NWC 2019
NAFEMS WORLD CONGRESS
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A WORLD OF ENGINEERING SIMULATION

Route Toward the "Additive Manufacturing Using Metal Pilot Line": MANUELA's Ambition & Status

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MANUELA Project @ a Glance:

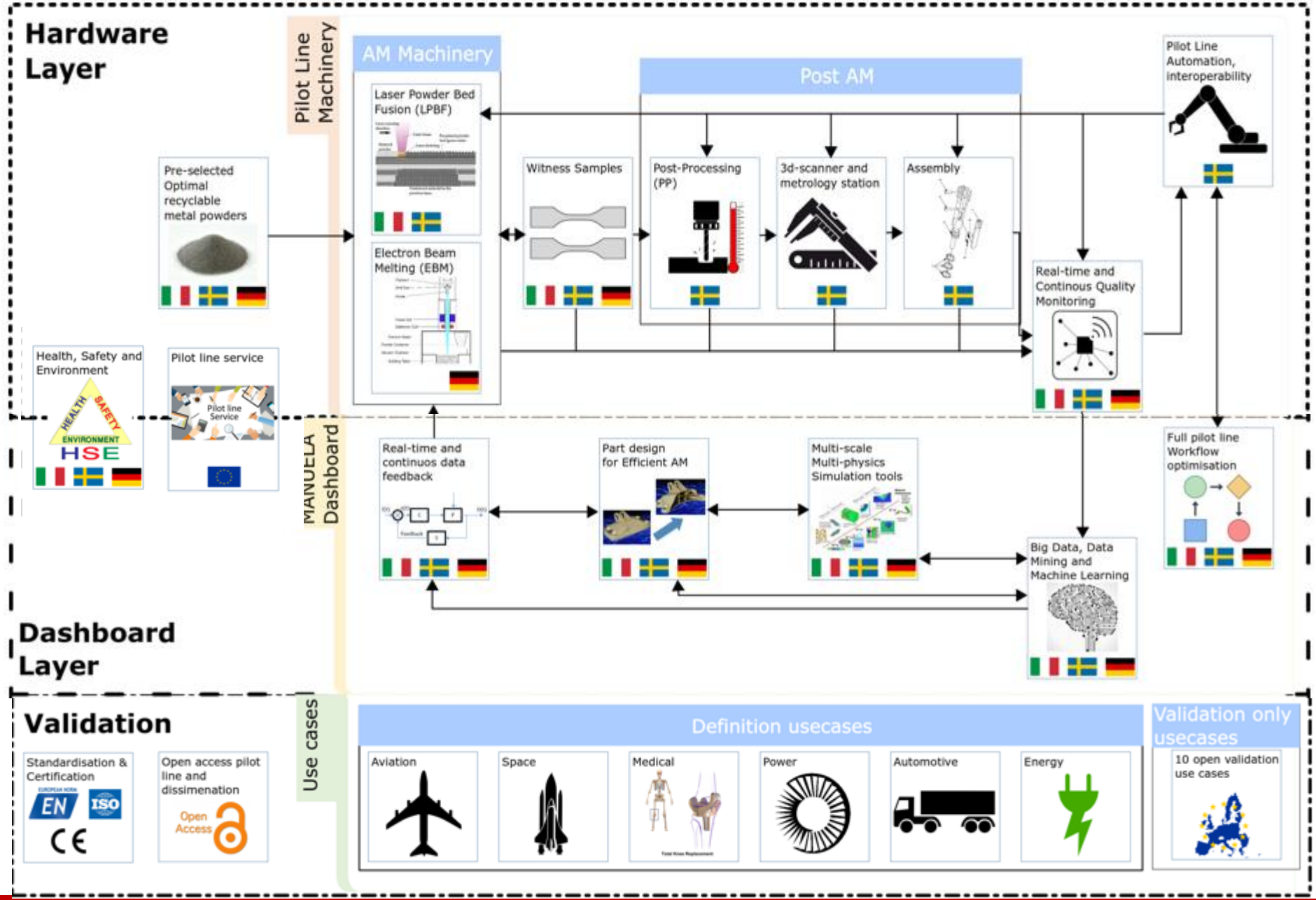
Additive Manufacturing Using Metal Pilot Line

- Objectives
  - Develop metal Additive Manufacturing (AM) pilot line, covering full AM development cycle for
    - Laser Powder Bed Fusion (LPBF)
    - Electron Beam Melting (EBM),
  - Mature Additive Manufacturing processes & functionalities (TRL 5 to TRL 7)
  - Optimize AM process parameters (increase process productivity by 50 %)
    - Increase in material property repeatability by 50% (Material qualification)
    - Development of automated & tailored post AM processes
    - Assuring component performance through Dashboard
      - **Design tool & simulation tool for efficient AM (decreasing part volume by 30%)**
      - **Design feedback through big data, data mining & Artificial Intelligence (reducing material, process & parts parameters uncertainty by 30%, while increasing AM process robustness by 30%).**
- Principle based on 5 Innovations
  - Tailored recyclable metal powder(robust & reliable part manufacturing)
  - Comprehensive pilot line dashboard (design, simulate & track manufacturing process)
  - Full pilot line workflow optimization & automation
  - Collect process data towards real-time in-line process monitoring & adaptation.
  - Establish qualification & certification standard for chain process

