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NVIDIA

SimNet: An End-to-End AI-Driven Simulation Framework

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developer.nvidia.com/simnet

Introduction

SimNet is an AI-accelerated simulation framework based on Neural Network Solvers (NNS) , that can efficiently solve coupled forward and inverse problems and is generalizable to multiple configurations by network parameterization.

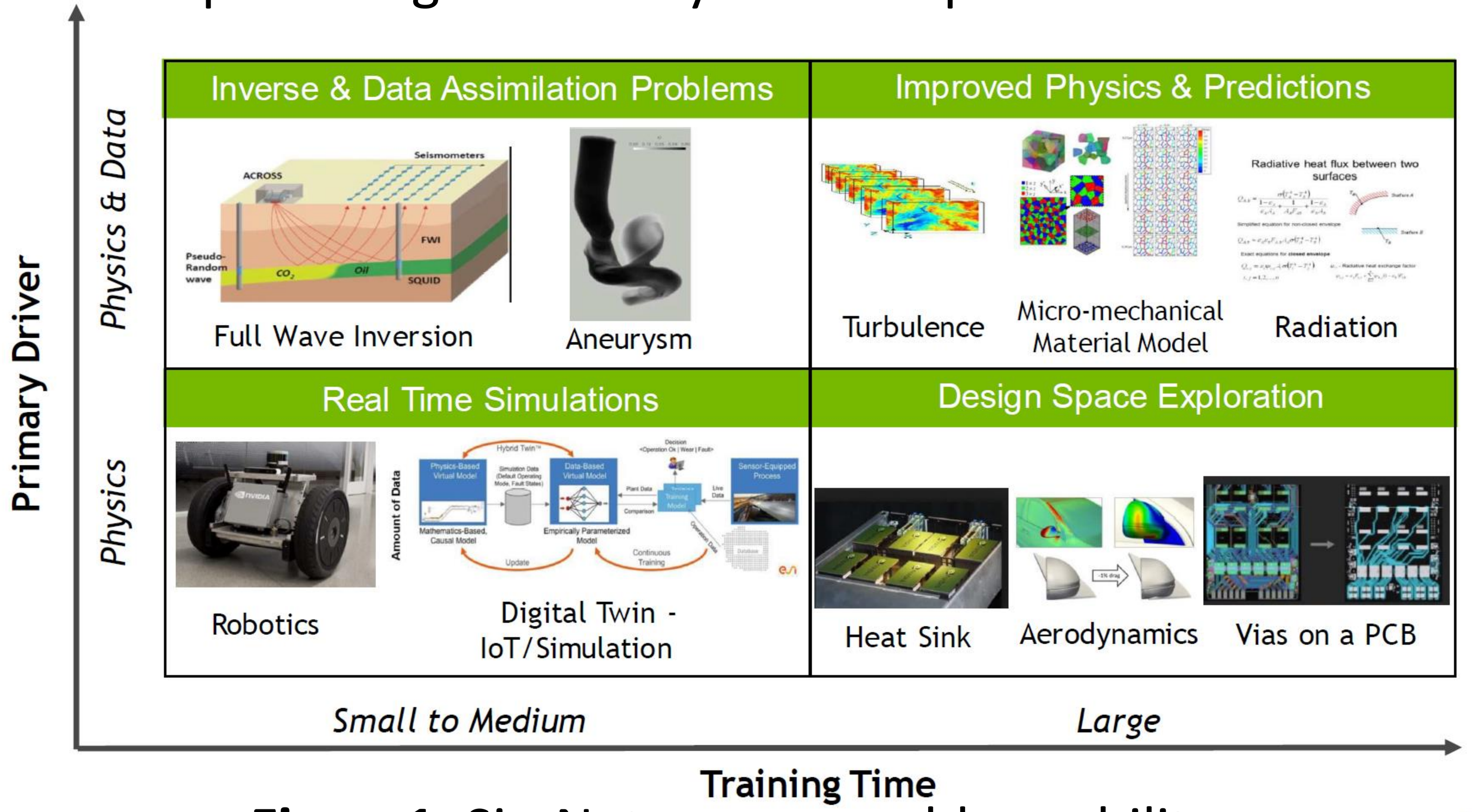

Figure1: SimNet use case addressability.

