

# AutoHood3D: A Multi-Modal Benchmark for Automotive Hood Design and Fluid–Structure Interaction



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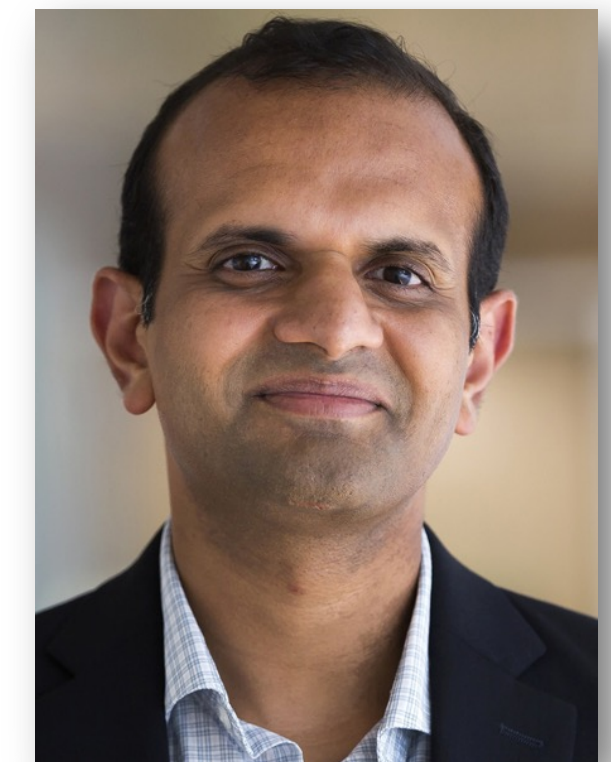
Harish Jai Ganesh



Maryam Akram



Wanjiao Liu

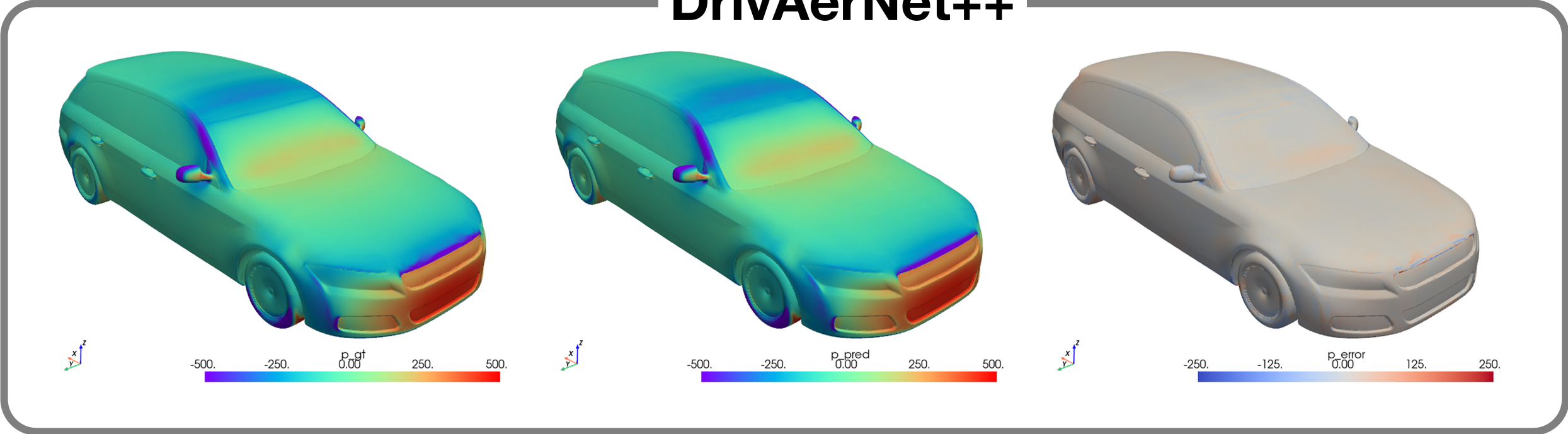


Venkat Raman

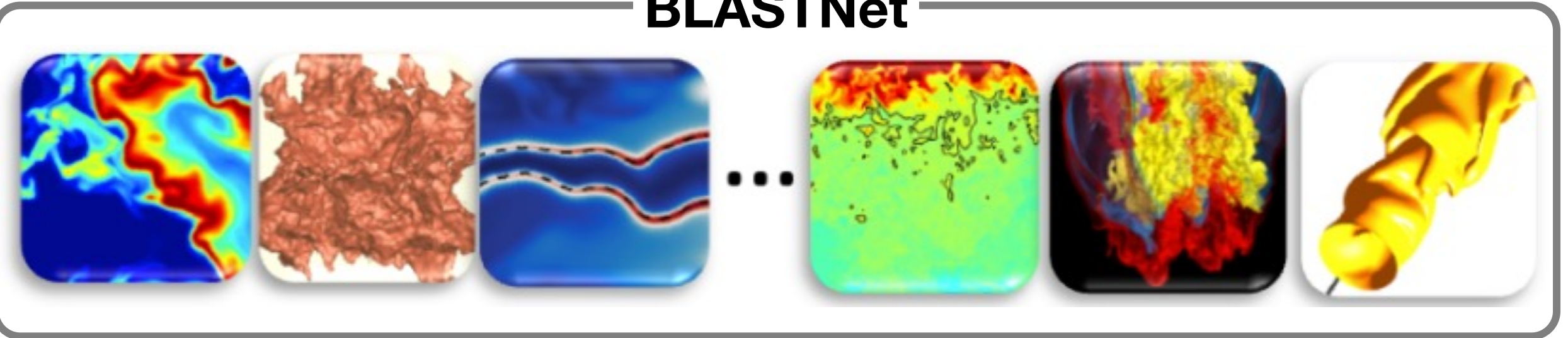


# Existing Physics Datasets

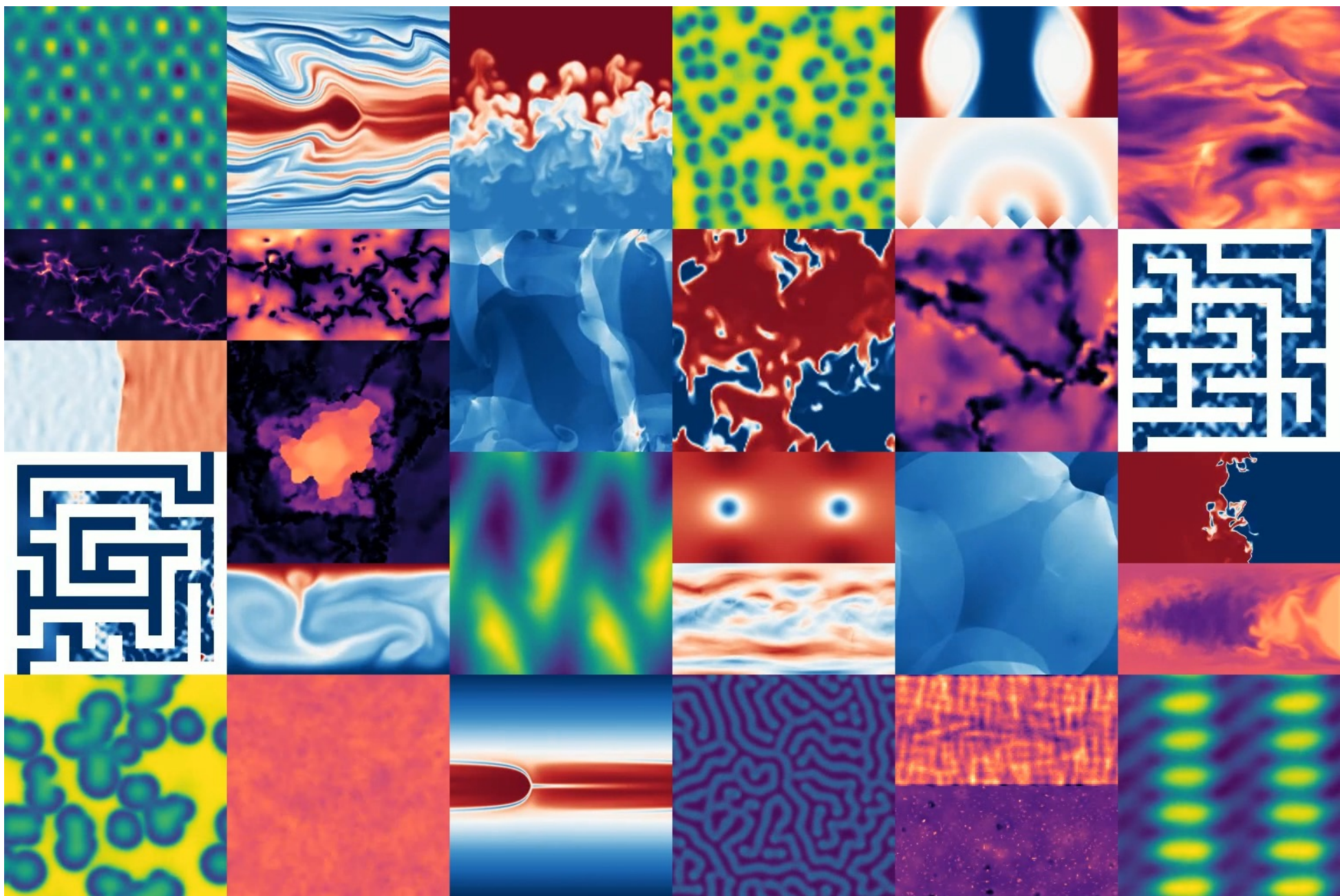
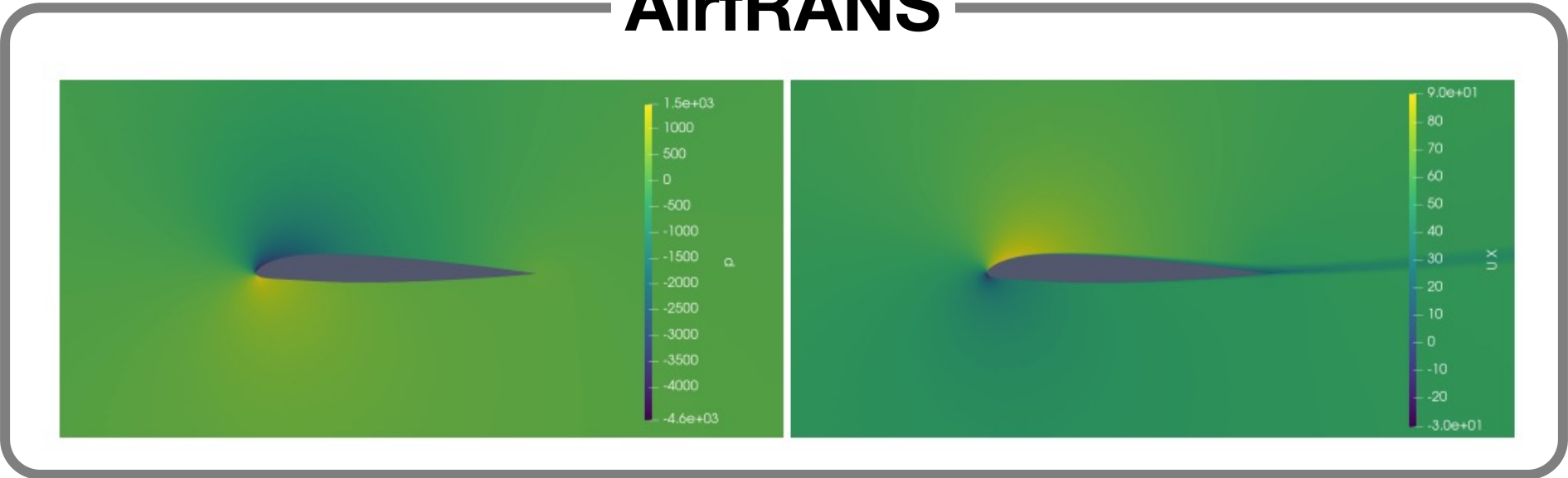
DrivAerNet++



