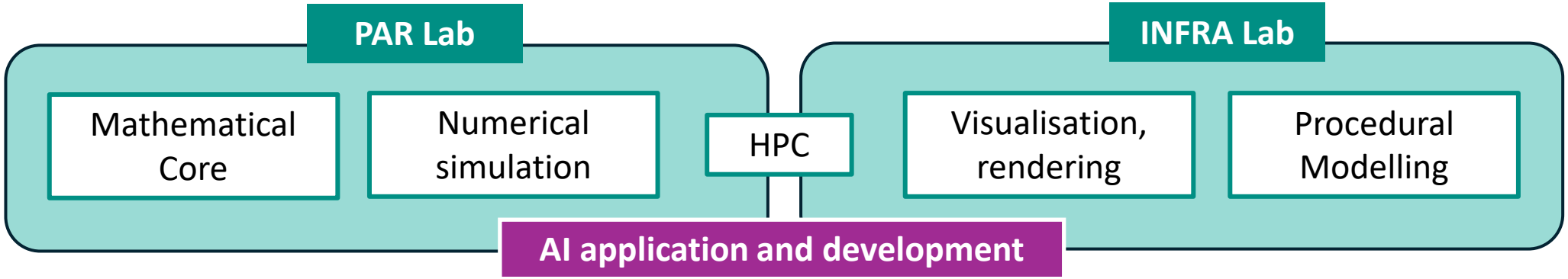
AI Simulations

Tomas Brzobohaty

VSB TECHNICAL UNIVERSITY OF OSTRAVA | IT4INNOVATIONS NATIONAL SUPERCOMPUTING CENTER

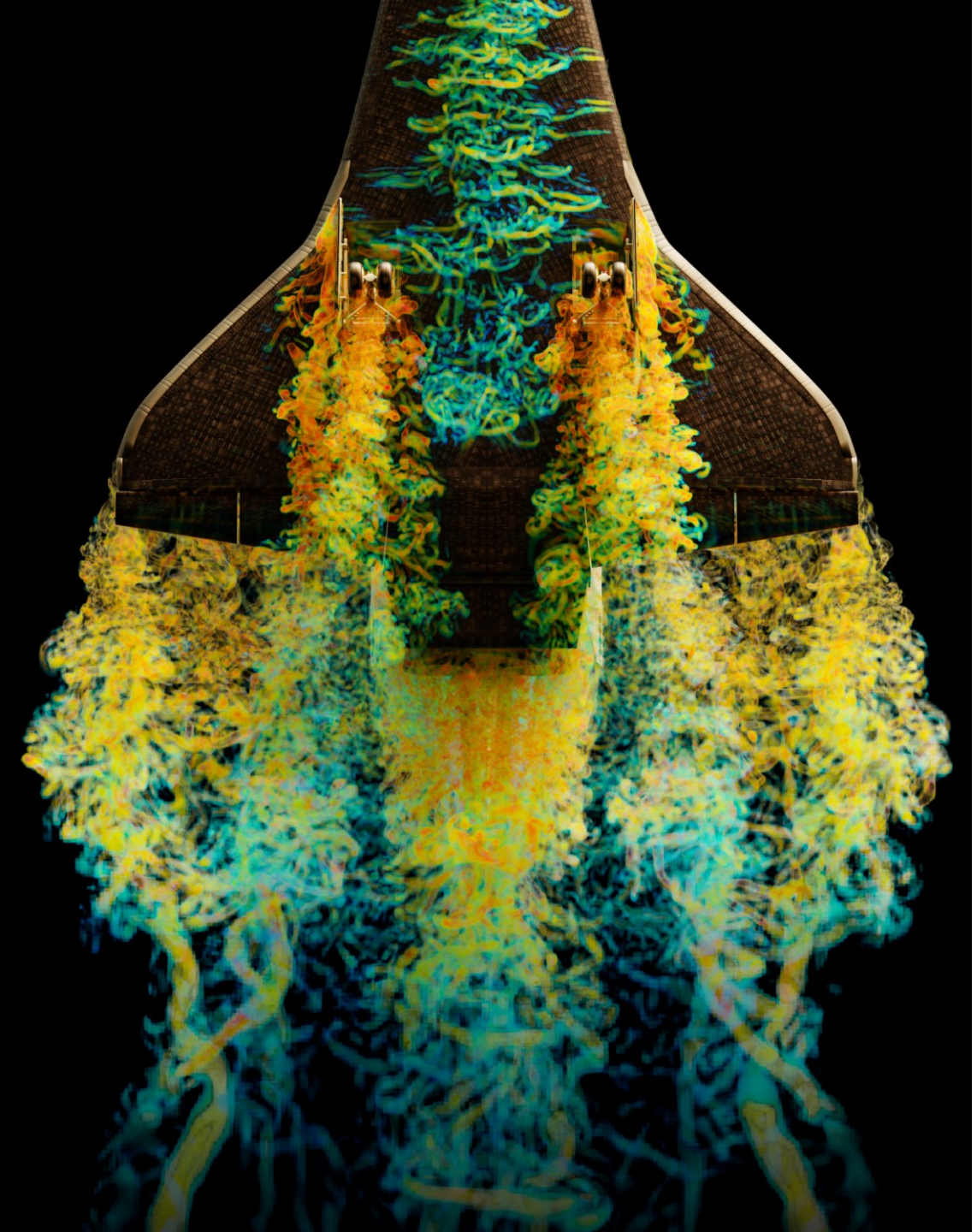
Who We Are

Multidisciplinary research team combining expertise in HPC, AI, numerical simulations, and visualisation.



Our Vision

- Transform how complex engineering and scientific problems are solved by combining HPC, Artificial Intelligence, domain expertise and Advanced Visualisation.



Artificial Intelligence for Unified Representation Observation, Rendering and Advanced Simulation

Main Objectives

- The development of AI-based surrogate models capable of accelerating or replacing classical numerical simulations while maintaining high accuracy and robustness, forming a core computational component for next-generation Digital Twins,
- The creation of high-quality synthetic datasets and visual data to support reproducible research, open collaboration, and the scalable development of Digital Twin frameworks,
- The establishment of a unified framework within IT4Innovations, enabling consistent methodologies for AI-based visual data processing, data handling, model evaluation, visualisation, Digital Twin integration, and seamless coupling with HPC workflows.


KAR0L1NA

Numerical Simulation Expertise

VSB TECHNICAL UNIVERSITY OF OSTRAVA | IT4INNOVATIONS NATIONAL SUPERCOMPUTING CENTER

Structural Mechanic

- modal analysis of constructions with calculation of natural frequencies and vibrational modes
- harmonic analysis, amplitude-frequency response to harmonic and random waveform excitation
- dynamics of rotor systems
- nonlinear harmonic balance response
- linear and nonlinear static analysis of systems with geometric and material nonlinearities, contact problems, plasticity, hyperelasticity, viscoplasticity
- dynamics of complex systems – implicit/explicit dynamics
- evaluation of marginal states related to material cohesion failure
- fatigue analysis

Heat Transfer

- linear and nonlinear heat transfer
- steady states and time-dependent problems
- diffuse radiation, solar radiation
- heat transfer in contact interface
- phase transition/solidification

Flow simulations - CFD

- steady state and time-dependent fluid flow solutions
- incompressible/compressible flow
- turbulent flow - RANS/LES/DES
- moving meshes, mesh morphing
- multiphase flow
- combustion

Sound wave propagation

- aeroacoustics, vibro-acoustics
- harmonic sound wave propagation
- time-dependent simulation of sound wave propagation