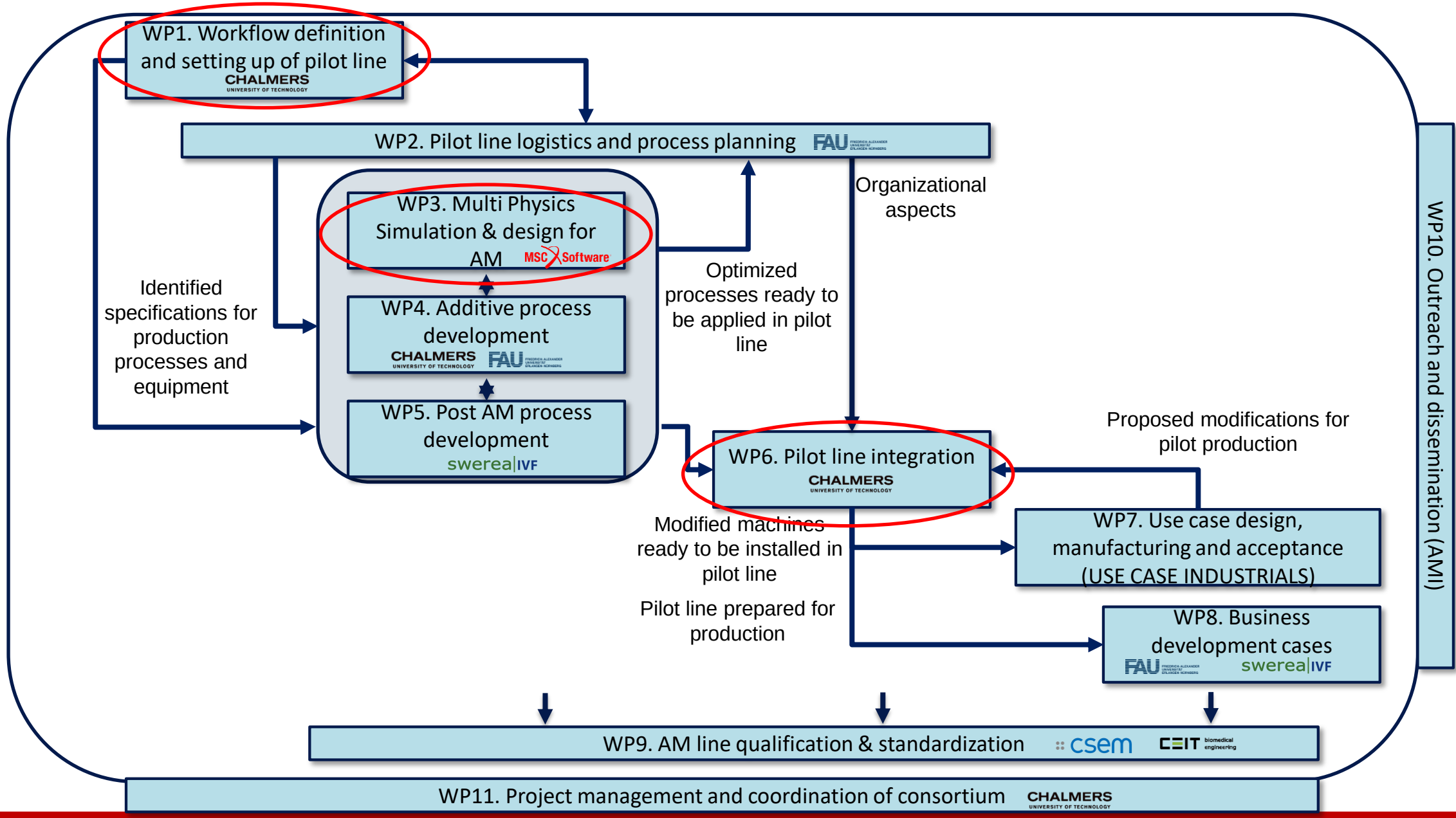
https://manuela-project.eu/

Project acronym	MANUELA
Project title	Additive Manufacturing using Metal Pilot Line
Starting date	01/10/2018
Duration in months	48
Call (part) identifier	H2020-NMBP-FOF-2018
Topic	DT-FOF-04-2018: Pilot lines for metal Additive Manufacturing (IA 50%)
EU contribution	12,448,116.26 €

MANUELA Conceptual Approach



MANUELA Implementation WBS



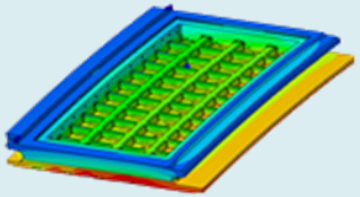
6 Initial Industrial Use Cases

AVIONICS — Helmet mounted displays components

QIOPTIQ Photonics for Innovation

Features	Lightweight, complex geometry, thin walled
Material	Al- and Ti-alloys
AM process	EBM

POWER — Power plant machinery components



SIEMENS

Features	geometric tolerances, surface roughness, thermo-mechanical properties, embedded sensors
Material	tbd
AM process	LPBF

MEDICAL — Custom made cranial implants

CEIT biomedical engineering

Features	Medical qualification, porous structure, precision ±25 µm
Material	Ti-6Al-4V ELI (grade 23)
AM process	LPBF

SPACE — Slip ring assembly

RUAG

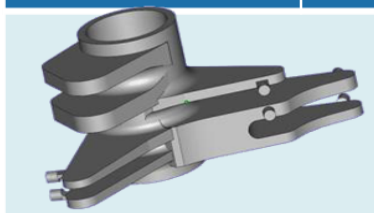
Features	High electrical conductivity
Material	Currently: AlSi10Mg + gold plating Proposed: Cu
AM process	EBM

POWER — Power plant machinery components

enel

Features	geometric tolerances, surface roughness, thermo-mechanical properties, embedded sensors
Material	tbd
AM process	LPBF