BLASTNet

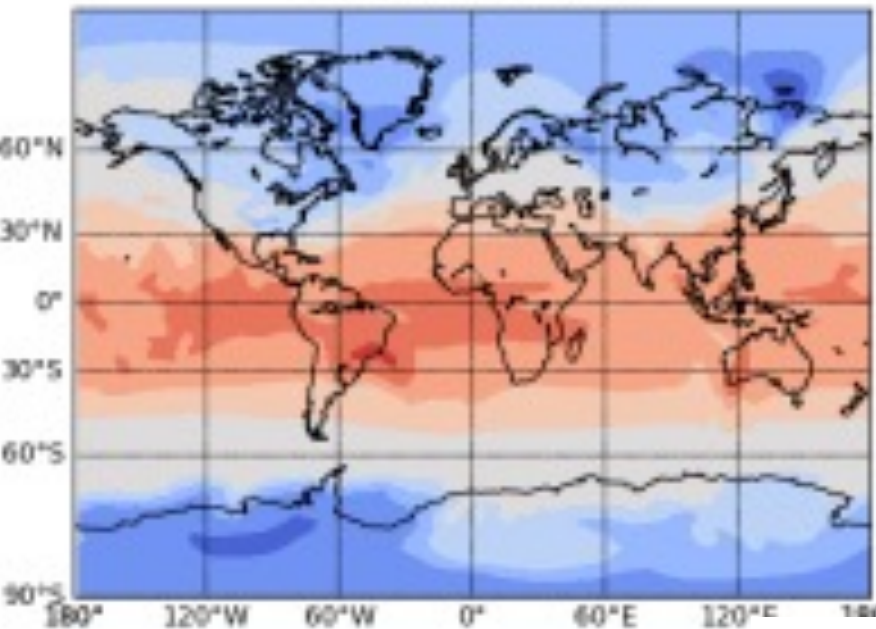


AirfRANS

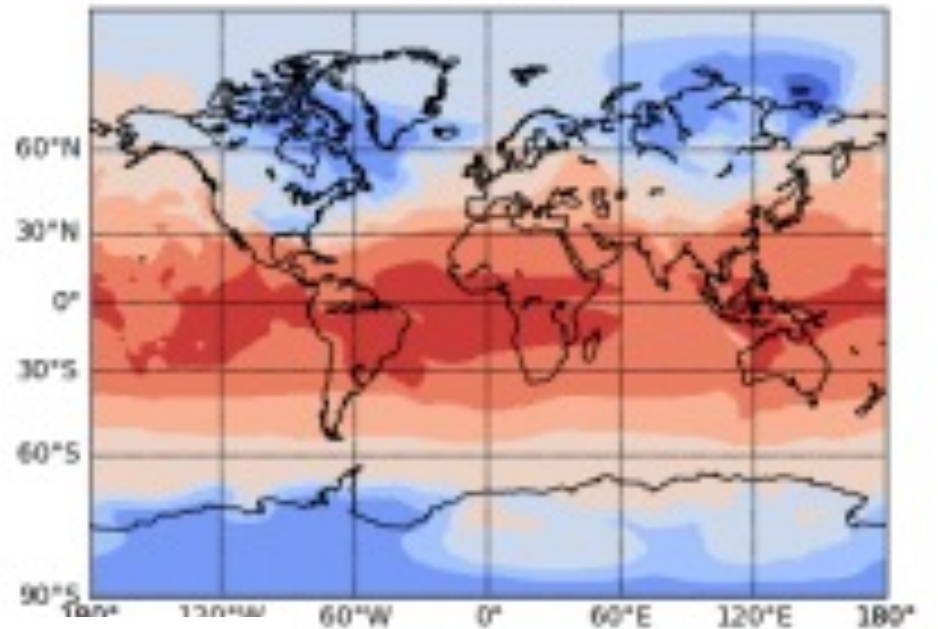


The Well

MPI-ESM1-2HR



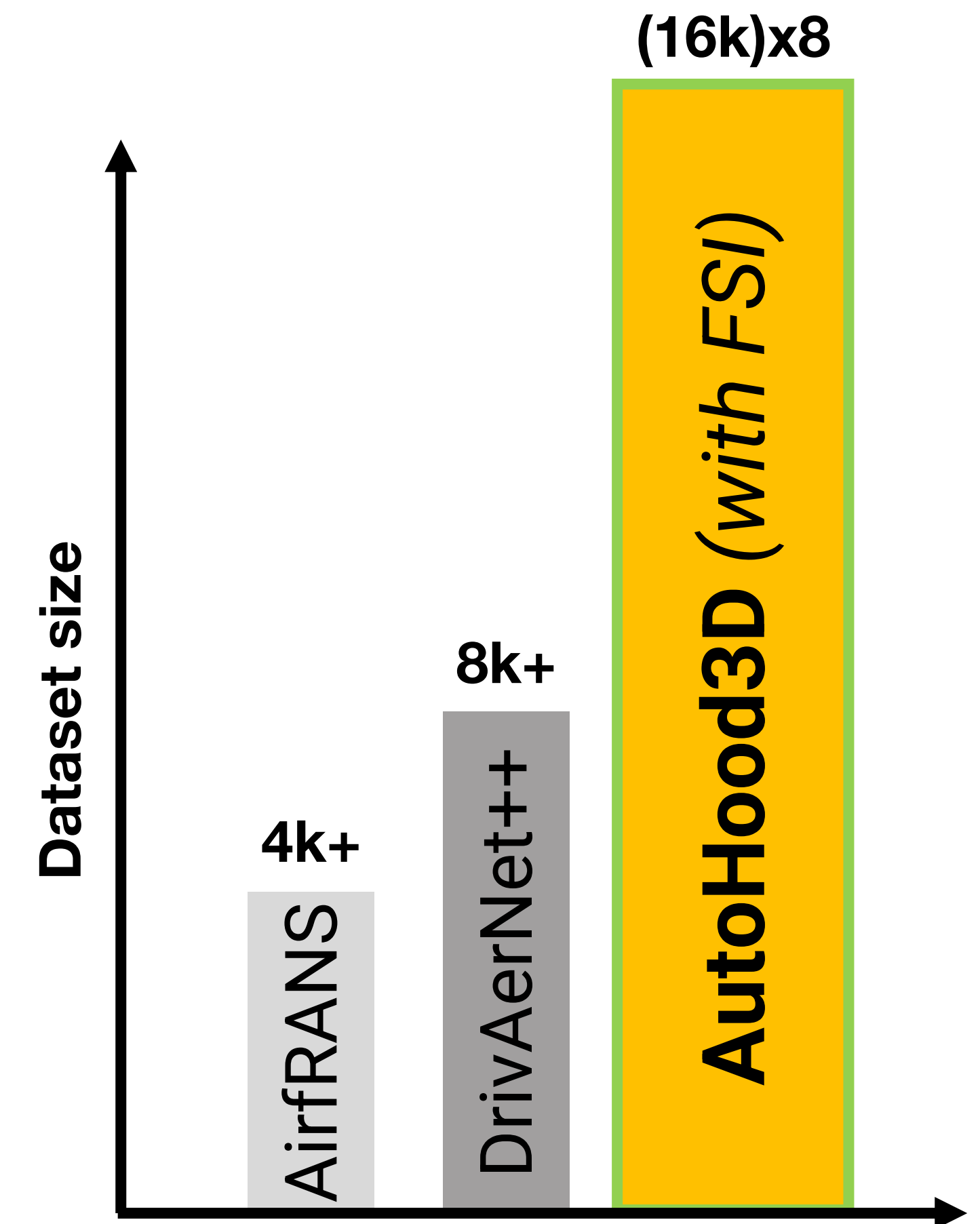
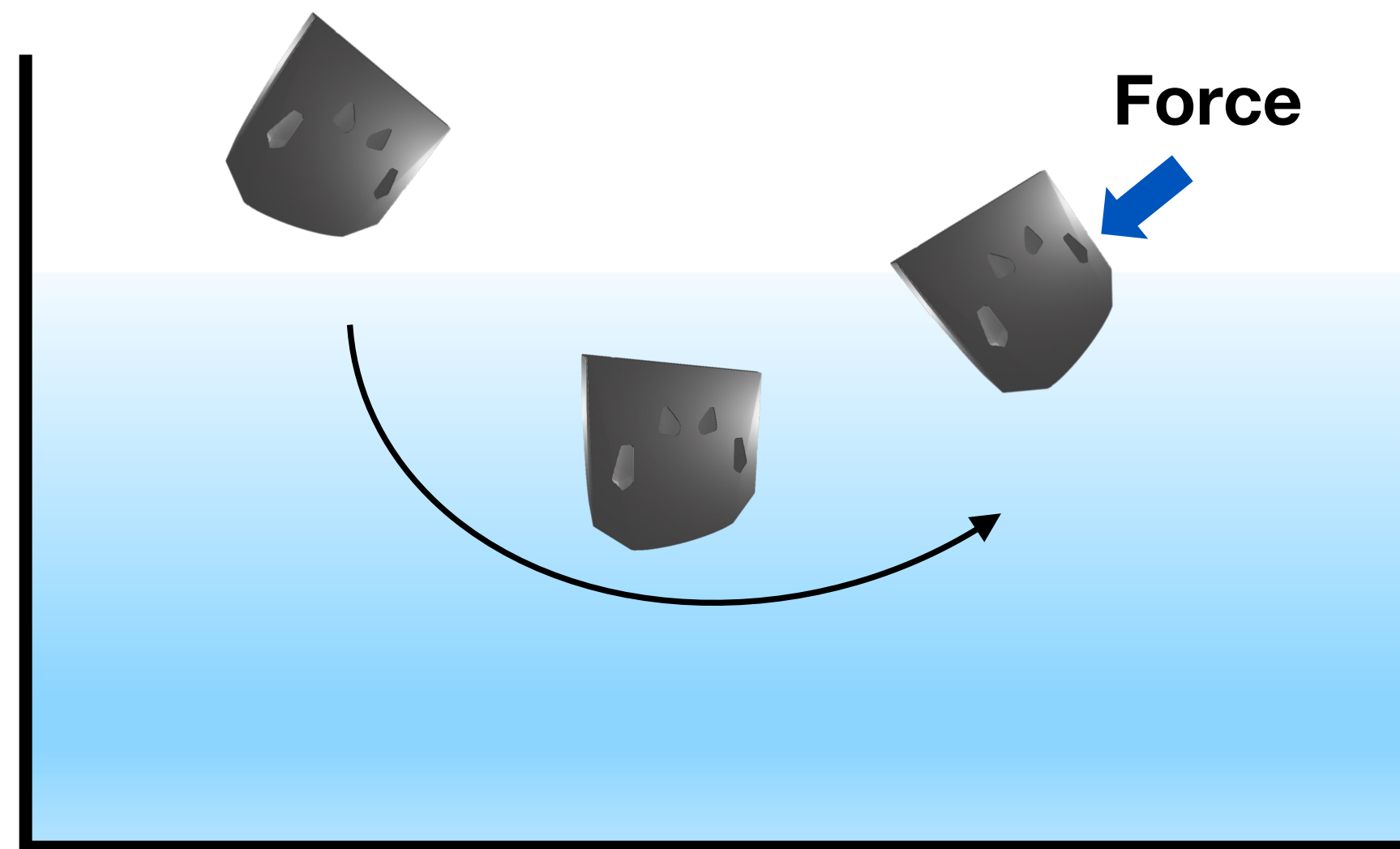
TaiESM1



