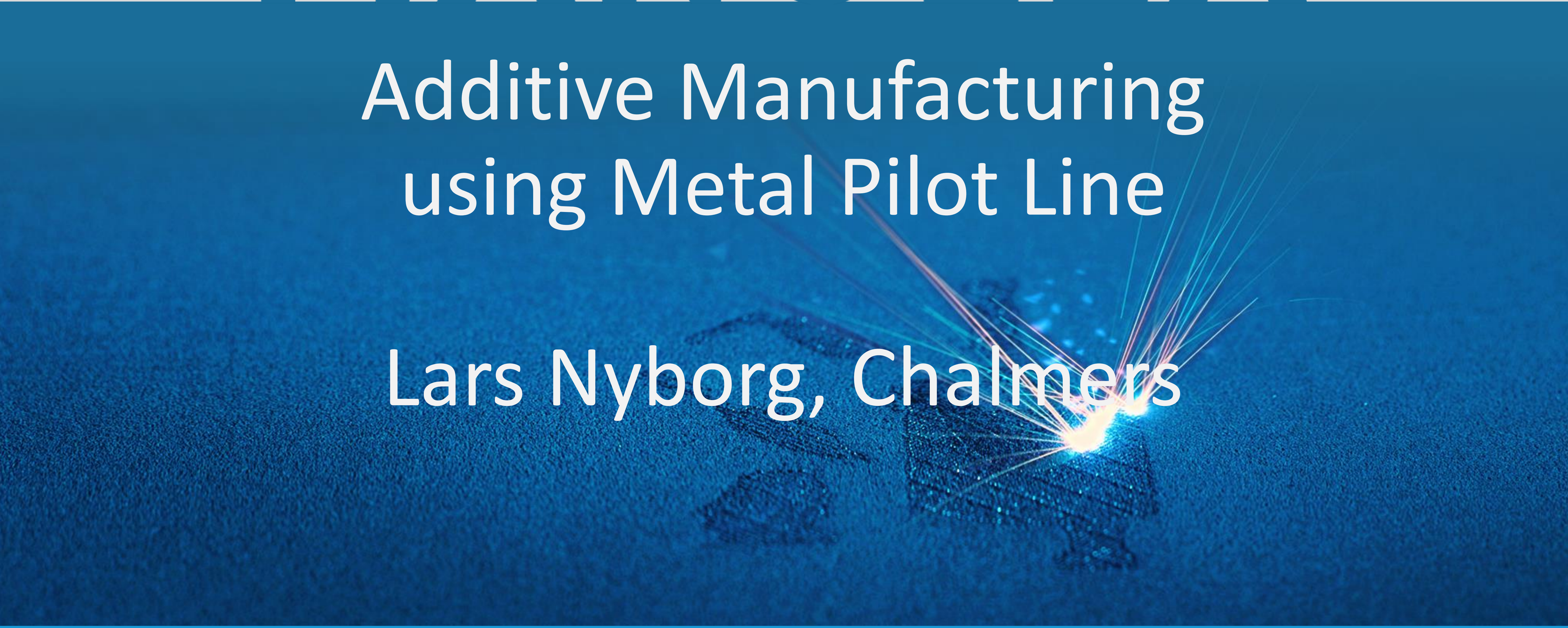

Additive Manufacturing using Metal Pilot Line

Lars Nyborg, Chalmers

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MANUELA consortium

www.chalmers.se	www.eos.info metal materials	www.oebsrl.it
www.csem.ch	www.new.abb.com	www.qioptiq.com
www.wtm.tf.fau.eu	www.osai-as.com	www.ceit-ke.sk
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www.polito.it	www.siemens.com	www.ruag.com
www.hoganas.com	www.chalmersindustriteknik.se	

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Why

BENEFITS OF METAL AM

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How

KEY INNOVATIONS OF MANUELA

MANUELA project

Post-MANUELA pilot line offering

TAILORED RECYCLABLE METAL POWDER

PILOT LINE DASHBOARD

WORKFLOW OPTIMIZATION AND AUTOMATION

REAL-TIME PROCESS MONITORING

QUALIFICATION AND CERTIFICATION STANDARD

- Pre-industrial testing for specific AM products
- Full manufacturing chain available
- Turn-key delivery/One-stop-shop
- Time to market reduction
- First-time-right product design
- Qualified products for new segments
- New materials integration into manufacturing line
- 'Green' technology approved by Life Cycle Analysis
- Definition of AM guidelines
- Advanced quality control process

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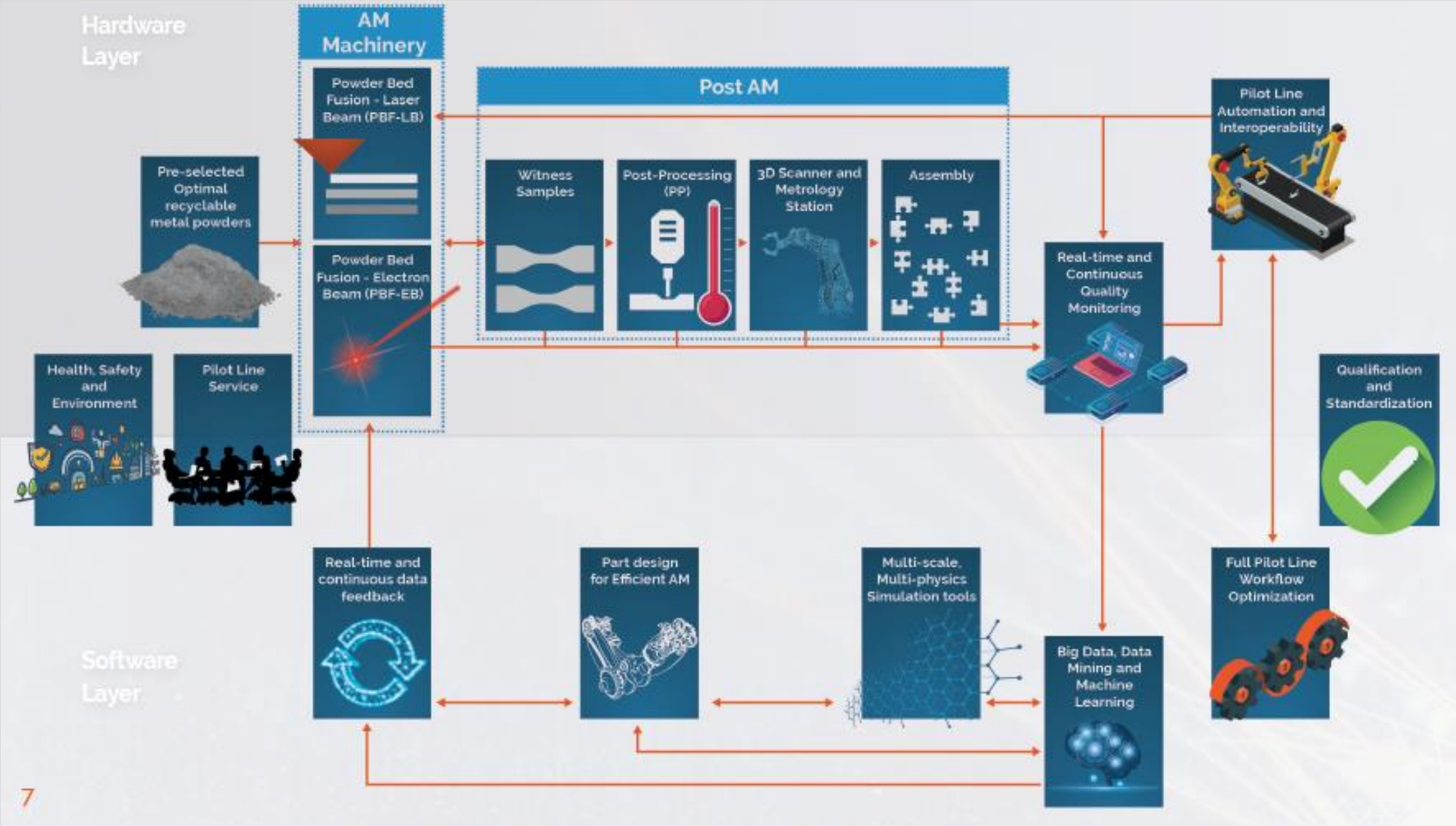
How SERVICES



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How SINGLE ENTRY POINT

CHALMERS INDUSTRITEKNIK

Chalmers Industriteknik (CIT) acts as single point of entry for the future customers to the MANUELA Pilot Line.

