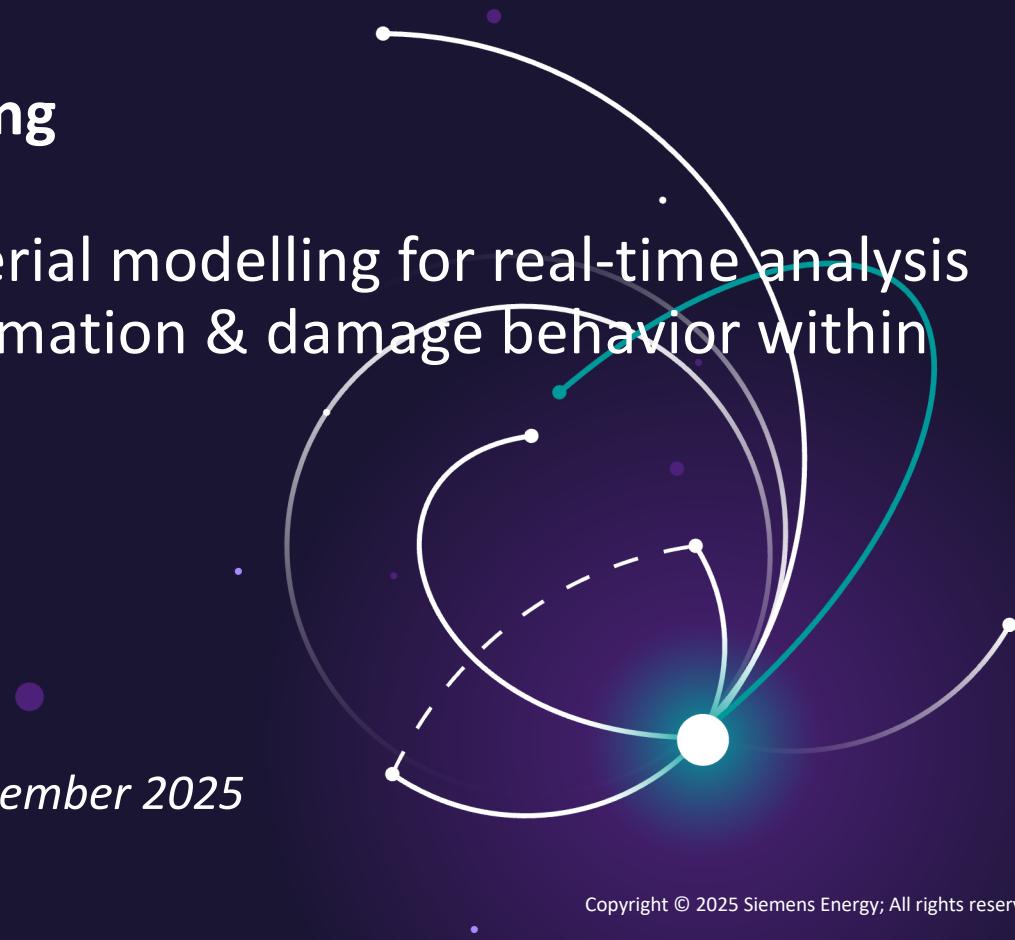


BMFTR-Project DigitalModelling

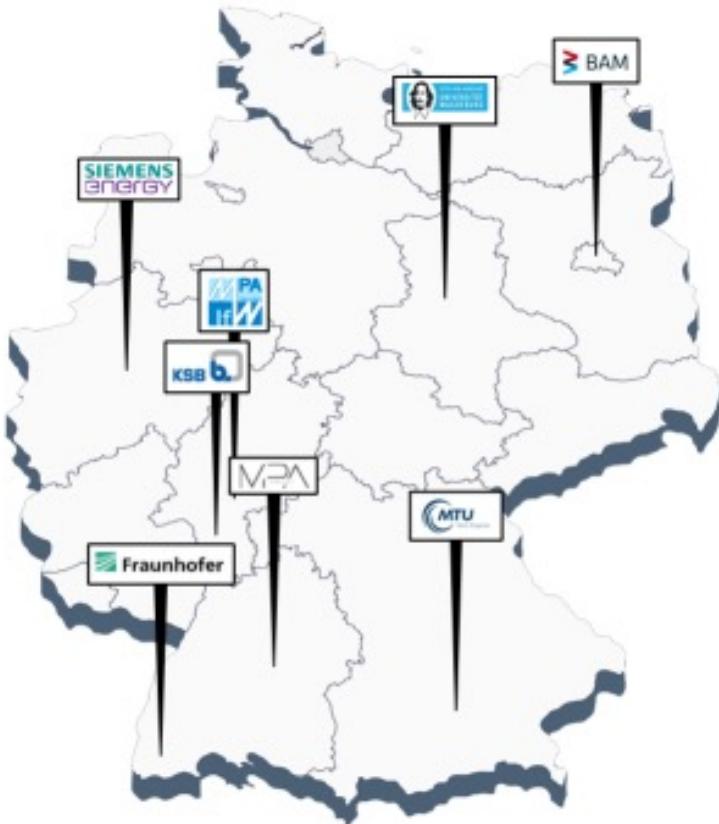
Fully digitalized & unified material modelling for real-time analysis of process & operational deformation & damage behavior within digital component twins