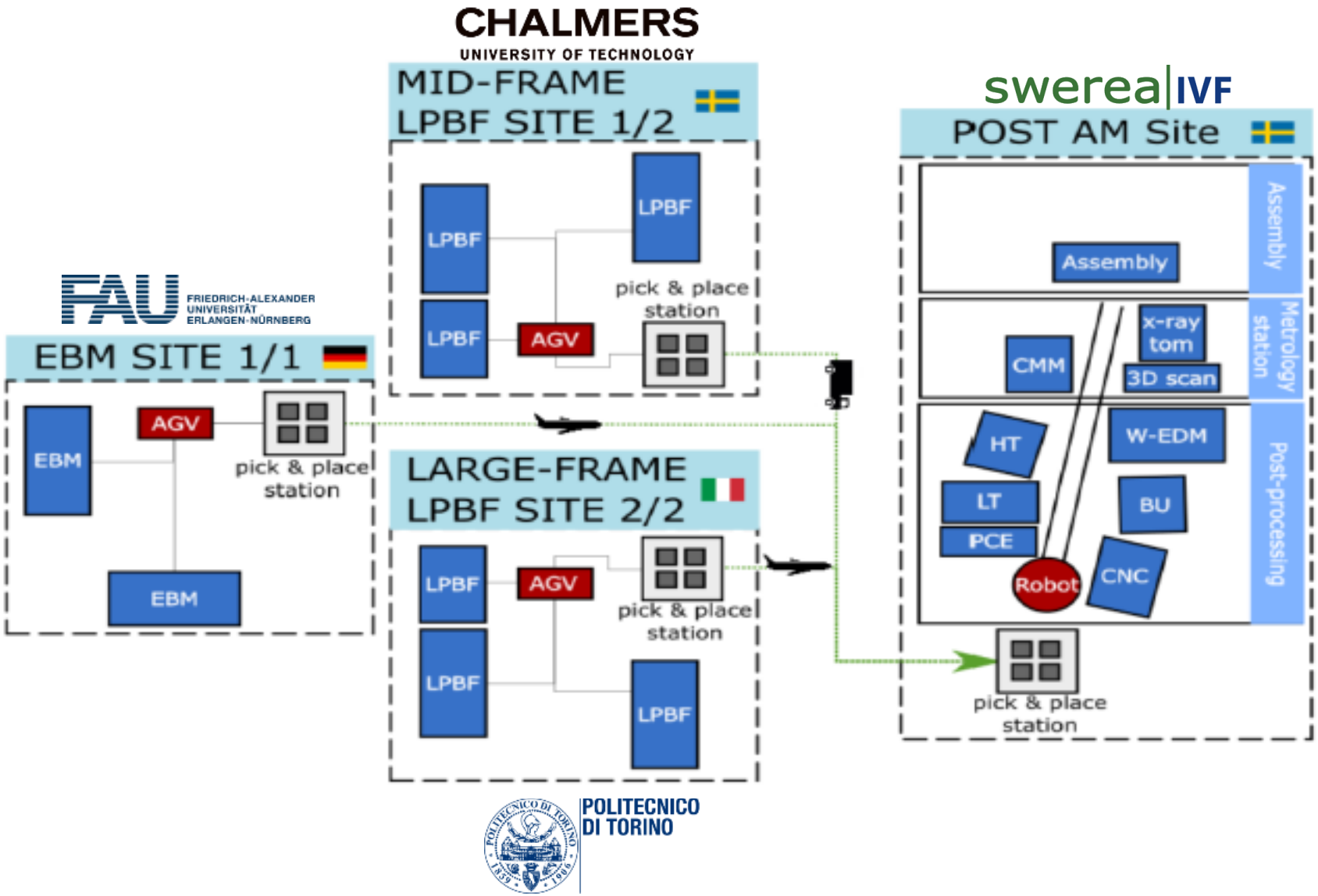
AUTOMOTIVE — Rocker for motorsport competition



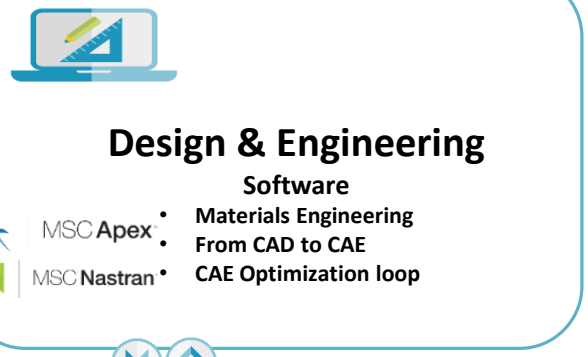
OEB

Features	fatigue resistance, surface finishing, geometric conformity, weight reduction, strain gauges
Material	tbd
AM process	LPBF