CHALMERS INDUSTRITEKNIK WILL PERFORM ALL FRONT ACTIVITIES INCLUDING MARKETING, CUSTOMER RELATIONSHIP, EVALUATION OF OPPORTUNITIES, REQUIREMENTS, OFFERS, MANAGEMENT AND SOURCING OF COMPLEMENTARY SERVICES, QUALITY CONTROL, INVOICING, AND CONTINUATION OF ECOSYSTEM BUILDING.

The Pilot Line will provide Open Access services according to the following flow:

CLIENT

BRINGS IDEA AND REQUIREMENTS TO CIT

CIT

PROVIDES DESIGN, MODEL, SIMULATION, 3D PRINTED PRODUCT WITH CHARACTERIZATION, AS WELL AS OPTIMIZED PROCESS BASED ON ONLINE MONITORING AND MACHINE LEARNING BASED DATA PROCESSING.

- Can act as neutral node
- Will not need to carry the infrastructure
- Can start as project office
- Can form agreements with the nodes (CSEM, POLITO, FU, CHALMERS) and others
- Possible to create a legal entity

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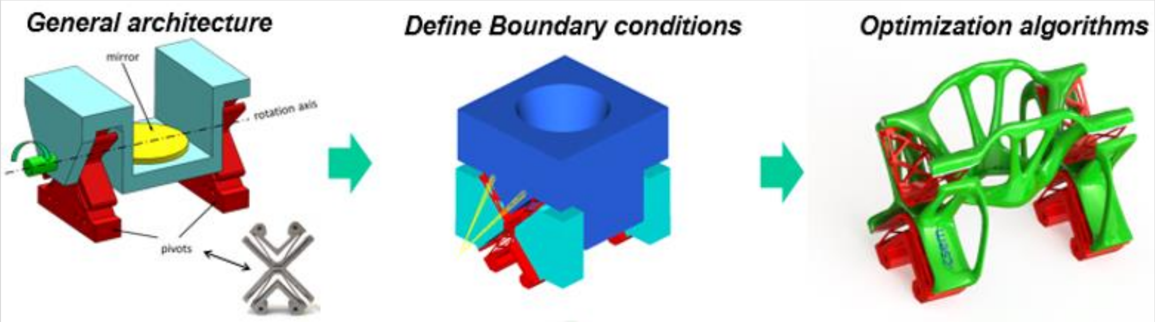
Design flow

DEVELOP

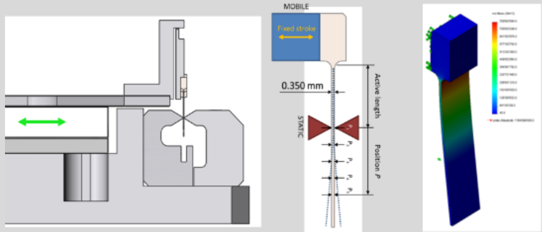
Design & Optimization

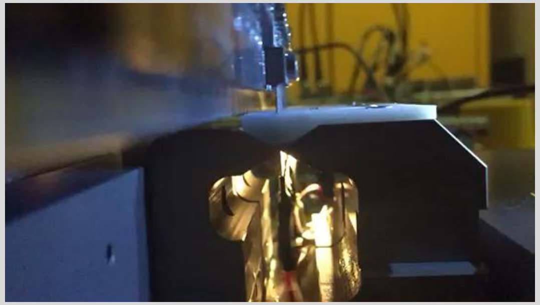


Process simulation

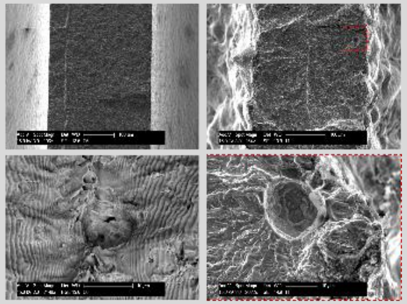
QUALIFY

Testing

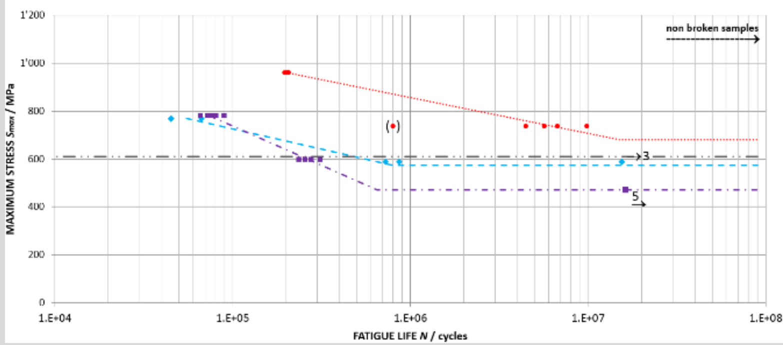




Analysis



Experimental Data



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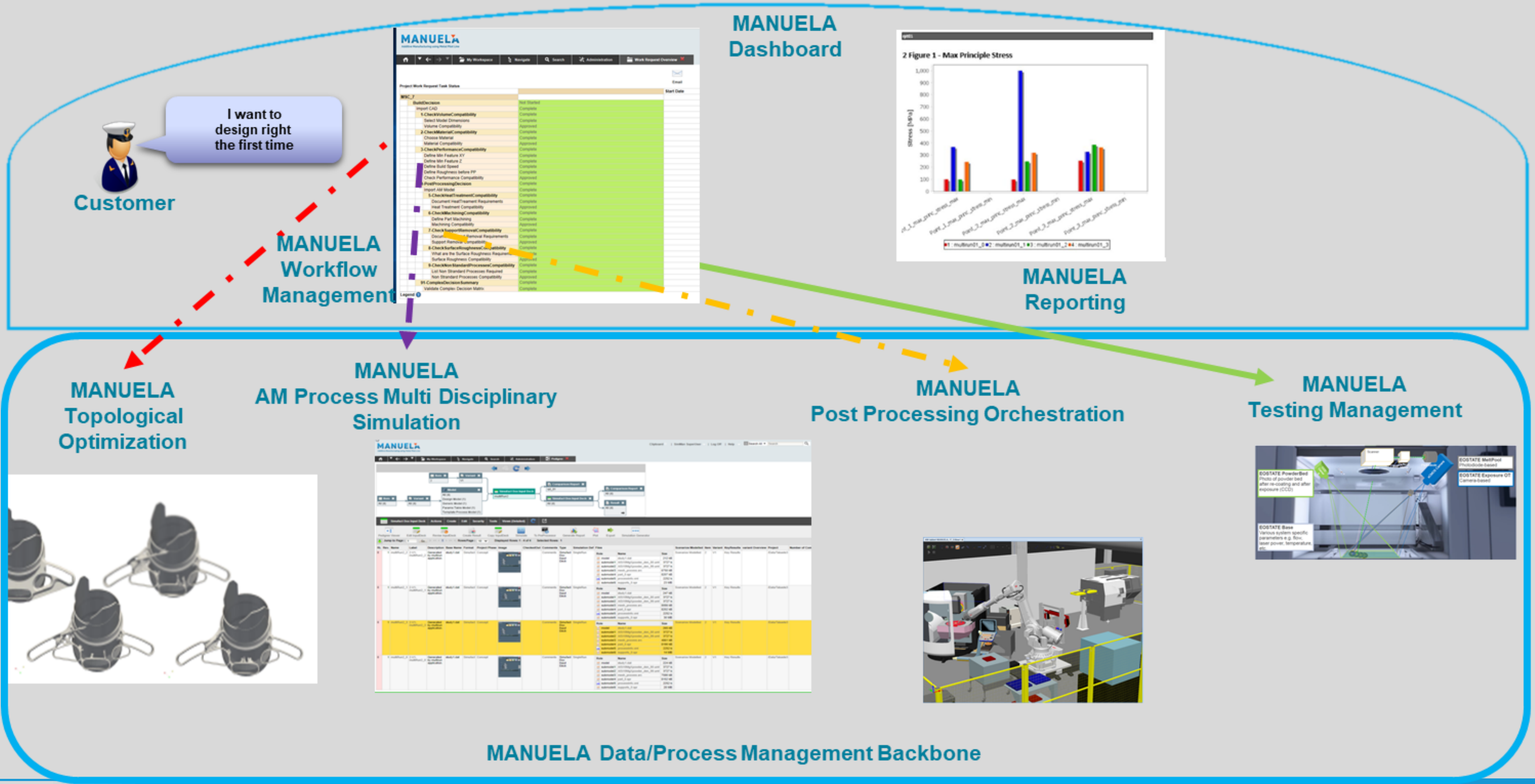
Dashboard and Digital Thread Management