SimNet Contributions

Existing NNS tools are not successful in solving industrial problems due to **gradients and discontinuities** caused by complex geometries or physics. SimNet is a novel NNS framework with tools for tackling these challenges, such as **SDF loss weighting, flow integral continuity planes, and advanced architectures**. SimNet also enables high Re flow simulation in industrial applications using NNS.

Neural Network Solvers

Neural network solution to PDE and the training loss:

$$u_{net}(\mathbf{x};\theta) = \mathbf{W}_n\{\phi_{n-1}\circ\cdots\circ\phi_1\circ\phi_E\}(\mathbf{x}) + \mathbf{b}_n,\ \ \phi_i(\mathbf{x}_i) = \sigma\left(\mathbf{W}_i\mathbf{x}_i + \mathbf{b}_i\right)$$

$$\mathcal{L}_{res}(\theta) = \sum_{i=1}^{N_N}\int_{\mathcal{D}} \lambda_N^{(i)}(\mathbf{x}) \left\| r_N^{(i)}(\mathbf{x}; u_{net}(\theta))\right\|_p d\mathbf{x} + \sum_{j=1}^{N_C}\int_{\partial\mathcal{D}} \lambda_C^{(j)}(\mathbf{x})\left\|r_C^{(j)}(\mathbf{x};u_{net}(\theta))\right\|_p d\mathbf{x}$$

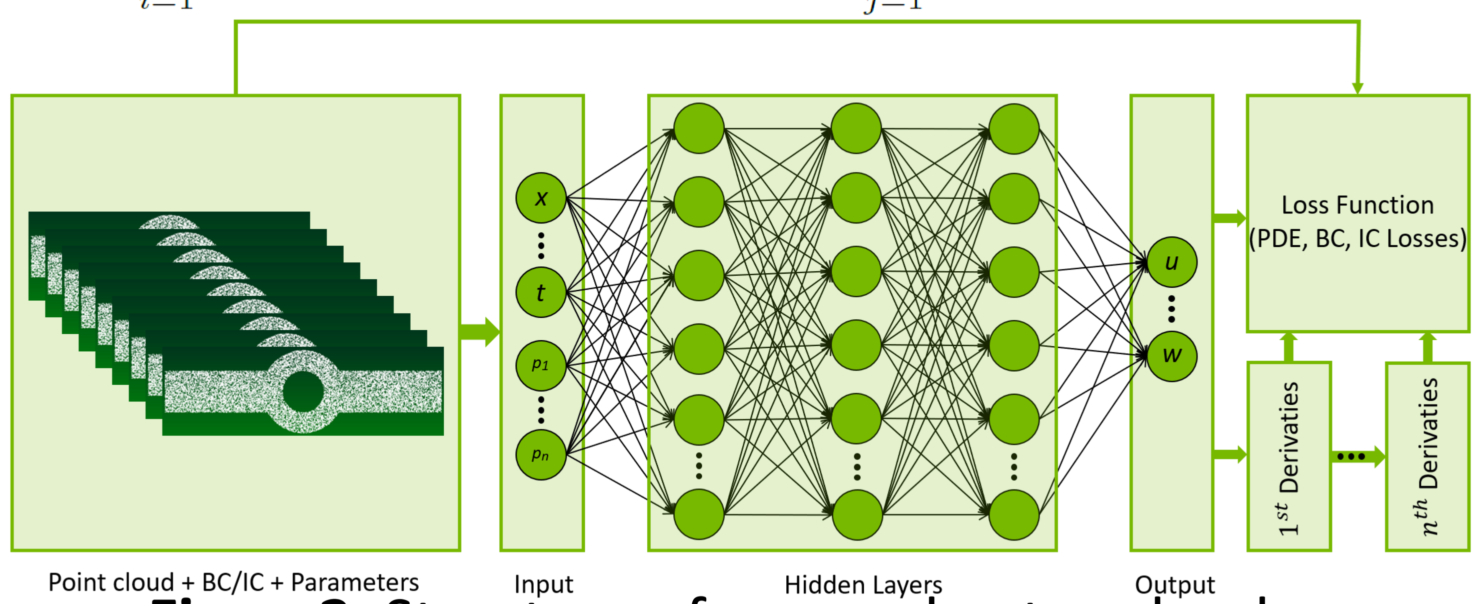

Figure2: Structure of a neural network solver.