MANUELA Workshop Structure



HxGN SFx | Additive Manufacturing Serving MANUELA Dashboard Layer 1/4



Supply Chain

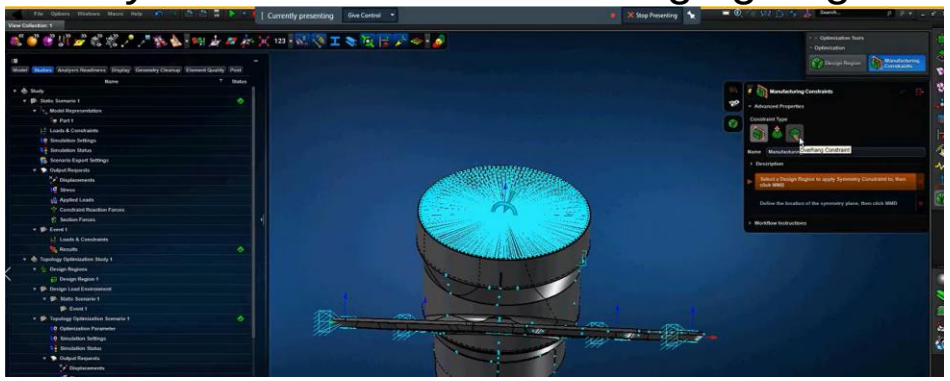
Manufacturing

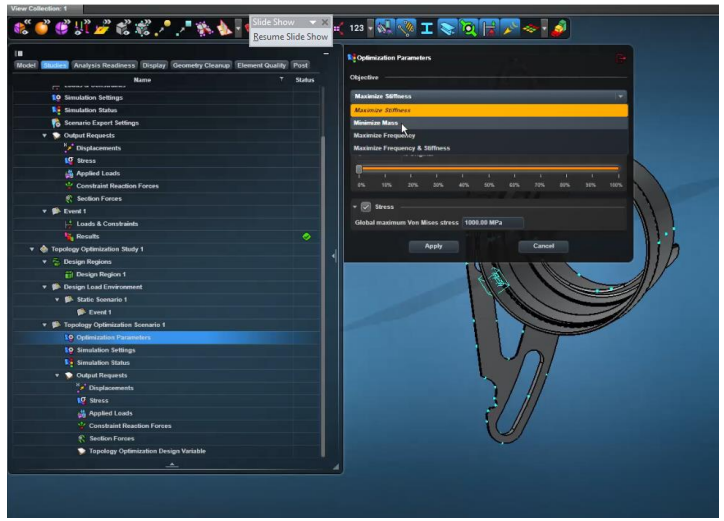
Service Life

Digital Thread

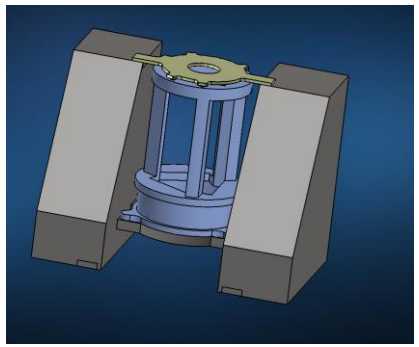
Topological Optimization with Manufacturability

- Beyond conventional Topological optimization:
  - Manufacturability constraints like overhanging angles have been added

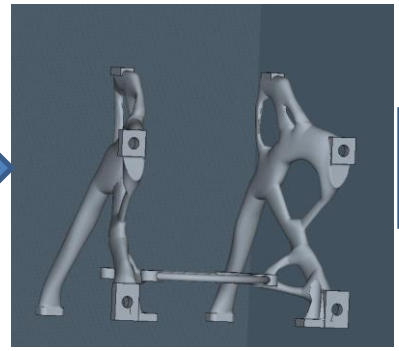




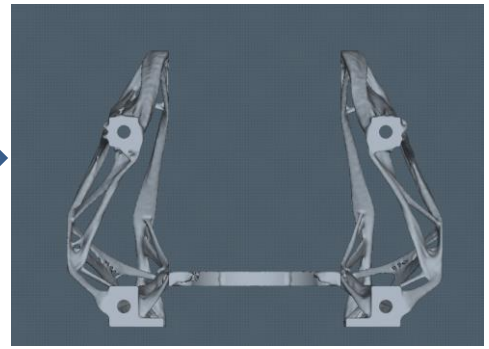
  - Advanced technologies, beyond Nastran Sol200 have been included (to be announced in July by HxGN)
- Initial MANUELA use cases rely on already optimized parts. CSEM/MSC tested new techno vs conventional optimizers: from Light Brown Part (functional constrains view) :



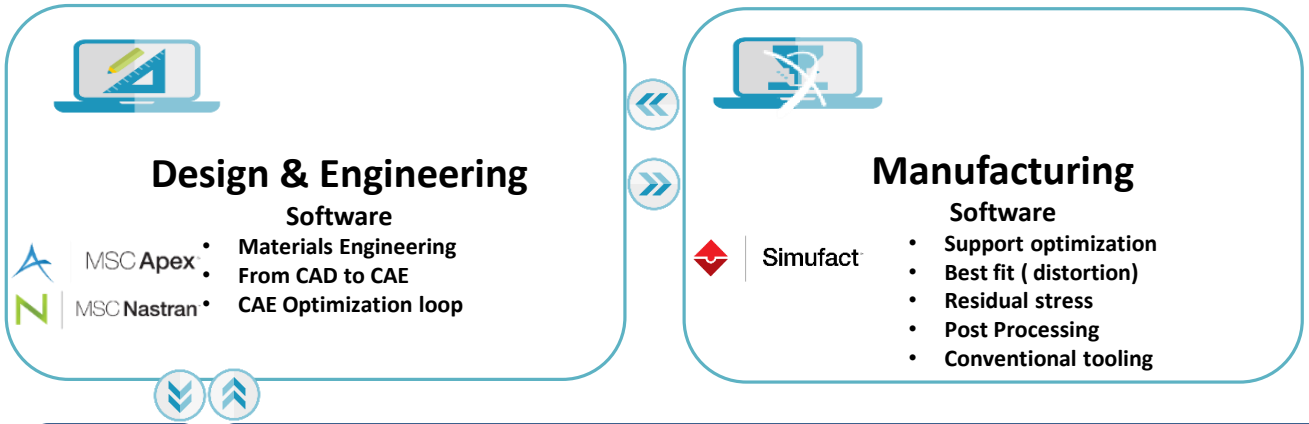
Initial Optimization



MANUELA Optimization (25% lighter)

