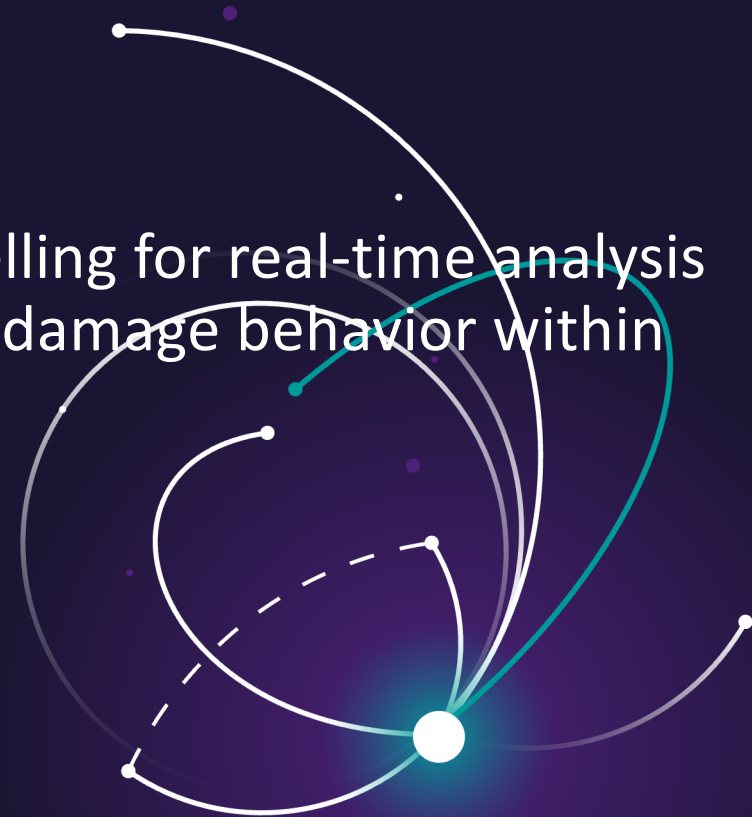


BMFTR-Project DigitalModelling

Fully digitalized & unified material modelling for real-time analysis of process & operational deformation & damage behavior within digital component twins

Y. Kostenko, C. Schweizer

PMD Vollversammlung, BAM, Berlin, November 2025



„DigitalModelling“ - Our Consortium



2025-05-08



Specialization **Siemens Energy**, Project-Coordinator:



Internationally leading German manufacturer, among others, of stationary turbomachinery

Specialization **MTU Aero Engines**:



Internationally leading German manufacturer of aircraft engines

Specialization **KSB**:



One of the leading manufacturers of pumps and valves

Specialization **BAM**:



Deformation mechanisms at the microstructural level

Specialization **IWM Freiburg**:



Description of objects and processes, knowledge graphs & causal inference

Specialization **TU Darmstadt**:



Objective parameter determination and meta-modeling

Specialization **MPA Stuttgart**:



Data-based characterization and evaluation of the microstructure

Specialization **Otto-von-Guericke-University Magdeburg**:



Modeling under complex transient load conditions

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Agenda



- **Motivation and project objectives**
- **Technological components and project infrastructure**
- **Our demonstrators**
- **Topics for community interaction**
- **Outlook**