Y. Kostenko, C. Schweizer

PMD Vollversammlung, BAM, Berlin, November 2025



„DigitalModelling“ - Our Consortium



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

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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

Dr. Kostenko 2

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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

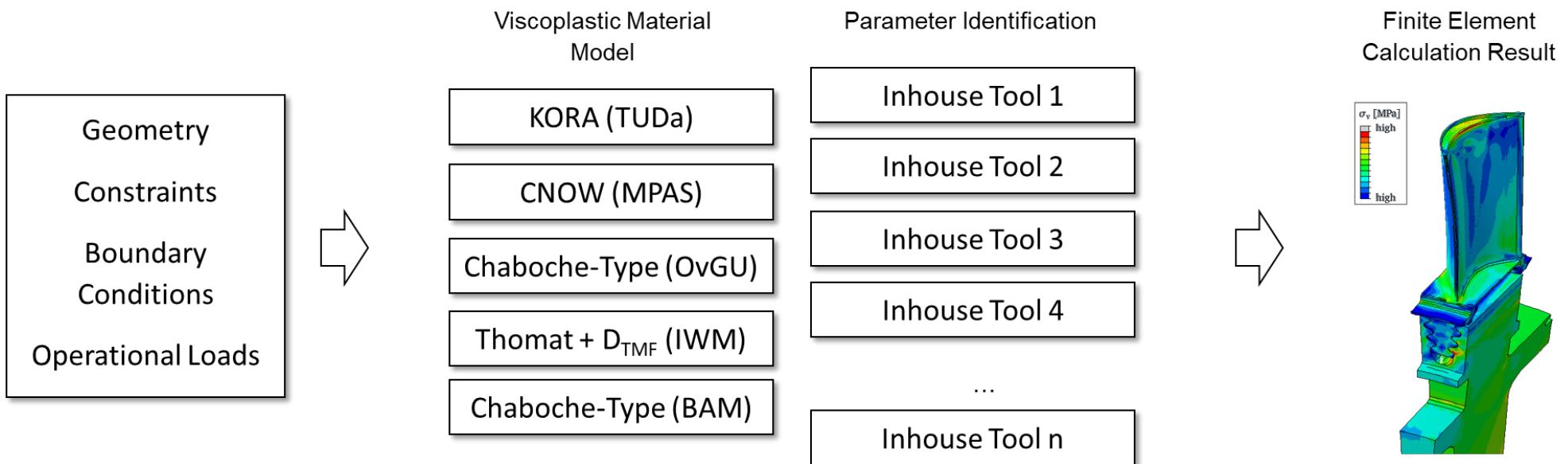


Industry needs and pain points

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

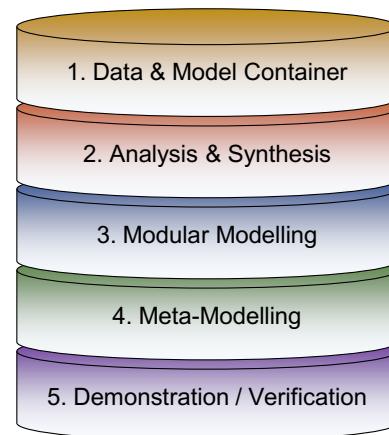
„Digital Modelling“ - Current Situation



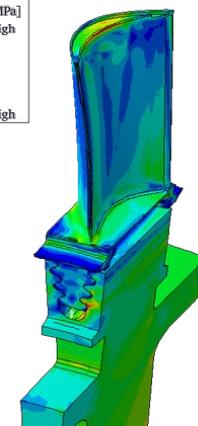
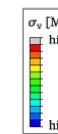
„Digital Modelling“ - Targeted Future Situation



