Challenges in data acquisition and management in additive manufacturing

InShaPe

INNOVATION THROUGH LASER BEAM SHAPING IN METAL-BASED AM

Mike Holenderski (TUE), Richard Off (TUM)

VMAP User Forum 2025

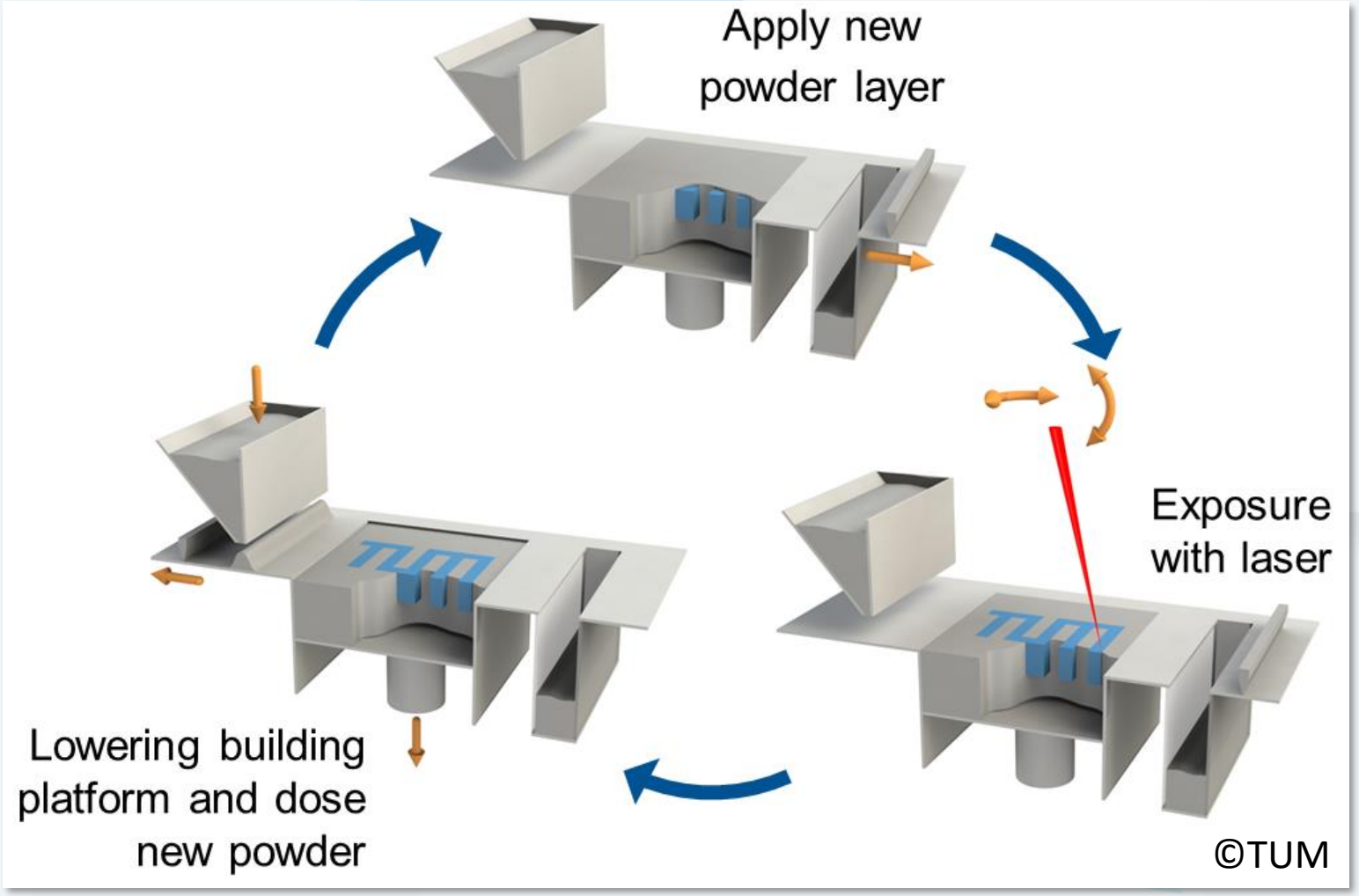
Schloss Birlinghoven, 18th of February 2025

Outline

1. **Introduction to InShaPe**
2. Data acquisition and management in InShaPe
3. Challenges
4. Vision

