



WEBINAR:
**Introduction to Additive
Manufacturing (AM) using
metals to SMEs**

Lars Nyborg, Emmanuel Onillon, Paul Häyhänen, Karolina Kazmierczak



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 a real case – 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

Introduction

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

MANUELA



Additive Manufacturing using Metal Pilot Line

Lars Nyborg, Chalmers

A close-up photograph of a laser powder bed fusion process. A bright, intense blue and white laser beam is focused on a surface of fine metal powder, creating a glowing point of contact. Numerous bright, colorful sparks (red, orange, and blue) are being ejected from the point of fusion, radiating outwards. The background is a dark, textured surface of the same powder.

MANUELA consortium

	www.chalmers.se		www.eos.info metal materials		www.oeb srl.it
	www.csem.ch		www.new.abb.com		www.qioptiq.com
	www.wtm.tf.fau.eu		www.osai-as.com		www.ceit-ke.sk
	www.ri.se		www.metas.ch		www.enel.it
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	www.polito.it		www.siemens.com		www.ruag.com
	www.hoganas.com		www.chalmersindustri teknik.se		

Why

BENEFITS OF METAL AM



Innovative
and flexible
product design
enabling complex
geometries



Optimized
material utilization
reducing waste
generation



Energy cost
savings



Reduced lead
times



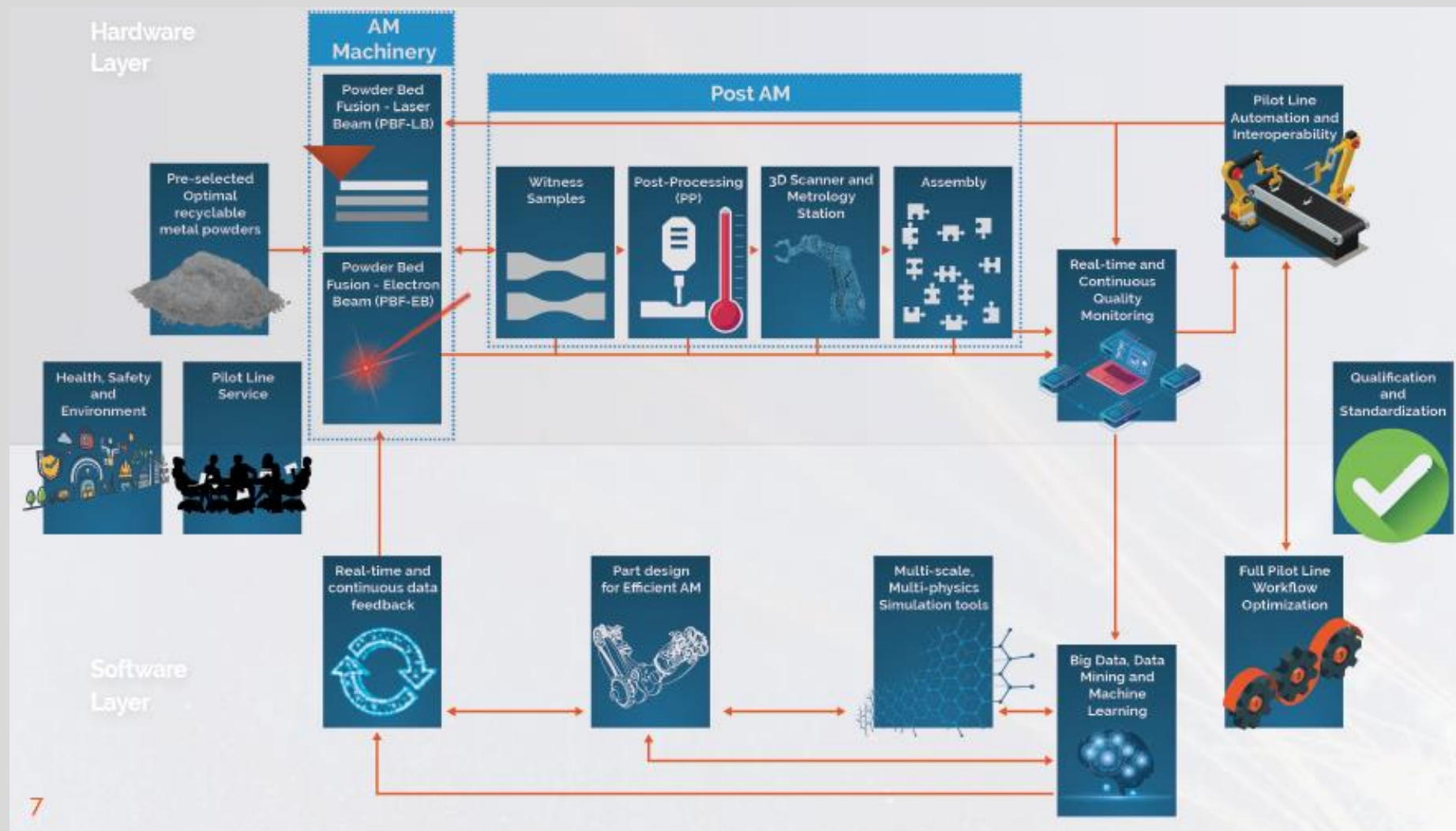
Enhanced product
differentiation

How

KEY INNOVATIONS OF MANUELA



How SERVICES



7

How SINGLE ENTRY POINT



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

CHALMERS INDUSTRIKTEKNIK 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

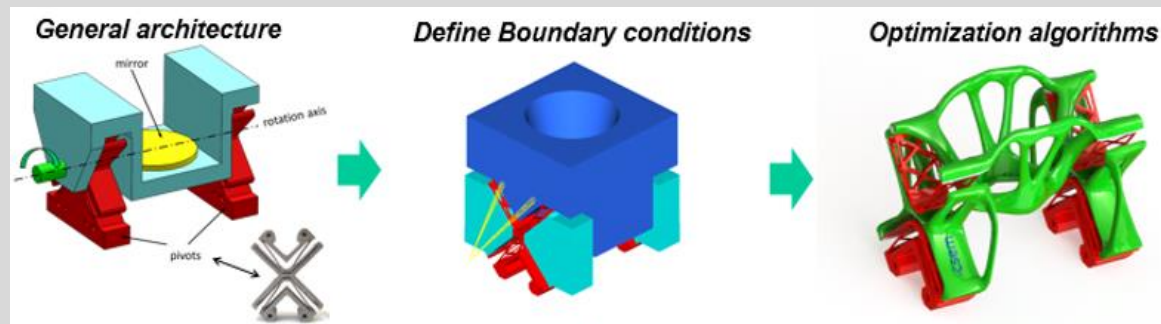
PROVIDES DESIGN, MODEL, SIMULATION, 3D PRINTED PRODUCT WITH CHARACTERIZATION, AS WELL AS OPTIMIZED PROCESS BASED ON ONLINE MONITORING AND MACHINE LEARNING BASED DATA PROCESSING.