ClimateSet



- ❖ Extensive geometric and solution data but **lack generative workflows** for creating new variants
- ❖ Some datasets provide generative workflows but are **2D domains with idealities**
- ❖ 3D datasets have **limited design variations**
- ❖ Datasets for **Fluid-Structure Interaction (FSI)** missing



## Dataset Specs

- 16000+ parametrized hood datapoints
- 16000 x 8 temporal solutions for each impact scenario
- 1750+ engineered curves for designing new variants
- 2500+ GenAI Text-to-CAD pairs

## Data Generation

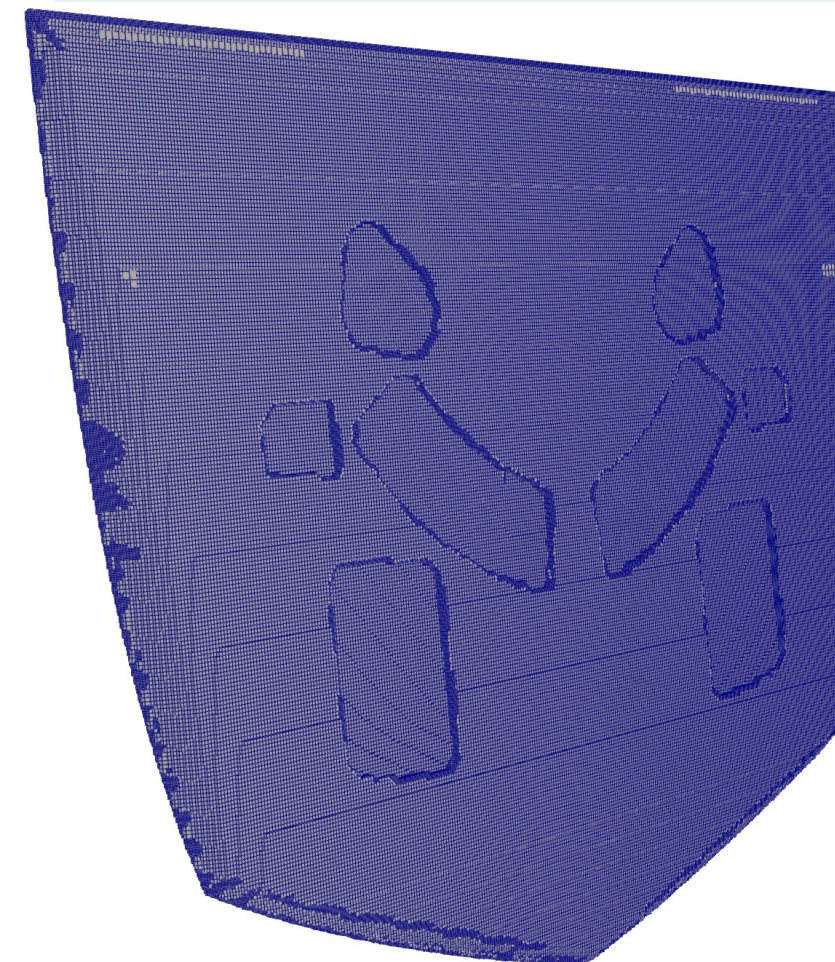
- Co-Simulation workflow with CFD and FEA solvers
- Solvers are fully customizable
- Additional physics for different force scenarios possible
- Curate new 3D FSI datasets



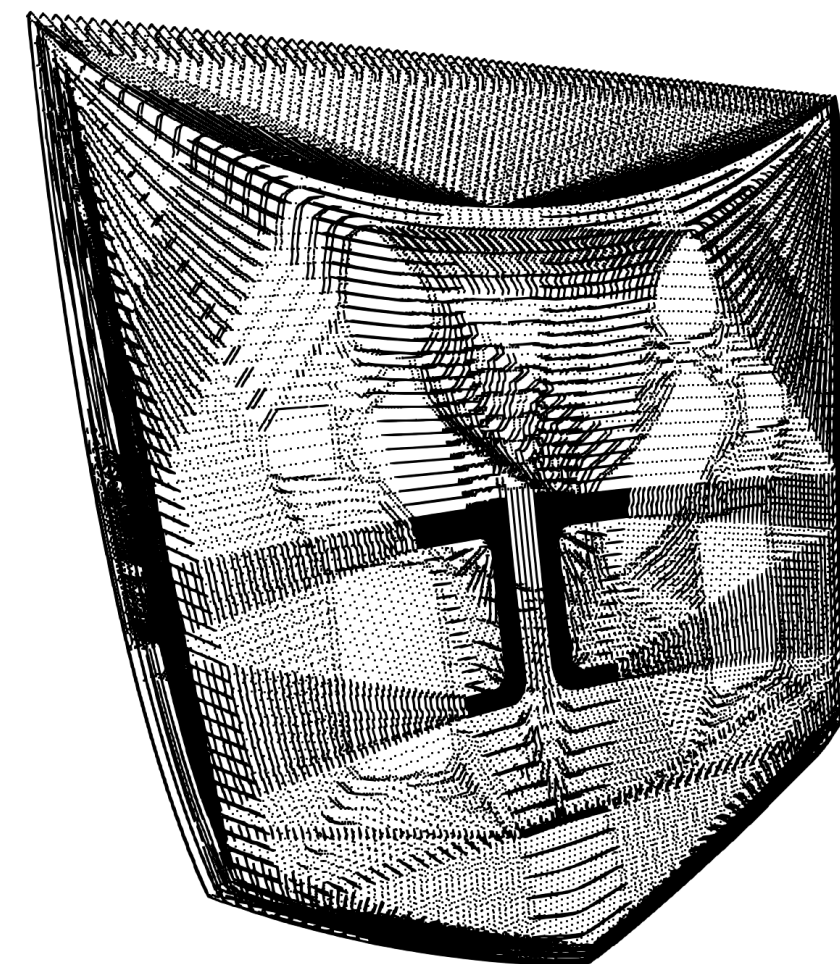
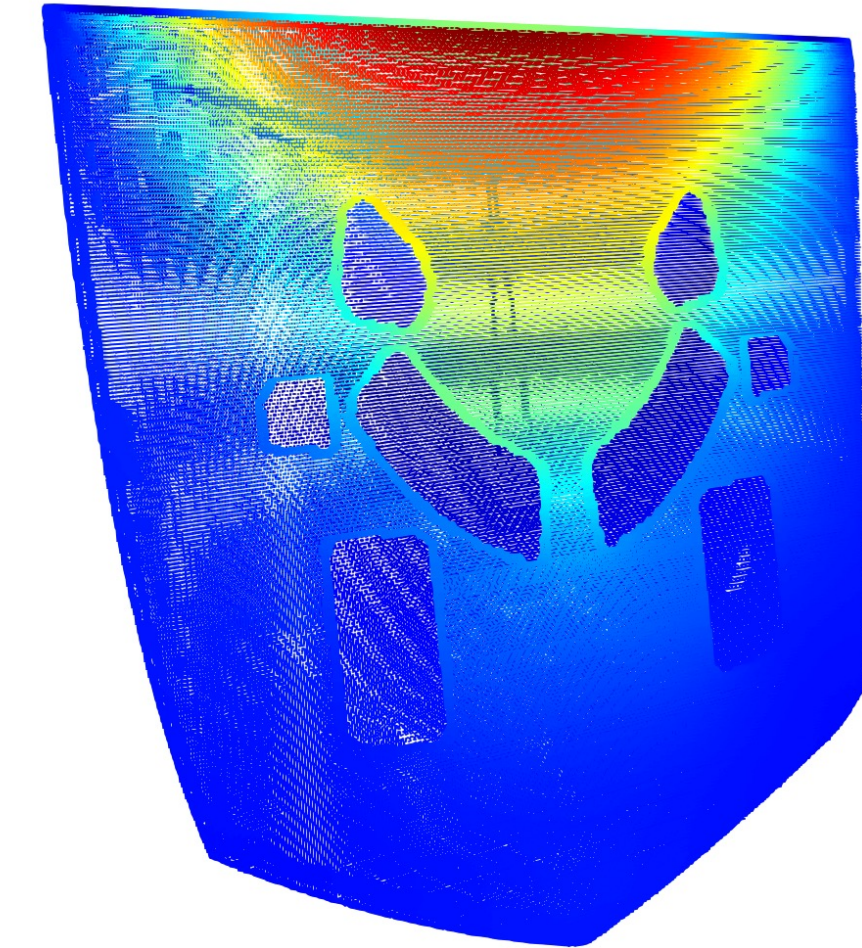
3D Mesh (STL)



Mesh – Solid (VTP)