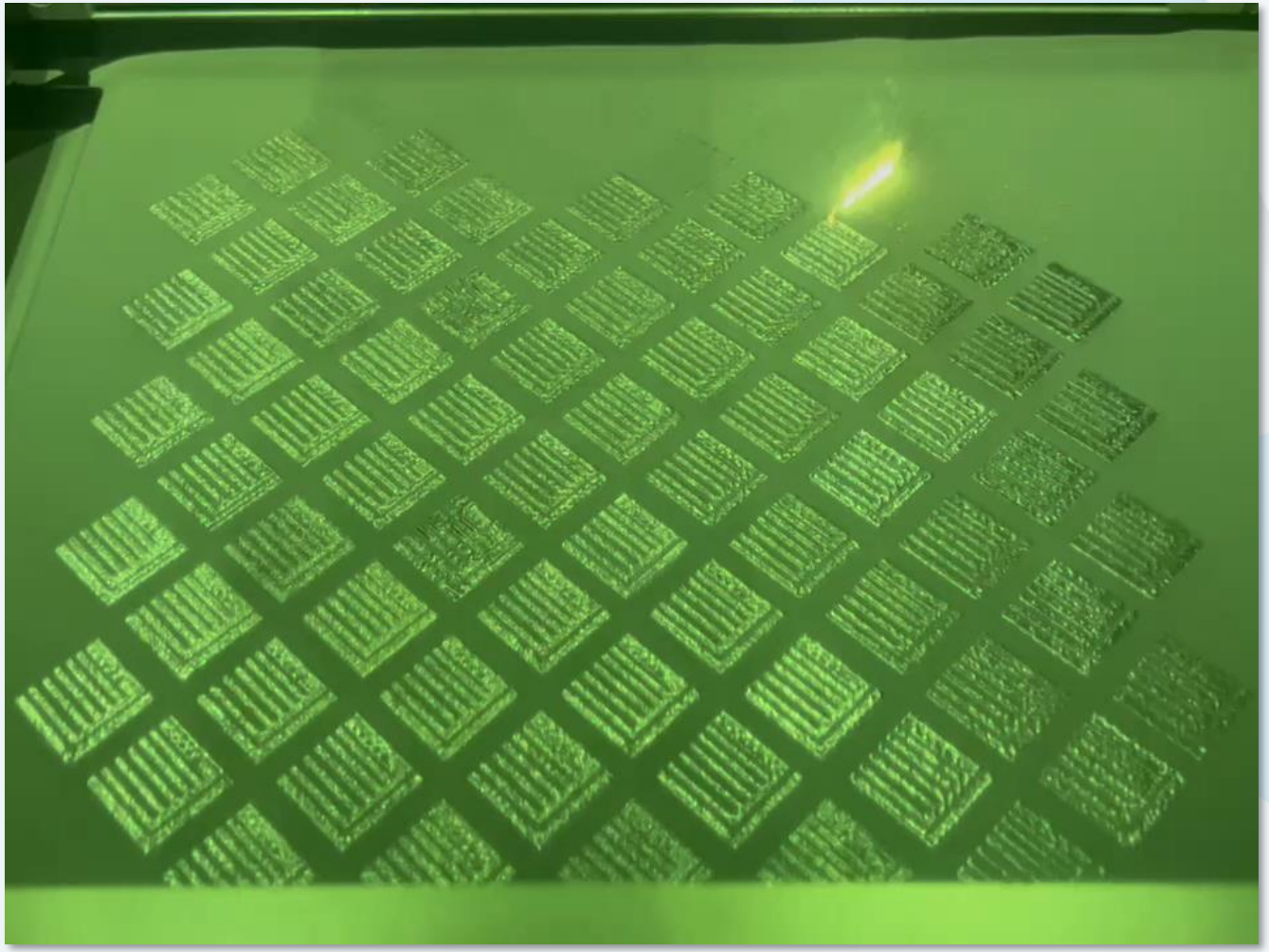
PBF-LB/M process

PBF-LB/M process overview: Recoating, Exposure, Next layer

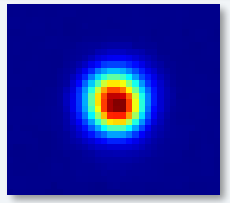


PBF-LB/M process