- 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

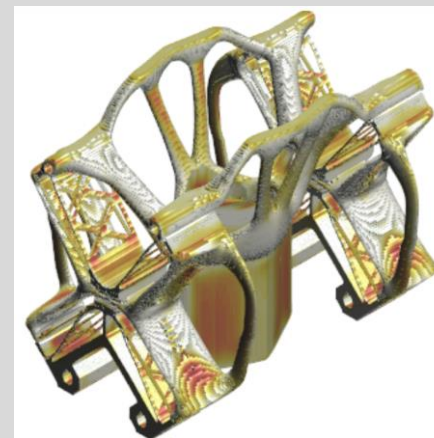
Design flow

Design & Optimization

DEVELOP



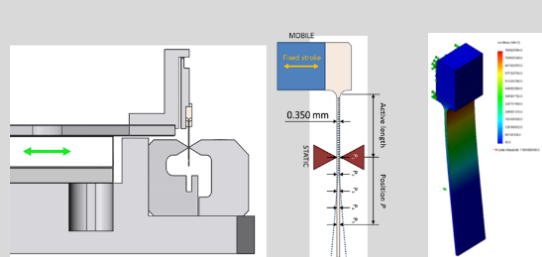
Process simulation



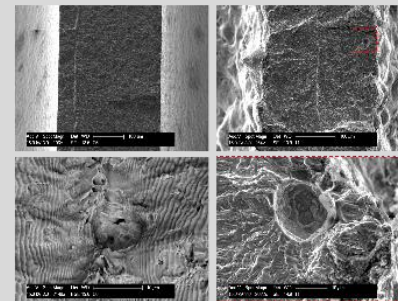
Testing



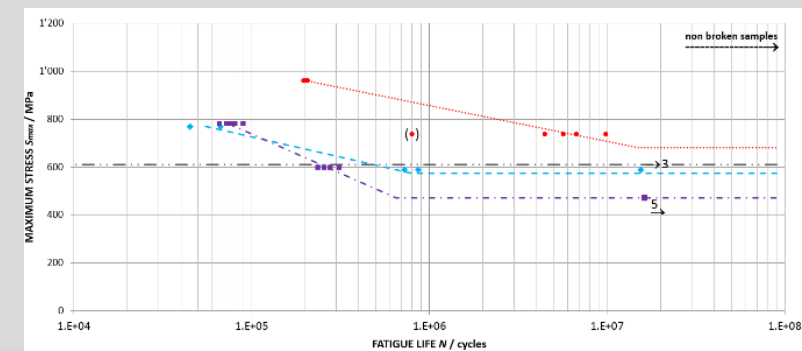
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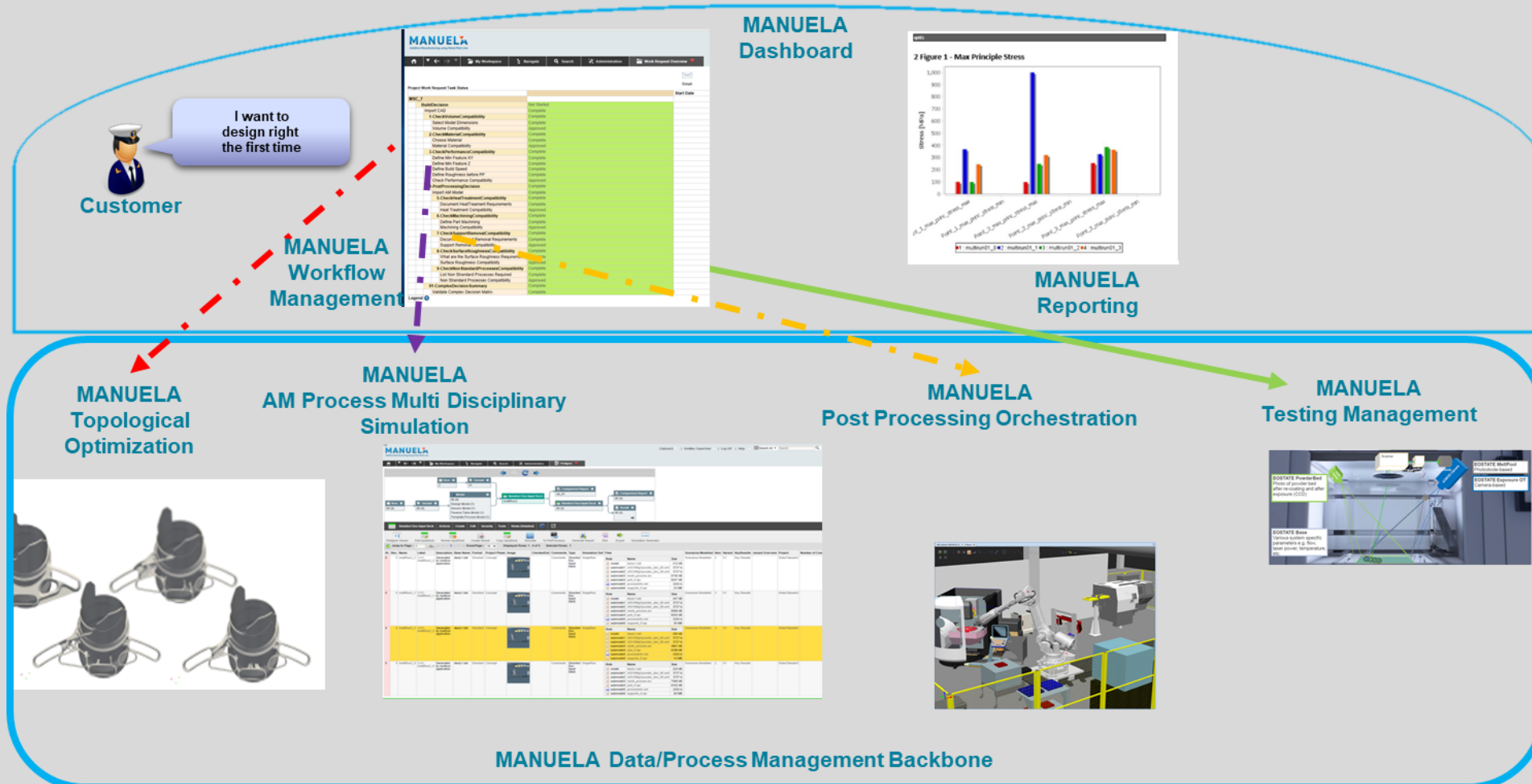
Analysis



Experimental Data



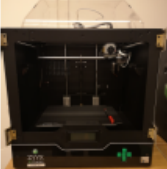
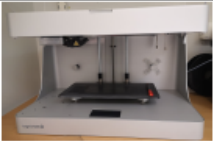



Dashboard and Digital Thread Management



RESOURCES AT CHALMERS (Sweden)


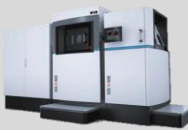



WHAT

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 µm X-Y: 11 µm positioning
Markforged (1 unit)		320x132x154	FDM	Nylone Onyx Glass fibre Carbon fibre Kevlar	Via Markforged web service	Z-layer: 100 µm
Zortrax Inspire (1 unit)		132x74x175	UV photo-polymerization	Resins	Z-suite	Z-layer: 25 µm X-Y: 50 µm

- 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

RESOURCES AT POLITO (Italy)

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)