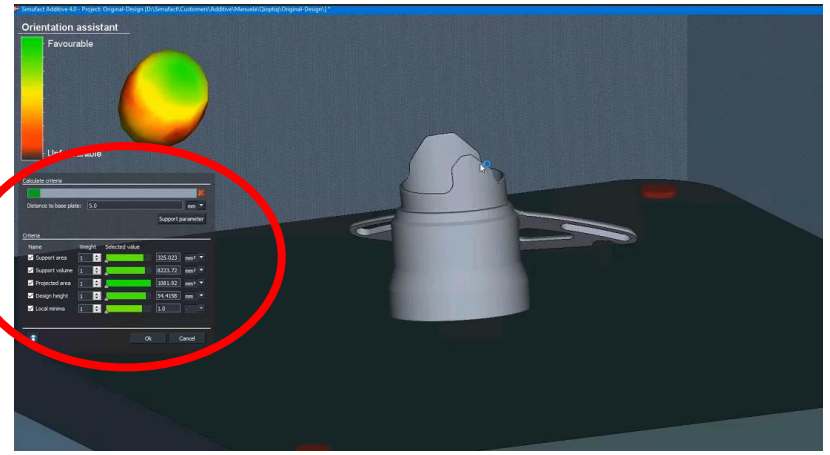


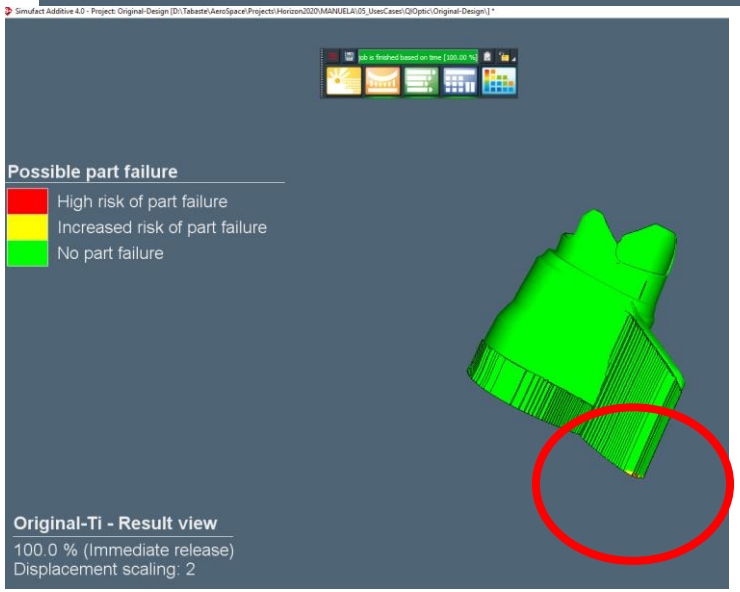
HxGN SFx | Additive Manufacturing Serving MANUELA Dashboard Layer 2/4