Turbulent & Multi-Physics Simulations

Using our proposed advanced architectures, SDF loss weighting, and integral continuity planes, SimNet is capable of solving multi-physics industrial problems involving high Re flows. Here, we solve a conjugate heat transfer problem for an FPGA heat sink, with one-way fluid-heat coupling.

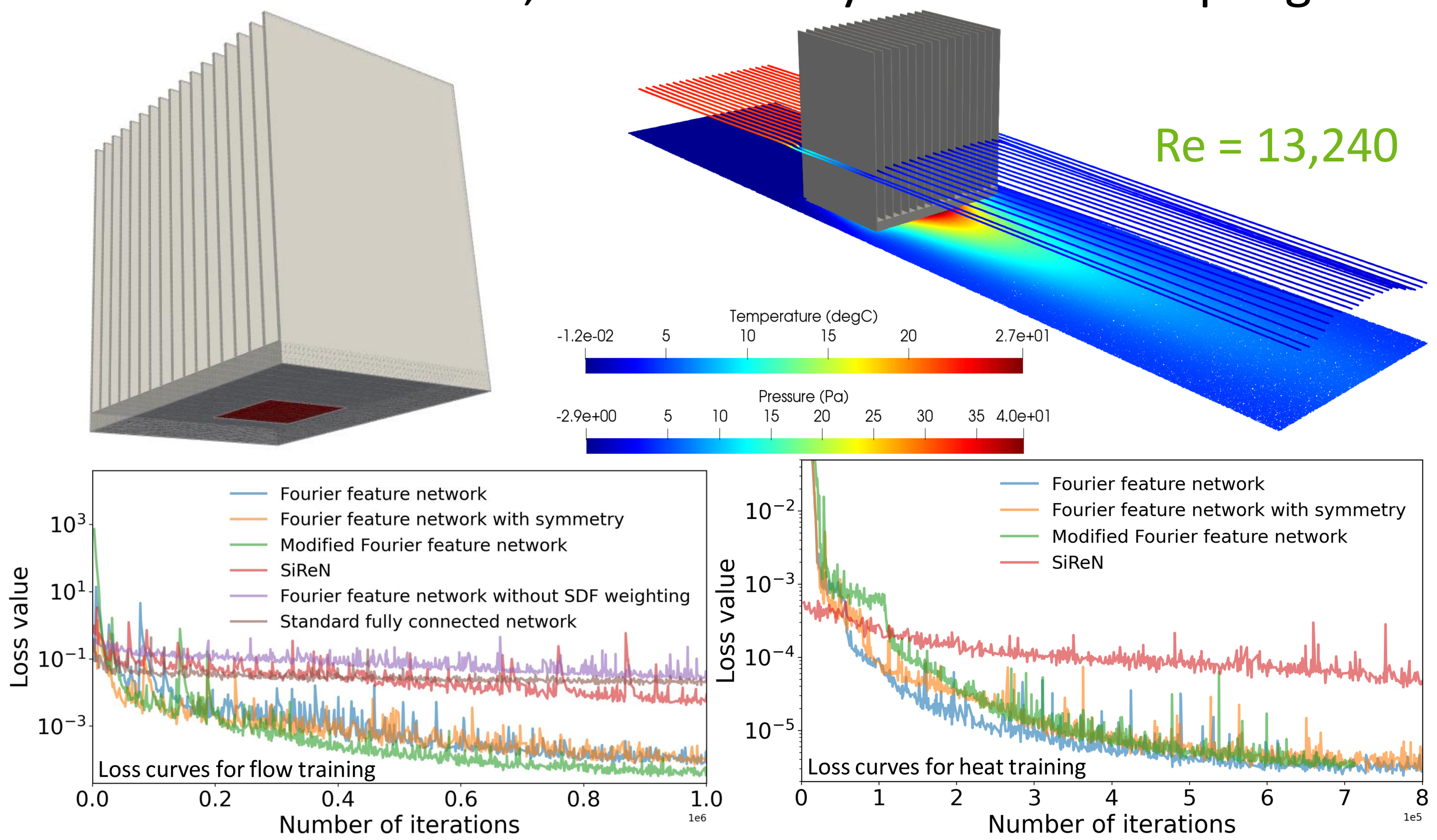

Figure3: SimNet results for the FPGA heat sink problem.