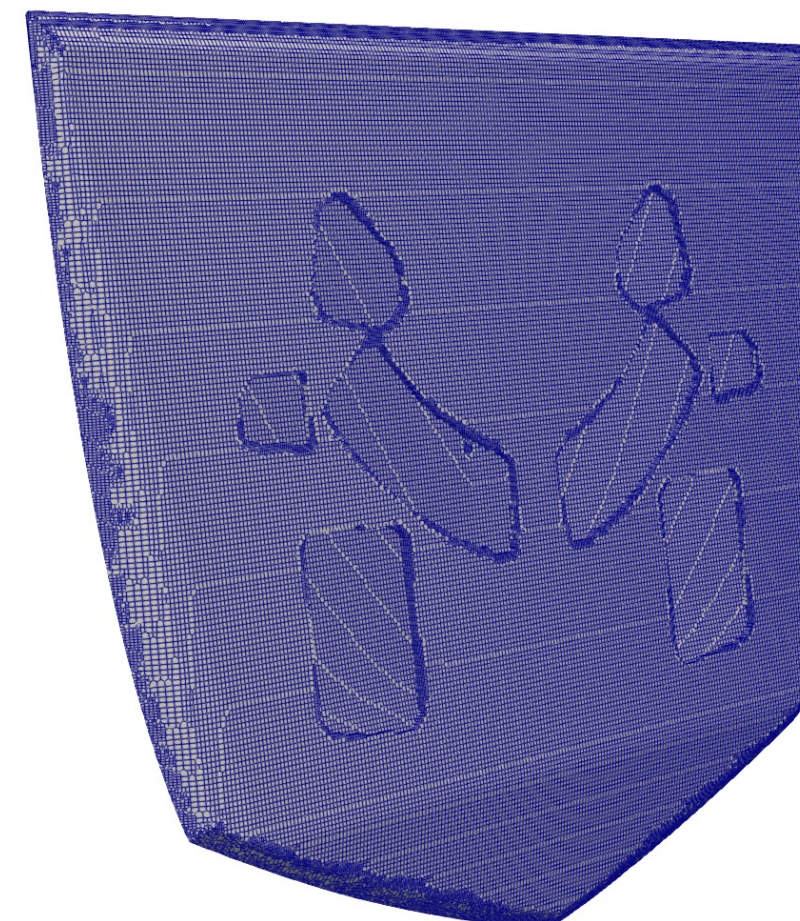


Surface Field Displacement

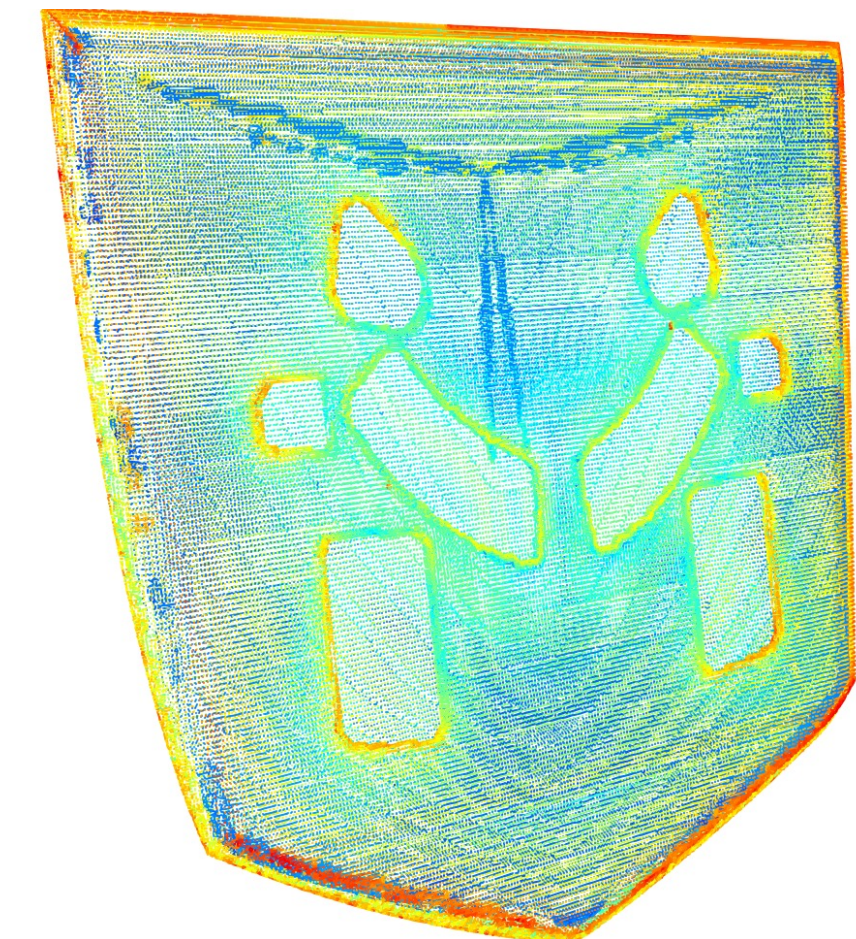


Point Cloud

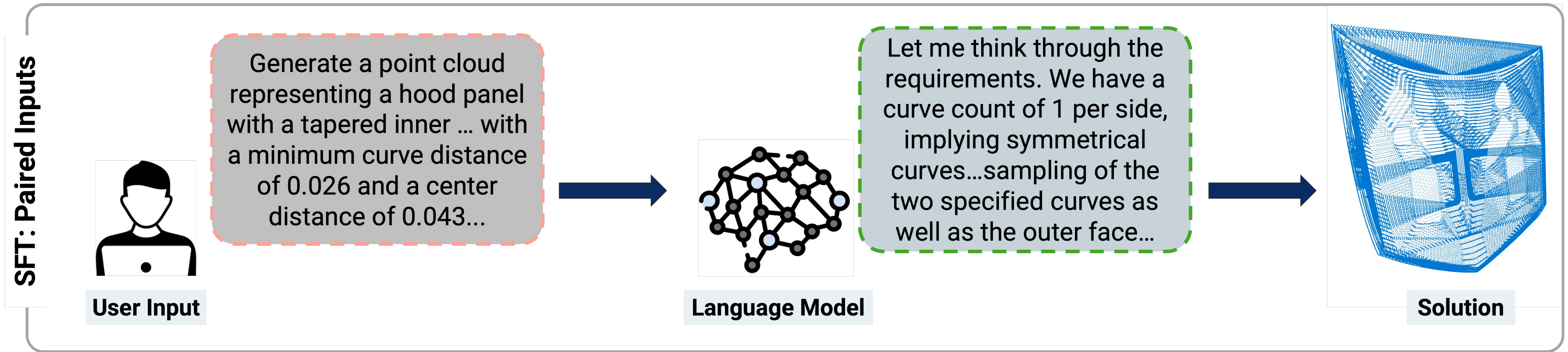
Mesh – Fluid (VTP)



Surface Field Pressure Gradient

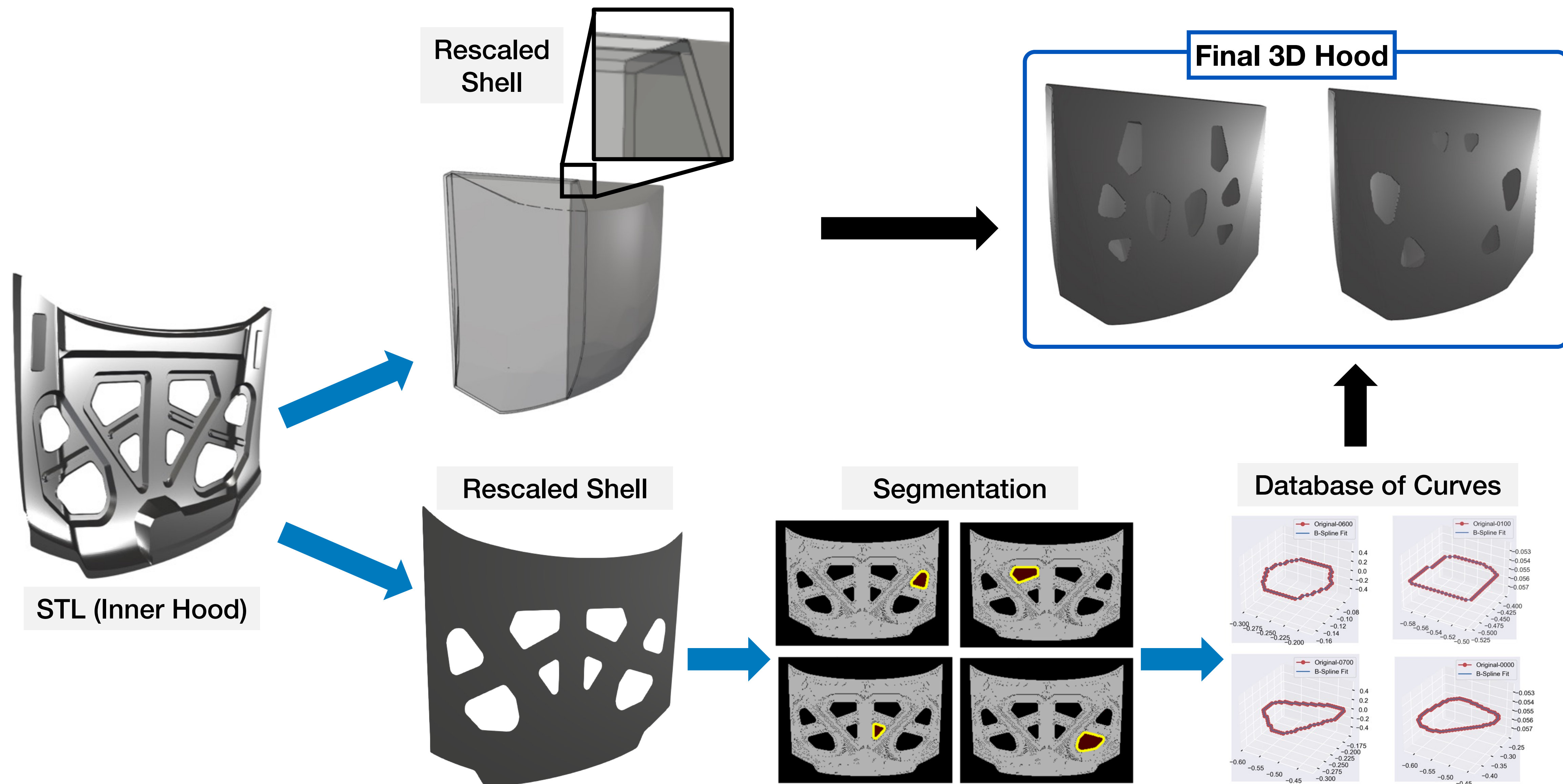






- ❖ Text-based paired corpus of 2587 hood geometries
- ❖ Gemma3-27B VLLM for annotation
- ❖ Additional reasoning traces included
- ❖ Prompts included to create new datasets