Motivation and project objectives

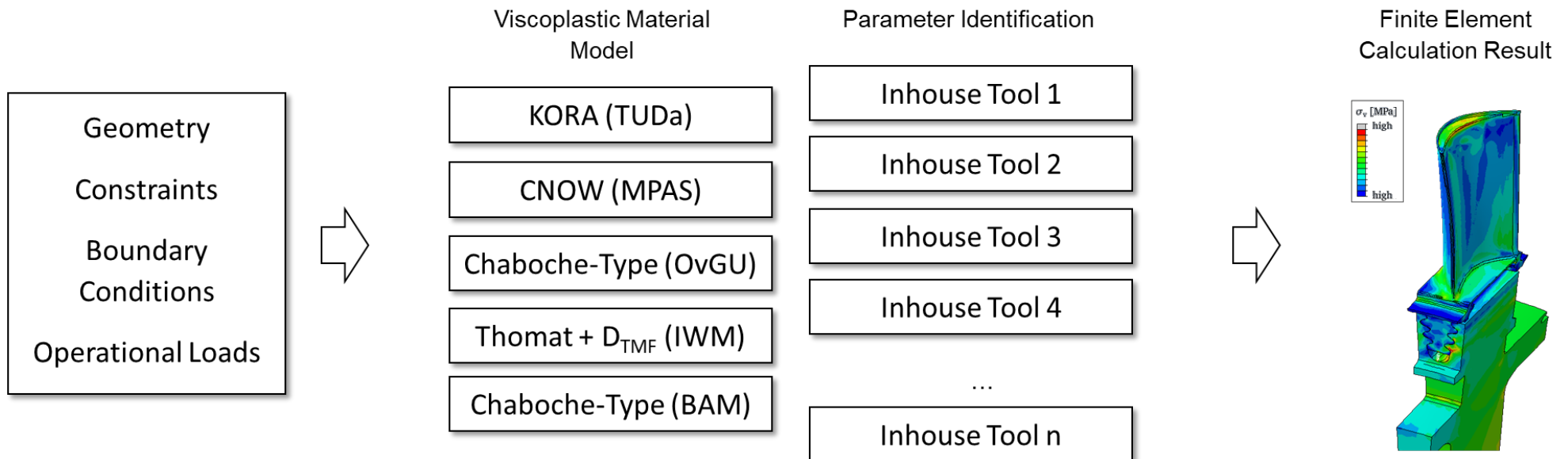


Industry needs and pain points

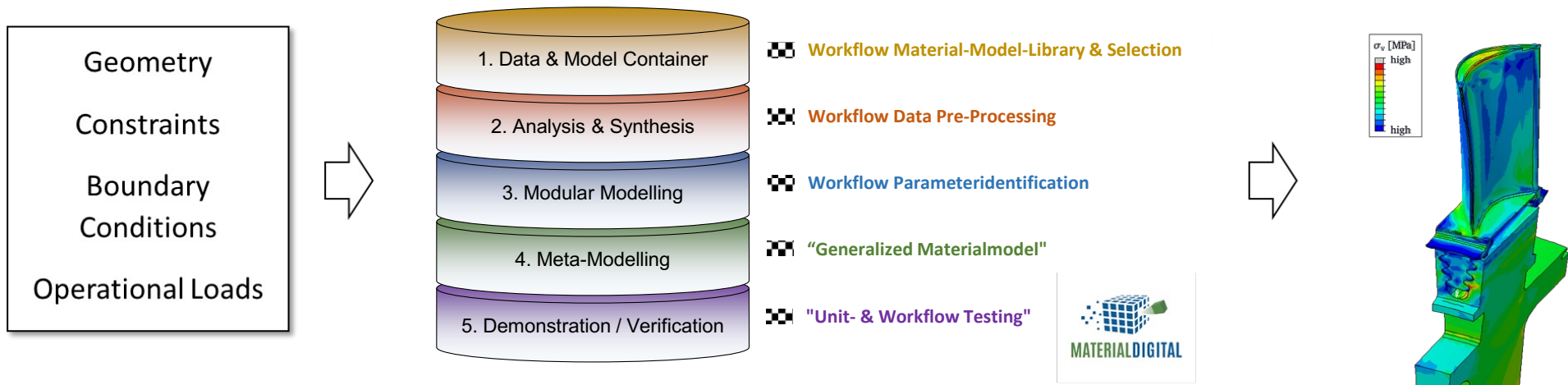
with regard to advanced material models for high temperature applications

- **Accelerate the integration of new material models** from research institutes into industrial use (takes many years)
- **Improve decision making** regarding the choice of material models (lack of model robustness, suitable with regard to component loading and material mechanisms)
- **Reduce the time to get a material card** (finding data, automatic workflows for parameter optimization)
- **Improve traceability** from material card to batch specific data points