Geometry
Constraints
Boundary
Conditions
Operational Loads



- Workflow Material-Model-Library & Selection
- Workflow Data Pre-Processing
- Workflow Parameteridentification
- “Generalized Materialmodel”
- “Unit- & Workflow Testing”



Finite Element
Calculation Result

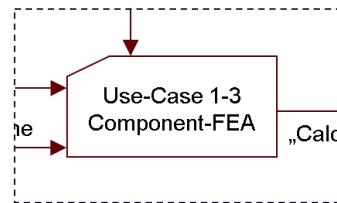
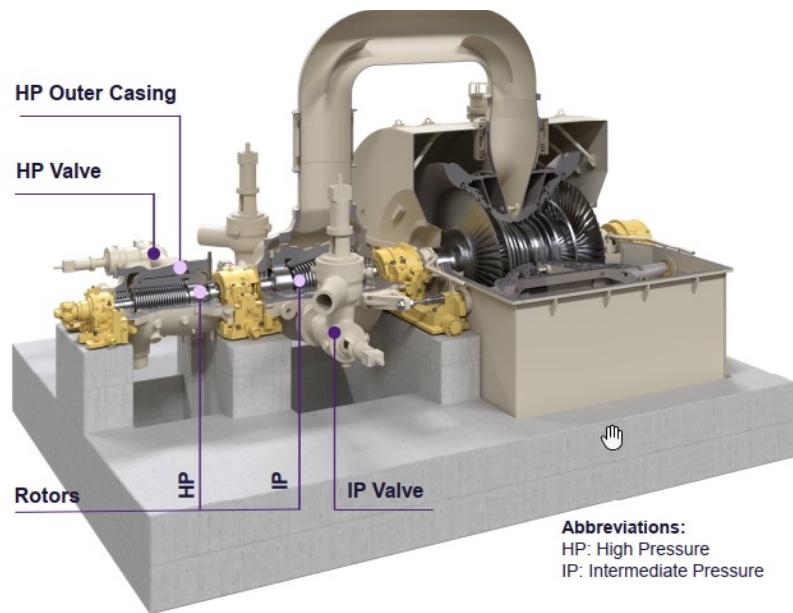
It's not about the material – it's about enabling faster integration of advanced models,

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

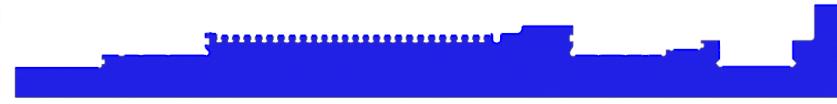
Application example

Industrial Use Cases & Demonstrators

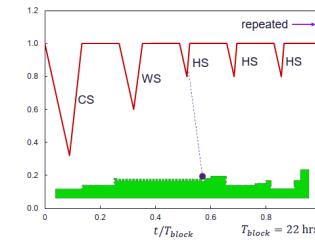
Steam Turbine and its Critical Components