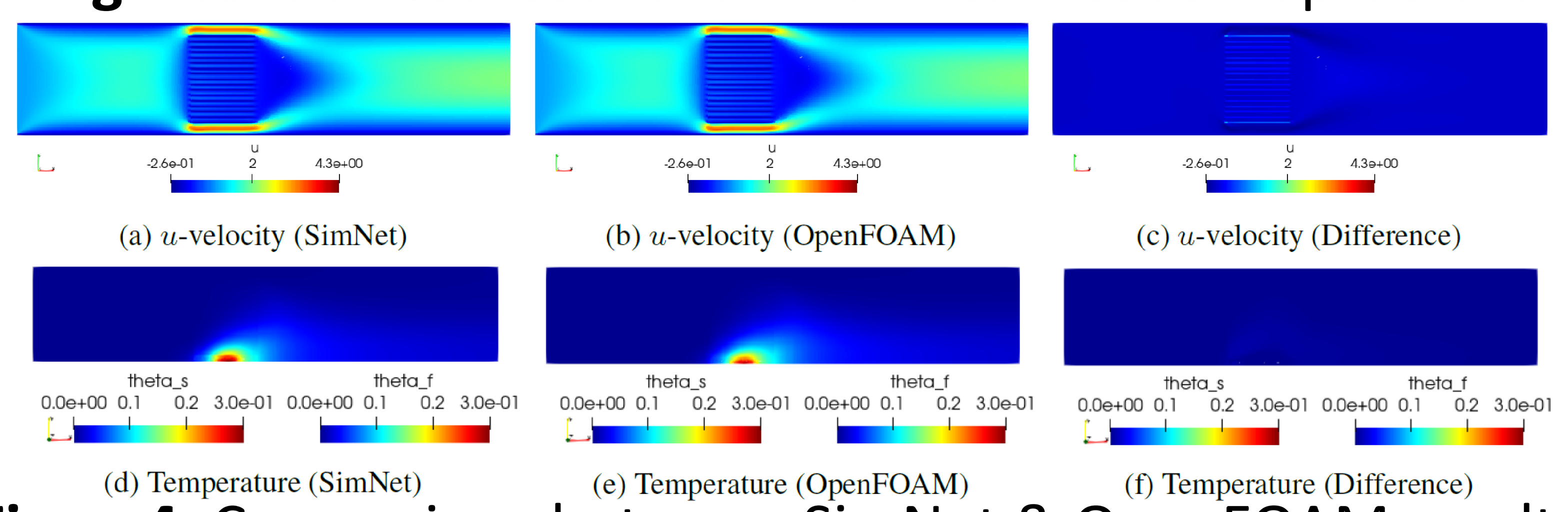

Figure4: Comparison between SimNet & OpenFOAM results.

Blood Flow in an Intracranial Aneurysm

SimNet's TG module enables the import any tessellated geometry from CAD programs. Here, we simulate the flow inside a patient specific geometry of an aneurysm.