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



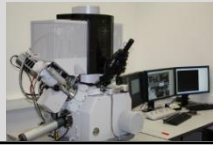






RESOURCES AT FAU (Germany)

WHAT

Printer	Picture	Build. Vol. (mm)	Method	Materials	Software	Remarks
Athene		120 × 120 × 200	EBM	Ti-based alloys	Freely programmable	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 programmable	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)

WHAT







Device	Picture	Function
FEI – Helios NanoLab 600i FIB Workstation		High-resolution <u>S</u> canning <u>E</u> lectron <u>M</u> icroscope (SEM) equipped with <u>E</u> nergy- <u>D</u> ispersive <u>X</u> -ray spectroscopy (EDX), <u>E</u> lectron <u>B</u> ack <u>S</u> catter <u>D</u> iffraction (EBSD) and <u>F</u> ocused <u>I</u> on <u>B</u> eam (FIB).
Microprobe Jeol JXA 8100		<u>E</u> lectron <u>P</u> robe <u>M</u> icro <u>A</u> alyzer (EPMA) for the chemical analysis with high local resolution.
Fraunhofer EZRT CT Alpha system		<u>C</u> omputed <u>T</u> omography (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)

RESOURCES AT RISE IVF (Sweden)

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		



Thank you

MANUELA



Use Case – Aerospace

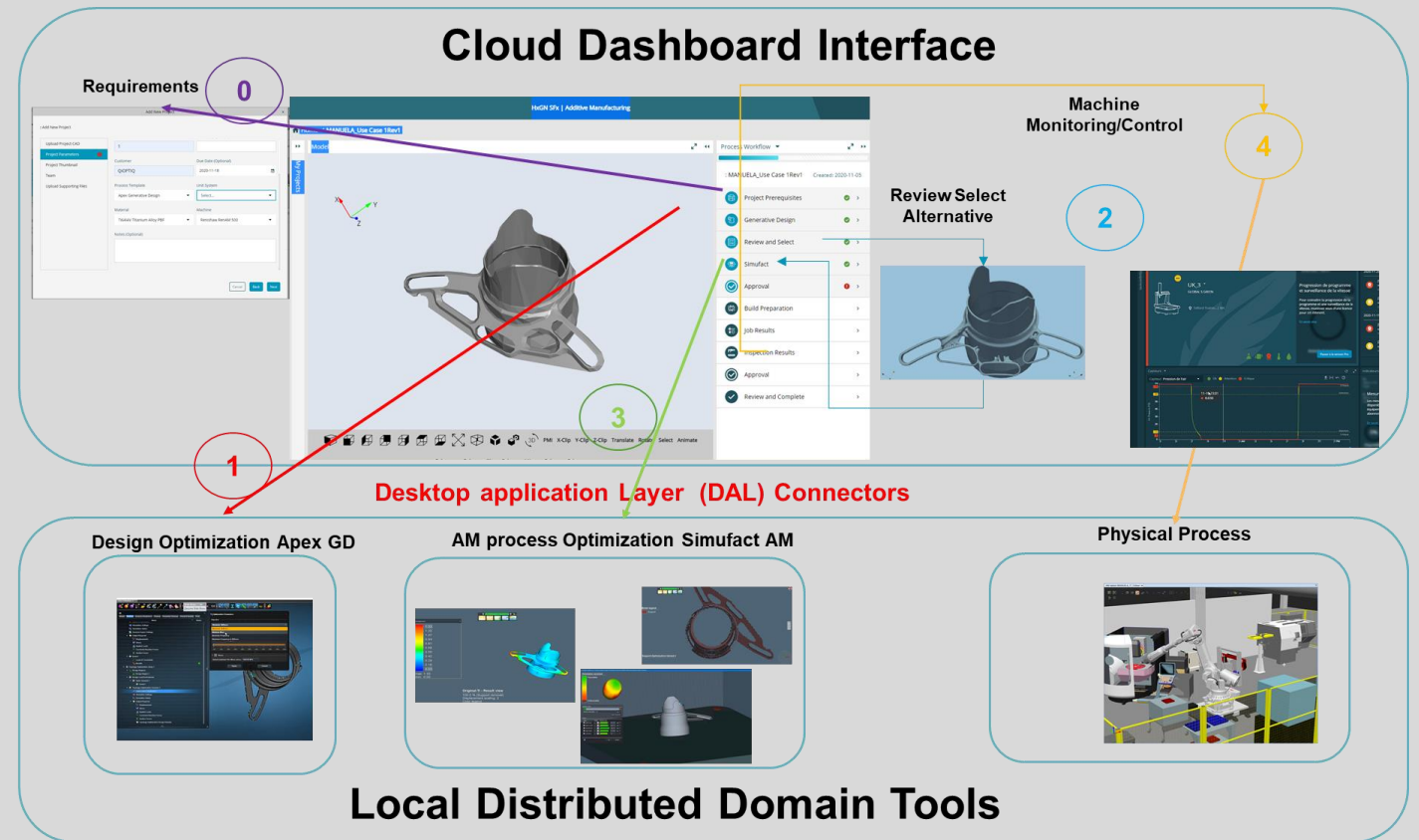
Emmanuel Onillon, CSEM

Overview

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

Design tools

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

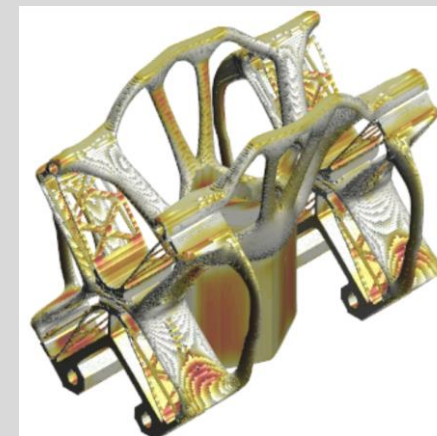
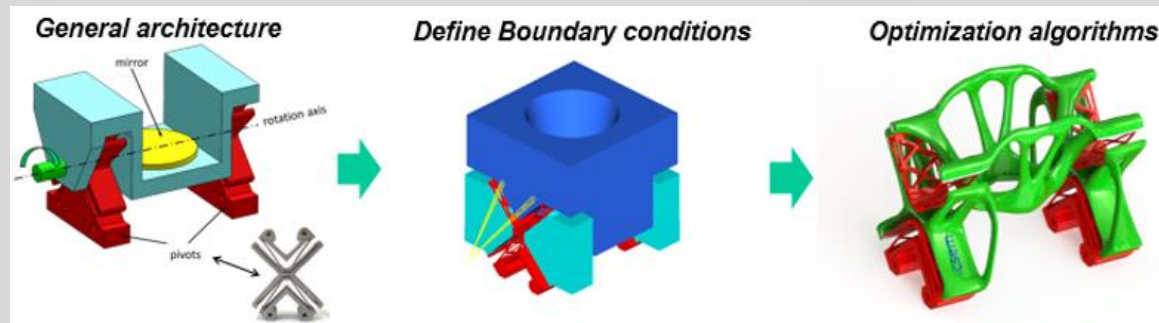


