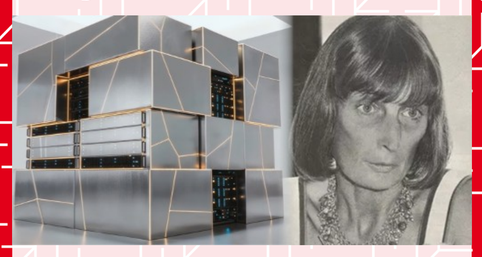
TRUST on the path to exascale with Kokkos

Context

- **TRUST** is a CFD solver for thermohydraulics started in 1993
- Incompressible and weakly-compressible flows for nuclear applications
- 300 × 10^3 lines of C++, parallelized with MPI
- Extended by *Baltiks* (e.g. TrioCFD)

- **TRUST** is a flexible HPC program
- Workstations to supercomputers
- Simulations of a few minutes to several months
- Developed and optimized for CPUs
- Gradually ported to GPU

Objective



Run on the Alice Recoque exascale supercomputer in 2026 (hosted at CEA)

Acceleration of the solver

Linear solvers

- Targeting the most time consuming parts of the code
- Use of linear solvers already ported to GPU
- NVIDIA AmgX, rocALUTION and PETSc
- Work started in 2014

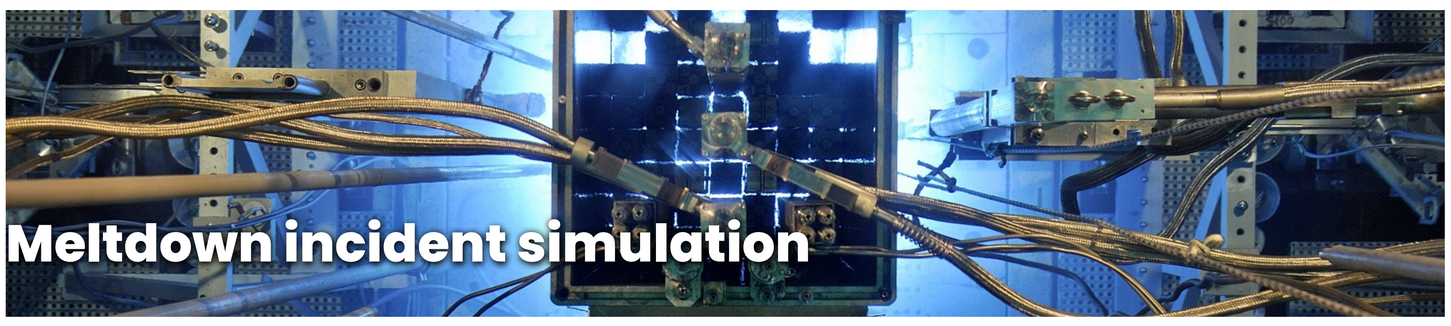
Repartition of simulation time

PETSc kokkos NVIDIA AmgX rocALUTION

Kernels

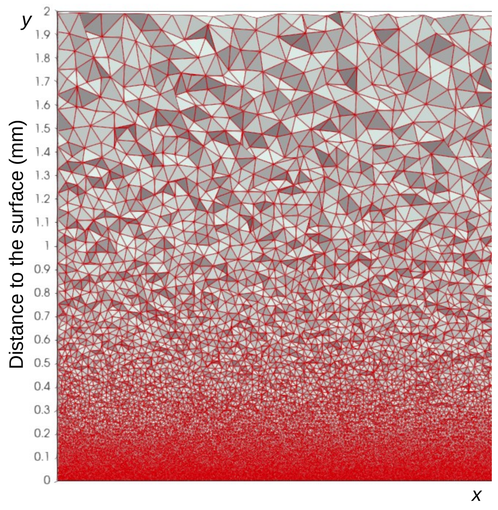
- Compute operators and models ported with Kokkos
- Progressive rewriting of the code
- Work started in 2023
- Encapsulation of a device View and a host View in **TRUST** arrays
- Manual Kokkos allocation for now
- Explicit CPU to GPU synchronization with accessors
- Implicit GPU to CPU synchronization (hybrid behavior)