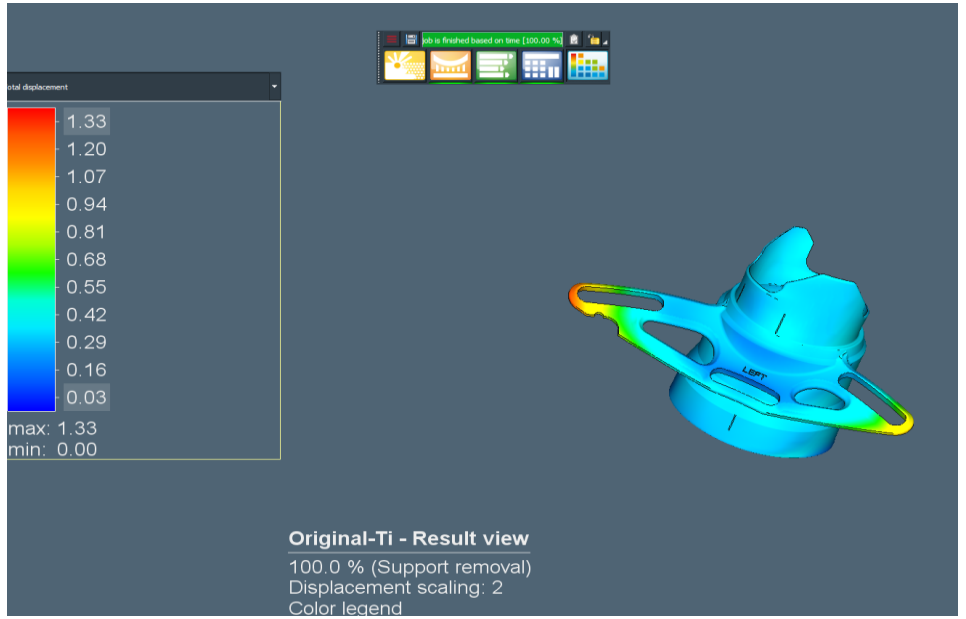


AM Process Optimization

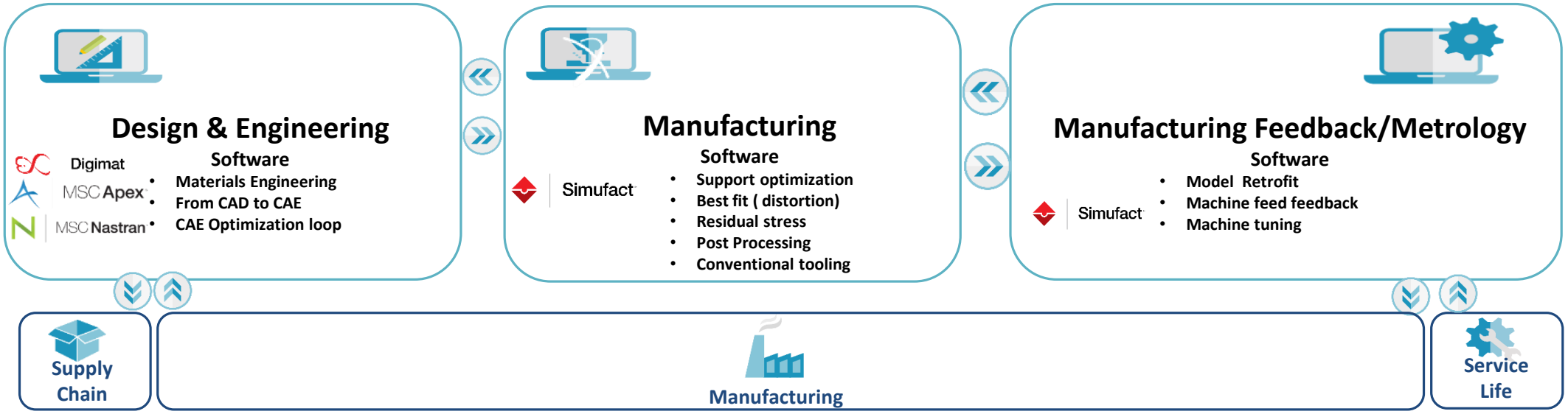
- Part positioning trade off
- Support Optimization
- Possible Part Failure
- Recoater contact
- Displacements
  - Best Fit (scale exported disp. for compensation
- Stresses
- Strains





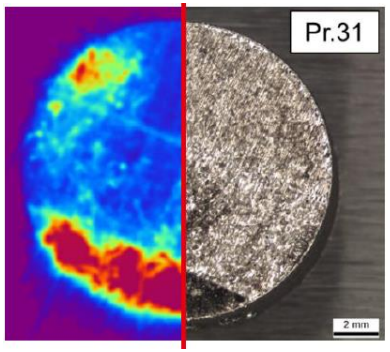


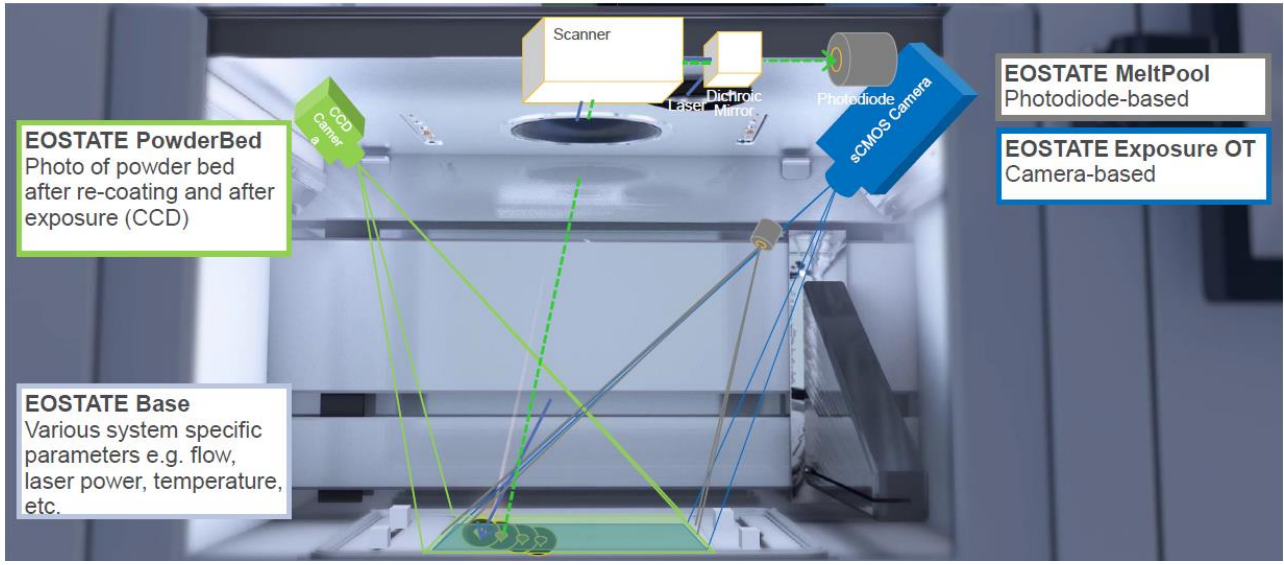
HxGN SFx | Additive Manufacturing Serving MANUELA Dashboard Layer 3/4



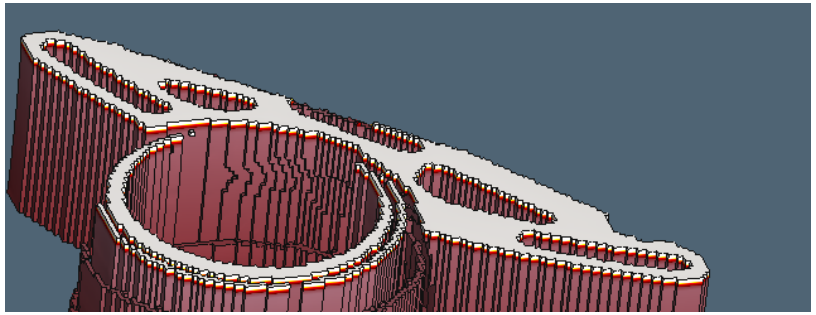
In-Process Quality Monitoring

- In process Monitoring of LBPF machine
  - Parameter set optimized for reporting real defects
  - Is the part quality reached