Design flow

Design & Optimization

Process simulation

DEVELOP

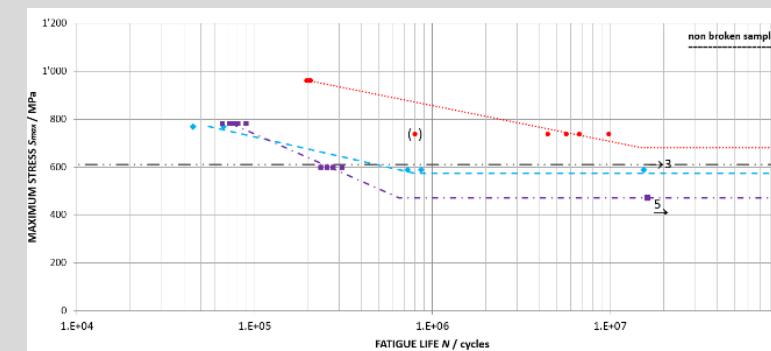
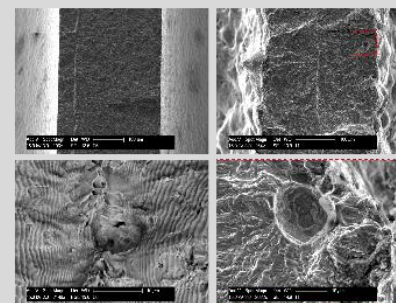
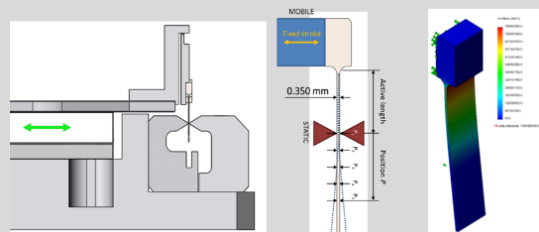


Testing

Analysis

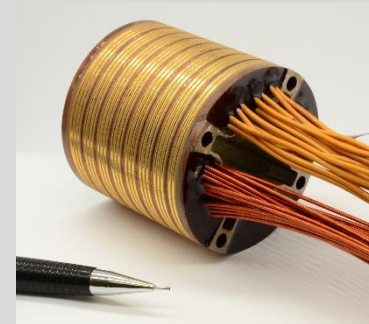
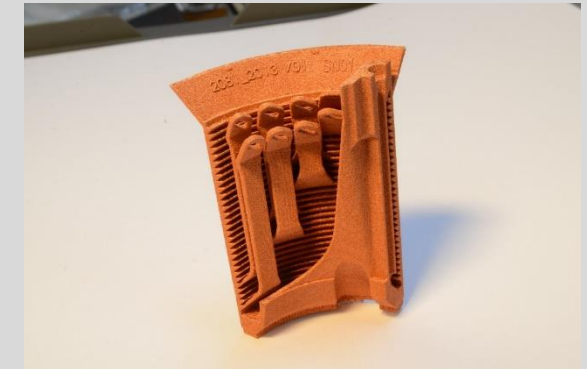
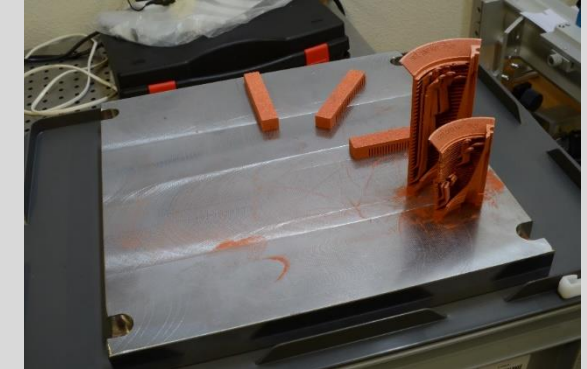
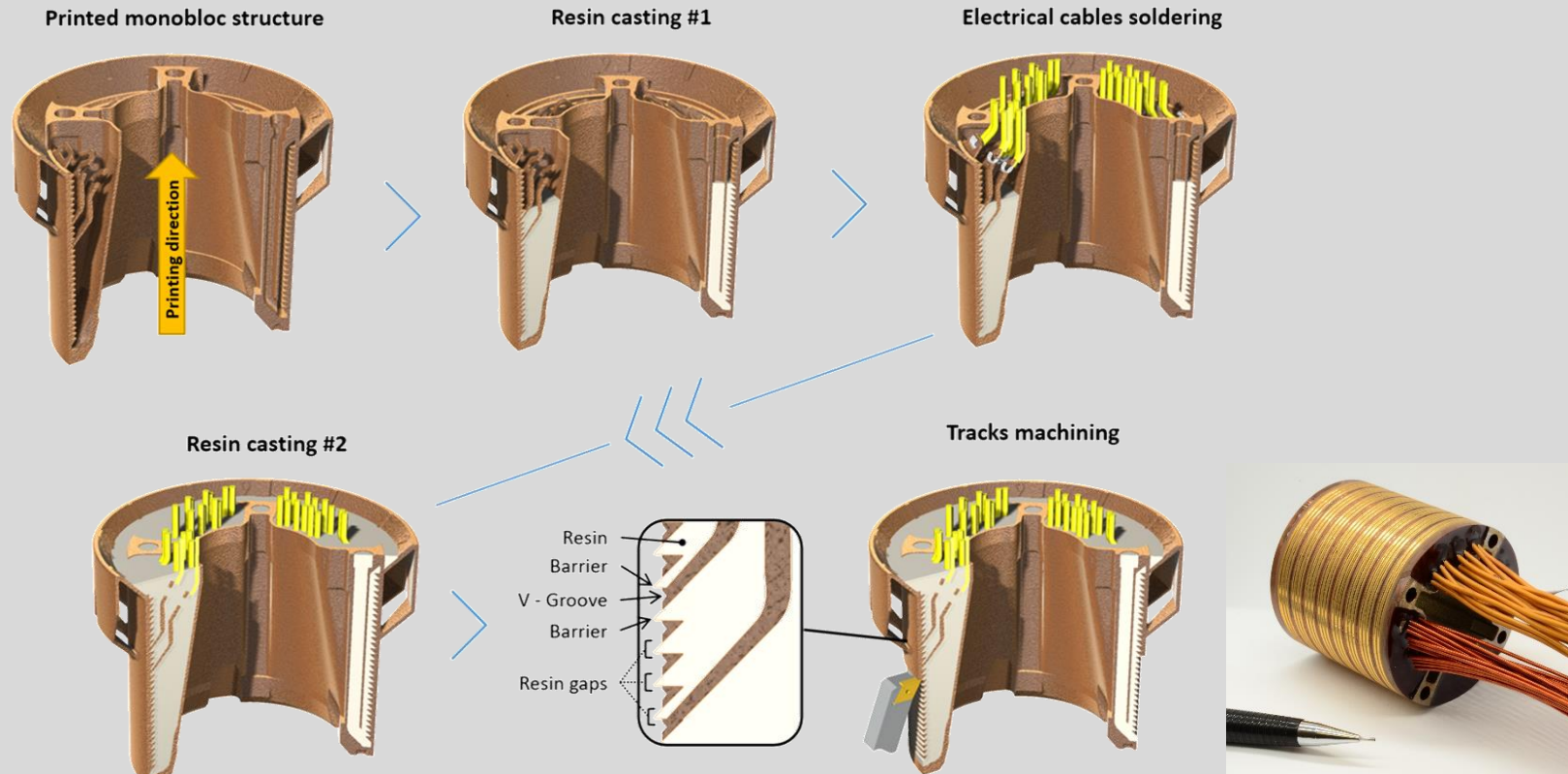
Experimental Data