Multiphysical problems

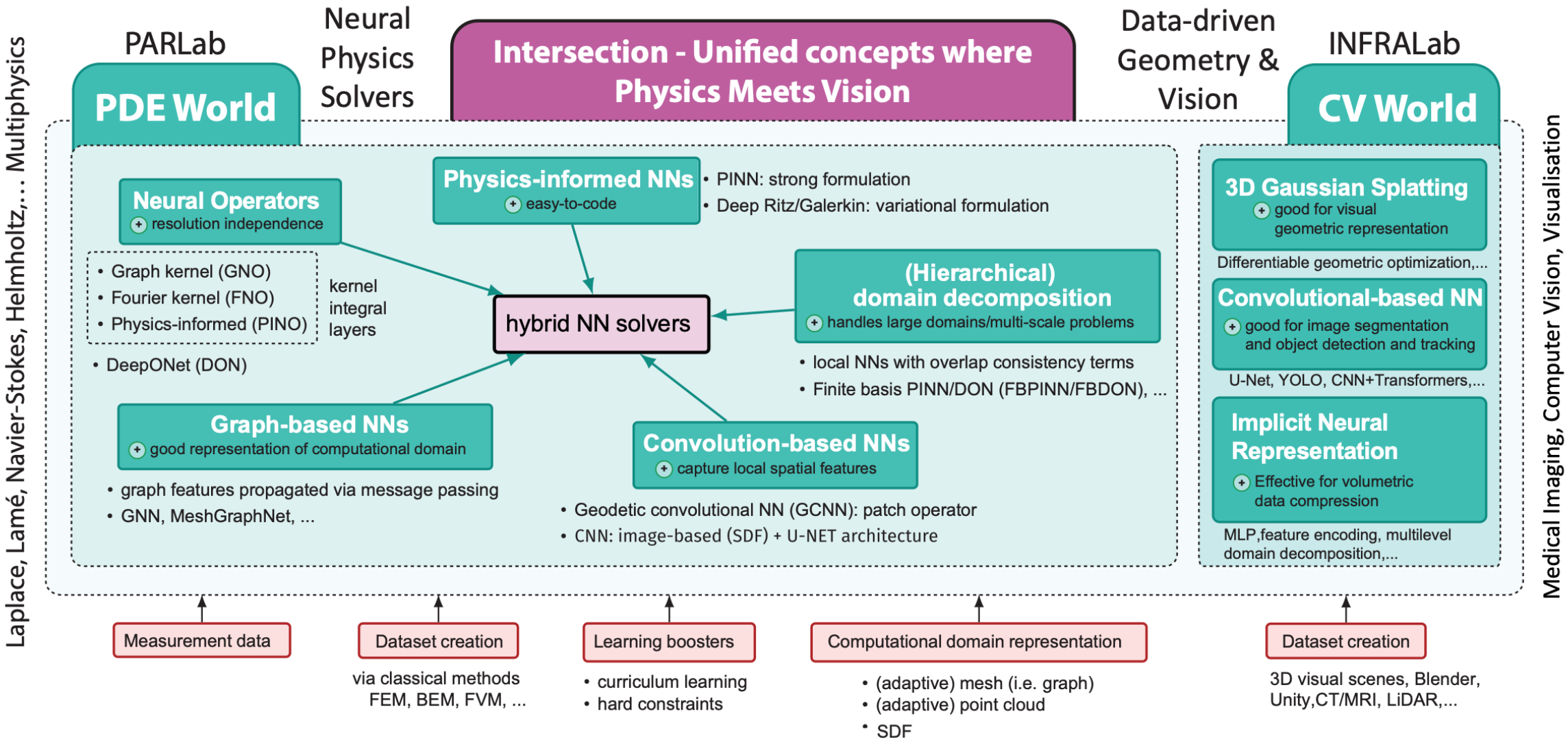
- thermal-structural problems
- CFD–flow, heat, radiation, chemical processes
- FSI – fluid-structure interaction
- …

3D Visualisation

- Procedural Modelling,
- Medical Imaging,
- Path-traced rendering
- General/Scientific Visualisation
- HPC rendering

PDE and CV Worlds

VSB TECHNICAL UNIVERSITY OF OSTRAVA | IT4INNOVATIONS NATIONAL SUPERCOMPUTING CENTER



Ongoing Projects

VSB TECHNICAL UNIVERSITY OF OSTRAVA | IT4INNOVATIONS NATIONAL SUPERCOMPUTING CENTER

These projects combine methodological innovations in HPC and artificial intelligence with close collaboration with industrial partners across aerospace, energy, materials, healthcare, and advanced manufacturing.