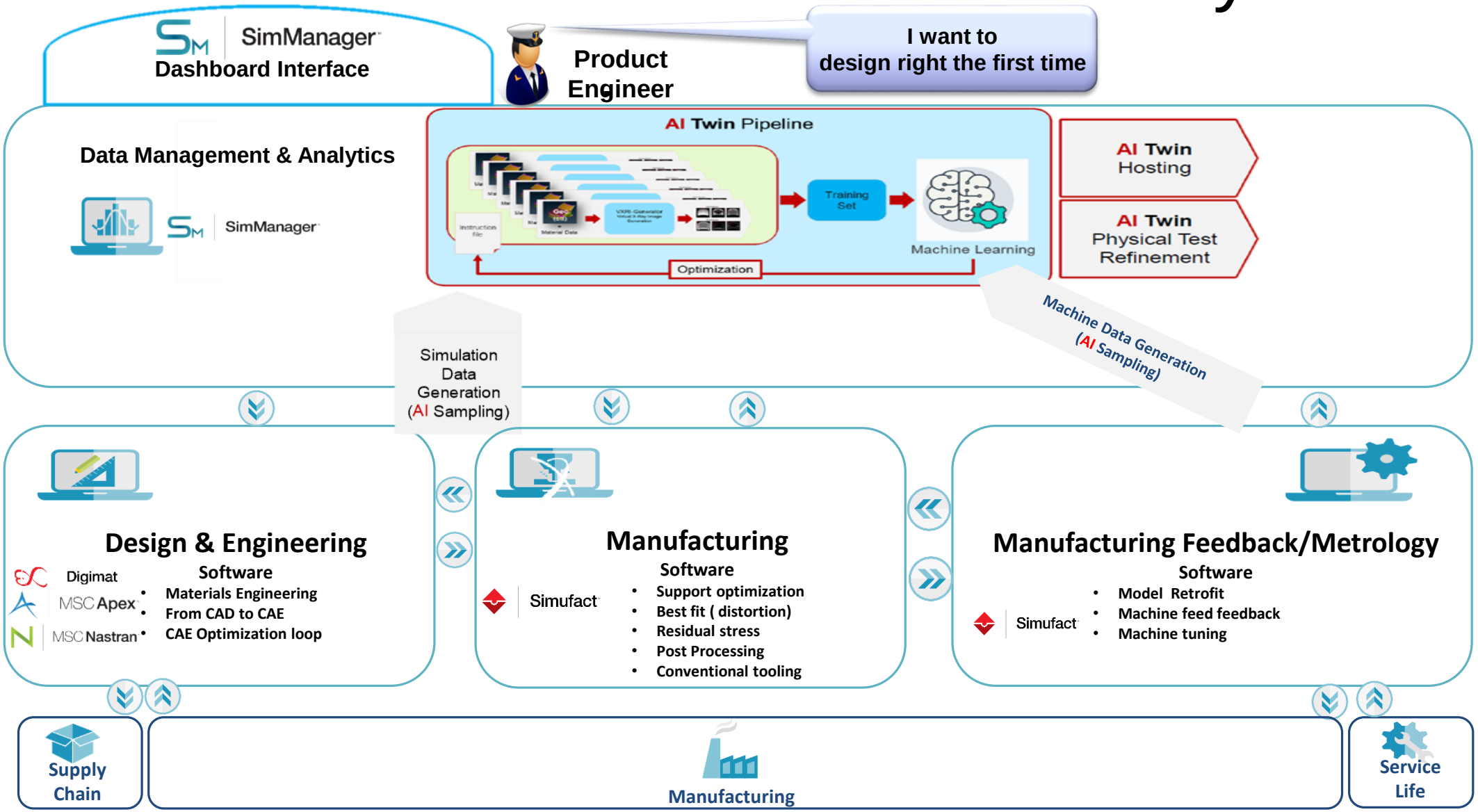




- Simulation calibration
  - Thermal gradient along Thermo-mechanical simulation
  - Inherent strains
  - Stress gradient

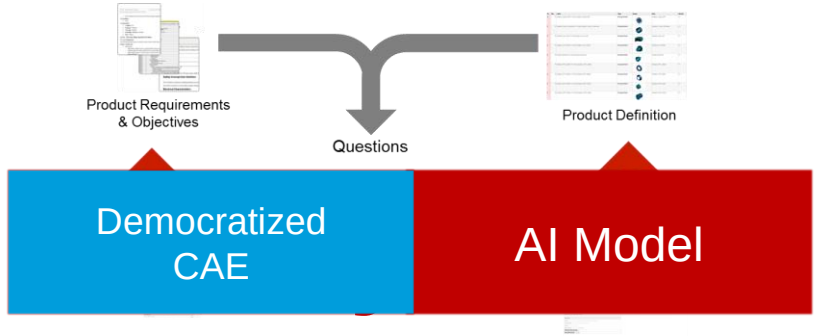


HxGN SFx | Additive Manufacturing Serving MANUELA Dashboard Layer 4/4



Simulation Decision Based Problem Statement

- During Product Life Cycle, there are many situations where simulation could answer questions, but:
  - Takes too long (weeks)
  - Not all data is available (too early)
  - Too expensive (labor costs)
  - Lack skilled resources