„Digital Modelling“ - Current Situation



„Digital Modelling“ - Targeted Future Situation



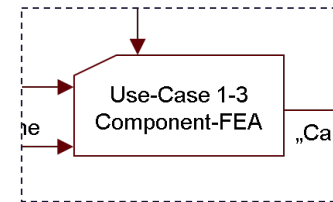
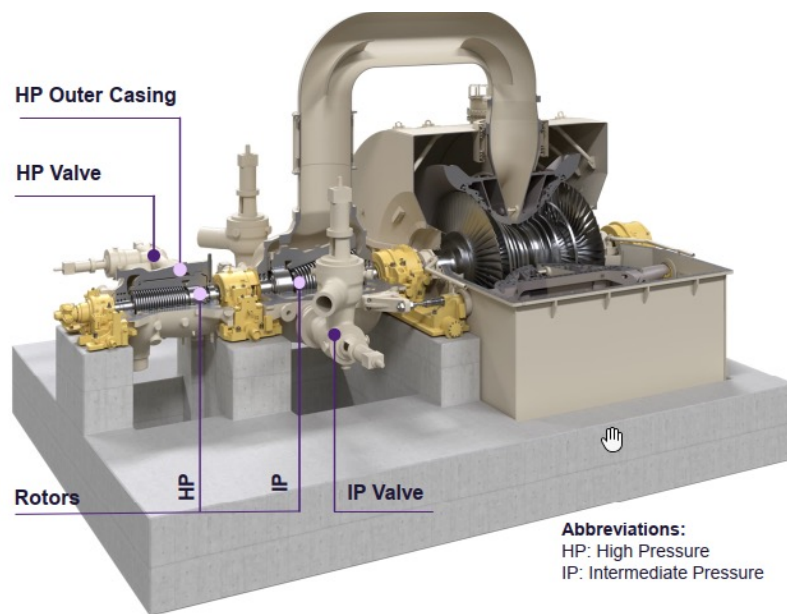
It's not about the material – it's about enabling faster integration of advanced models,

- smarter and more robust model choices,
- streamlined generation of material cards,
- and full traceability from batch data to industrial application.

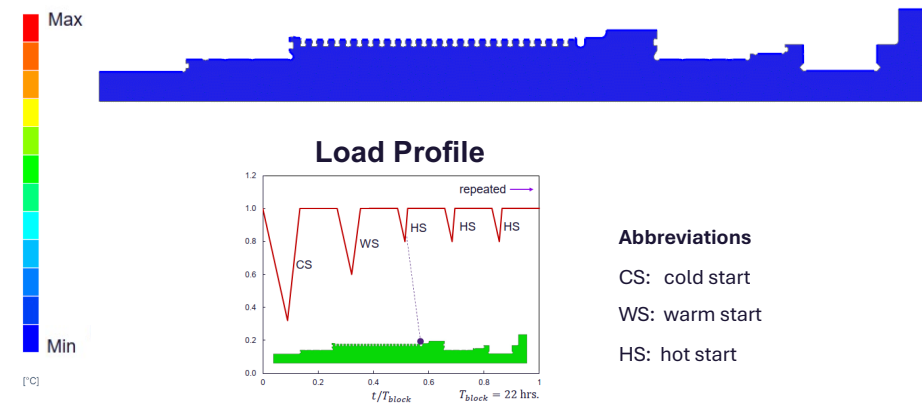
Application example

Industrial Use Cases & Demonstrators

Steam Turbine and its Critical Components



Temperature



Damage



Stress



Source: Journal of Engineering for Gas Turbines and Power DECEMBER 2023, Vol. 145 / 121007-1, Copyright VC 2023 by Siemens AG