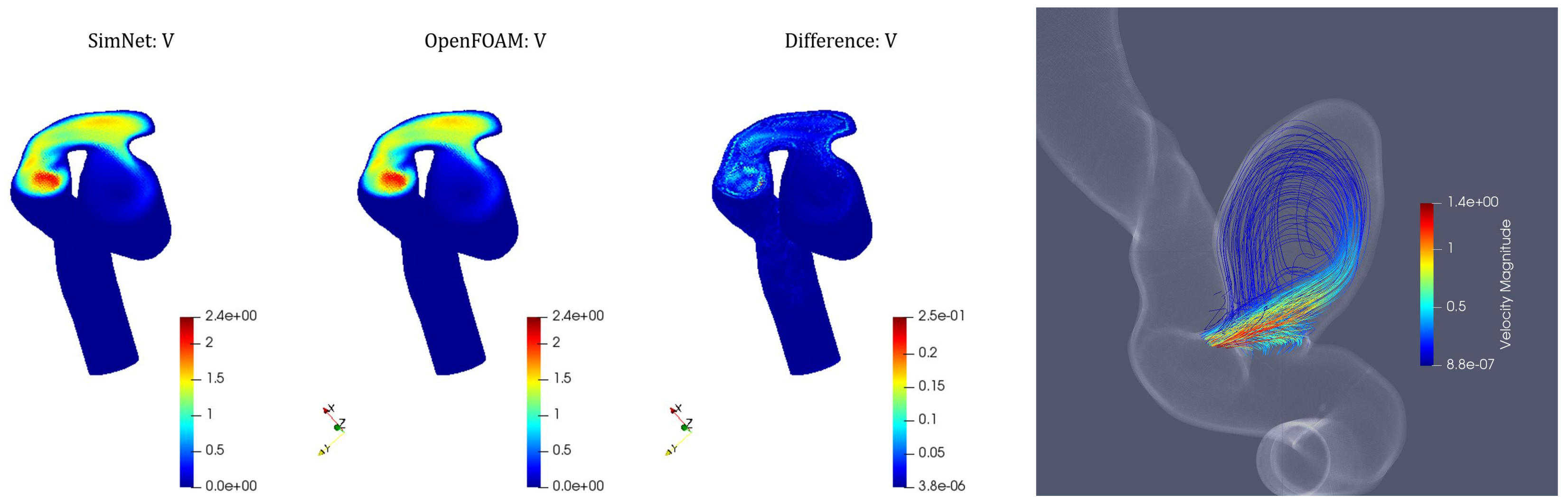

Figure5: SimNet results for the patient specific aneurysm.

NVSwitch Heat Sink Design Optimization

By network parameterization, SimNet solves for simultaneous design configurations in a design space exploration problem significantly more efficient than traditional solvers.