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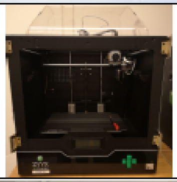
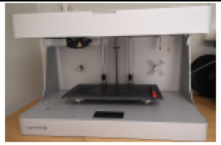
RESOURCES AT CHALMERS

WHAT

Printer	Picture	Build Vol. (mm)	Method	Material	Software	Remarks
EOS M100 (1 unit)		Ø 100 x 95 (incl. build plate)	LPBF	Ni-base, steel, tool steel, Al-alloy, bronze, HEA	Magics	N2 or Ar
EOSM290 (1 unit)		250 x 250 x 325 (incl. build plate)	LPBF	Ni-base, steel, tool steel Stainless steel	Magics	N2 or Ar EOSTATE process monitoring
ZYYX+ (3 units)		265x225x195	FDM	ProPLA ProABS ProFLEX	Simplify3D	Z-layer: 50 um X-Y: 11 um positioning
Markforged (1 unit)		320x132x154	FDM	Nylone Onyx Glass fibre Carbon fibre Kevlar	Via Markforged web service	Z-layer: 100 um
Zortrax Inspire (1 unit)		132x74x175	UV photo-polymerization	Resins	Z-suite	Z-layer: 25 um X-Y: 50 um

- Dedicated printers (metals, polymers and composites)
- CAM2 competence centre (hosted by Chalmers)
- Application centre under development (hosted by RISE IVF)
- Design, pre-processing and process modelling software (CAD, Magics, Ansys, Simufact,…)
- Materials and powder characterisation
- Materials testing
- Post-processing

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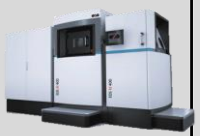
RESOURCES AT POLITO

WHAT

Printer	Picture	Build. Vol (mm)	Method	Materials	Software	Remarks
EOS M270		250*250*215	LPBF	Al-based, Ni-based, Ti-based, Steels	Magics	N_2 or Ar
EOS M400		400*400*400	LPBF	CoCr alloy In718 AlSi10Mg	Magics	N_2 or Ar
Concept Laser MLab		90*90*80	LPBF	Al-based, Ni-based, Ti-based…	Magics	N_2 or Ar
Printsharp 250		250*250*300	LPBF	Al-based, Ni-based, Ti-based, Steels	Magics	N_2 or Ar
Arcam A2X		200*200*280	EBM	Ti-based Ni-based	Magics	Vacuum

- Dedicated printers (metals, polymers and composites)
- CIM4.0 Competence Center
- Design, pre-processing and process modelling software (CAD, Magics…)
- Material development (gas atomisation)
- Materials and powder characterisation
- Materials testing
- Post-processing (Heat treatments, HIP and finishing)

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WHAT

Other metal equipment

- PSI Gas atomisation system
- Quintus Hot Isostatic Pressing (HIP)
- Ovens for post processing

Polymer based AM systems

- SLS EOS Formiga (Nylon and Nylon matrix composites)
- FDM (ABS, PC, PLA, Nylon…)
  - 3ntr A4
  - Stratasys F370 and Dimension Elite
  - Markforged Mark Two
- DLP
- Stereolithography

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RESOURCES AT FAU

WHAT

Printer	Picture	Build. Vol. (mm)	Method	Materials	Software	Remarks
Athene		120 × 120 × 200	EBM	Ti-based alloys	Freely program-mable	Vacuum, 6 kW, BSE-detector (online monitoring)
A2		200 × 200 × 200	EBM	Ni-based superalloys; high temperature materials	Arcam & Magics	Vacuum
Q10 plus		200 × 200 × 200	EBM	Ti-based, Cu-based, Co-based alloys	Arcam & Magics	High brightness cathode: LaB_6 (higher print resolution, long service time)
Freemelt One		130 × 200 (Ø × H)	EBM	Unlimited	Freely program-mable	Vacuum, 6 kW, LaB_6 cathode online monitoring, small build tank

- Dedicated printers (metals, composites)
- Design, pre-processing and process modelling software (CAD, Magics…)
- Application centre (ZMP)
- Materials and powder characterisation
- Materials testing
- Post-processing (Heat treatments)

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RESOURCES AT FAU

WHAT

Device	Picture	Function
FEI – Helios NanoLab 600i FIB Workstation		High-resolution Scanning Electron Microscope (**SEM**) equipped with Energy-Dispersive X-ray spectroscopy (**EDX**), Electron BackScatter Diffraction (**EBSD**) and Focused Ion Beam (**FIB**).
Microprobe Jeol JXA 8100		Electron Probe MicroAnalyzer (**EPMA**) for the chemical analysis with high local resolution.
Frauenhofer EZRT CT Alpha system		Computed Tomography (**CT**) for three-dimensional imaging of complex parts.
Ovens (vacuum, inert gas) for heat treatments	 	FCT - Pressure sintering furnace; Gero – HTK 25 sintering furnace; Gero – LHTM 250/300 vacuum glowing furnace
Optical & laser microscopes	 	Carl Zeiss – Axio A1m Imager; Carl Zeiss – SteREO; Olympus – Lext OLS 4000; Carl Zeiss – Axio M1m Imager
Malvern – Mastersizer 3000		Laser diffractometry for the determination of particle size distribution from 0.01 to 3500 µm
Sigmatest – Creep tester		Characterization of creep properties of metallic compounds

- Dedicated printers (metals, composites)
- Design, pre-processing and process modelling software (CAD, Magics…)
- Application centre (ZMP)
- Materials and powder characterisation
- Materials testing
- Post-processing (Heat treatments)

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RESOURCES AT RISE IVF

WHAT

Printers at RISE

Printer	Picture	Build Vol. (mm)	Method	Material	Software
SLM125HL		125x125x125 reduced by substrate plate thickness	LPBF	Ni-base, steel, tool steel, Al-alloy, bronze, maraging steel	Magics
SLM280		280 x 280 x 365 mm reduced by substrate plate thickness	LPBF	Ni-base, steel, tool steel, maraging steel	Magics
Formlabs Form 2		145 x 145 x 175 mm	SLA	Resins	From machine provider
CeraFab 7500		76 x 43 x 170 mm	LCM technology	Ceramics	From machine provider
IRBAM		Ca. 2x2x6m	Large scale FDM	Thermoplastics, short-fiber composites	Simplify3D & RISE developed software
An assortment of small desktop printers			FDM		

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Use Cases – Aerospace

Emmanuel Onillon, CSEM

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Overview

- Which tools will be available?
- What will be the design flow?
- What optimization can bring?
- Slip ring and helmet mounting device examples