Consequent simulations run on GPU



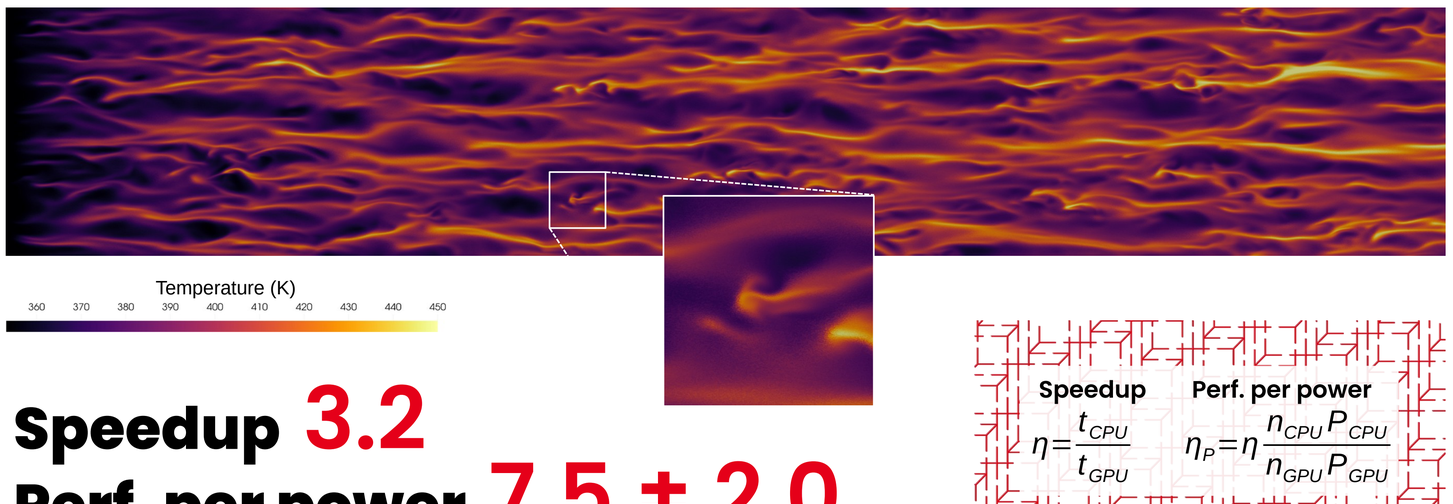
- Work done by É. Roumet during his PhD
- Simulation with TrioCFD
- Analysis of turbulent structures in a region of flow in contact with an exponentially heated surface
- Hybrid DNS/LES simulation
- Finite Volume Element method

Mesh close to the heated surface



- Mesh of tetras, smallest cell 1 µm (Batchelor and Kolmogorov resolution)
- Re = 20 × 10^3, p = 10 bar
- 312 × 10^3 time steps of 80 ns
- 29 s/it on 8000 Intel Skylake CPU cores (3 months long, estimated)
- 9 s/it on 64 NVIDIA A100 GPUs (1 month long)

Slice in the (x, z) plane at y^+ = 8 and t = 19.100139 ms



Speedup 3.2

Perf. per power 7.5 ± 2.0

Speedup

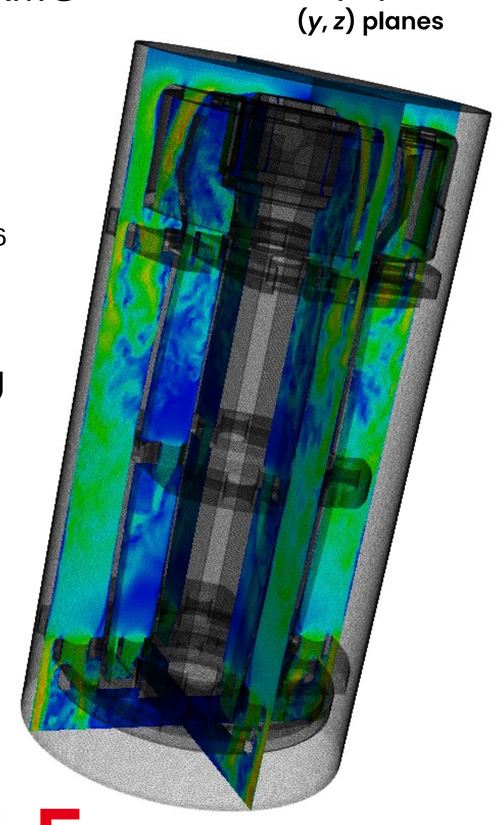
$$\eta = \frac{t_{CPU}}{t_{GPU}}$$

Perf. per power

$$\eta_P = \eta \frac{n_{CPU} P_{CPU}}{n_{GPU} P_{GPU}}$$

- Work done by P. Ledac
- CFD simulation of a test section of the FLOREAL reactor
- LES simulation
- PETSc preconditioned conjugate gradient
- Hypre BooomerAMG multigrid module

Sections in the (x, z) and (y, z) planes



- Mesh of 25 × 10^6 tetras
- 6.8 s/it on 512 AMD Rome CPU cores (in 2021)
- 1.5 s/it on 8 AMD MI250X GPUs (in 2025)

Speedup 4.5

Perf. per power 1.5 ± 0.3

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TRUST repo

github.com/cea-trust-platform/trust-code