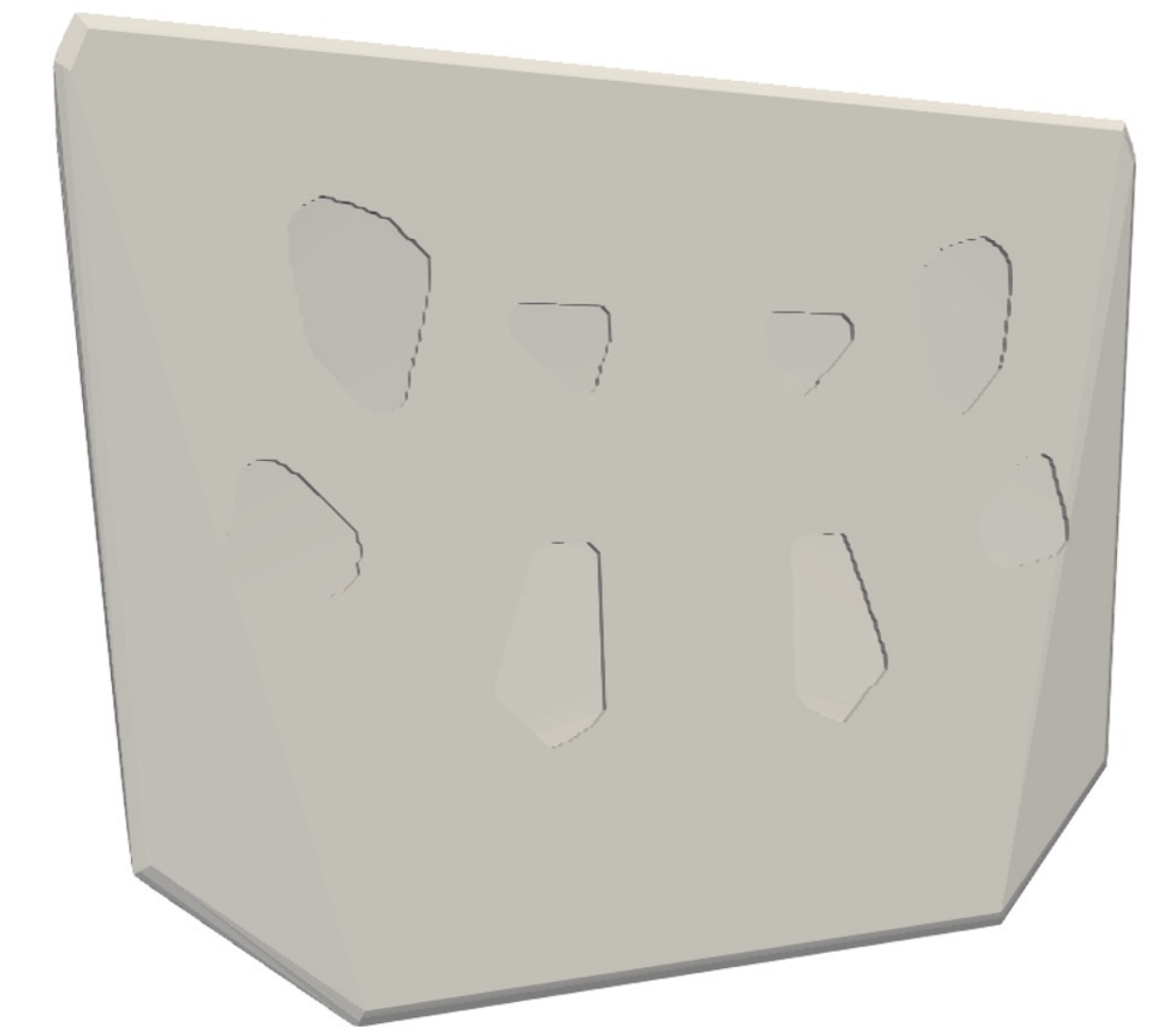
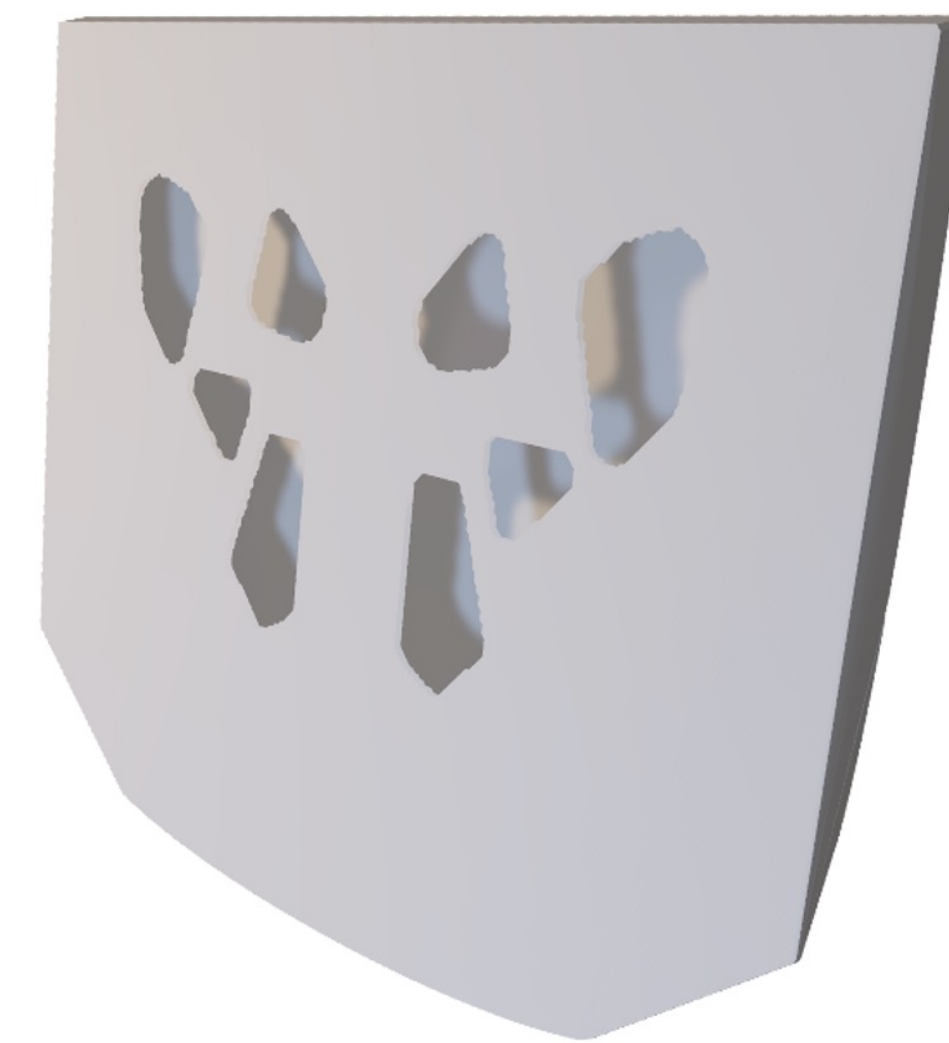
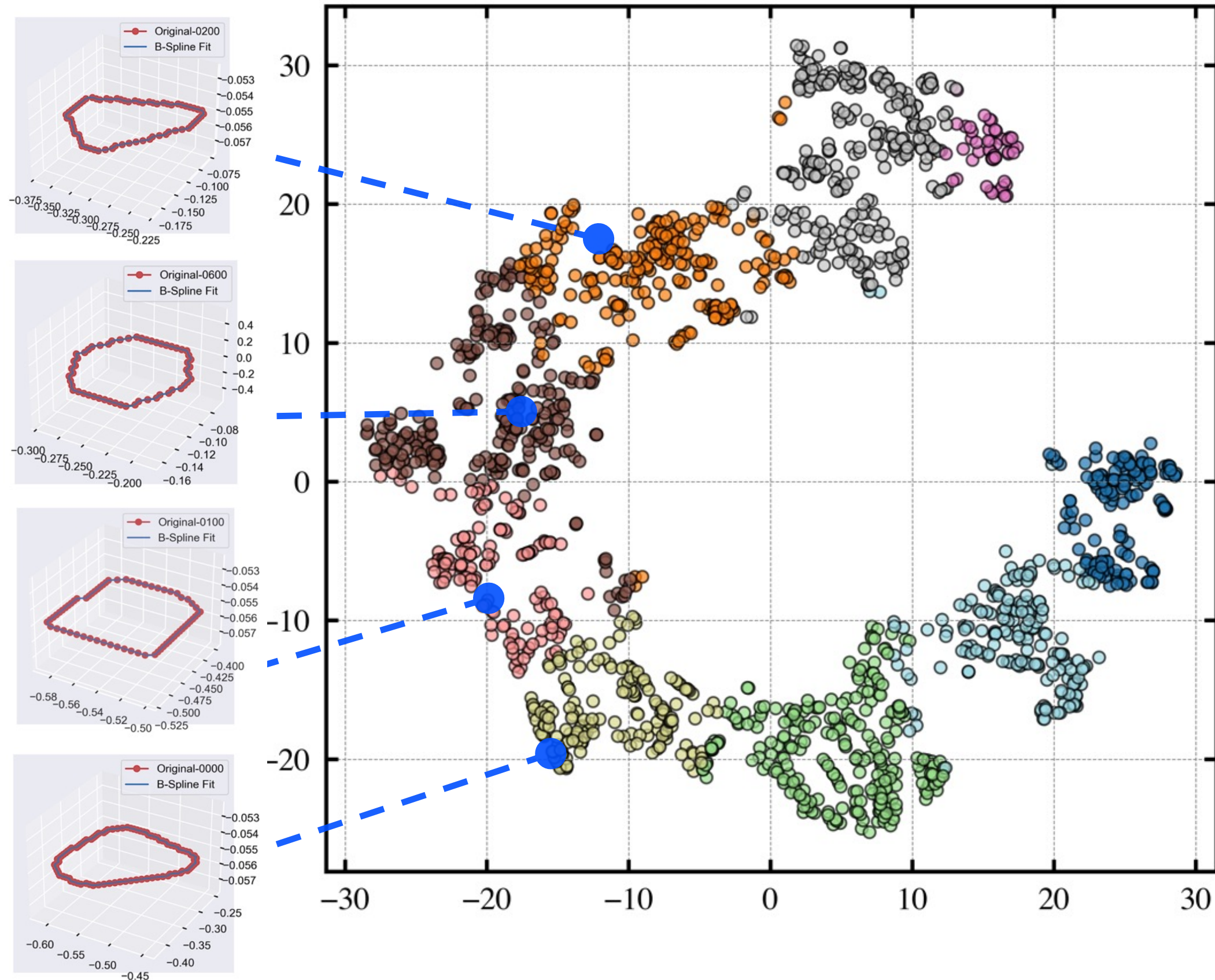






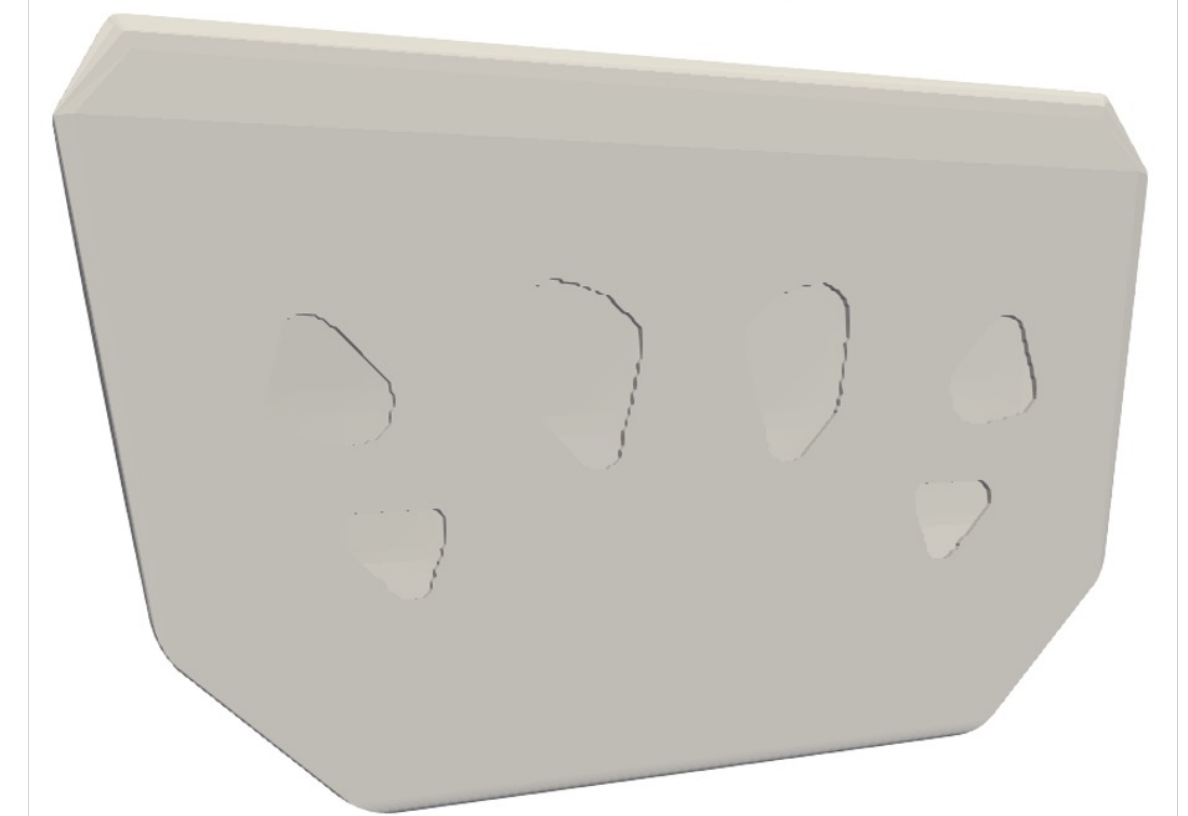
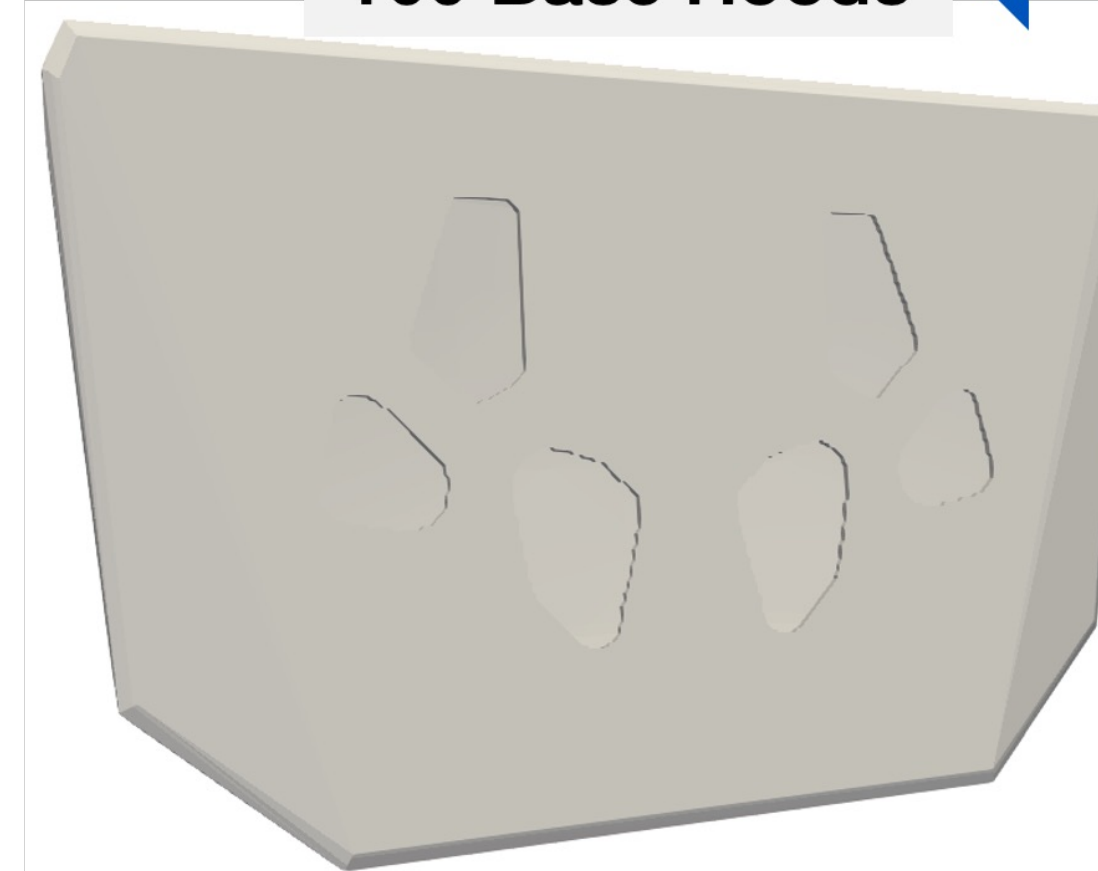
## Curve Features