2025-05-08

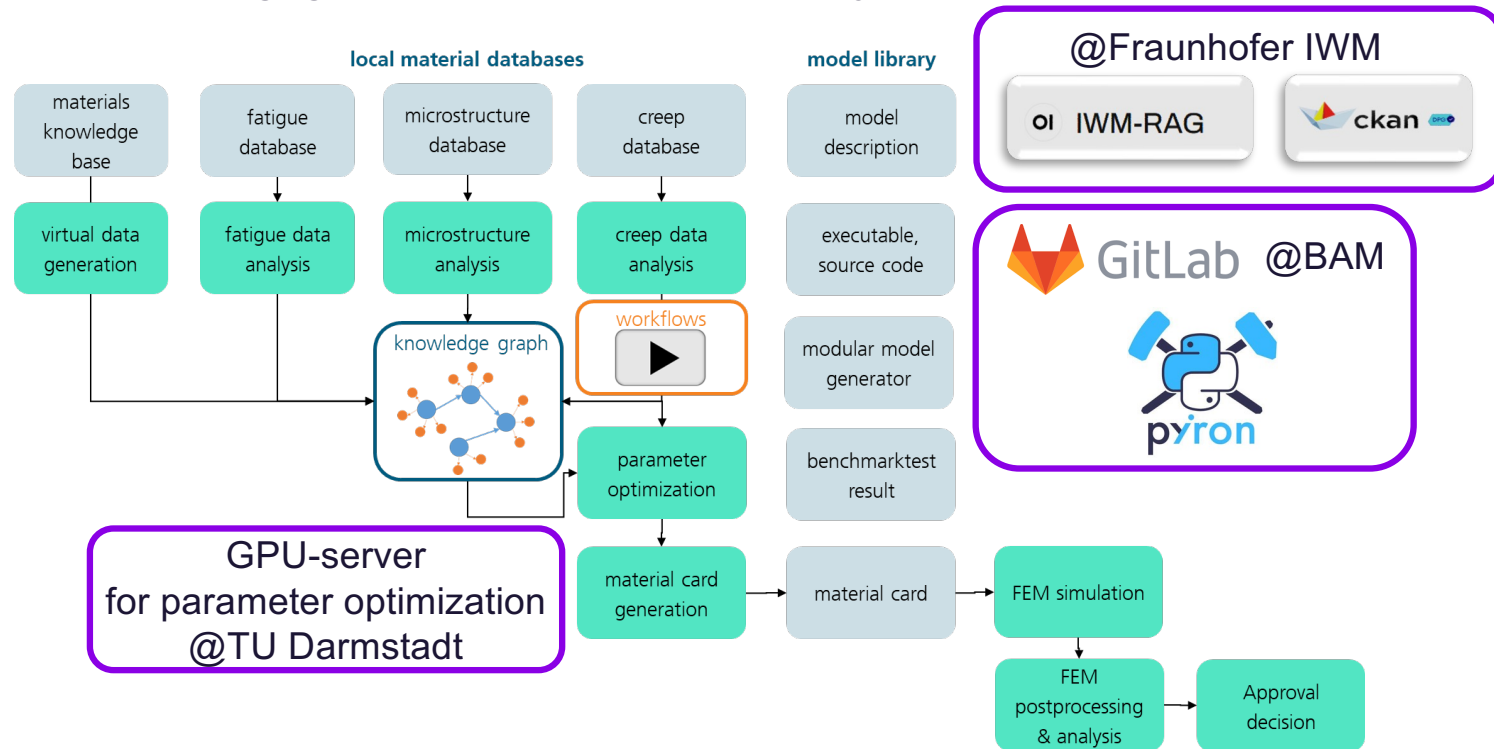
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Technological components and infrastructure



Connection between knowledge graph, workflows and model library



Our demonstrators: Example 1

oi IWM-RAG



Chatbot to select and interact with material models for high-temperature applications

Example: Query the adjustable model parameters for a creep-fatigue model with units and typical values

Benefit: Can be used as starting values for parameter optimization

AI-assisted expert system



Please give me a table for the model parameters of the DFC model including units and reasonable values.