InnovFite SLOVAKIA

Digital twins of factories & buildings, energy efficiency

Falcon

AI acceleration
of fluid–structure interaction simulations

FORTISSIMO PLUS

AI-based surrogate model for aircraft flap optimisation

FuturEMold TRANSFORMS MANUFACTURING

AI models for incremental sheet forming

SEANERGYS ENERGY EFFICIENT EXASCALE

Developing of AI models designed to predict HPC cluster behavior

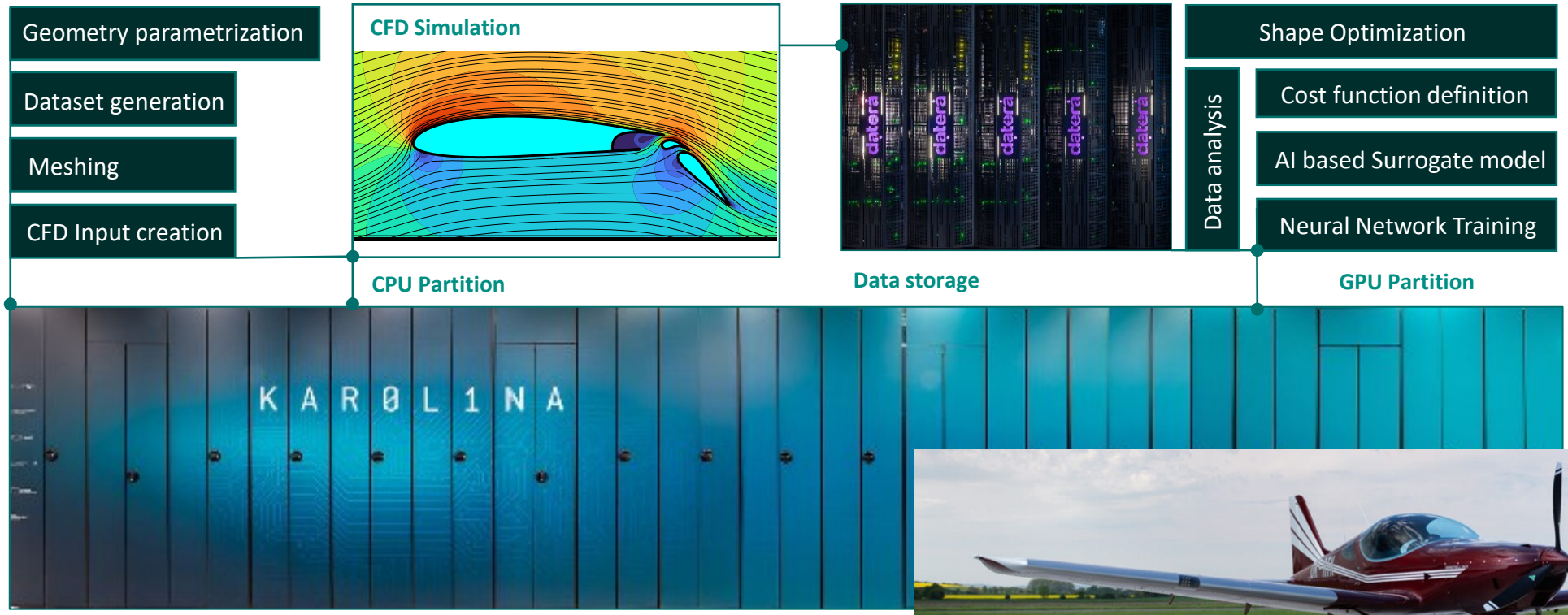
Project	Focus
TAČR TREND – Sigma a.s.	AI optimisation of vertical pump design and manufacturing
TAČR Sigma – VŠB	AI for interactive shape optimisation and digital twins
TAČR TREND – Optaglio	AI and image hashing for secure holographic verification
TAČR TREND – Timotec	AI for real-time image analysis in pharma isolators
OP TAK – Misterine	AI-based medical image segmentation
TAČR TWIST – Activair	AI for atomic force microscopy data processing
Zeus	Digital twin of hydrogen production and storage
LERCO	AI segmentation for biomedical imaging
REFRESH	AI for data compression, materials research, hydrogen systems