## t-SNE Plot for Clusters

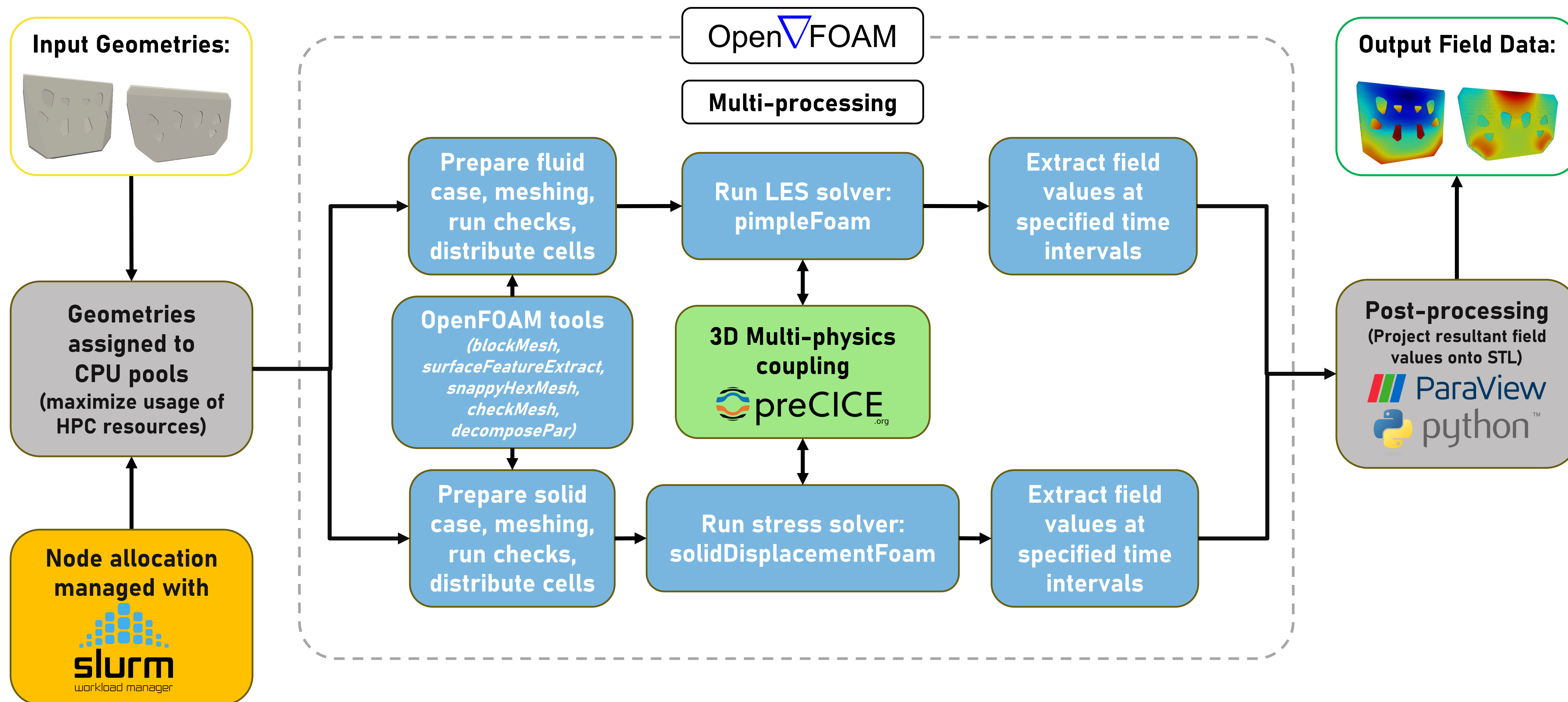


100 Base Hoods

1750 Curve Cutouts

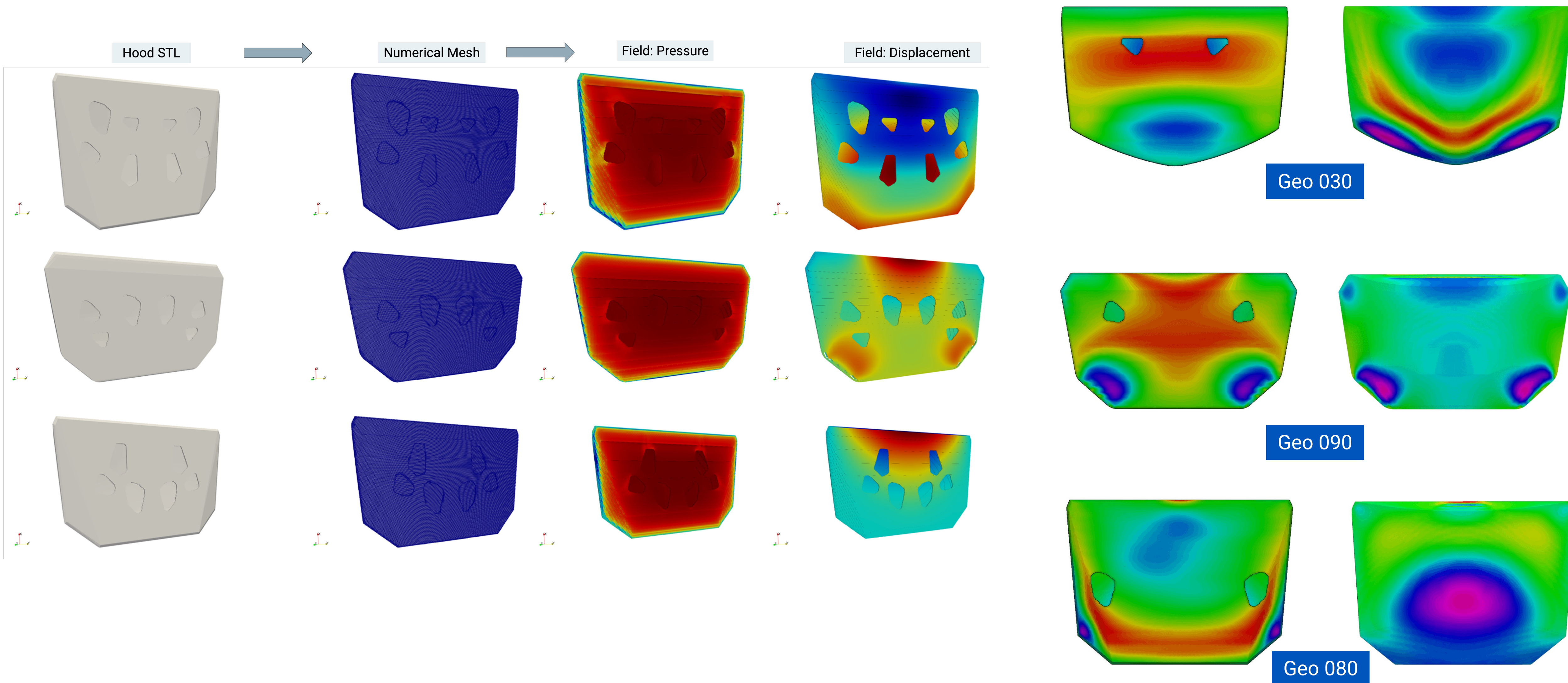








# Surface Fields and Features





## ❖ Five Models:

- PointGNNCon
- GraphUNet
- GraphSAGE
- PointNet
- MLP

### In-Distribution Test

Model	$U_x$ ( $\times 10^{-2}$ )	$U_y$ ( $\times 10^{-2}$ )	$U_z$ ( $\times 10^{-2}$ )	$p$ ( $\times 10^{-2}$ )	$D_x$ ( $\times 10^{-2}$ )	$D_y$ ( $\times 10^{-2}$ )	$D_z$ ( $\times 10^{-2}$ )
MLP	<b>0.25</b>	0.27	<b>0.44</b>	<b>0.37</b>	2.80	0.51	0.76
PointNet	0.31	<b>0.26</b>	0.48	0.55	<b>0.29</b>	<b>0.40</b>	<b>0.43</b>
GraphSAGE	4.89	1.31	2.04	4.22	14.88	3.98	6.86
Graph U-Net <sup>[2]</sup>	1.91	0.86	1.18	3.09	2.89	0.92	0.97
PointGNNConv	4.50	1.42	2.69	7.70	11.71	8.92	15.41