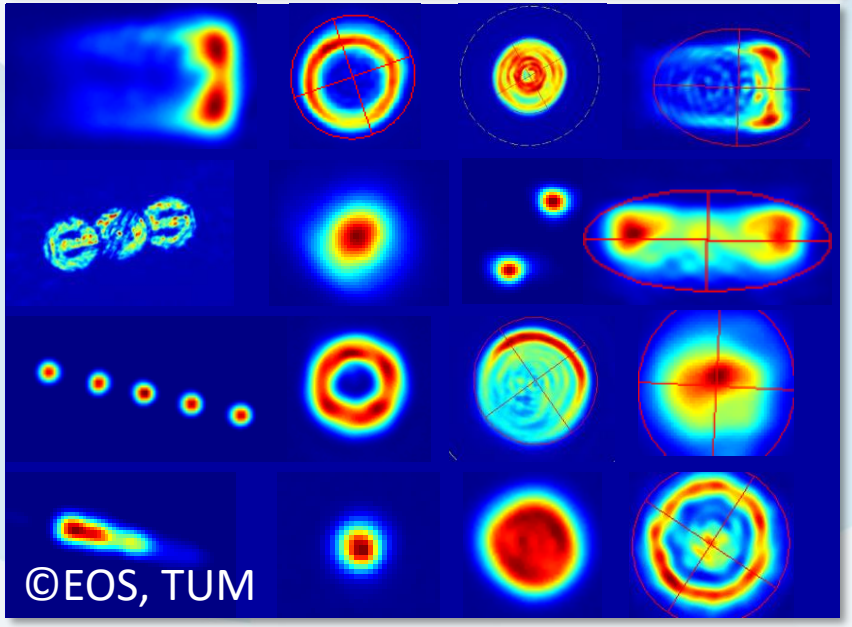
Beamshaping within EU project InShaPe: Changing the laser beam intensity profile in the working plane from a gaussian to an arbitrary distribution