Temperature



Load Profile



Abbreviations

CS: cold start

WS: warm start

HS: hot start



Damage

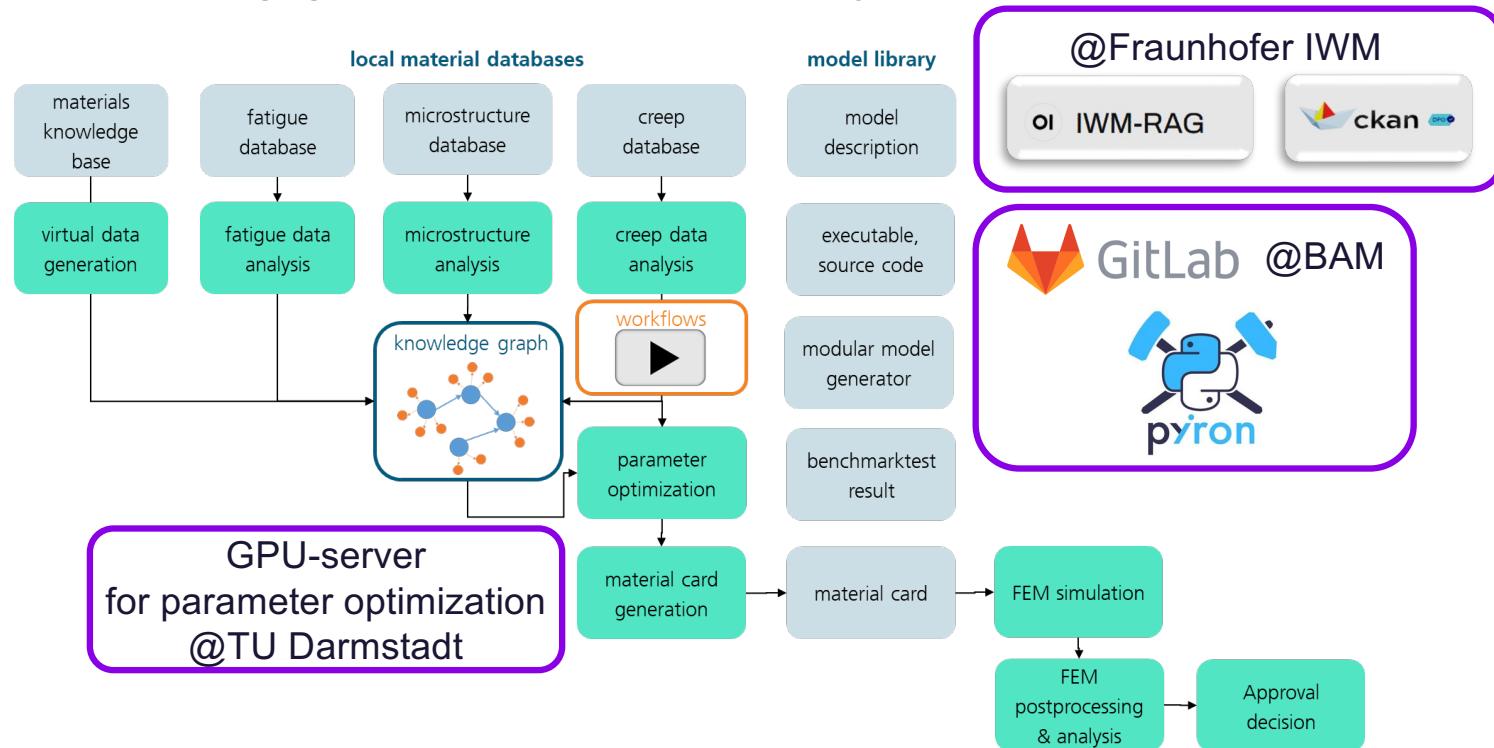


Source: Journal of Engineering for Gas Turbines and Power DECEMBER 2023, Vol. 145 / 121007-1, Copyright © 2023 by Siemens AG

