The mesh is not a preprocessing step

It is the simulation.

80%

of your CFD accuracy is determined

before the solver even starts.

Informed by the NASA CFD Vision 2030 Study (Slotnick et al., NASA/CR-2014-218178, 2014)

Sound Familiar?

“Your simulation converged. Residuals dropped 4 orders. Everything looks smooth. You present the results with confidence. Then experimental data comes back — and you're 15% off. What went wrong?”

✓ You tried lowering under-relaxation — it converged to the same wrong answer, just slower

✓ You switched to first-order upwind — the oscillations stopped, but so did the accuracy

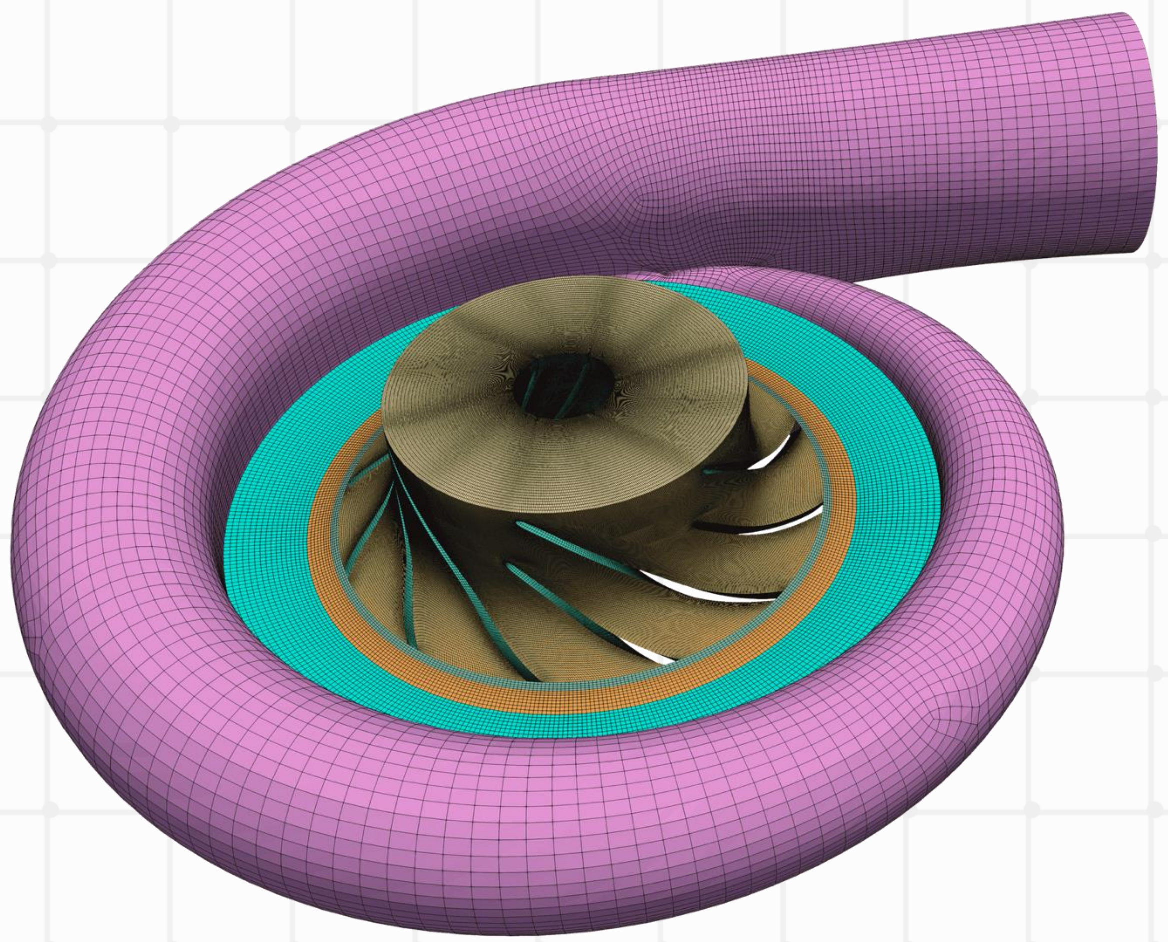
✓ You ran 5,000 more iterations — same wrong answer, more confidently

✓ The mesh was telling you something. You weren't listening.

Structured Meshes -Powering Simulation Driven Design

GridPro + CAESES — Structured Meshing & Parametric Automation for CFD

CAESES North America User Conference 2026 | March 31 – April 1 | Virtual



Program Development Company LLC

- Partnering with companies in the CAE market for more than 35 years and providing solutions in the field of Grid generation.