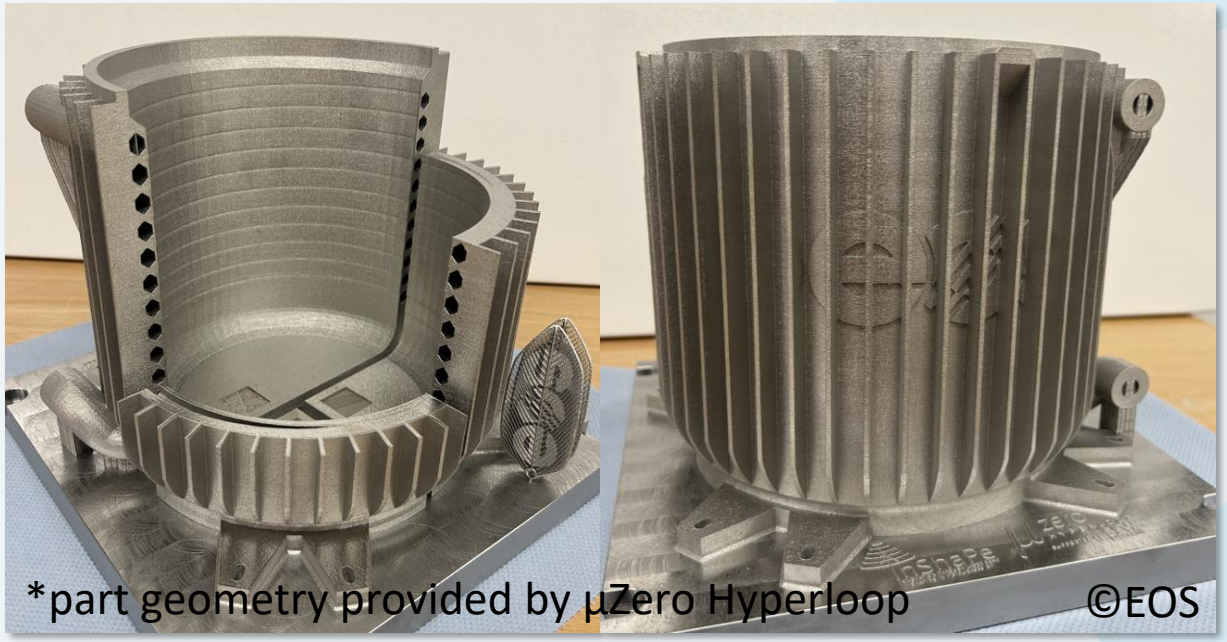
State of the Art: Gaussian beam

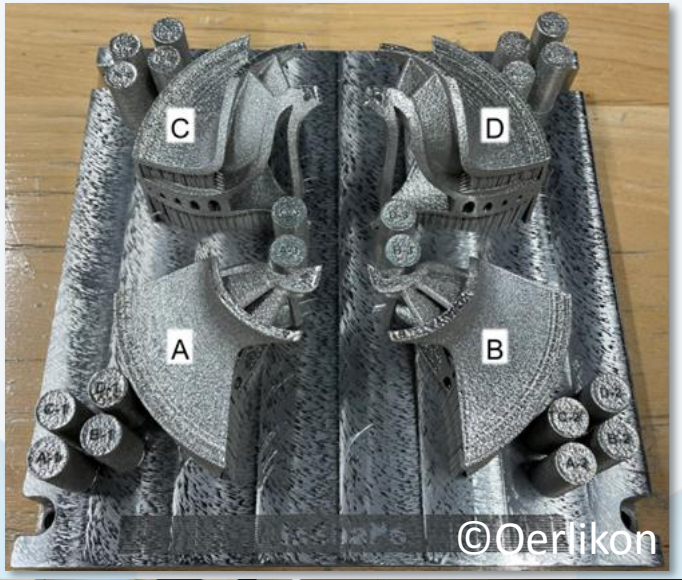


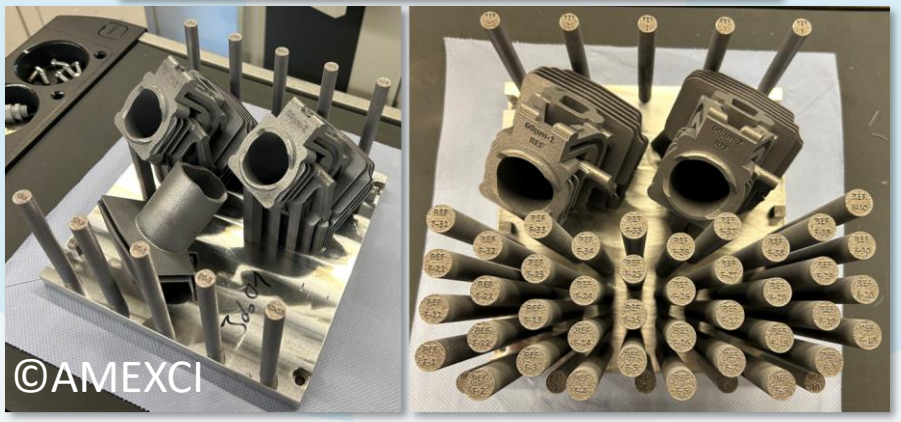
InShaPe: Arbitrary beam



InShaPe – Use-Case Demonstrations and KPIs







Demonstrator KPI‘s (IN718, 250µm Ring-Shape):

4.6x	-46%	-45%	-43%
Productivity	Part cost	Energy consumption	Material waste

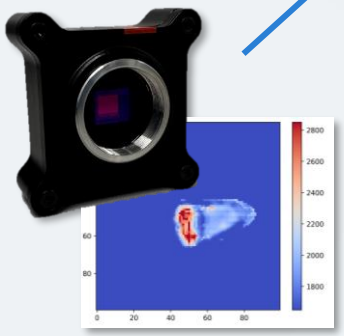
Technology innovations

InShaPe key technology innovations:
Beam shaping +
Multispectral imaging

Optical module
for generating various
beam shapes

©EOS

Multispectral (MSI) camera
for monitoring **absolute temperatures** and **melt pool geometries**