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

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AI-assisted expert system



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

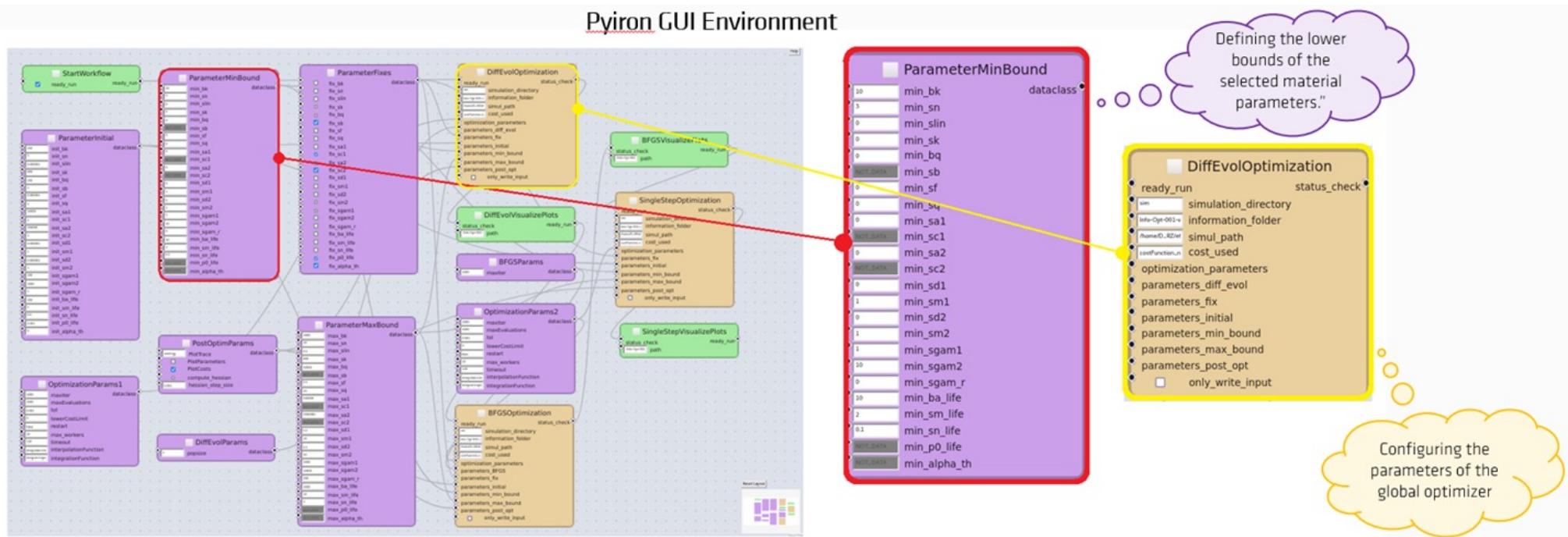
delete



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
(σ_{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	$(\text{MPa}^n * \text{s})^{[-1]}$	2.8 for P92
Q	Activation Energy for Creep	kJ/mol	620 for P92
(Ω)	Atomic Volume	$\text{m}^{[3]}$	$1.18 \times 10^{[-29]}$ for P92
(δD_{b0})	Grain Boundary Diffusion Coefficient	$\text{m}^{[3]}/\text{s}$	$1.1 \times 10^{[-12]}$ for P92
(λ)	Distance of Creep Porosity	μm	10 for P92
d	Grain Size	μm	100 for P92

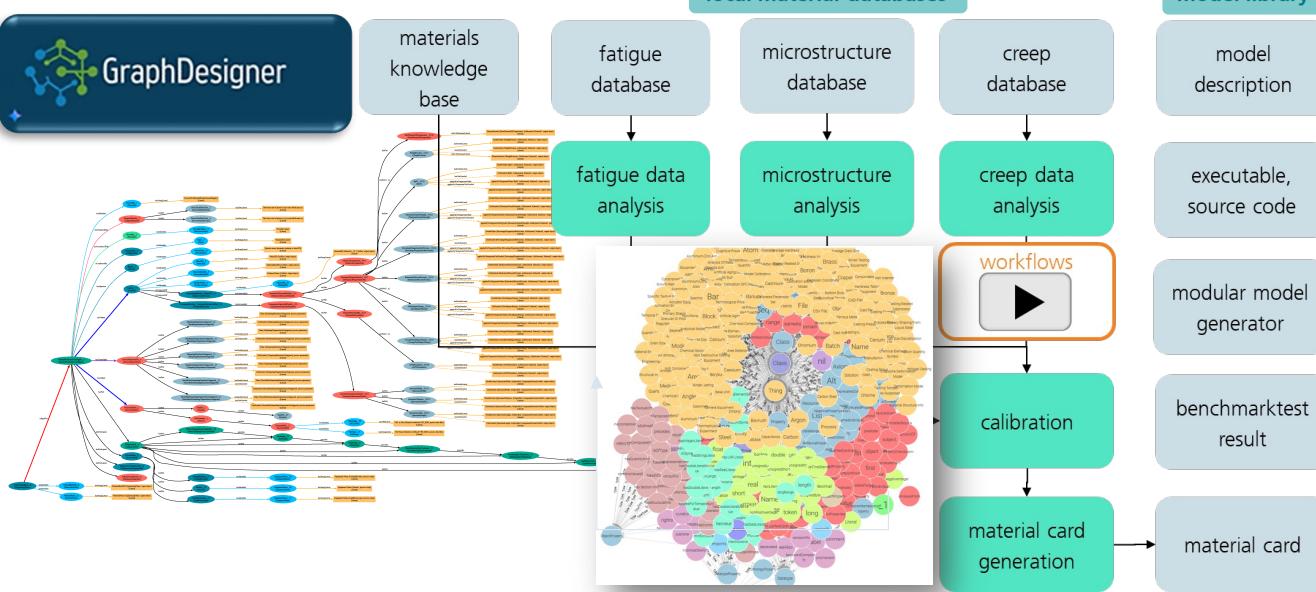
Our demonstrators: Example 2



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

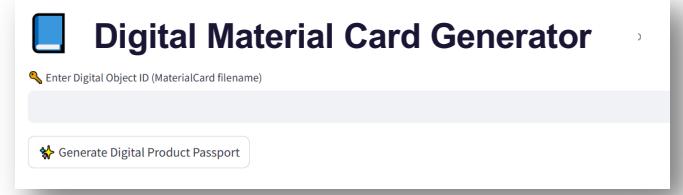
Our demonstrators: Example 3

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

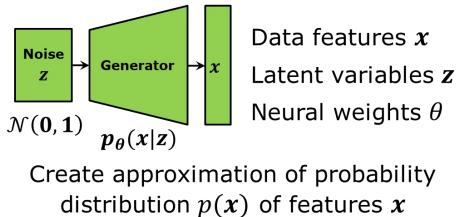
Enlarging existing material data sets by synthetic material data