- Started Development under NASA SBIR to cater to the needs of NASA Glenn.

- Flagship Solution - GridPro

Garbage In, Garbage Out

“The mesh IS the discrete representation of reality. The solver never sees the continuous domain — it sees cells, faces, volumes, and area vectors. If the mesh is a poor representation of the geometry, the solver will compute a perfect answer to the wrong problem.”

- ✓ Navier-Stokes equations are continuous — computations are discrete. The mesh is the bridge.
- ✓ Cell-averaged values only approximate reality — smaller cells → closer to truth
- ✓ Conservation does NOT imply accuracy: fluxes balance perfectly on bad meshes, but they are the wrong fluxes
- ✓ You cannot fix a bad mesh with solver settings — no relaxation factor or scheme compensates

The Hidden Cost: Mesh Quality Controls Compute Time

“The CFL condition is local — the smallest, worst-quality cell in the entire mesh dictates the maximum time step. A handful of tiny degenerate cells can increase total simulation time by 100×.”

✓ High-skewness cells produce ill-conditioned matrix entries → more linear solver iterations

✓ NASA Vision 2030: meshing consumes 50–80% of total engineering time in CFD projects

Where Does the Time Go? CFD Workflow Breakdown

Geometry / CAD Cleanup 15–25%

Removing features, closing gaps, defeaturing

Meshing 40–60%

The dominant bottleneck — quality checks, refinement, iteration

Solving 10–30%

Often faster than meshing on modern HPC

Post-Processing 5–15%

Visualization, report generation

Source: NASA CFD Vision 2030 Study (Slotnick et al., 2014) and industry surveys. Meshing alone consumes more time than all other stages combined.

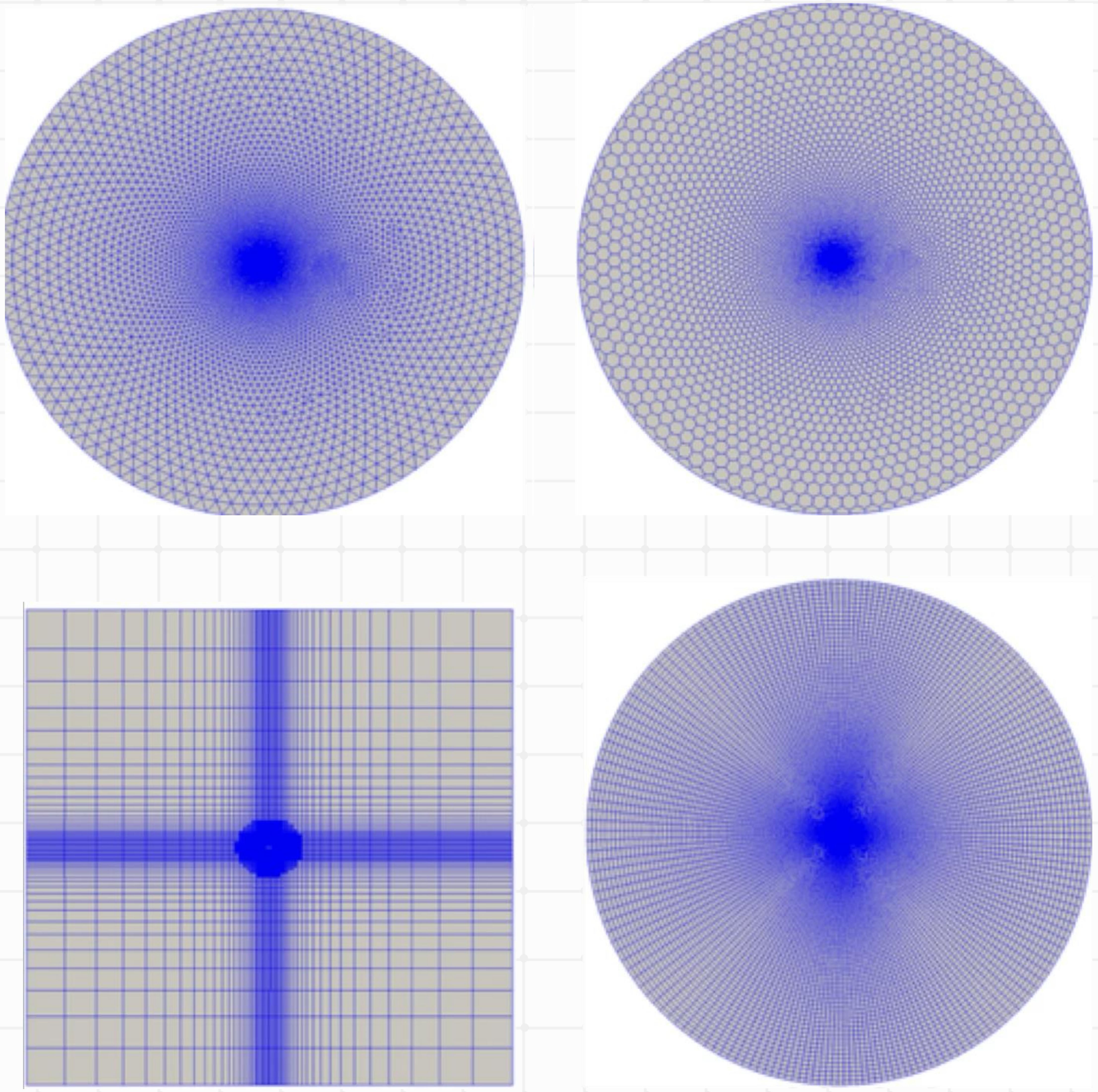
Four Mesh Types. One Geometry. Who Wins?