delete

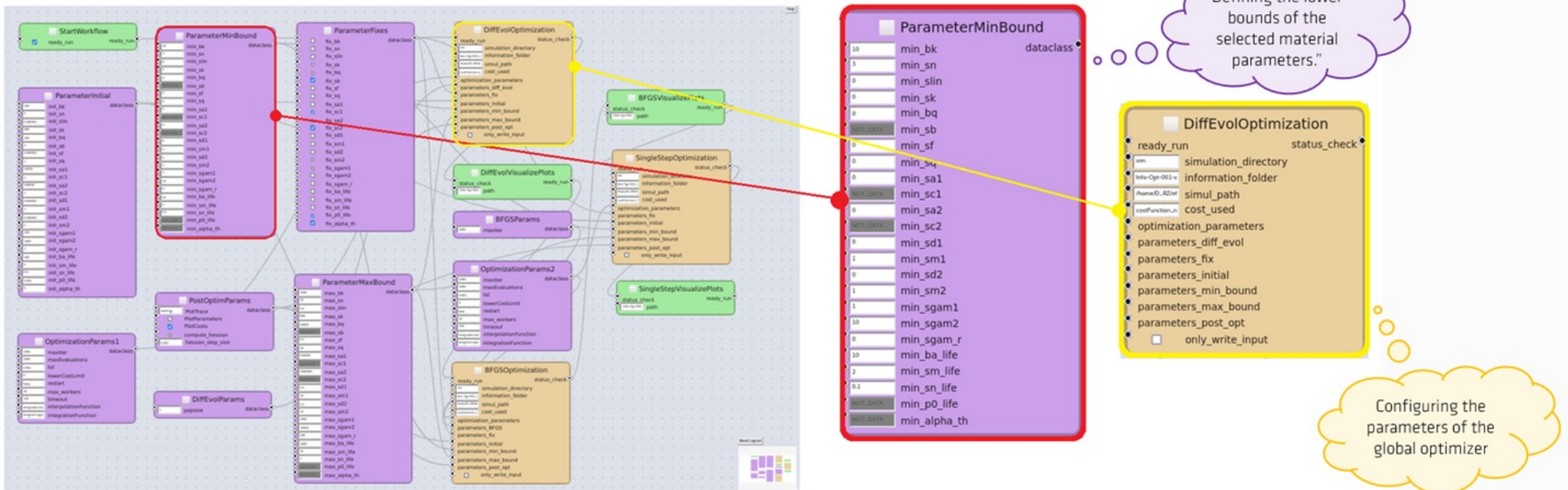


Certainly! Here is a table summarizing the model parameters of the DFC model, including their units and typical value ranges:

Parameter	Description	Unit	Typical Values
E	Modulus of Elasticity	MPa	50,000 – 220,000
(\sigma_{cy})	Cyclic Yield Stress	MPa	10 – 2,000
N'	Hardening Exponent	Unitless	0.05 – 0.5
CMG	Monkman-Grant Product	Unitless	0.01 - 1
n	Norton Exponent	Unitless	1 – 50
B1	Pre-factor in Norton Creep Law	(MPa ⁿ * s) ^{-1}	2.8 for P92
Q	Activation Energy for Creep	kJ/mol	620 for P92
(\Omega)	Atomic Volume	m ^{3}	1.18*10 ^{-29} for P92
(\delta D_{b0})	Grain Boundary Diffusion Coefficient	m ^{3} /s	1.1*10 ^{-12} for P92
(\lambda)	Distance of Creep Porosity	μm	10 for P92
d	Grain Size	μm	100 for P92