### Out-of-Distribution Test

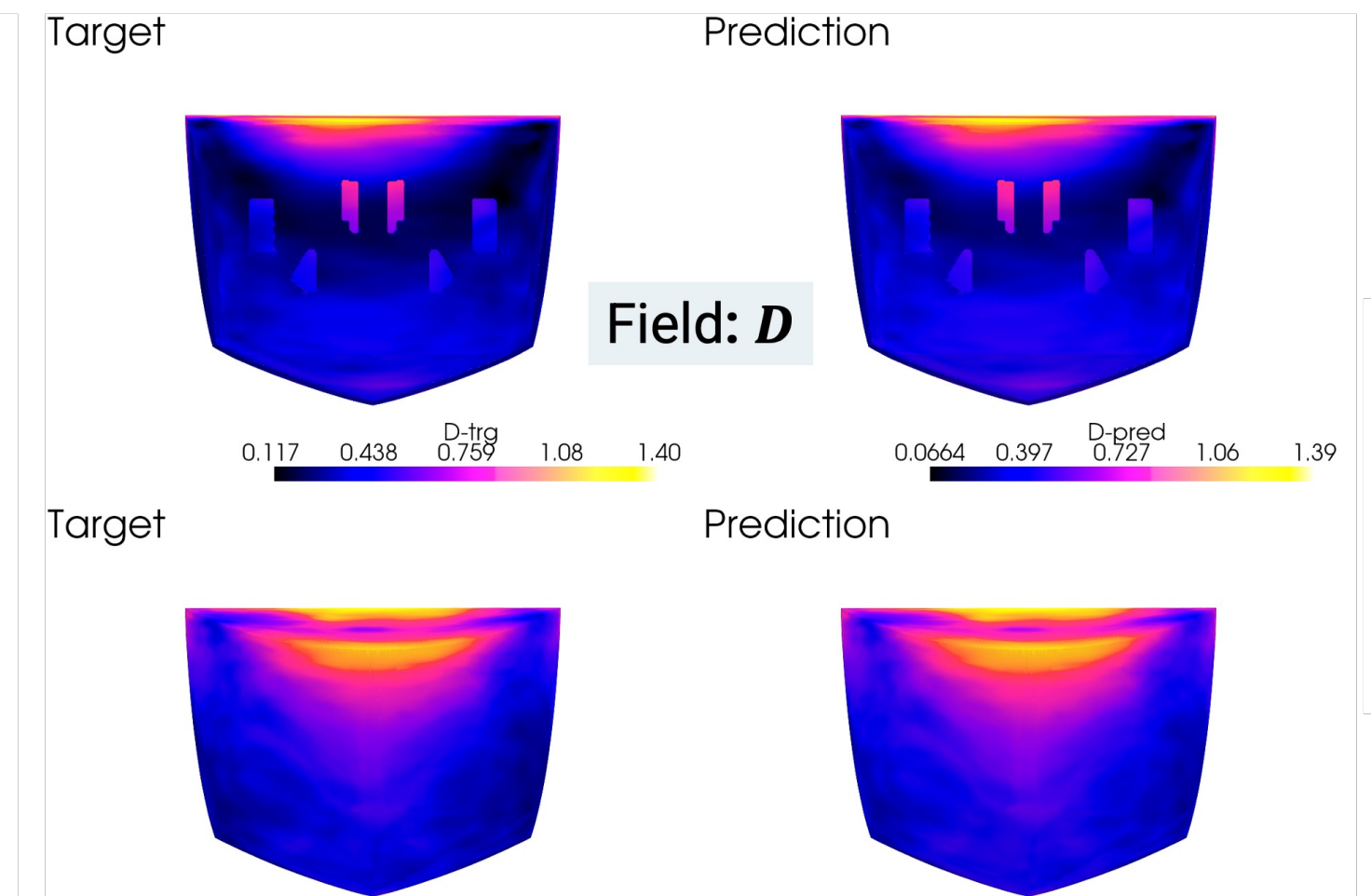
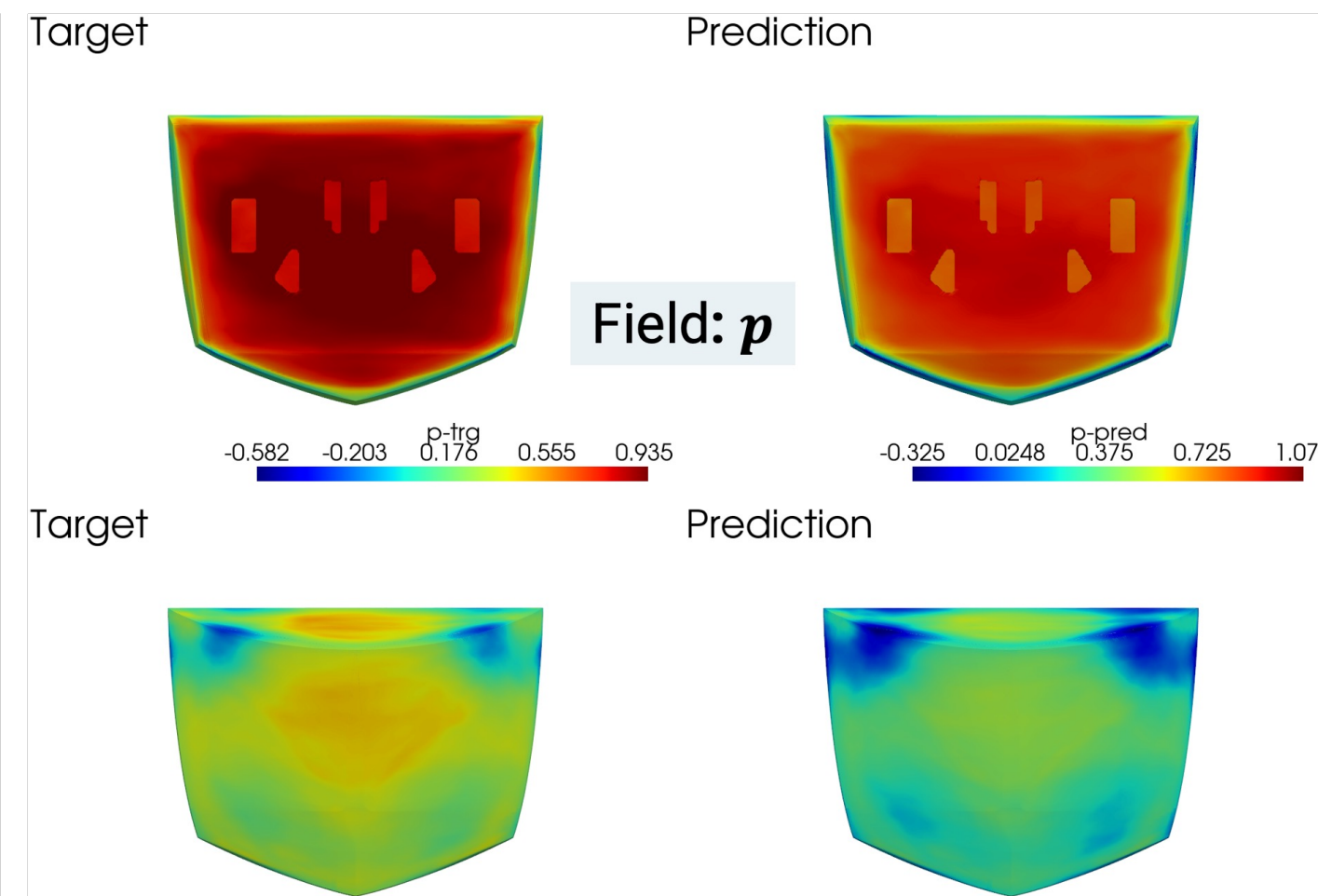
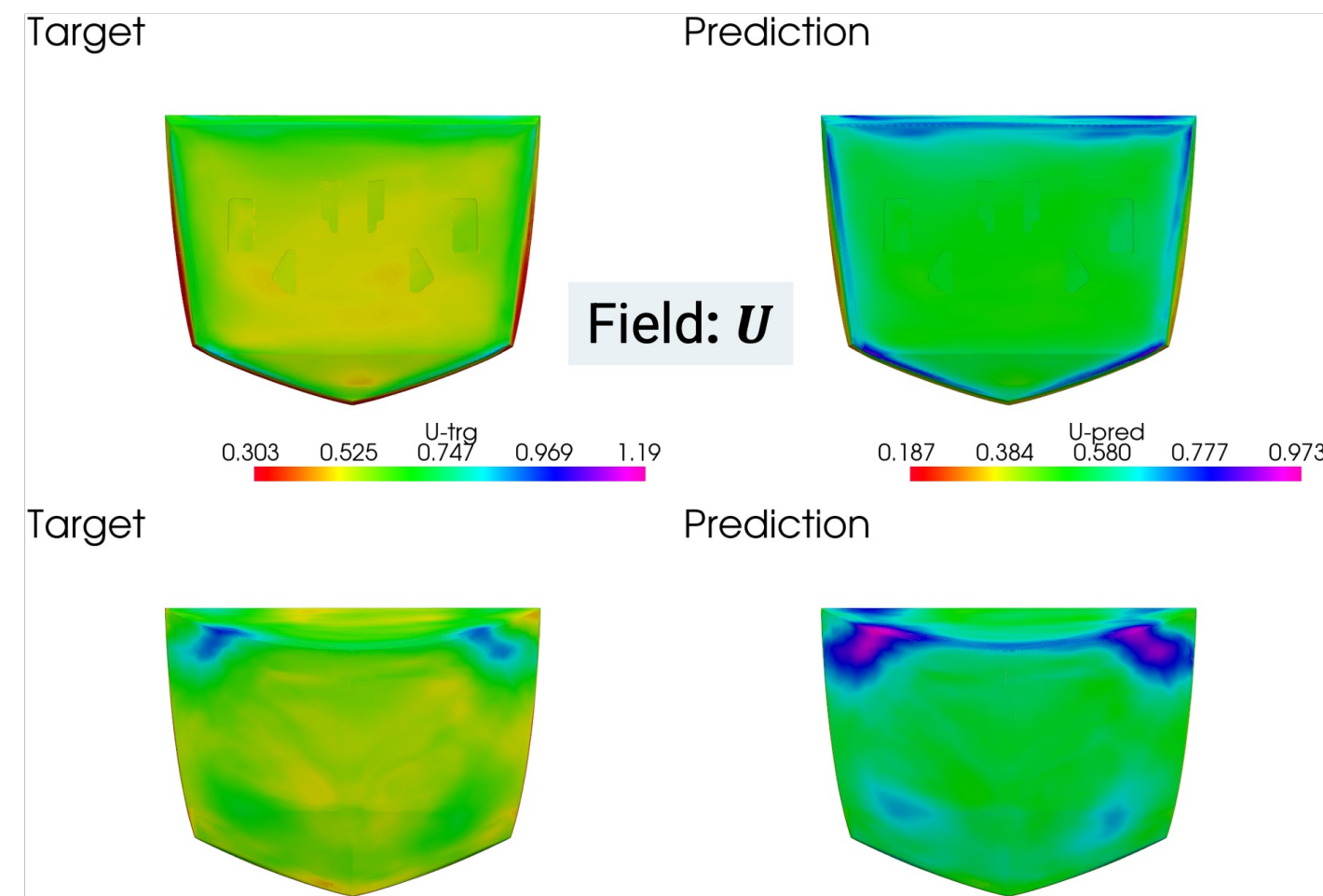
Model	$U_x$ ( $\times 10^{-2}$ )	$U_y$ ( $\times 10^{-2}$ )	$U_z$ ( $\times 10^{-2}$ )	$p$ ( $\times 10^{-2}$ )	$D_x$ ( $\times 10^{-2}$ )	$D_y$ ( $\times 10^{-2}$ )	$D_z$ ( $\times 10^{-2}$ )
MLP	<b>1.49</b>	1.89	2.97	4.96	181.02	5.87	19.81
PointNet	3.48	2.89	6.87	15.45	<b>73.79</b>	17.83	25.55
GraphSAGE	3.24	1.81	2.65	6.99	84.34	6.07	21.71
Graph U-Net <sup>[2]</sup>	2.04	1.29	1.45	<b>4.05</b>	126.62	7.69	16.13
PointGNNConv	2.84	<b>1.51</b>	<b>1.20</b>	5.79	130.08	<b>4.78</b>	<b>13.67</b>

- ## ❖ Additional tests for Homophily, Ablation and Neighbor sensitivity in full text