Unstructured Tetrahedral — easy to generate, fills any geometry automatically

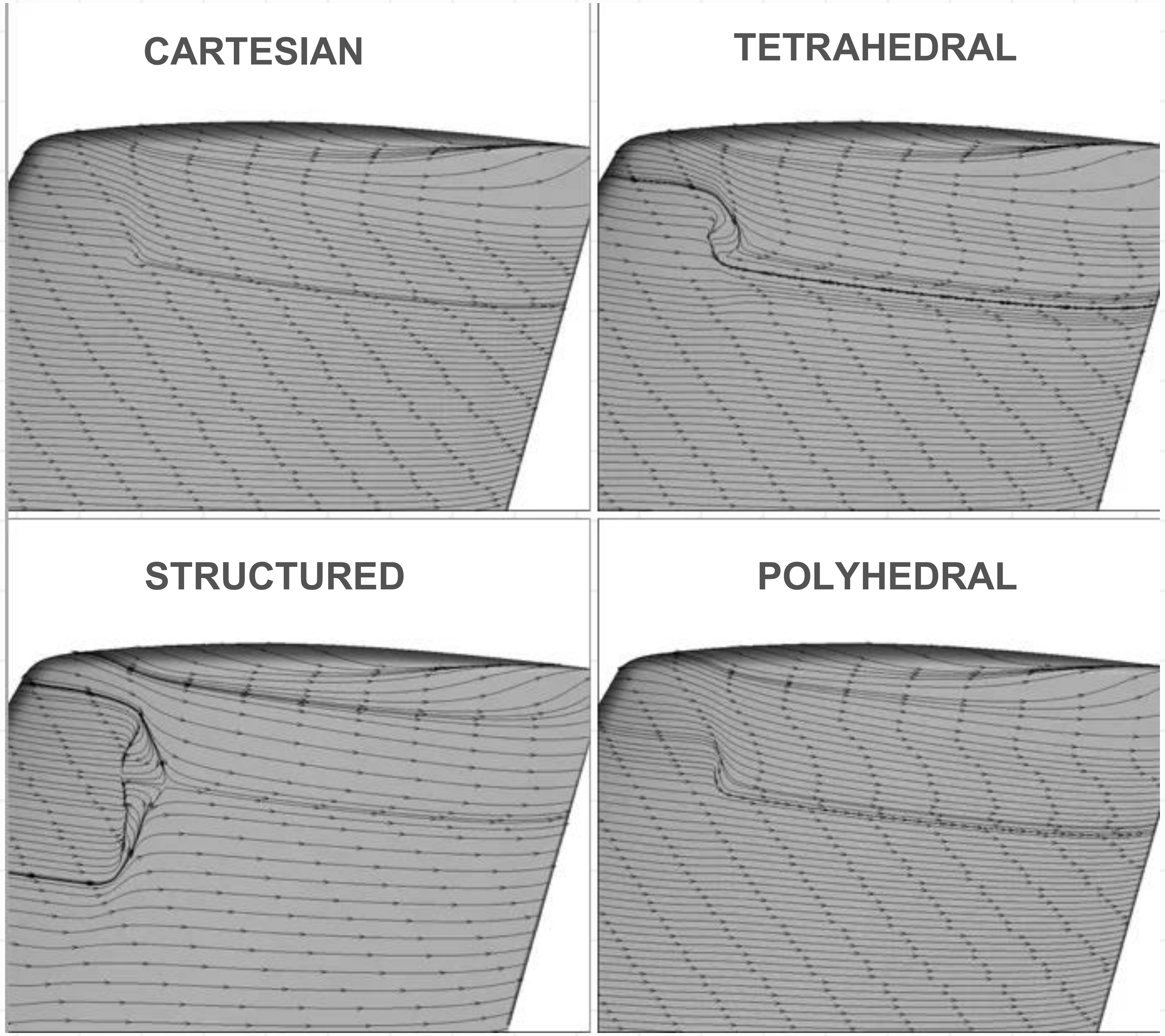
Cartesian / Cut-Cell — fast generation, AMR-friendly, but poor boundary conformity