QUALIFY



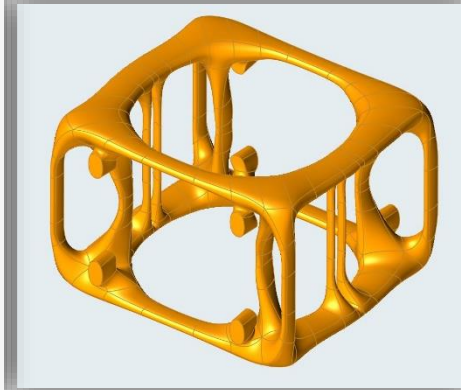
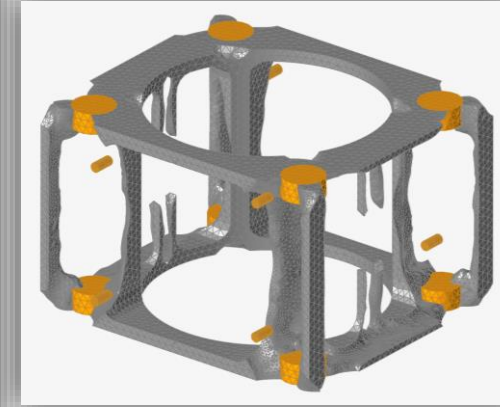
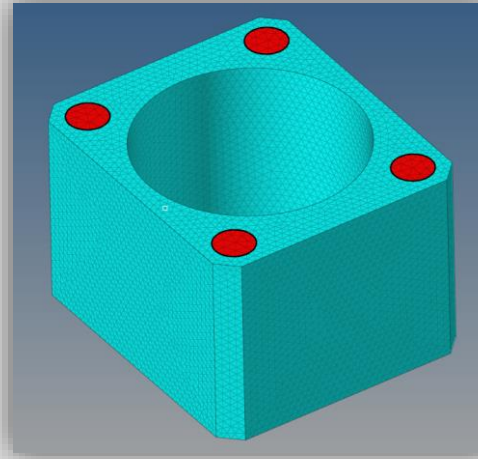
Aerospace design example – rotor slip ring (Ruag space)

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



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





Thank you

AM benefits

Lars Nyborg, Chalmers

Additive Manufacturing

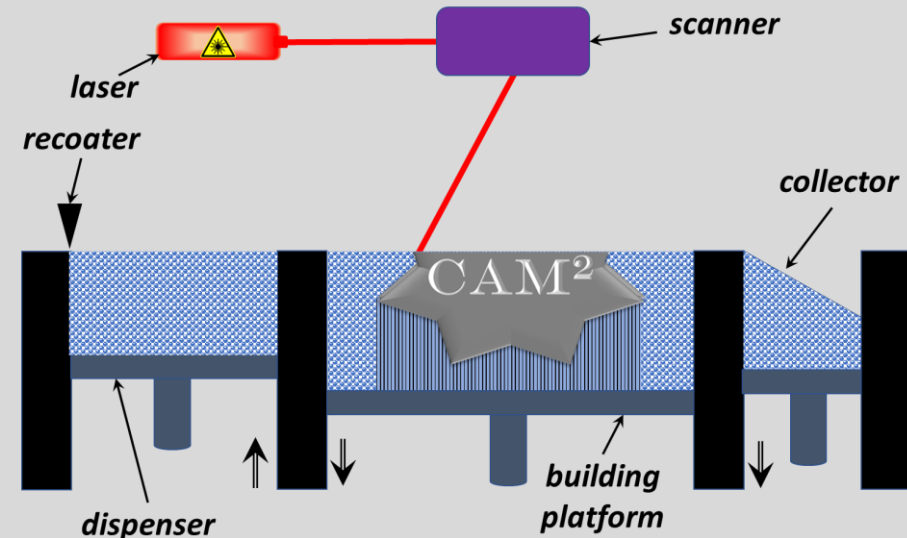
- ASTM categorizes additive manufacturing into seven process categories:
- Binder jetting
- Directed energy deposition
- Material extrusion
- Material jetting
- **Powder bed fusion**
- Sheet lamination
- Vat photopolymerization

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.).