Method

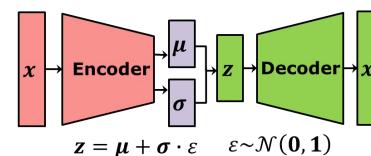
Deep Generative Artificial Neural Networks

Implementation

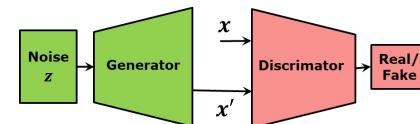
Latent variable models



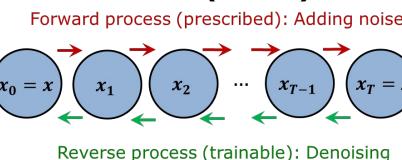
Variational Autoencoder (VAE)



Generative Adversarial Network (GAN)

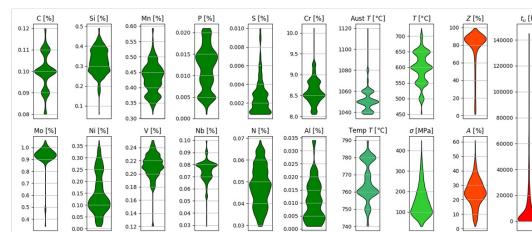


Denoising Diffusion Probabilistic Model (DDPM)

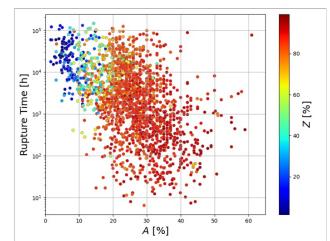


Example: Creep properties of 9% chromium steels

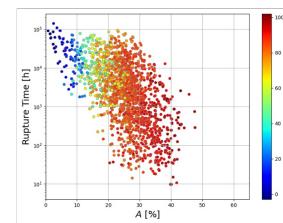
Input features x : Chemical composition, Heat treatment, Temperature, Load, Rupture time, Rupture strain, Contraction



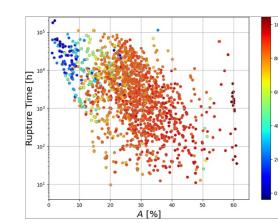
Real Data Distribution (~1900 data records)