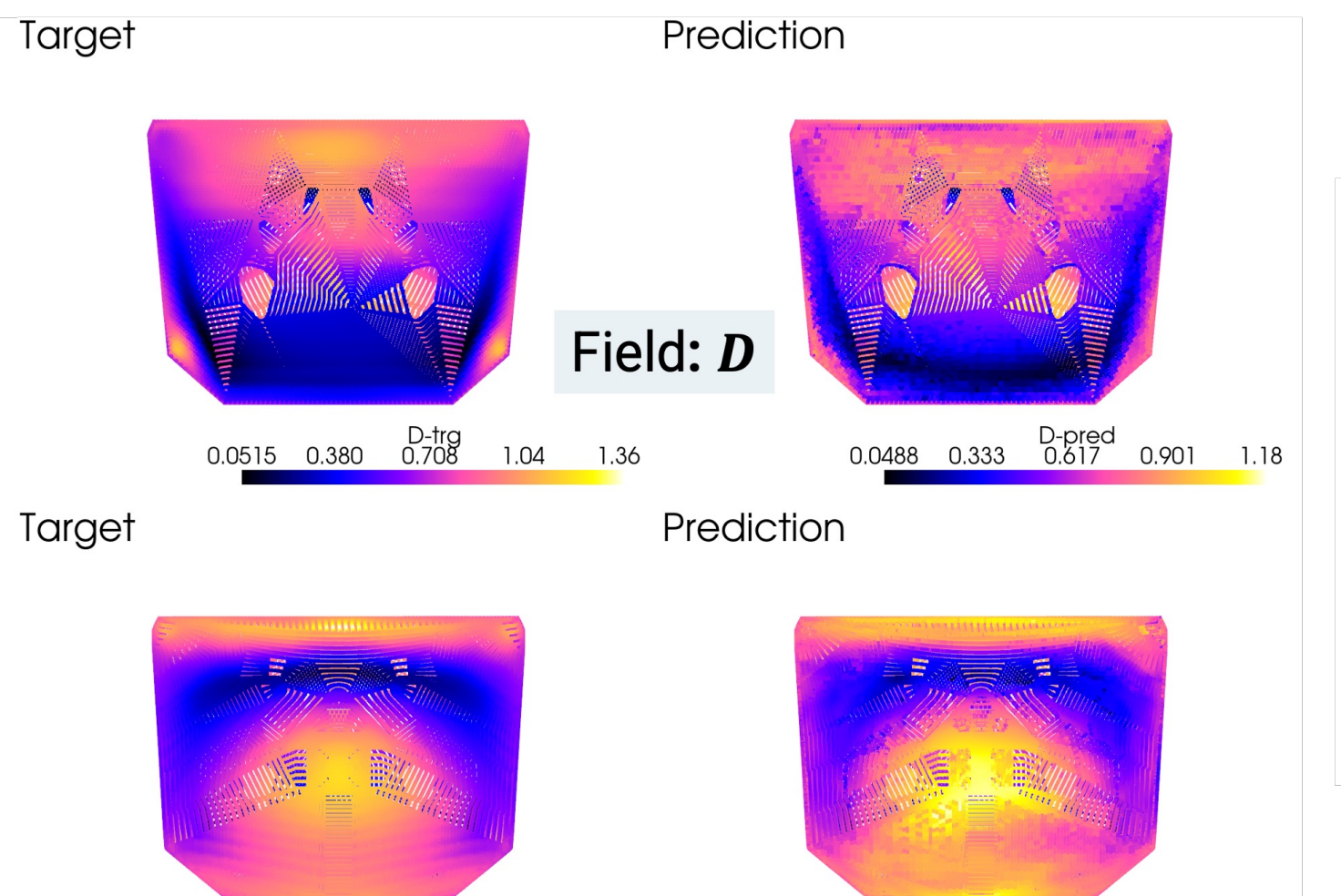
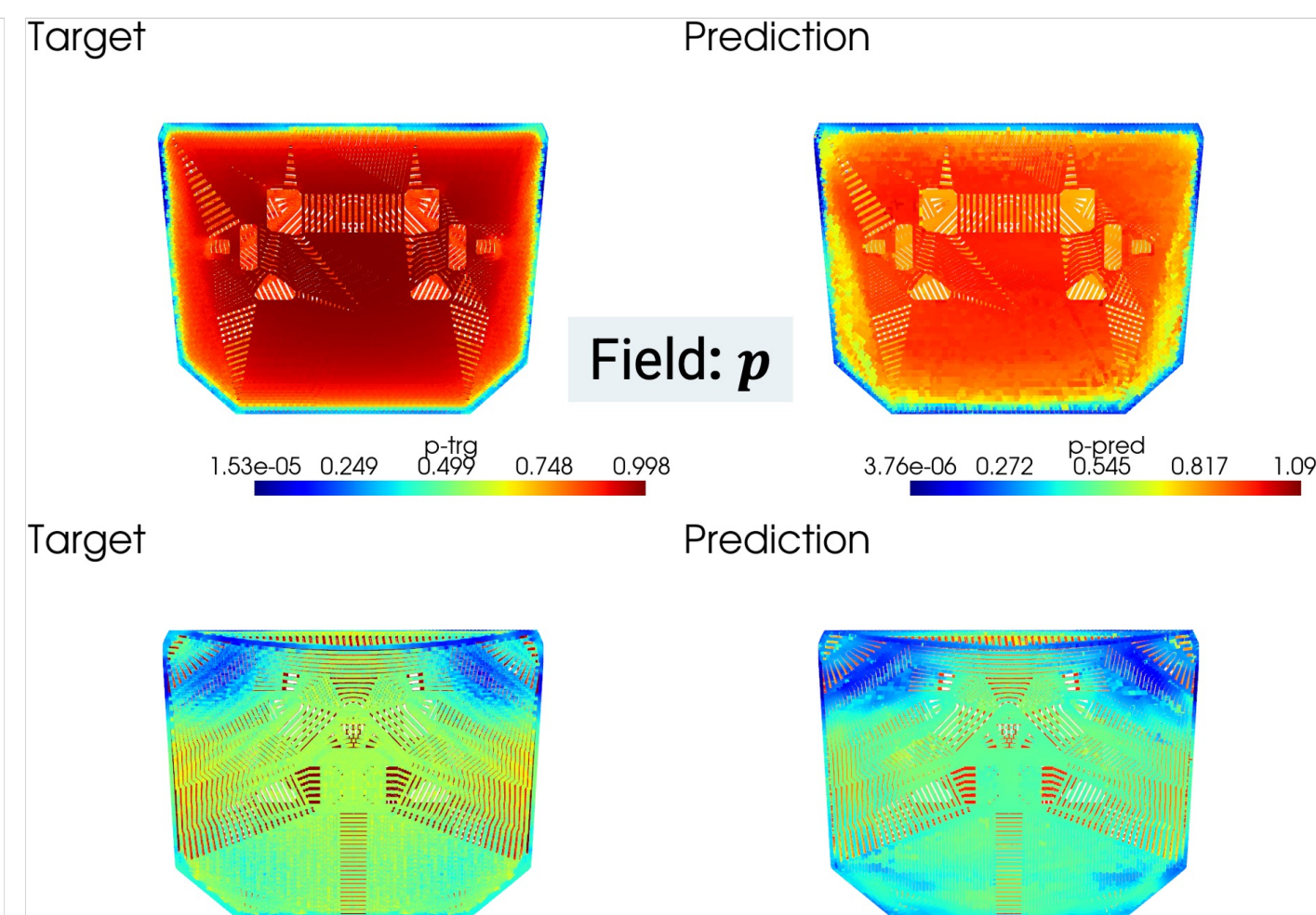
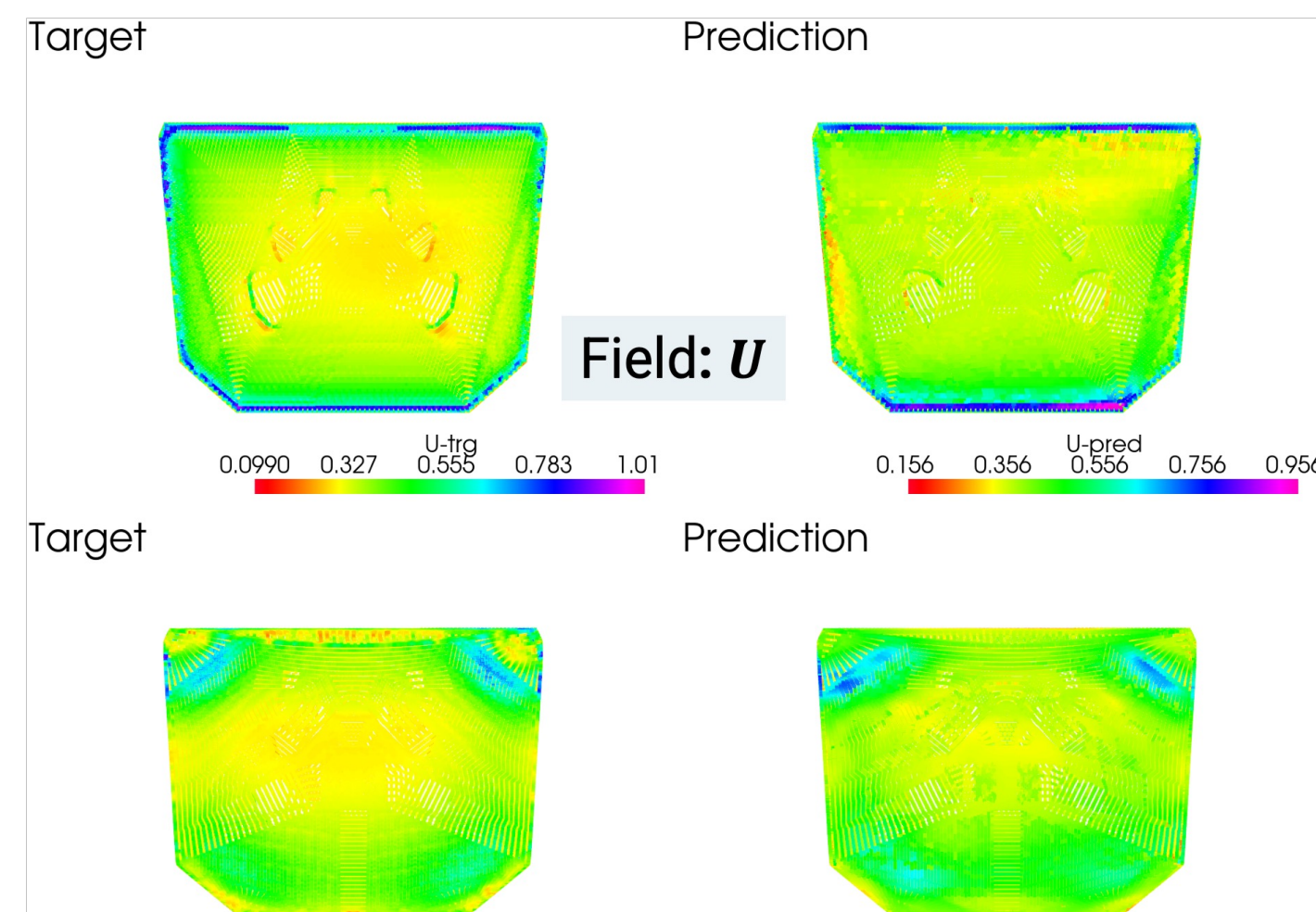
# Multi-Physics Loss Objective Needed

Model: MLP



Mode: STL

Model: GraphSAGE



Mode: Point Cloud



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Thank you!