Polyhedral — many faces average interpolation errors, better than tet, but still no flow alignment

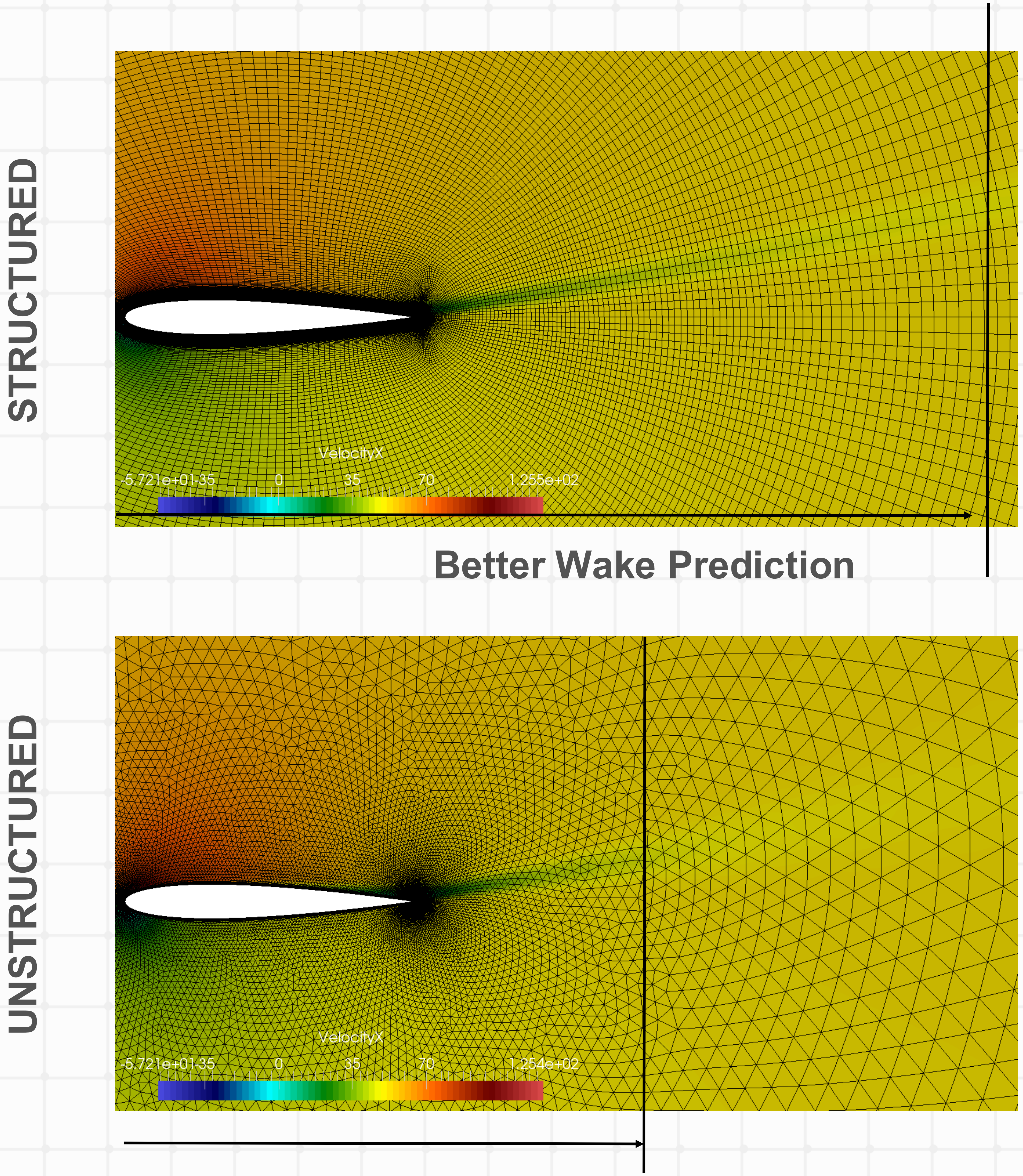
Structured Hexahedral — flow-aligned, orthogonal, lowest diffusion, but historically harder to generate