Our demonstrators: Example 2

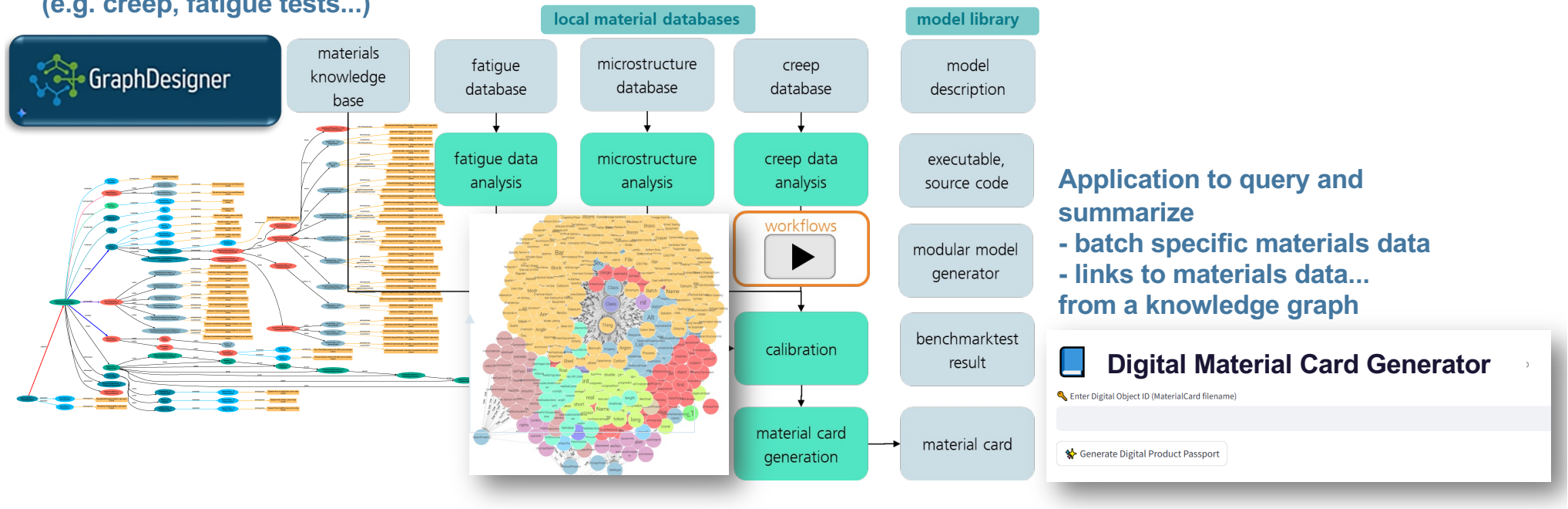
Pyiron GUI Environment



Usage of Pyiron-workflows for parameter optimization of a Chaboche-type model using creep tests

Our demonstrators: Example 3

User friendly application
to generate graph templates
(e.g. creep, fatigue tests...)



Application to query and
summarize
- batch specific materials data
- links to materials data...
from a knowledge graph

Usage of a knowledge graphs to create a retraceable material card
– from model parameters to batch specific materials data

Our demonstrators: Example 4

Virtual Data Generation (MPA Stuttgart)

Goal

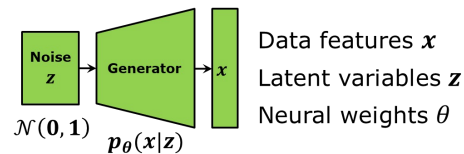
Enlarging existing material data sets by synthetic material data

Method

Deep Generative Artificial Neural Networks

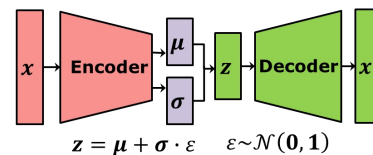
Implementation

Latent variable models

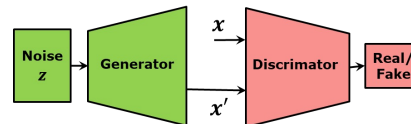


Create approximation of probability distribution $p(x)$ of features x

Variational Autoencoder (VAE)

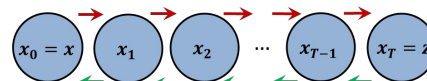


Generative Adversarial Network (GAN)



Denoising Diffusion Probabilistic Model (DDPM)

Forward process (prescribed): Adding noise

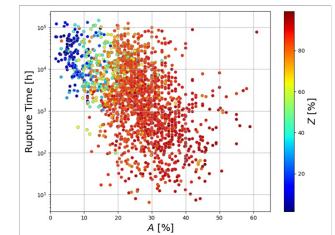
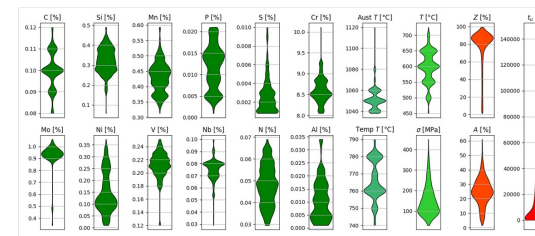


Reverse process (trainable): Denoising

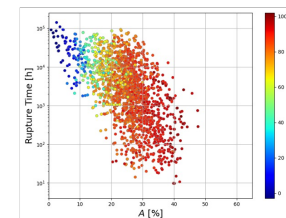
Example: Creep properties of 9% chromium steels

Input features x : Chemical composition, Heat treatment, Temperature, Load, Rupture time, Rupture strain, Contraction

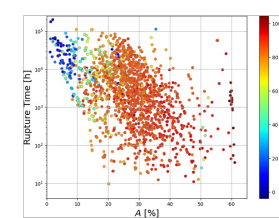
Real Data Distribution (~1900 data records)