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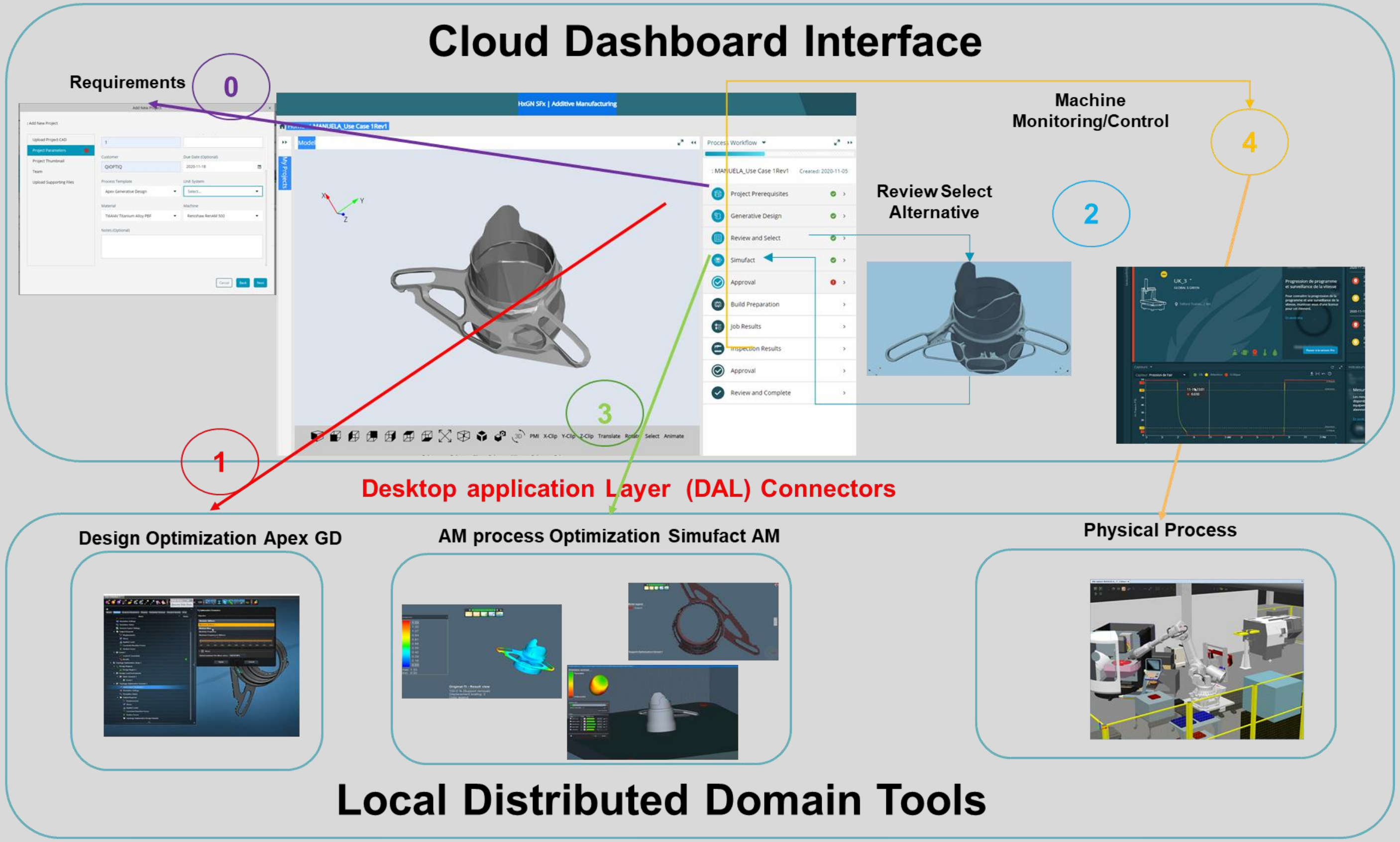
Design tools

- Covers the full development process:
  - Design analysis
  - Design optimization (APEX GD)
  - Process simulation (Simufact)
  - Manufacturing following



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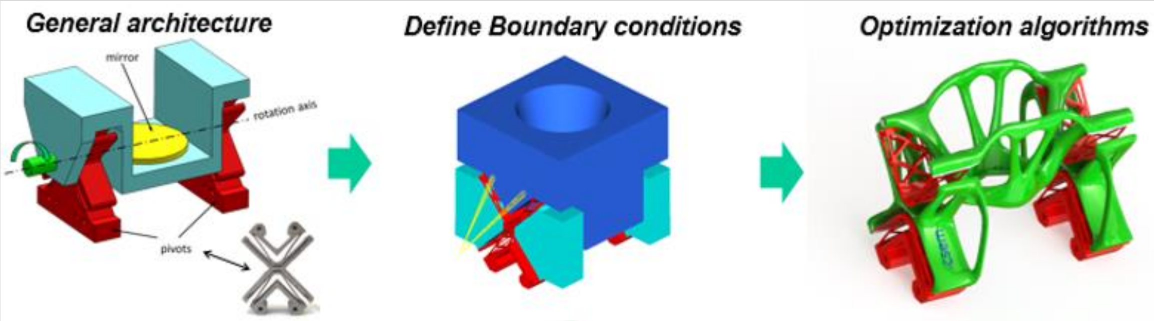
Design flow

DEVELOP

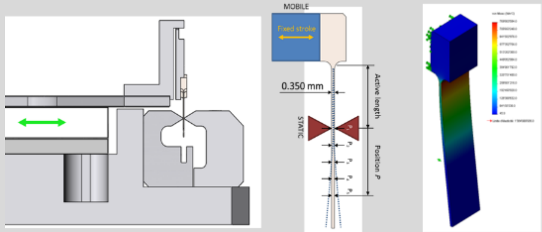
Design & Optimization

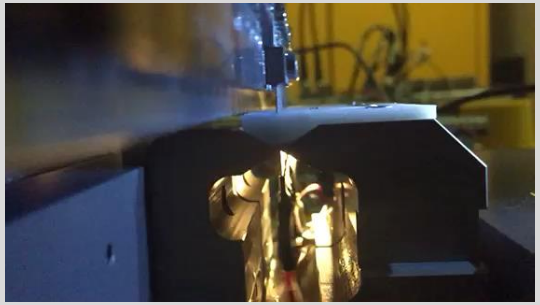


Process simulation

QUALIFY

Testing





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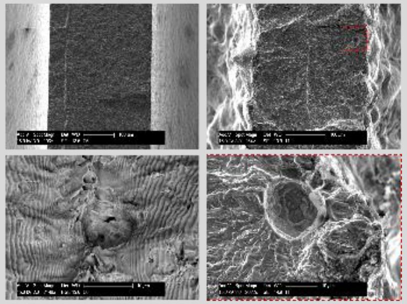
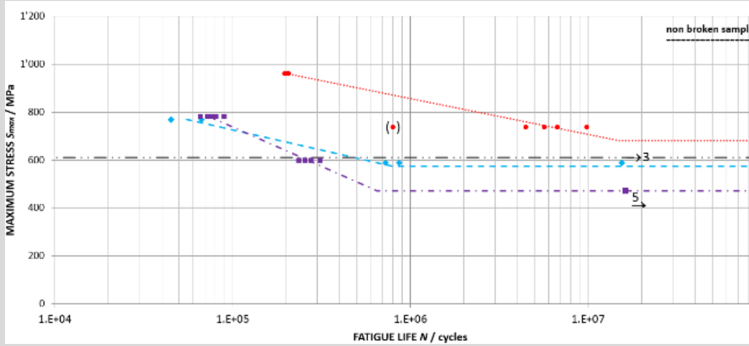