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

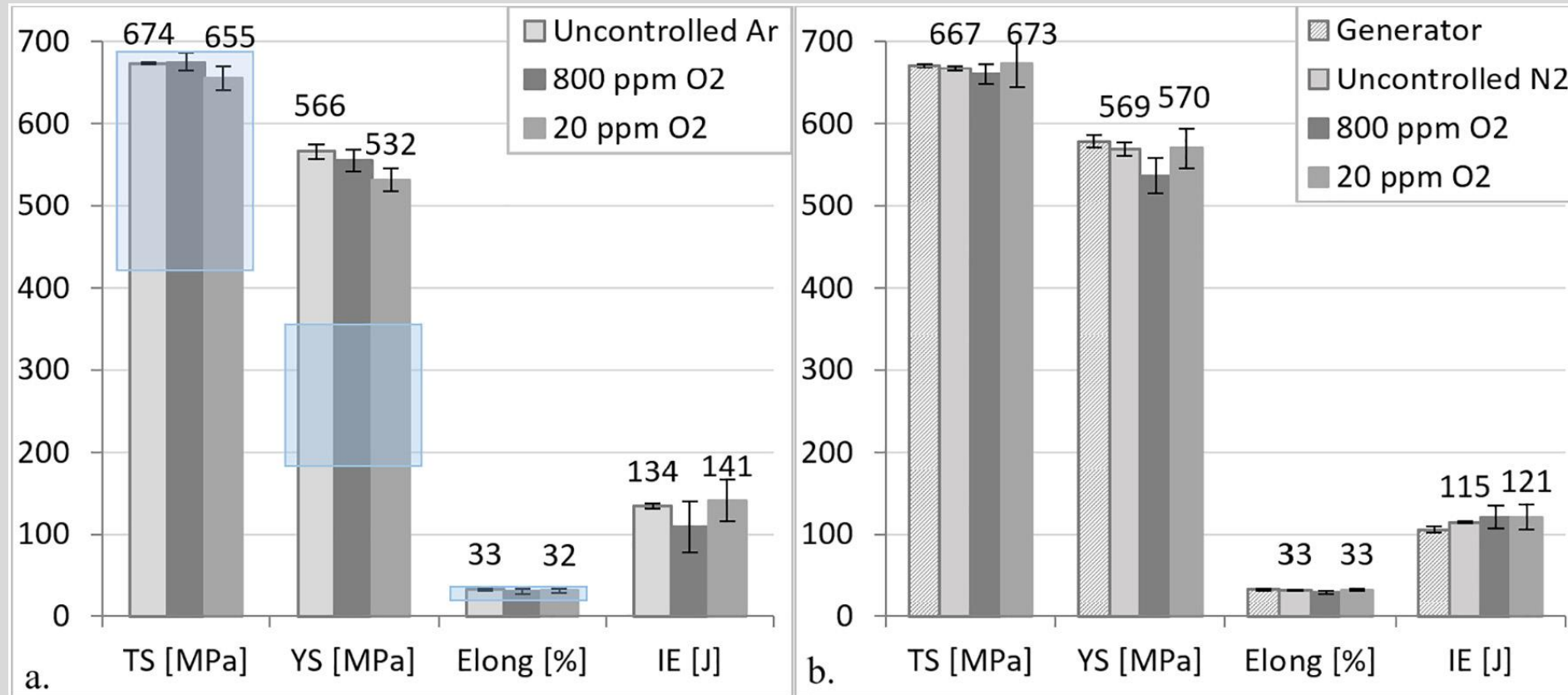


Key features of materials produced by AM

- Fine columnar microstructure
- Anisotropy in Z (build) direction
- Typically densities of $\geq 99.9\%$ are reached for optimized processes



316L Stainless Steel

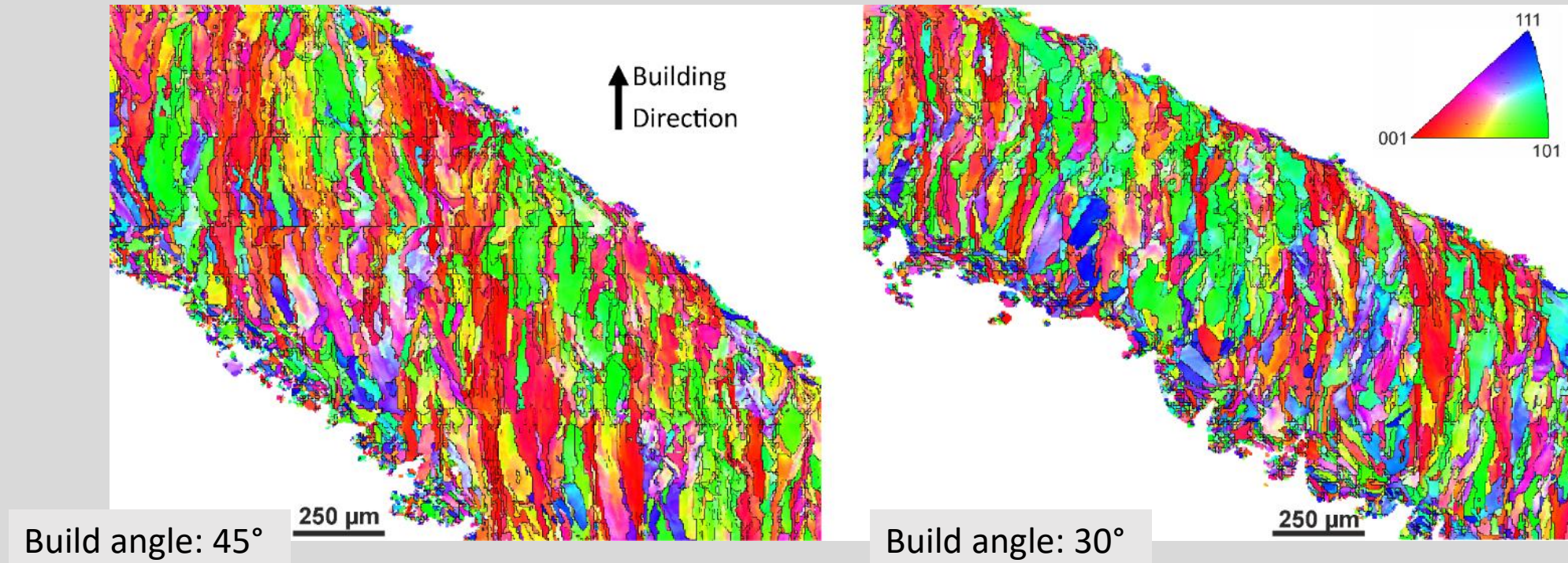


Properties **similar** or **better** than wrought material for established materials/processes

C. Pauzon et al., Materials and Design, V179(2019), 107873

Microstructure of AM materials – LPBF-316L

- Large elongated grains in building direction
- Small grains close to the surface
- Random orientation



Design of the **component** taking into account AM microstructure

A. Leicht etc., Materials Characterisation, V143, pp.137-143

Robust Powder for Additive Manufacturing

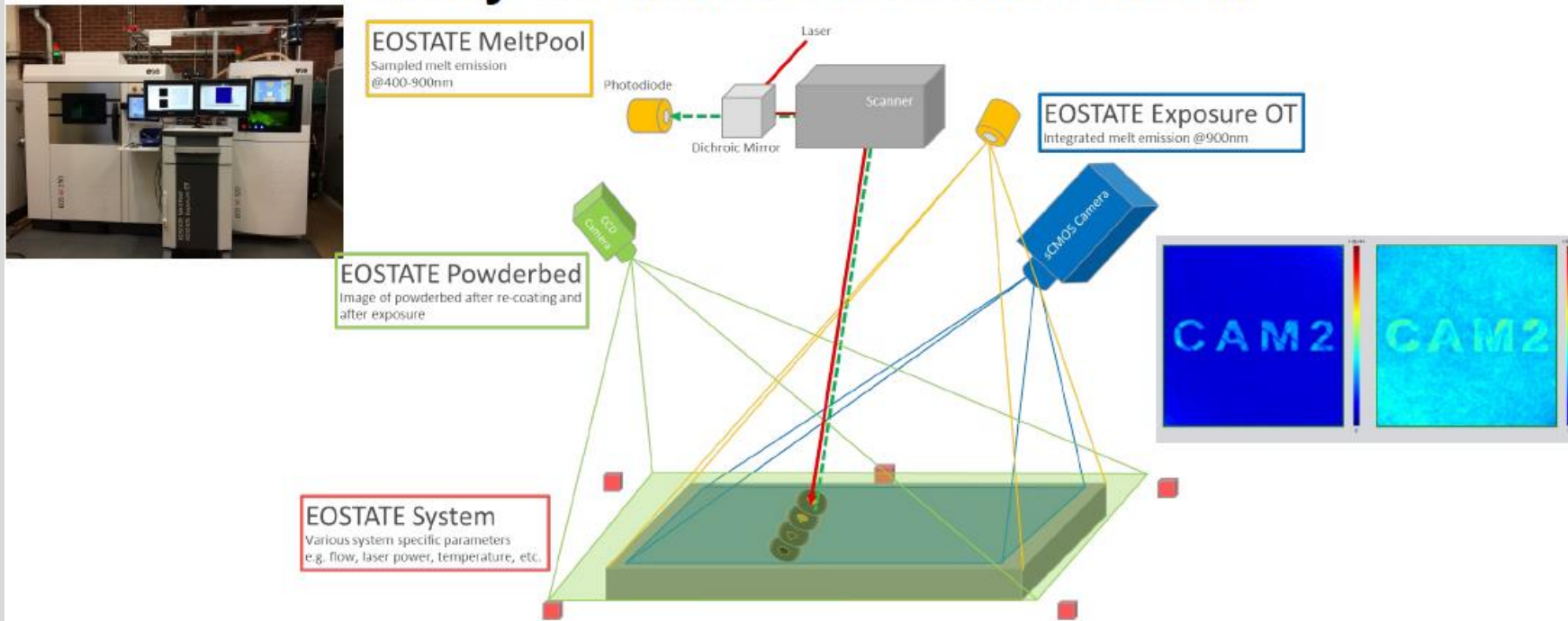
Technology	Alloys	# of Alloys
PBF-L	Aluminum: Al-10Si-Mg, Al-12Si, Al-7Si-0.6Mg, Al-9Si-3Cu, Scalmalloy Cobalt: Co-Cr, Co-Cr-WC Copper: Cu, Cu-10Sn Nickel: IN625, IN718, IN939, HX Titanium: Ti, Ti-6Al-4V Stainless Steels: 15-5 PH, 17-4 PH, 316L SS, INVAR 36 Tool Steels: Maraging Steel, H13 Miscellaneous: Gold, Platinum, Silver	24
PBF-EB	Cobalt: Co-Cr Nickel: IN718 Titanium: Ti, Ti-6Al-4V	4