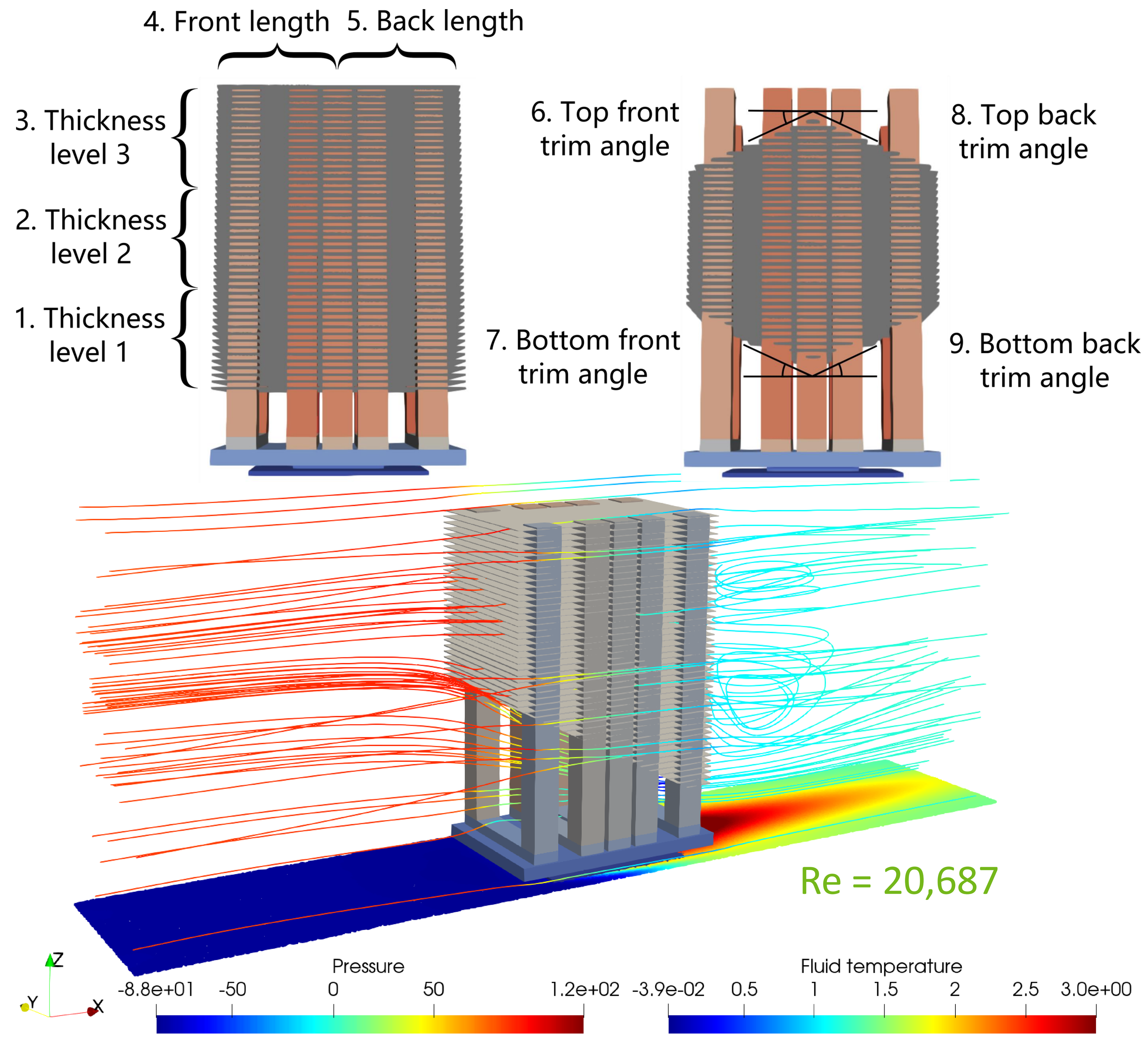

Figure6: NVSwitch heat sink design optimization.

Solver	OpenFOAM	Commercial Solver	SimNet
Compute Time (days)	7, 892, 361	2, 673, 610	21

Table 1: Optimization compute time for 5M design samples.

Multi GPU/Node Training

SimNet supports multi-GPU/node scaling and reduces the convergence time by scaling LR linearly with the number of GPUs. SimNet also supports TF32 for accelerated training.

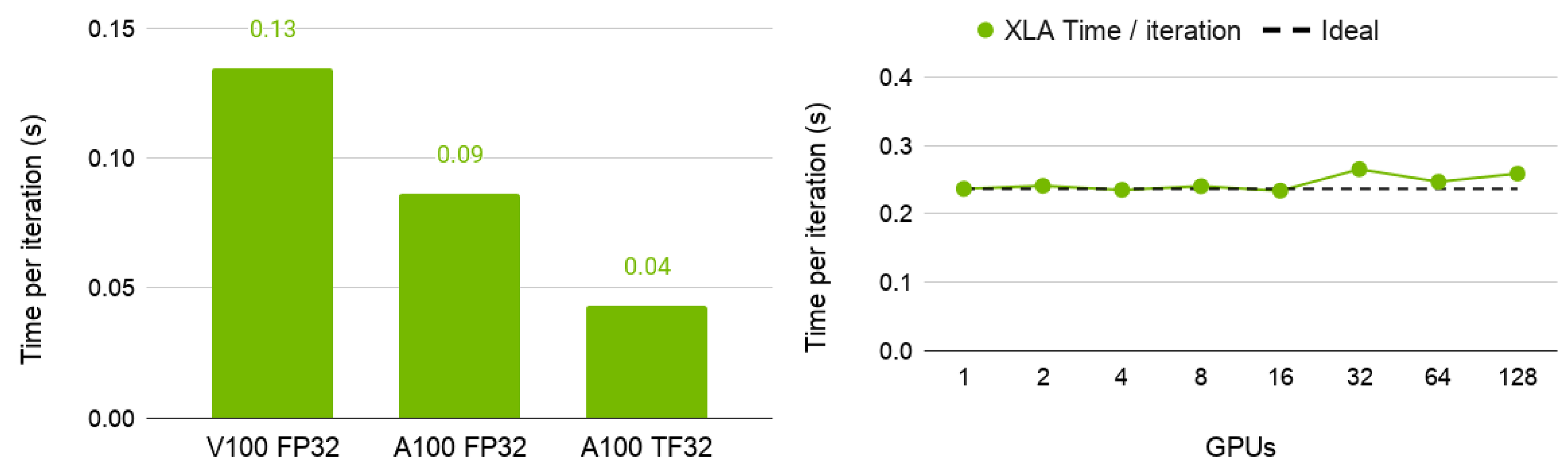

Figure7: SimNet performance upgrades.