Experimental Data



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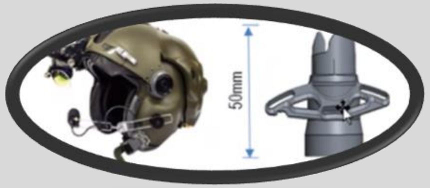
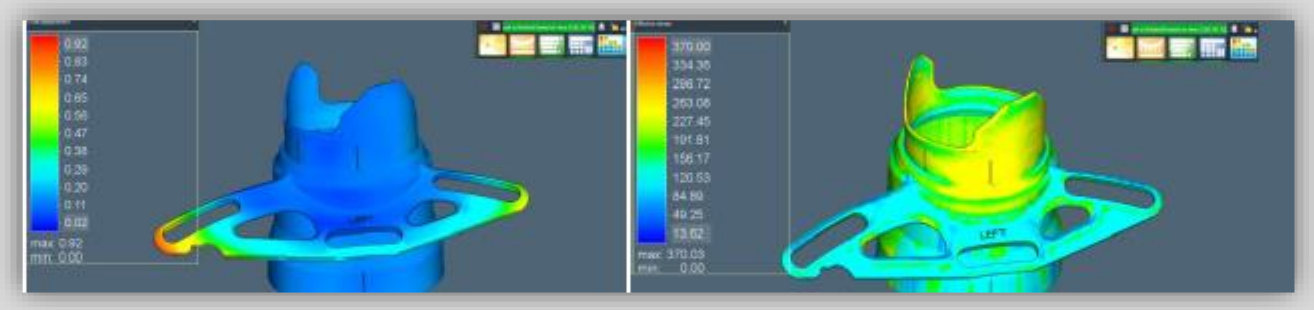
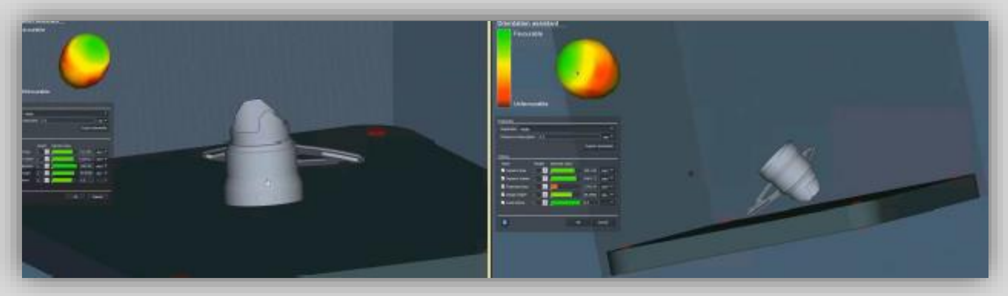
Aerospace design example – Helmet mounting support (Qioptiq)



- Target:
  - Mass optimization
  - Support structure optimization
- Part build plate position and orientation optimization
- Manufacturing simulation

	Original	Optimization 1	Optimization 2	Optimization 3
Weight (g)	10.75	9.46	9.57	9.48
Savings (%)		14	12	13





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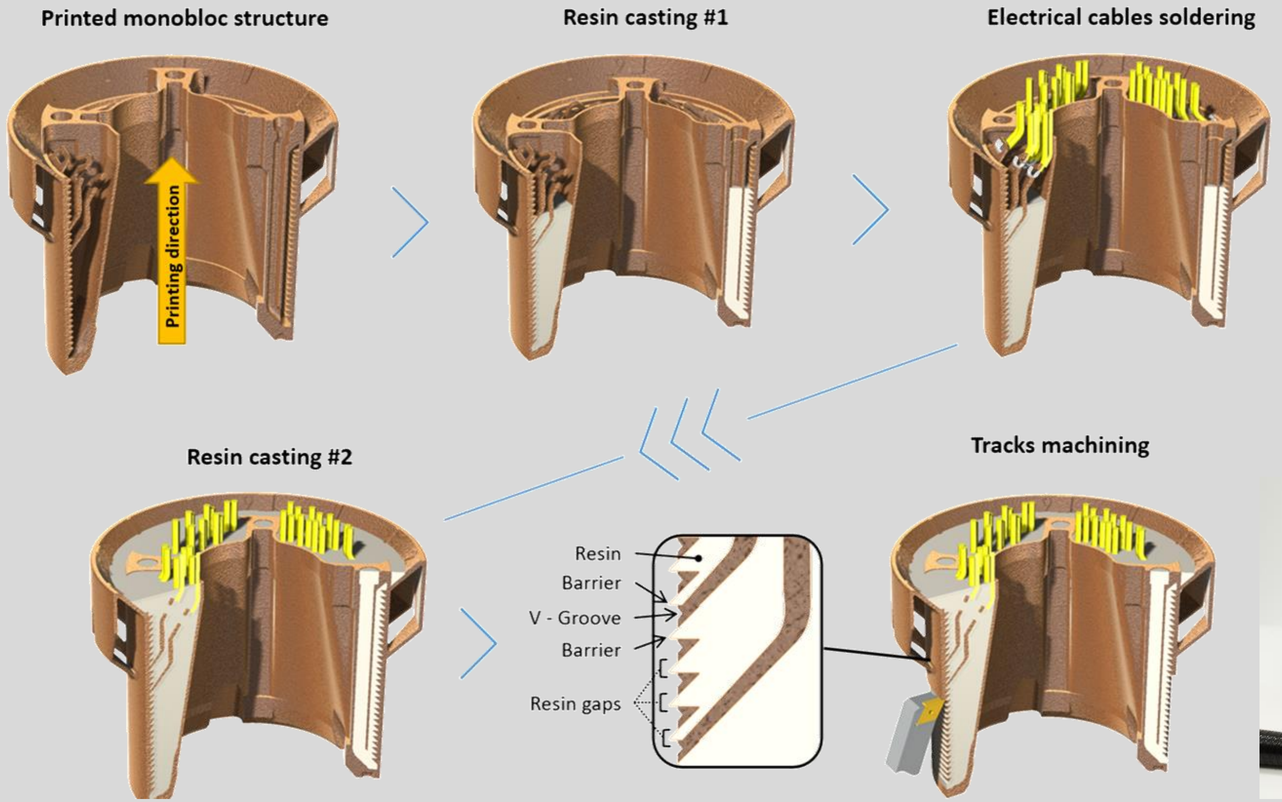
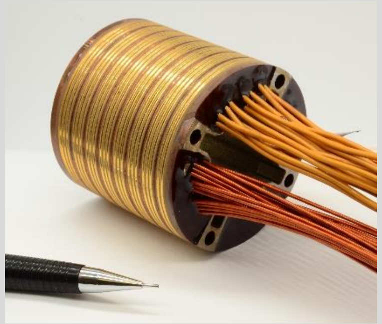
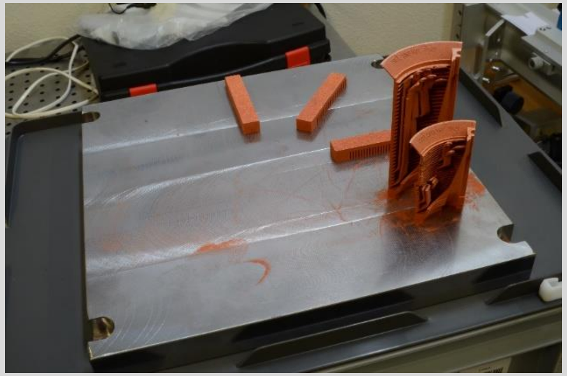
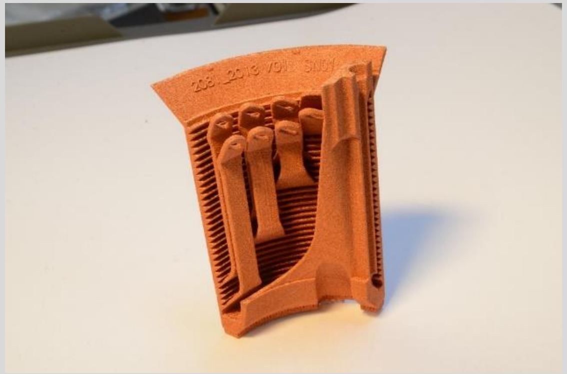
Aerospace design example – rotor slip ring (Ruag space)

- Rotor – reduction of number of parts and assembly time
- Possibility of Copper printing