Absence of powder developed for AM!

Design of the powder material for AM!

Additive Manufacturing

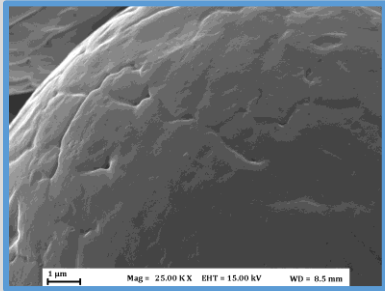
Quality assurance and control in AM



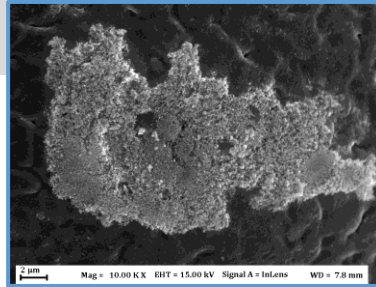
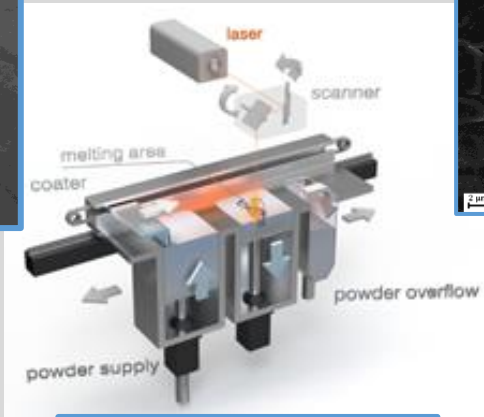
On-line Process Monitoring for LB-PBF (EOS)

Robust Powder for Additive Manufacturing

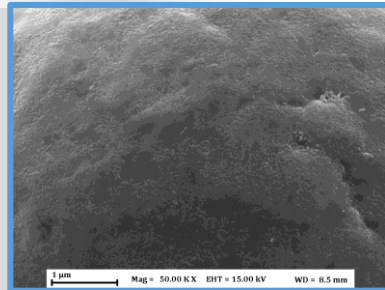
Powder recycling – Powder Bed Fusion - Laser