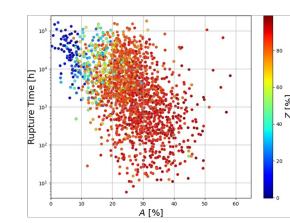
Conditional VAE



Conditional GAN



Conditional DDPM



Topics for community interaction

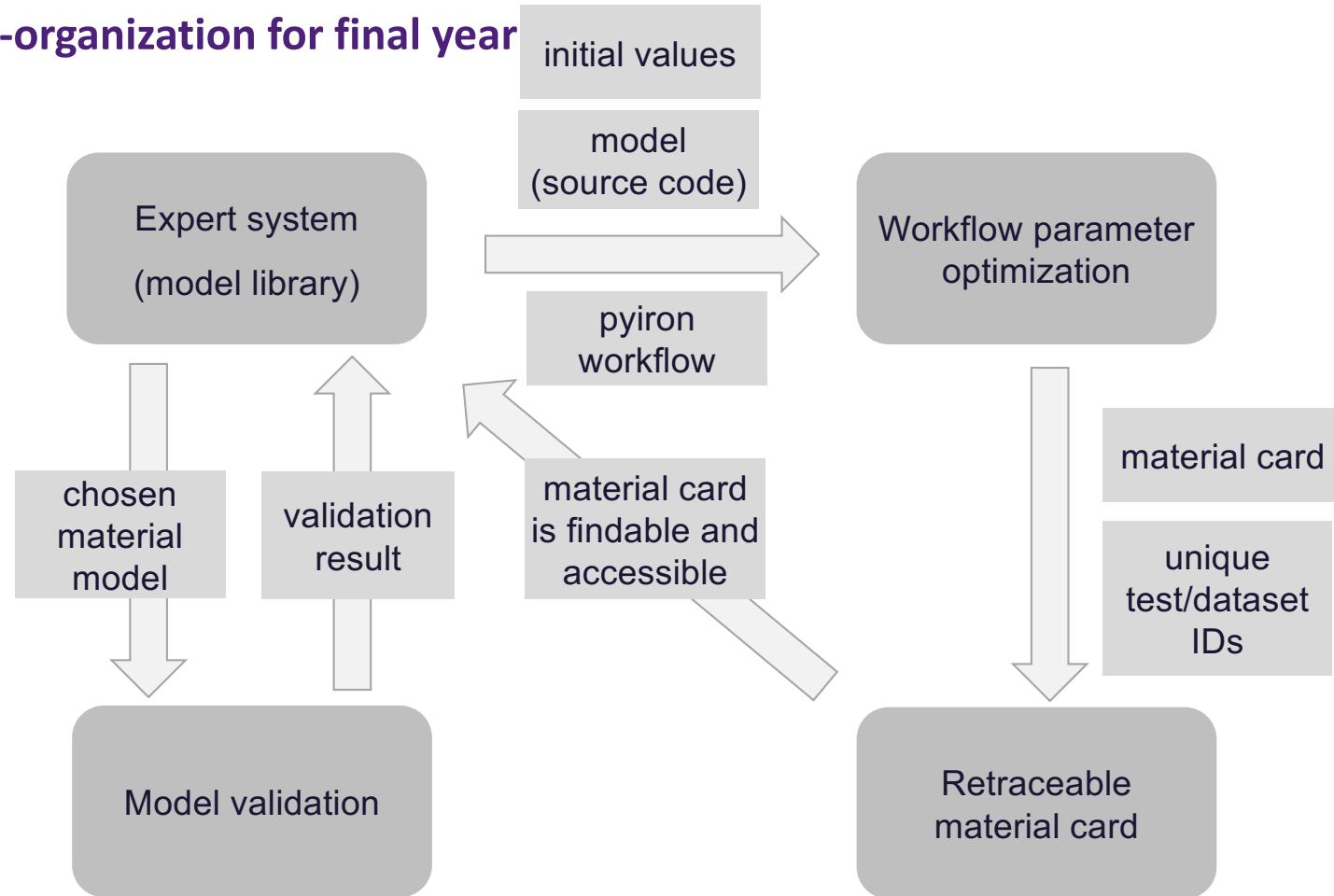
Topic 1: How to make knowledge graphs and ontology development more scalable?

- 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

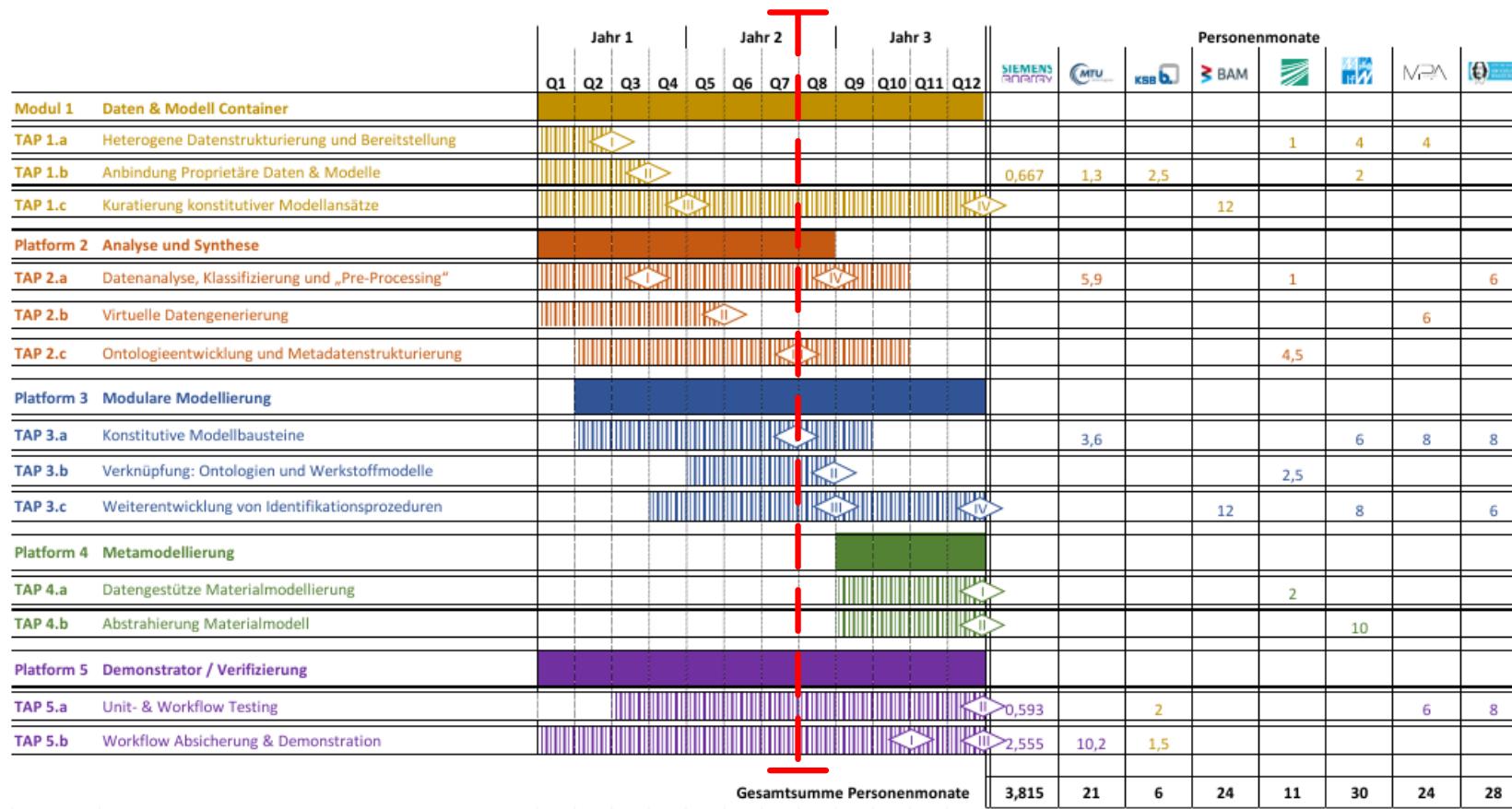
- Industry partners signal to us the need to operate the infrastructure beyond the end of the project