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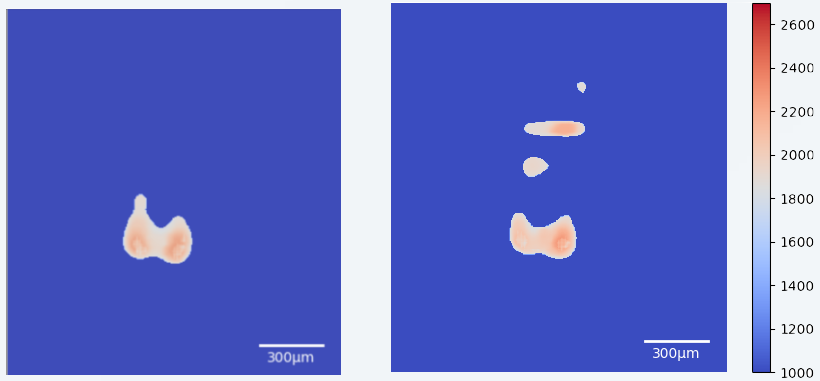
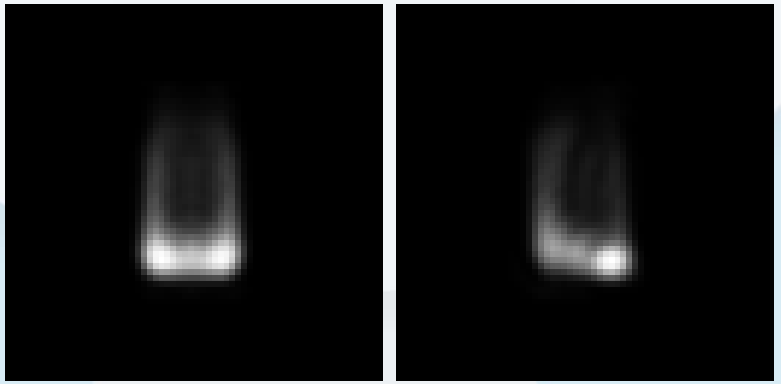
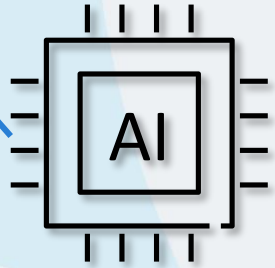
Light engine

EOS M290







1. **Beam correction**
2. **MSI processing**
3. **“Recipe book“**

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3. Challenges
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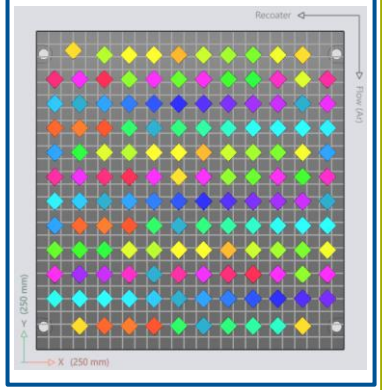
Overview of InShaPe Data Points

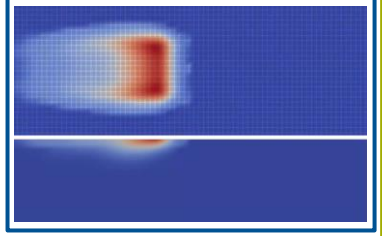
AM data points can be clustered in Pre-, In-, and Post-Process data points. A central data storage and processing is desirable for better analysis possibilities

Pre-Process

Job Data:
Layout, Geometries, Parameters, …

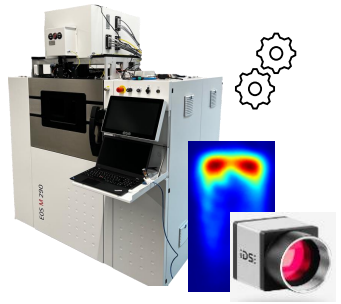


Simulation Data:
Temperatures, Melt pool geometry, …



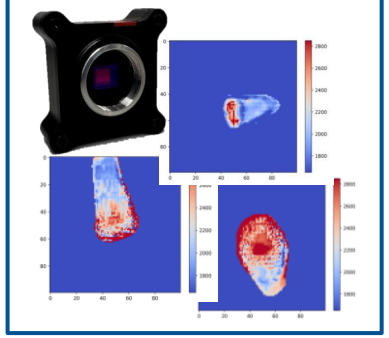
In-Process

Machine Data:
Scanner position, Laser power, Laser velocity, Beam shape, Part ID, …



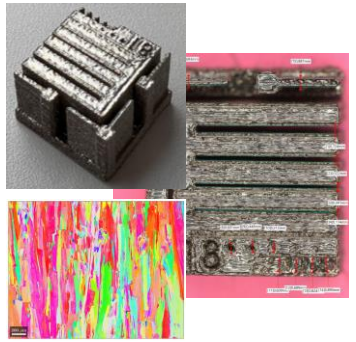
Sync

MSI Monitoring Data:
On-axis and Off-axis images, Temperatures, Process information, …