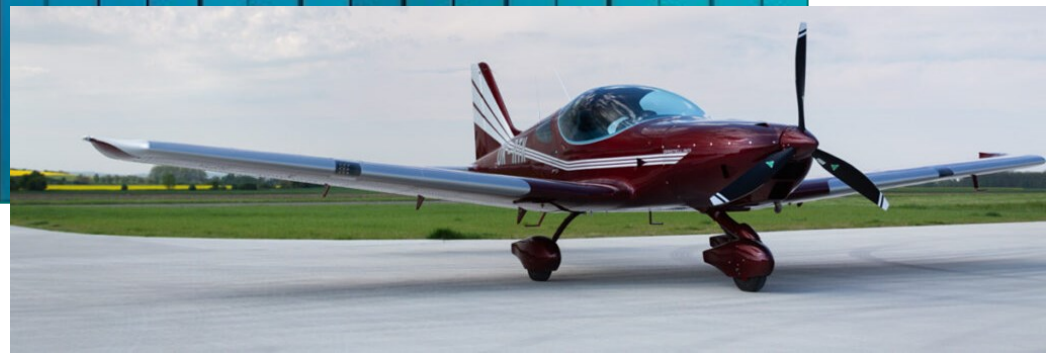
Fortissimo+

VSB TECHNICAL UNIVERSITY OF OSTRAVA | IT4INNOVATIONS NATIONAL SUPERCOMPUTING CENTER

Automatized HPC Workflow for CFD Shape Optimization

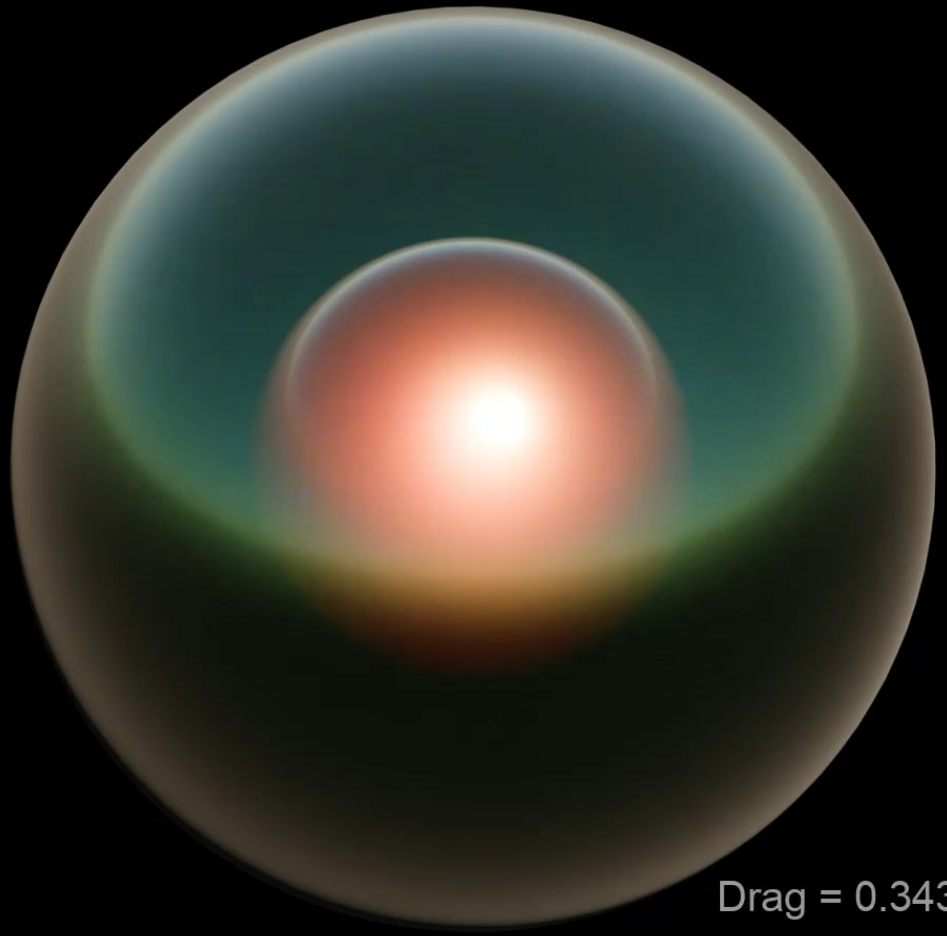
Cooperation with the aircraft manufacturer on the shape optimisation of the flap system