Outlook: re-organization for final year



Time Schedule, Milestones & Resource Planning

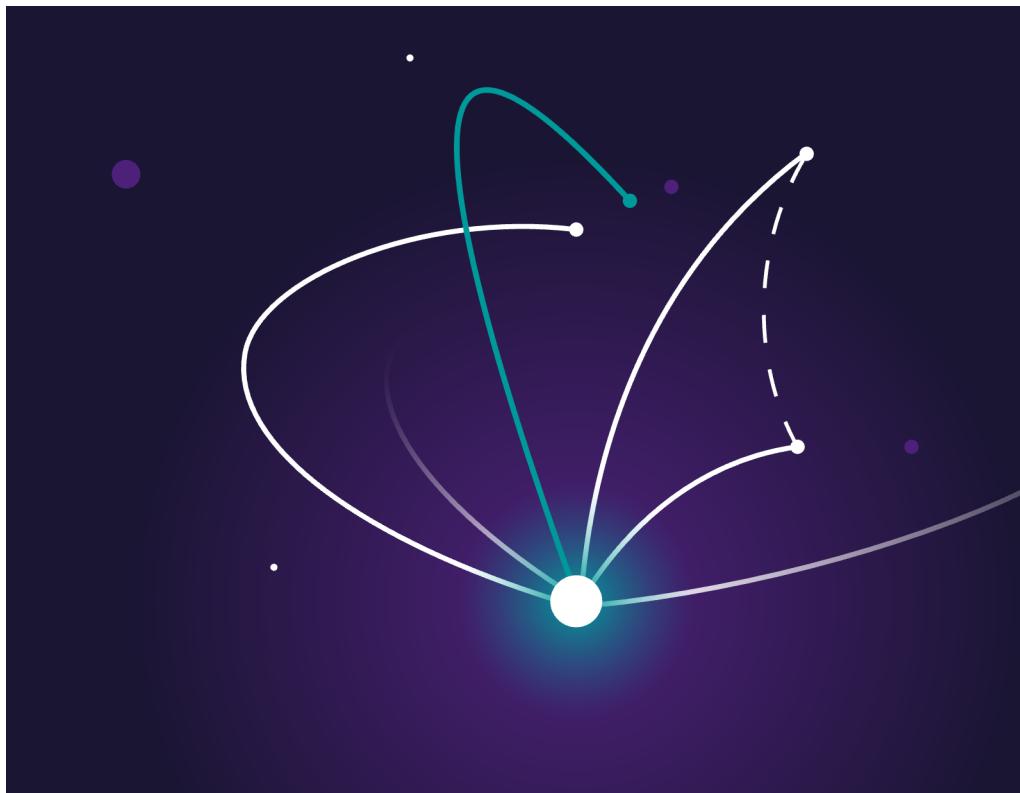
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Thank you.