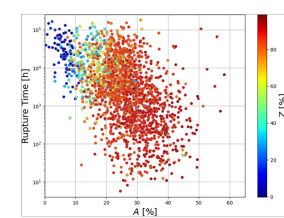
Conditional VAE



Conditional GAN



Conditional DDPM



Topics for community interaction

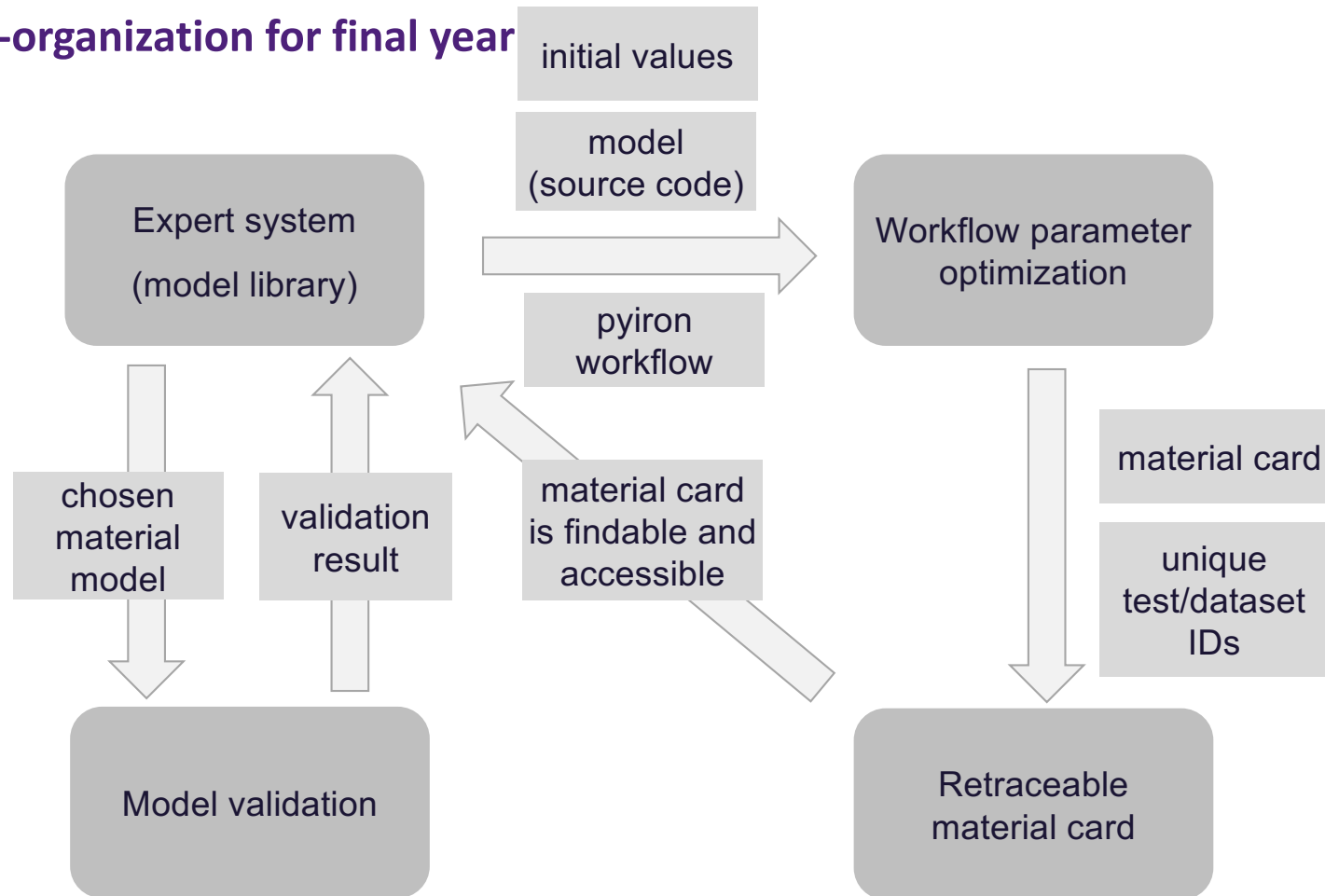
Topic 1: How to make knowledge graphs and ontology development more scalable?