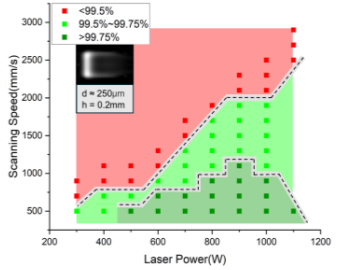


Post-Process

Analysis results:
Density, Microstructure, Mechanical properties, Roughness, Accuracy



Evaluation results:
Process map, …

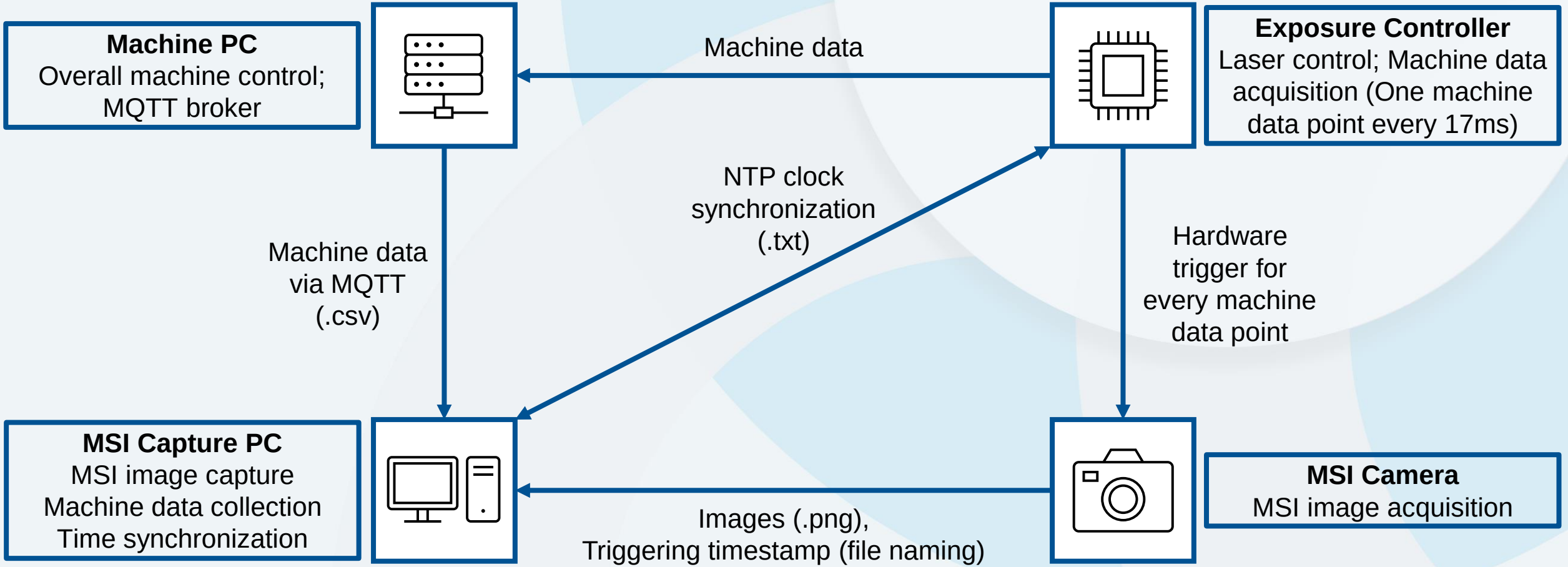


Central Data Acquisition, Storage and Processing Node

- Systematic storage in a database
- Process investigation and research
- Foundation for AI-based approaches

In-Process data synchronization concept

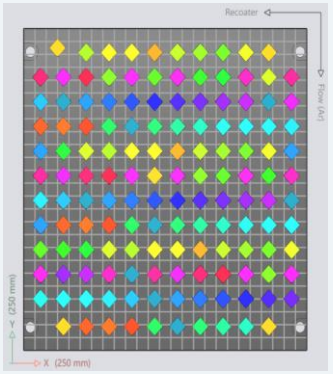
Concept for synchronizing the In-Process data to match MSI images with important process data points (position, part, etc.)