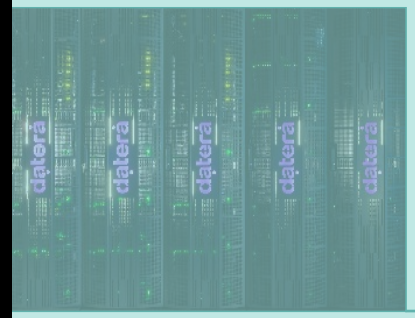


Simple parametrised input MLP, GCNN, SDF-UNET, Neural Operators

Neural Network for Real Time Aerodynamic Shape Optimization



shape optimisation of the flap system



Shape Optimization

Data analysis

Cost function definition

AI based Surrogate model

Neural Network Training

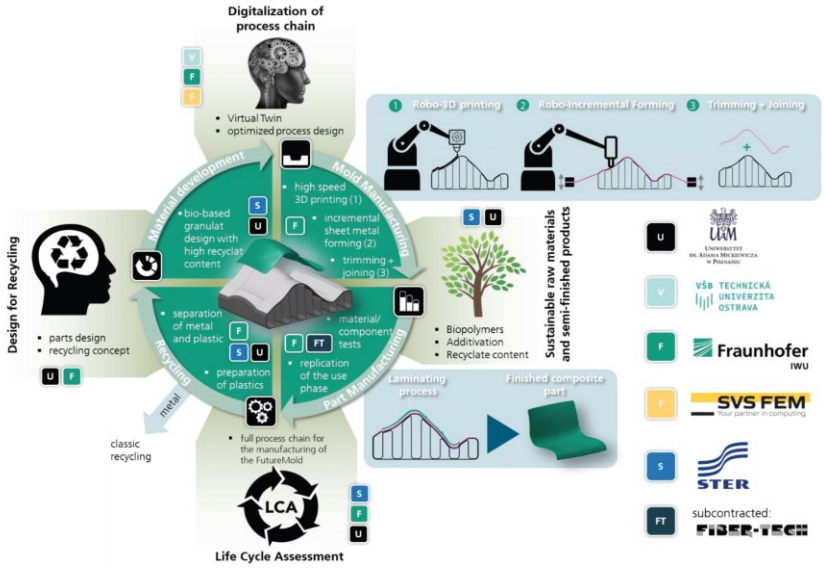
Data storage

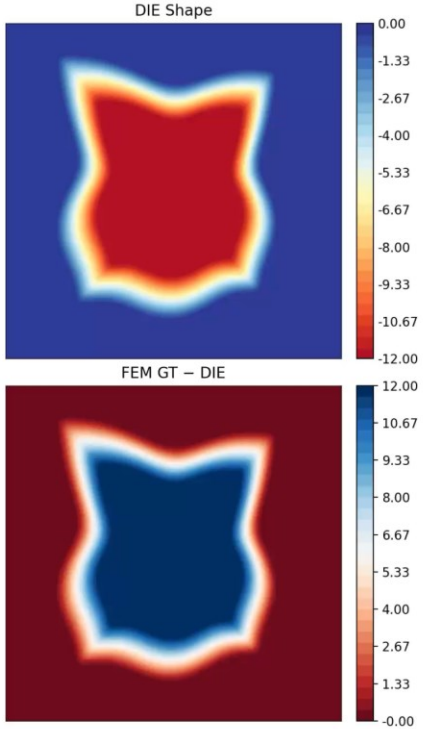
GPU Partition

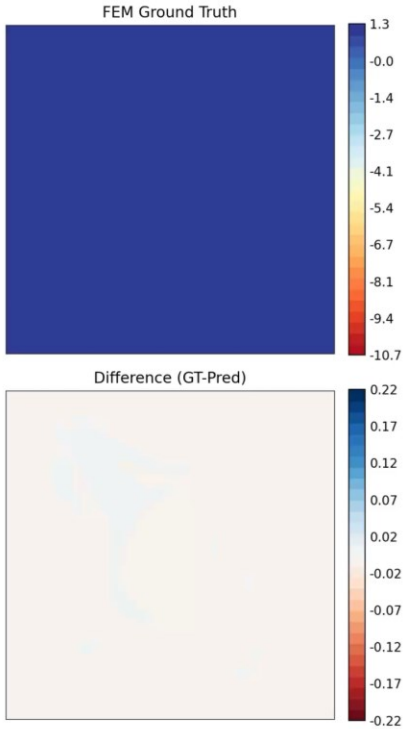
FutureMold

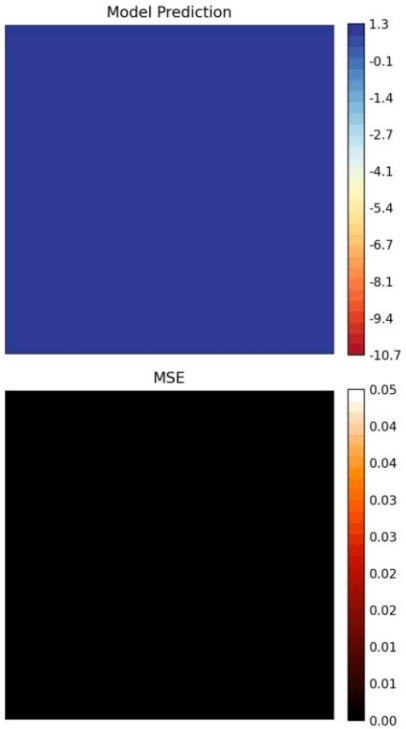
Digitalisation of the ISF process

- We develop an FEM-base surrogate with a multiple tool strategy and accelerated physics, reducing FEM to tens of hrs.
- Allow us to create thousands of simulations on an HPC scale - a synthetic dataset for an AI-based model
- Developing a neural network-based surrogate for the ISF process
- Real-time optimisation of die shape for minimisation of springback










```
Model: Transformer Cross-Attention Unet

Variant: ISF - Every 1 Timestep

Sample: 720

  Forming Strategy:  Z constant
  Number of Tools:   1
  Tool Radius        3.00 mm
  Trajectory length: 8.13 m

Evaluation:
  GPUs:       1
  batch_size: 1
  samples:    3377
  total time: 96.998 s
  avg/sample: 28.72 ms
  avg/batch:  28.72 ms
  throughput: 34.8 samples/s

Timestep: 1/3377

Local metrics:
  RMSE   2.509e-03
  MSE    6.295e-06
  MAE    2.213e-03
  MaxAbs 3.670e-02
  RelL2  2.509e-03
  PSNR_L -64.18 dB
  SSIM_L 0.0000
  PSNR_G 73.61 dB
  SSIM_G 1.0000

Global metrics:
  RMSE   2.268e-02
  MSE    5.144e-04
  MAE    1.397e-02
  MaxAbs 2.220e-01
  RelL2  8.482e-03
```