- Industry partners signal the need for scalable solutions (e.g. 80% solution for different test types, heat treatments)
- Fraunhofer IWM has supported the **project DigiChrom** with workshops on semantic data structuring and the GraphDesigner App → valuable feedback

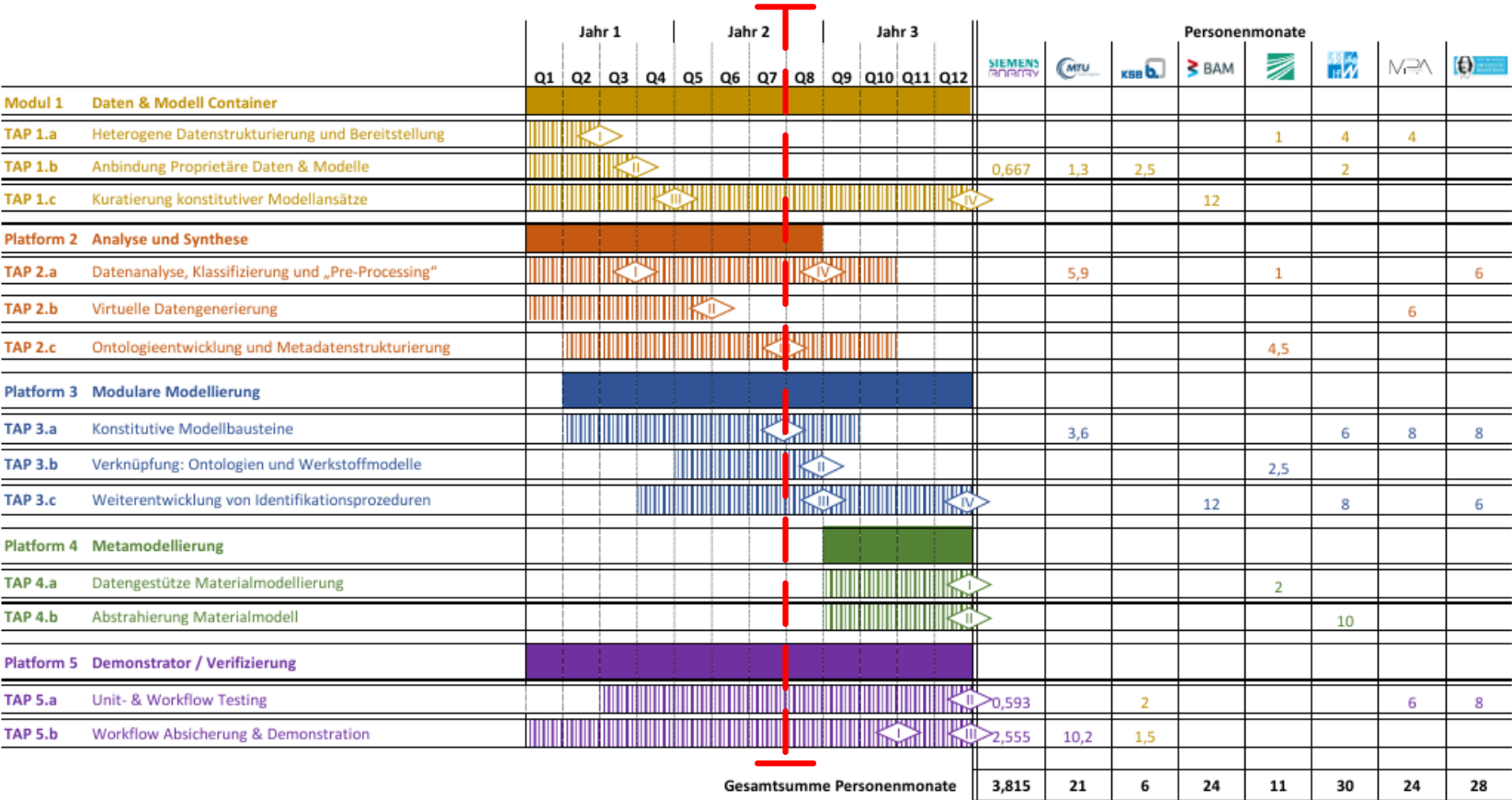
Topic 2: Development of a business model to operate the infrastructure and technology beyond the end of the project

- Industry partners signal to us the need to operate the infrastructure beyond the end of the project

Outlook: re-organization for final year



Time Schedule, Milestones & Resource Planning



Contact “DigitalModelling” Project Coordinators



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Thank you.