Democratized CAE

- Full automation of the CAE process.
- Latency: length of computation

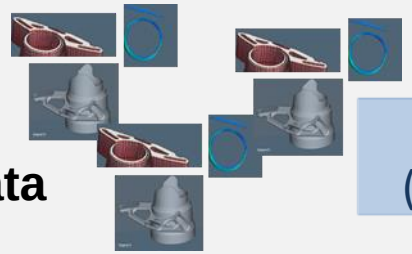
AI Models

- Delivers answers in minutes
- Doesn't replace simulation, but:
  - Reliable and more consistent than Engineering Judgement
  - Better than the simplified ROM

Training an AI Model (example supervised)

INPUTs

CAD
Material
Functional Data
…



CAE process
(pre/solve/post)

OUTPUTs

Results
Values, classifications,
decisions, or complex outputs

Decision

Actions

!

One input / output

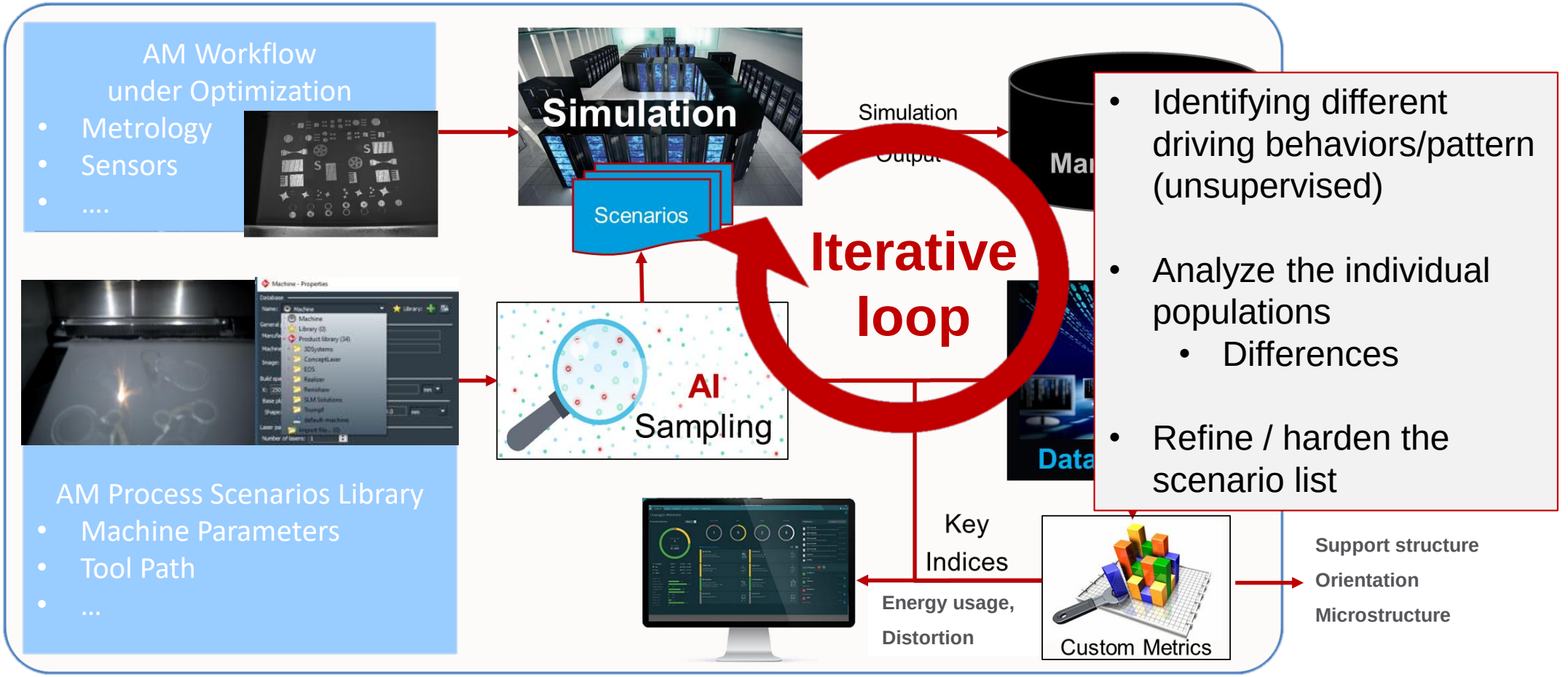
Features
Design, material, … parameters
… picture (50x50 columns)

Dimensionality

AI
Model

Machine Learning
(includes Validation, Test and Optimization)

Example in HxGN SFx | Additive Manufacturing



Smart Test Environment for Autonomous additive Manufacturing (STEAM)

Conclusion & Way Forward

- All Simulation Components for Design to Manufacturing Optimization are ready
  - Topological Manufacturability Constraints @ pre release level
  - Manufacturing Simulation process empowered with
    - Part Positioning, Support Optimization, Recoater Contact, Potential Part failure, Geometry Compensation
    - Stress, Strain, (elastoplastic) for thermomechanical behavior @ macro scale for simulation efficiency to be calibrated prior with lab specimens
- Dashboard Monitoring based on COTS SDMP validated
  - Data storage & traceability
  - Process execution monitoring
  - Workflow Management
- Next Year Focus
  - Validation of Generalized feature for Machine Learning Implementation
  - Automation of the Simulation steps
  - Envisioned plugging to “G-code” for Laser control
  - AI algorithms