Data Types

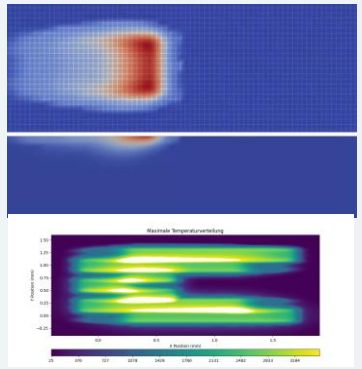
Overview of currently used data types. The main challenges are the high heterogeneity, a complicated acquisition as well as the overall high quantity (millions). Moreover, there is a lack of off-the-shelf, open-source solutions or handling AM data points.

Job Data:
Layout, Geometries, Parameters, …



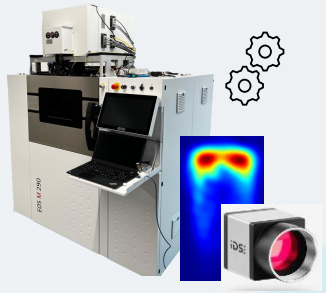
EOS-Job, CSV

Simulation Data:
Temperatures, Melt pool geometry, …



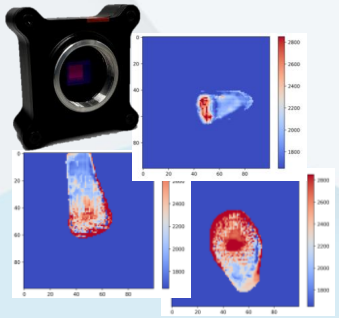
Paraview, ...?

Machine Data:
Scanner position, Laser power, Beam shape, …



Images, CSV

MSI Data:
On-/Off-axis MSI images, Temperatures, …

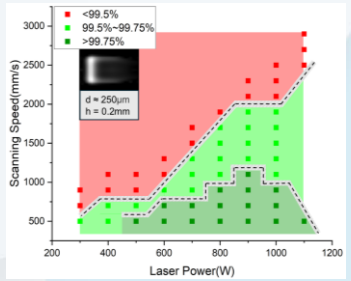


Images, CSV, …?

Analysis results:
Density, Microstructure, Roughness, …

Images, CSV, …?

Evaluation results:
Process map, correlations, …



Graphs, CSV, …?

Challenges: Heterogeneity, Acquisition, Quantity, Tools

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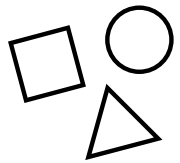
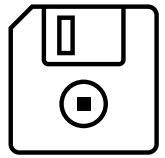
Challenges of data handling

The four main challenges within the InShaPe project regarding the data management and handling

Heterogeneity and Data formats

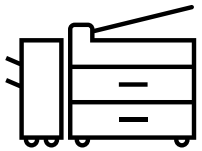
- Heterogeneity of data
- Closed, vendor-specific data types
- No fixed data structure (dependent on equipment)





Acquisition

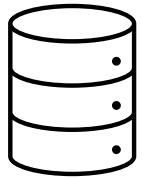
- Complicated data synchronization (In-process data)
- No easy-to use interfaces
- No central acquisition



Challenges

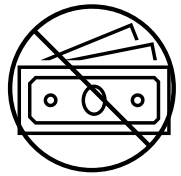
Quantity and Storage

- High quantity of data
- Data varies depending on build job and analysis (flexibility in storage)
- Data must be easily accessible



Standards and Open-source tools

- No standards and guidelines in use
- No open-source tools for data handling
- Commercial tools available (e.g., amsight)



Vision: easy

- Guidelines for acquiring, organizing and storing data
- Open-source reference implementation
- Impact: internal process development
  - ease of designing and running experiments
  - efficiency
  - validation
  - collaboration

A simple way to address the shown challenges would be a guideline for data acquisition, organization and storage with an open-source reference implementation. The impact of that would be mainly on internal process development.

Vision: bold

On the long term, a standardized data management for PBF-LB/M would be beneficial for multiple stakeholders along the supply chain.
A key challenges is thereby to get the support from the different companies to support newly established standards.

- Standardized data management in PBF-LB/M
- Open source reference implementation
- Impact: internal process development + external data exchange along supply chain
- Generalize:
  - laser-based material processing (powder bed fusion, **welding**, cutting)
  - electron-beam-based processing
  - other materials
- **Must be supported by companies (need clear business incentive)**

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