Who Wins? – When your simulation Counts



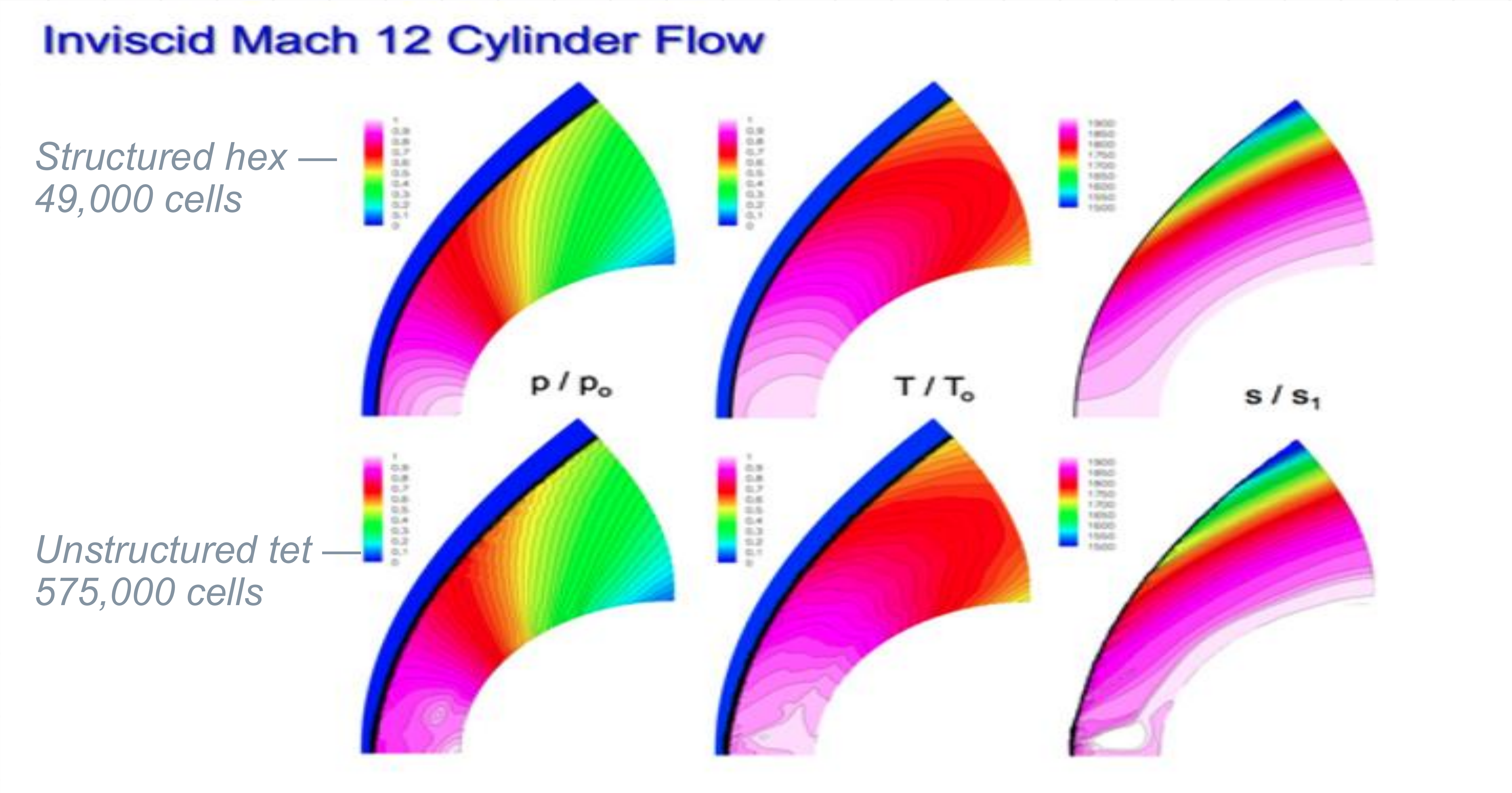
Flow Separation - Captured Better



Better Wake Prediction

Weaker Prediction

Inviscid Mach 12 Cylinder Flow — 11× Fewer Cells, Same Accuracy



Top row: Structured hex — 49,000 cells. Bottom row: Unstructured tet — 575,000 cells (11× more). Same accuracy, less numerical dissipation, sharper stagnation point on the structured mesh. Pressure (p/p_0), Temperature (T/T_0), and Entropy (s/s_1).