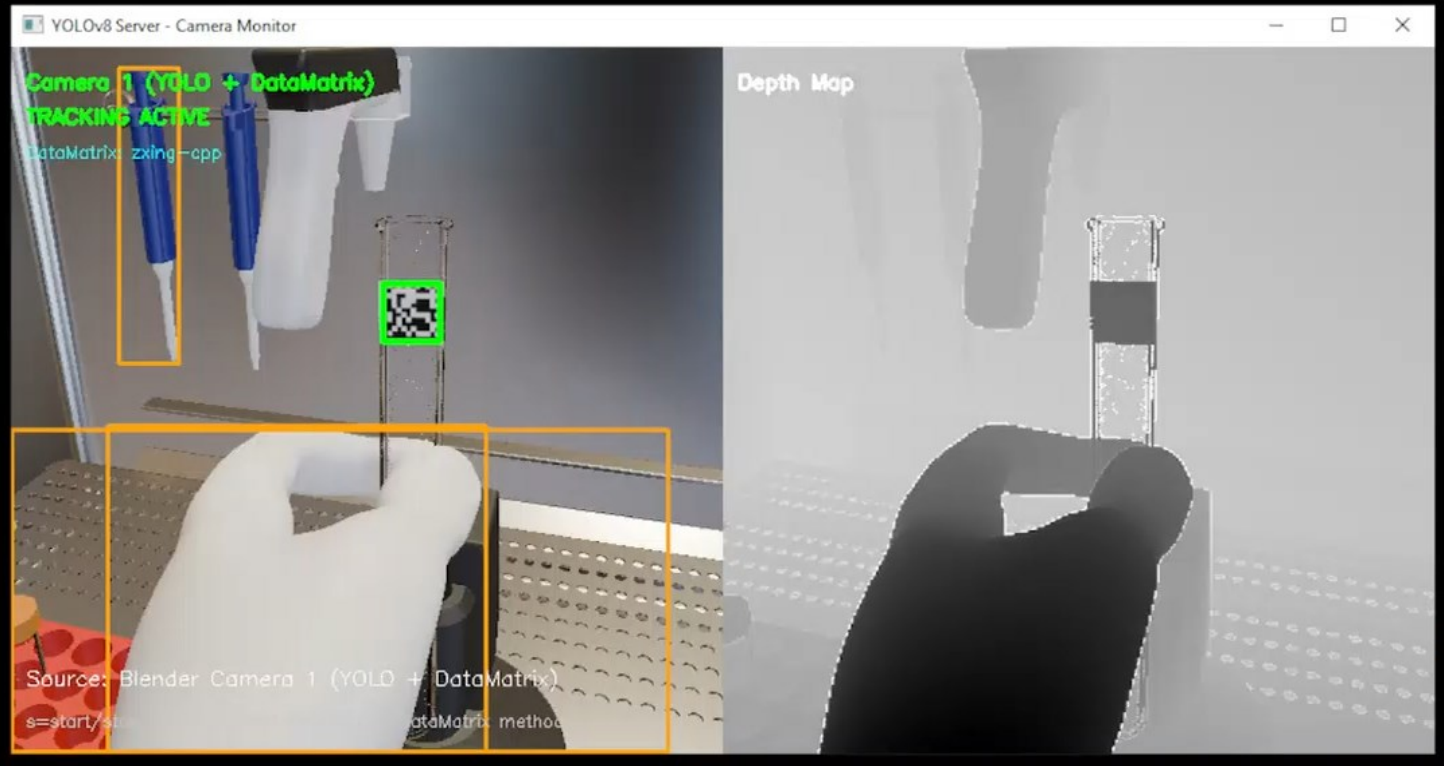
Falcon

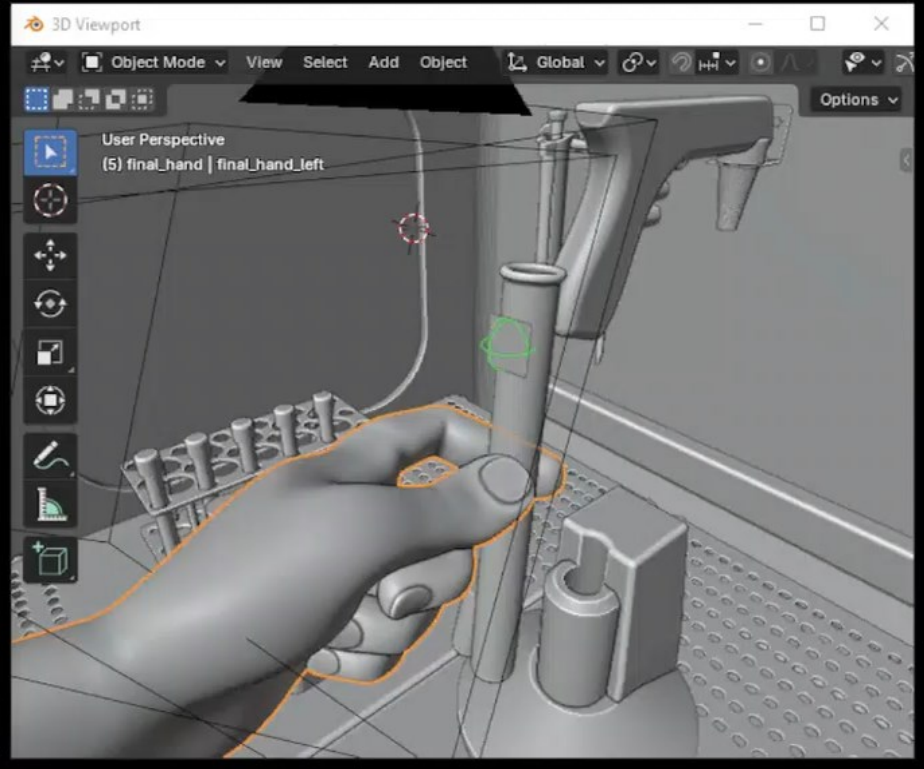
Foreseeing the next generation of Aircraft

HYBRID APPROACH USING LATTICE-BOLTZMANN, EXPERIMENTS AND MODELLING TO OPTIMIZE FLUID/STRUCTURE INTERACTIONS

15	6	4	01/01/24 31/12/27	4.8M€
PARTNERS	COUNTRIES	YEARS		BUDGET

VSB TECHNICAL UNIVERSITY OF OSTRAVA | IT4INNOVATIONS NATIONAL SUPERCOMPUTING CENTER


YOLOv8 Server - Camera Monitor
Camera 1 (YOLO + DataMatrix)
TRACKING ACTIVE
DataMatrix: zxing-cpp
Depth Map
Source: Blender Camera 1 (YOLO + DataMatrix)


3D Viewport
Object Mode
View
Select
Add
Object
Global
Options
User Perspective
(5) final_hand | final_hand_left

What We Seek / Offer

- **Methodological partners** who wish to engage in the development of new AI and hybrid algorithms for fast simulations of physical processes.

- **Application partners** who have their own technologies/data but do not yet use AI, and who can benefit from its integration or further development.

Vision and goals within the university collaboration

- Establish a ”competence centre” in the field of AI for simulations within VŠB.
- Develop methods in surrogate modelling, physics-informed neural networks, and hybrid AI–physics approaches.
- Support interdisciplinary collaboration across the university by connecting application domains with methodological AI development.

Thanks to our database of national and international contacts, we can efficiently prepare and submit projects in response to national and international calls.

VSB TECHNICAL UNIVERSITY OF OSTRAVA | IT4INNOVATIONS NATIONAL SUPERCOMPUTING CENTER

tomas.brzobohaty@vsb.cz