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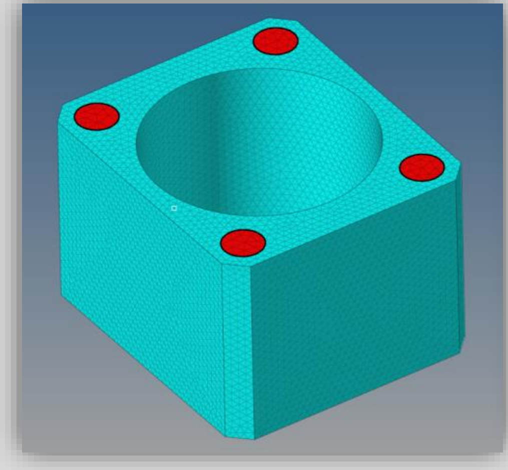
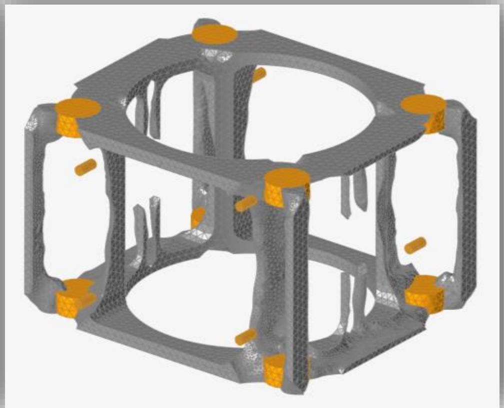
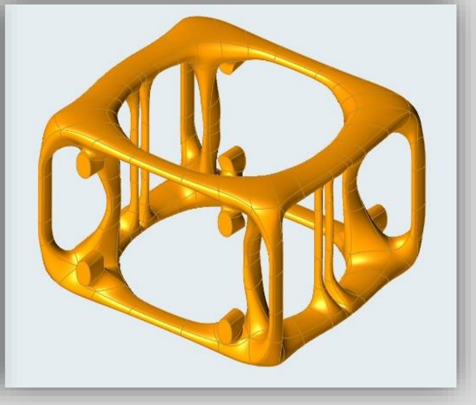
Aerospace design example - stator slip ring (Ruag space)

- Definition of interfaces and non-design space:
- Definition of design space (max. volume for topology optimization)
- Problem setup: objective and constraints
- Part simulation & manufacturing (Al10SiMg)

Design spaces in blue and non design spaces in red

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Thank you

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AM benefits – aerospace applications

Eduard Hryha, Chalmers

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Additive Manufacturing

- ASTM categorizes additive manufacturing into seven process categories:
- **Binder jetting**
- **Directed energy deposition**
- Material extrusion
- Material jetting
- **Powder bed fusion**
- Sheet lamination
- Vat photopolymerization

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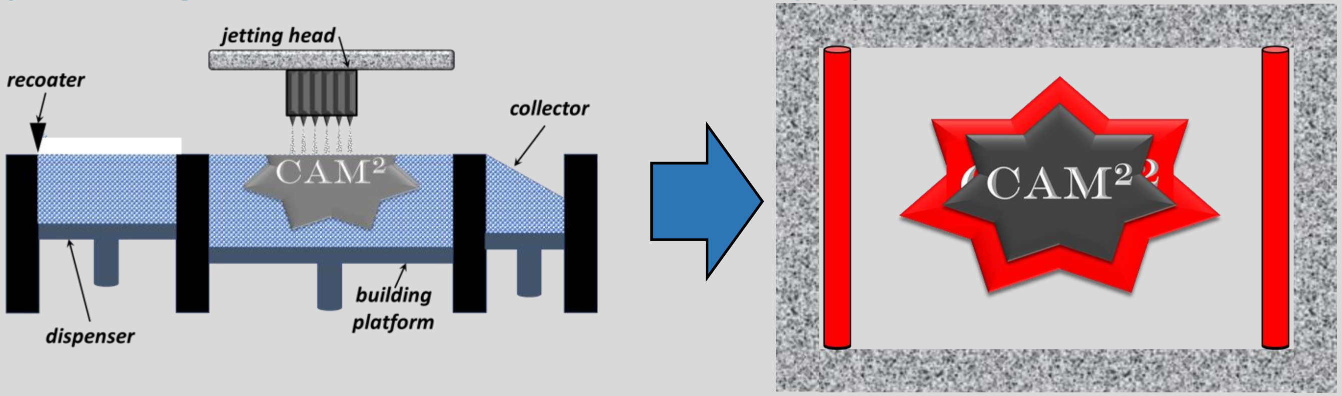
Additive Manufacturing

- Binder jetting – metal – multi-step process!



- The printed part is dried/cured in the powder bed after printing in order for the binder to fully set and for the green part to gain strength;
- Part is further debinded – separately or during sintering process
- Sintering is performed at high temperatures – shrinkage of up to 20% in all dimensions – has to be accounted during design!!!

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Binder jetting – metal

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Directed energy deposition

- Directed energy deposition (Laser Metal Deposition (LMD), Laser Engineered Net Shaping (LENS), Electron Beam Additive Manufacturing (EBAM), directed light fabrication, direct metal deposition, 3D laser cladding, etc.) —an additive manufacturing process in which focused thermal energy is used to fuse materials by melting as they are being deposited

- Materials: metal powder and wire

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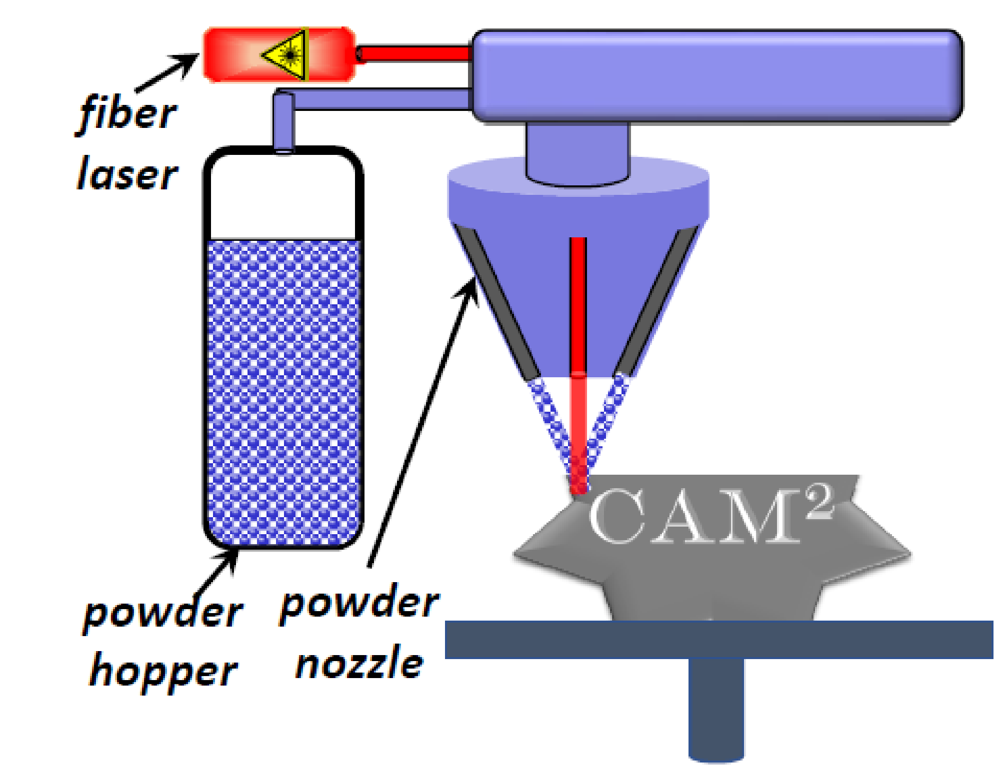
Directed energy deposition



- **powder**-blown systems (*Laser Metal Deposition (LMD) and Laser Engineered Net Shaping (LENS)*) – powder blown through nozzle is melted by a **laser beam** on the surface of the part;

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Powder bed fusion

- Powder bed fusion — an additive manufacturing process in which thermal energy selectively fuses regions of a powder bed
- Materials: Metal, polymer and ceramic powder
- Powder bed fusion:
  - the most growing technique
  - laser or electron beam is used to melt and fuse material powder together layer by layer
  - presence of the support structures – needs to be removed after AM fabrication
  - anisotropy – grain growth in the built direction
  - typically requires post-treatment – heat treatment, hot isostatic pressing, etc. in order to relieve residual stresses and minimize number of defects (pores, lack of fusion, etc.).