Virgin



Sputter



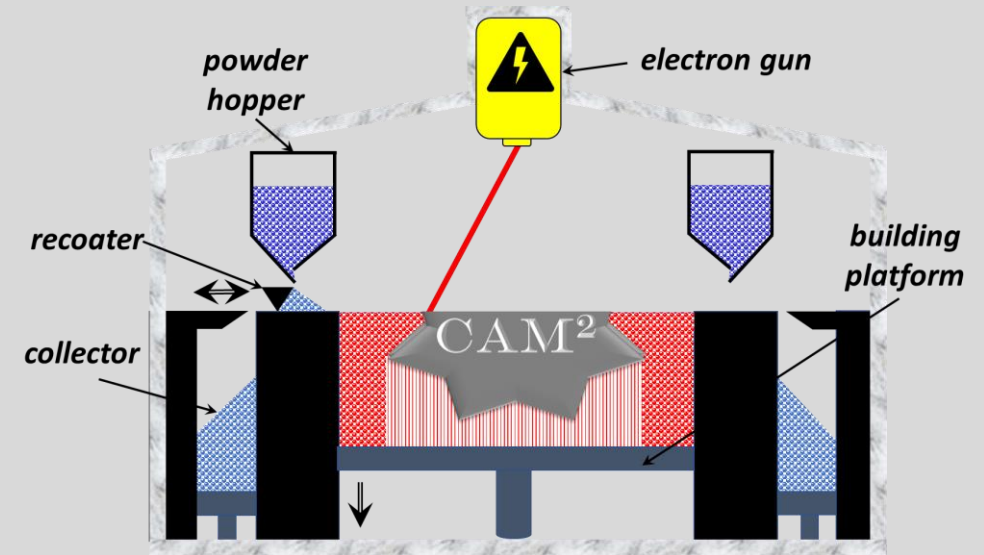
Reused



AM Material design for the robust powder recycling

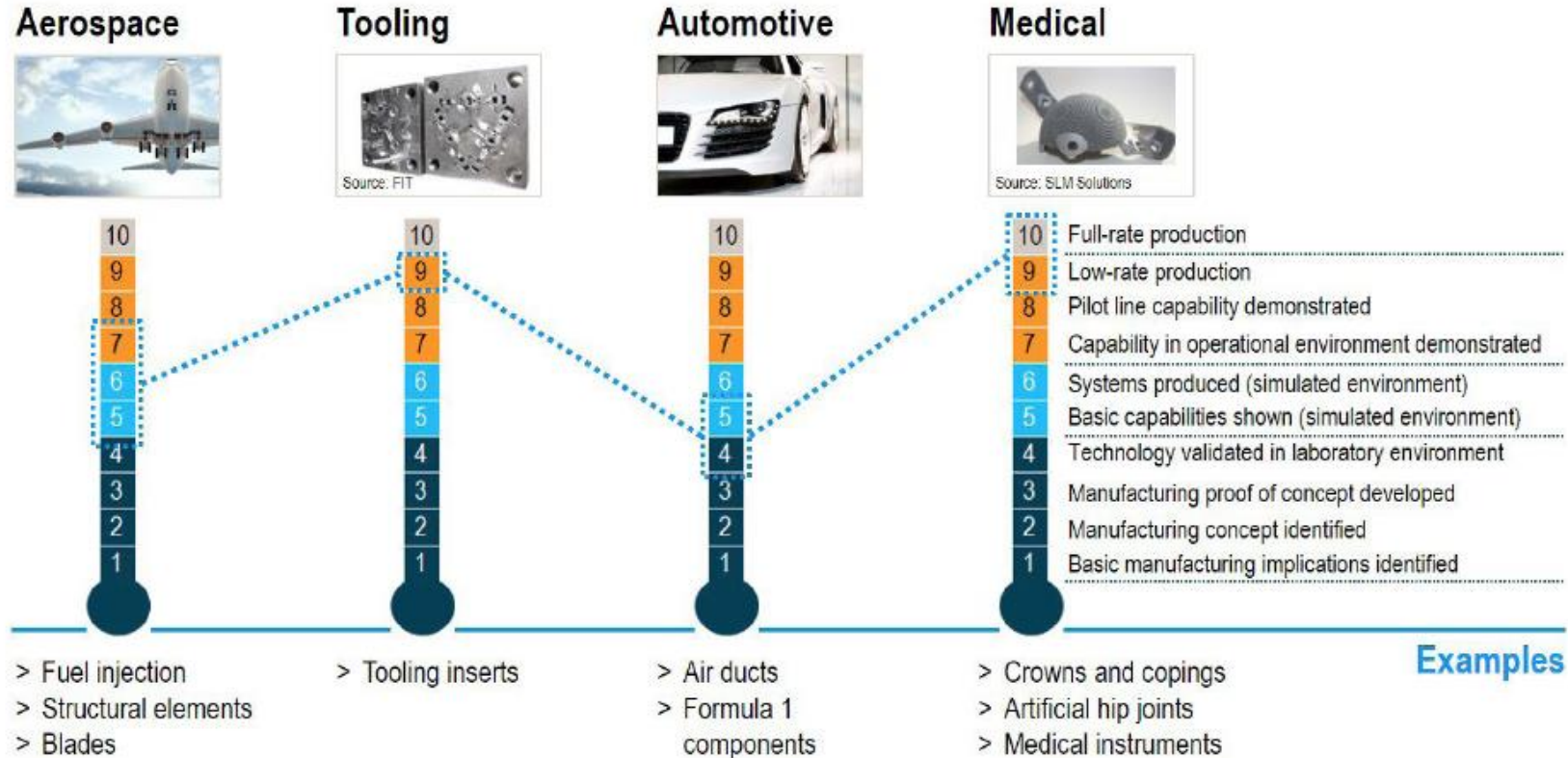
Additive Manufacturing

- 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



Additive Manufacturing

Manufacturing readiness level in various industry sectors



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

Markets- consumer products/electronics

Consumer Products/Electronics:

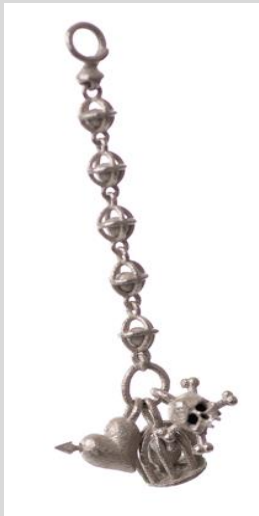
- leading sector
- prototypes and models
 - Fashion:
 - Jewelry & watches
 - Footwear
 - Design
 - Sports Equipment
 - Electronics – ink-jet
 - Passive components
 - Resistors
 - Capacitors
 - Inductors



Design “Icon”: Lionel T. Dean, Future Factories; Material: 18-carat yellow gold (Source: CPM) – Courtesy: EOS



Rendered heel images using 3D Software, made from titan (Design and source: Kerrie Luft. Courtesy: EOS)

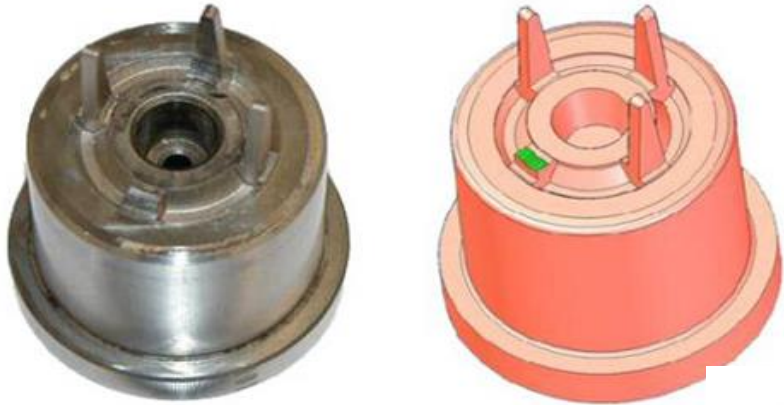


Courtesy: EOS

Digital Metal®

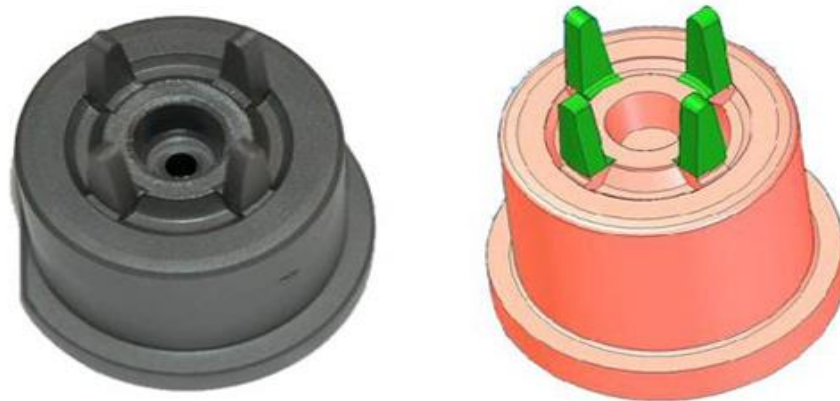
Markets- Tooling

- Tooling:
 - Injection moulding
 - Die casting
 - Tool repair



Tool insert before reparation. Courtesy: EOS

Tool insert after reparation. Courtesy: EOS



Tool insert for injection moulding made from Maraging Steel MS1. Courtesy: EOS

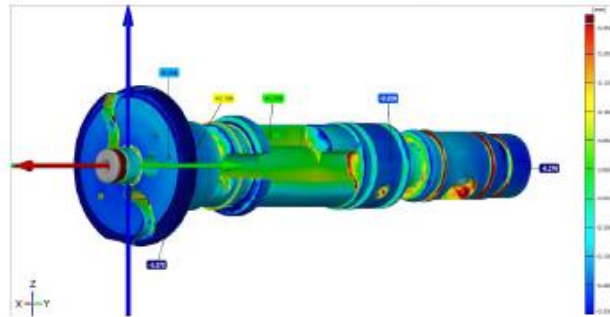


Tool insert for die casting. Courtesy: EOS

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/ca2/cases/Pages/case-productivity-of-laser-powder-bed-fusion.aspx>

Alex Leicht/ Lars Hammar
and Marie Fischer/Chalmers

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



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



Thank you

MANUELA

Open Call

Paul Häyhänen, CIT

▶ 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

▶ Open Call for Business Development Cases - info

- Evaluation criteria
 - Concept and level of innovation
 - Impact and market potential
 - Implementation

▶ Open Call for Business Development Cases – Schedule

- Start **1 December -20** – The Call is open!
- **30 September -21** – Second and last cut off for Applications and evaluation and selection of 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

▶ 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

Business Development Cases

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

Contact

manuela@chalmersindustriteknik.se

www.manuela-project.eu

MANUELA

Q&A Discussion