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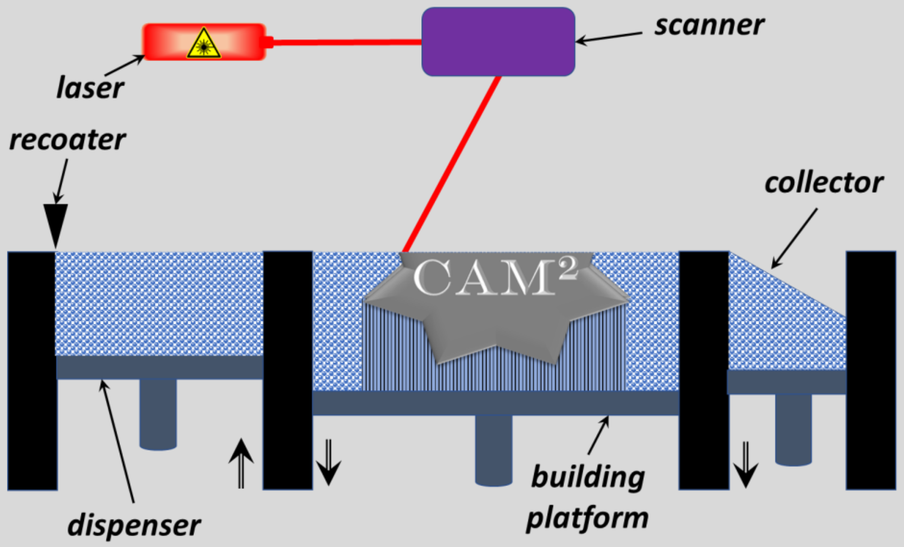
Laser Based Powder Bed Fusion - Metal

- LB-PBF/m:
- performed under protective gas
- larger built plates - 800 x 400 x 500 mm (x,y,z)
- variety of materials available
- powder recyclability
- fine powder – 20-80 µm is used – possibility to built small channels and obtain finer surfaces
- possibility to use number of lasers simultaneously – increase productivity



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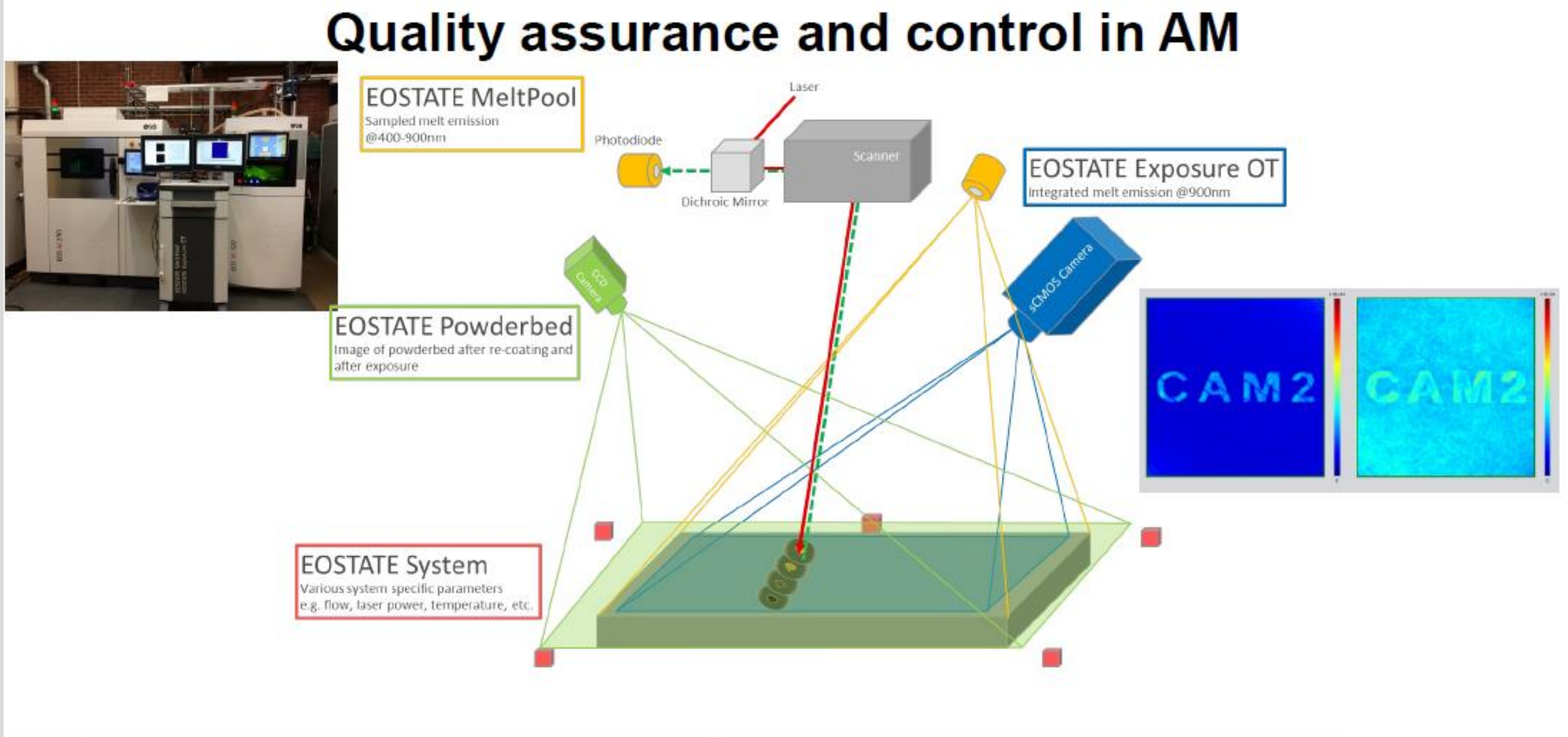
Additive Manufacturing



On-line Process Monitoring for LB-PBF (EOS)

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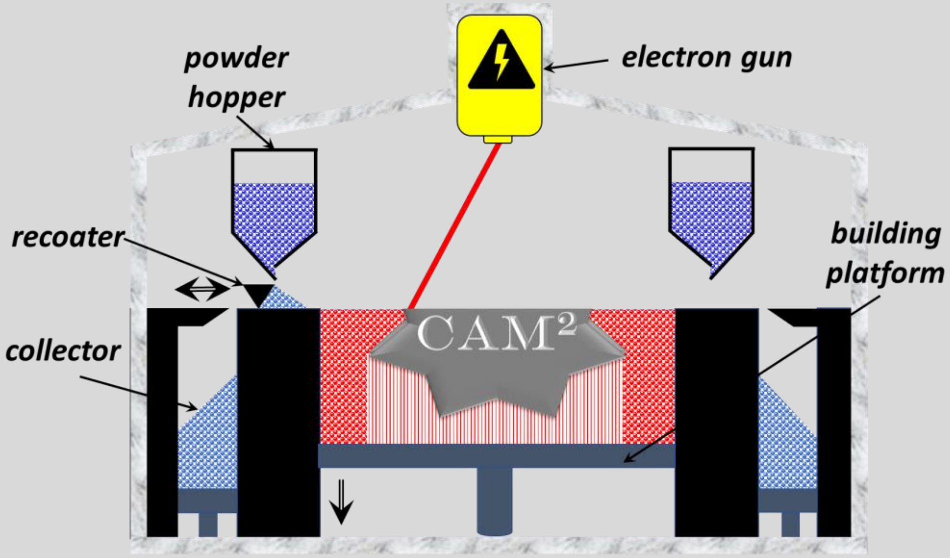
Additive Manufacturing

- Electron Based Powder Bed Fusion (EB-PBF):
  - requires vacuum
  - used solely for metals and alloys
  - build plate 2000*200*180 mm and up to Ø350×380 mm
  - robust processing for some materials – application in biomedical and aerospace
  - low number of materials available (Ti, Ti6Al4V, CoCr, In718)
  - powder bed “pre-sintering”
  - lowers recyclability of the powder
  - restricts possibility to produce small channels



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Markets – aerospace

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Markets – aerospace

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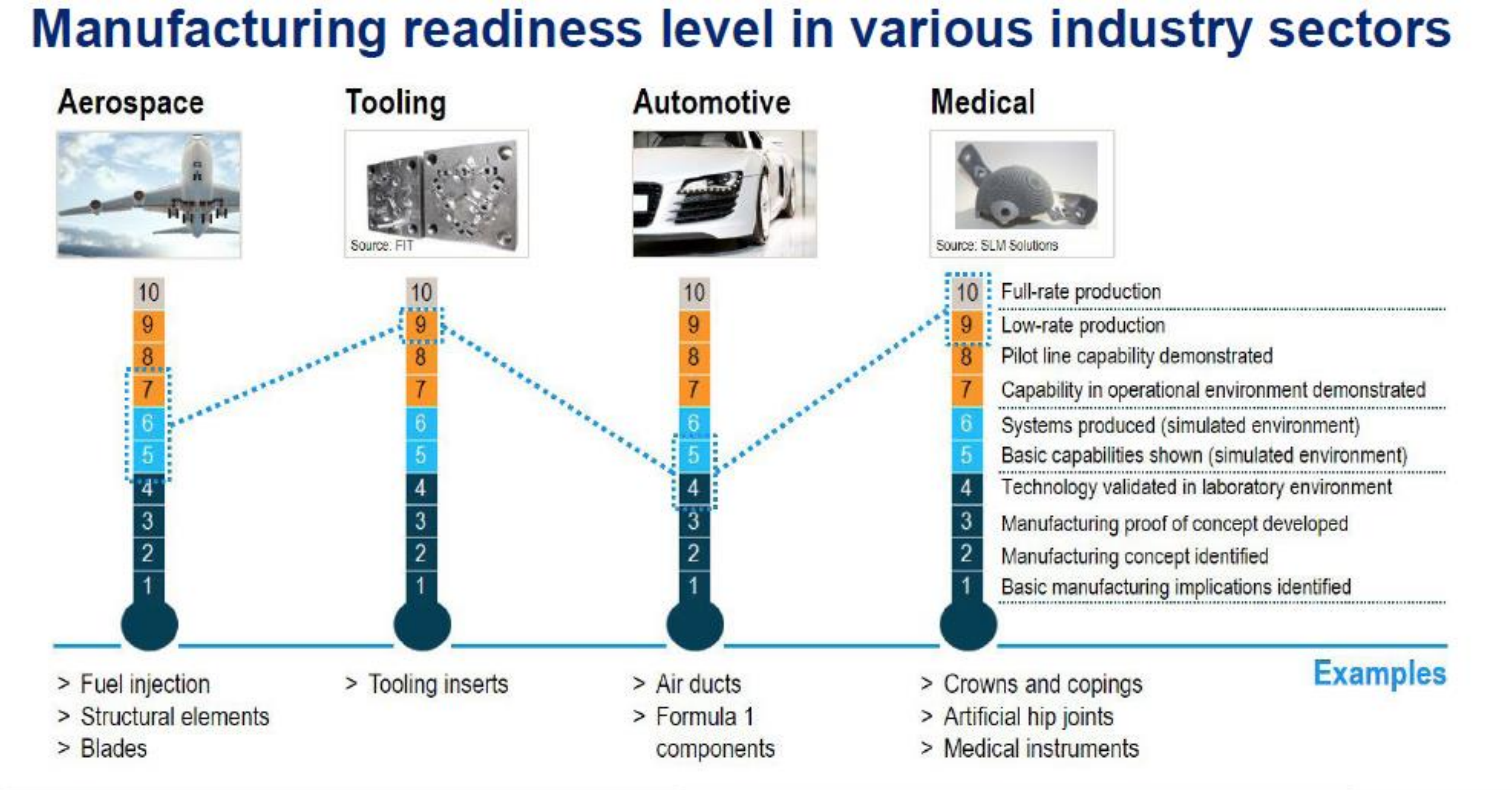
Additive Manufacturing



Courtesy of Roland Berger, Source: *Introduction to additive manufacturing technology, EPMA*

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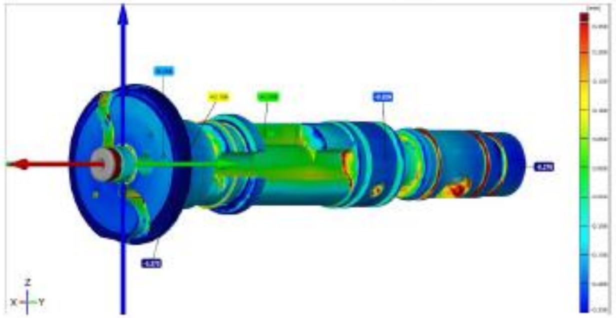
Additive Manufacturing

Productivity increase through tailored process development

- ✓ Printing time with standard parameters - **~120 hours**
- ✓ Developed process parameters: **30 hours!!!**
  - = full density
  - = static mechanical properties
  - + 4 times higher productivity
  - - a bit worse surface finish



https://www.chalmers.se/en/centres/cam2/cases/Pages/case-productivity-of-laser-powder-bed-fusion.aspx

Alex Leicht/ Lars Hammar and Marie Fischer/Chalmers

MANUELA

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Additive Manufacturing

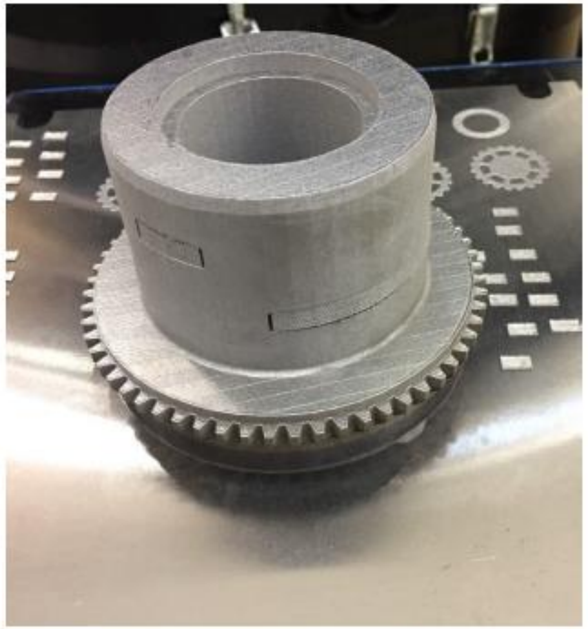
Powder development for L PBF

Control ring in 4130 steel

- ✓ Developed process for 4130 steel powder from Höganäs
  - ✓ Good printability
  - ✓ Full density
  - ✓ Defect-free, perfect for structural components for automotive industry

Höganäs

VOLVO



Control ring, courtesy of Volvo Cars

https://www.chalmers.se/en/centres/cam2/cases/Pages/Case-Development-of-Ferrous-Alloys-for-L-PBF.aspx

William Hearn/Chalmers

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Open Call

Paul Häyhänen, CIT

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Open Call for Business Development Cases - info

- Targeting European companies
- 10 business use cases to be selected in total
- Each case will be co-funded by the applicant and the MANUELA project at 50/50%
- Application through portal: https://apply.manuela-project.eu/
- Helpdesk and any questions about the Open Call: helpdesk@manuela-project.eu

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Open Call for Business Development Cases - info

- All or any of AM sub-processes: development, design, production/processing, post-processing
- Evaluation criteria
  - Concept and level of innovation
  - Impact and market potential
  - Implementation

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Open Call for Business Development Cases – Schedule

- **1 December -20** – The Call is open!
- 30 March -21 – First cut off for Applications and evaluation and selection of 5 use cases for Implementation
- 30 September -21 – Second and last cut off for Applications and evaluation and selection of 5 use cases for Implementation
- Winners will be notified directly, and planning of implementation will start
- 1 June -22 – All cases shall be processed and closed

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Open Call for Business Development Cases – info

- Implementation
  - CIT is the interface with the company and project manages the implementation of the business development case
  - User requirements, process flows charts, resource allocation, budgeting, contract will be setup for each use case
  - Planning tool will be ProjectPlace

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Business Development Cases

If you are interested in the Open Call contact us already now- the Call is open!

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Contact

manuela@chalmersindustriteknik.se

www.manuela-project.eu

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Q&A Discussion

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