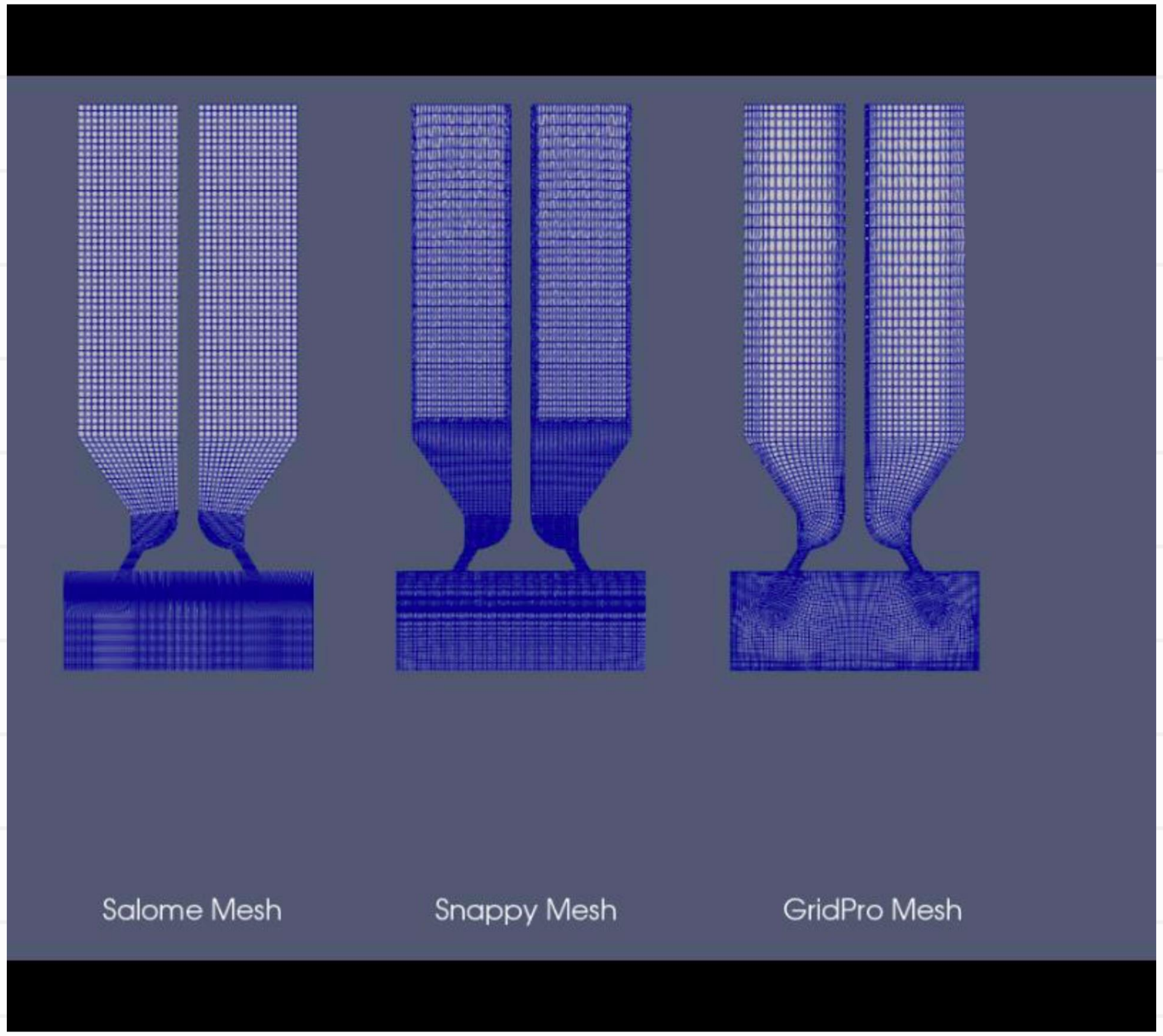
6–27×

less CPU time

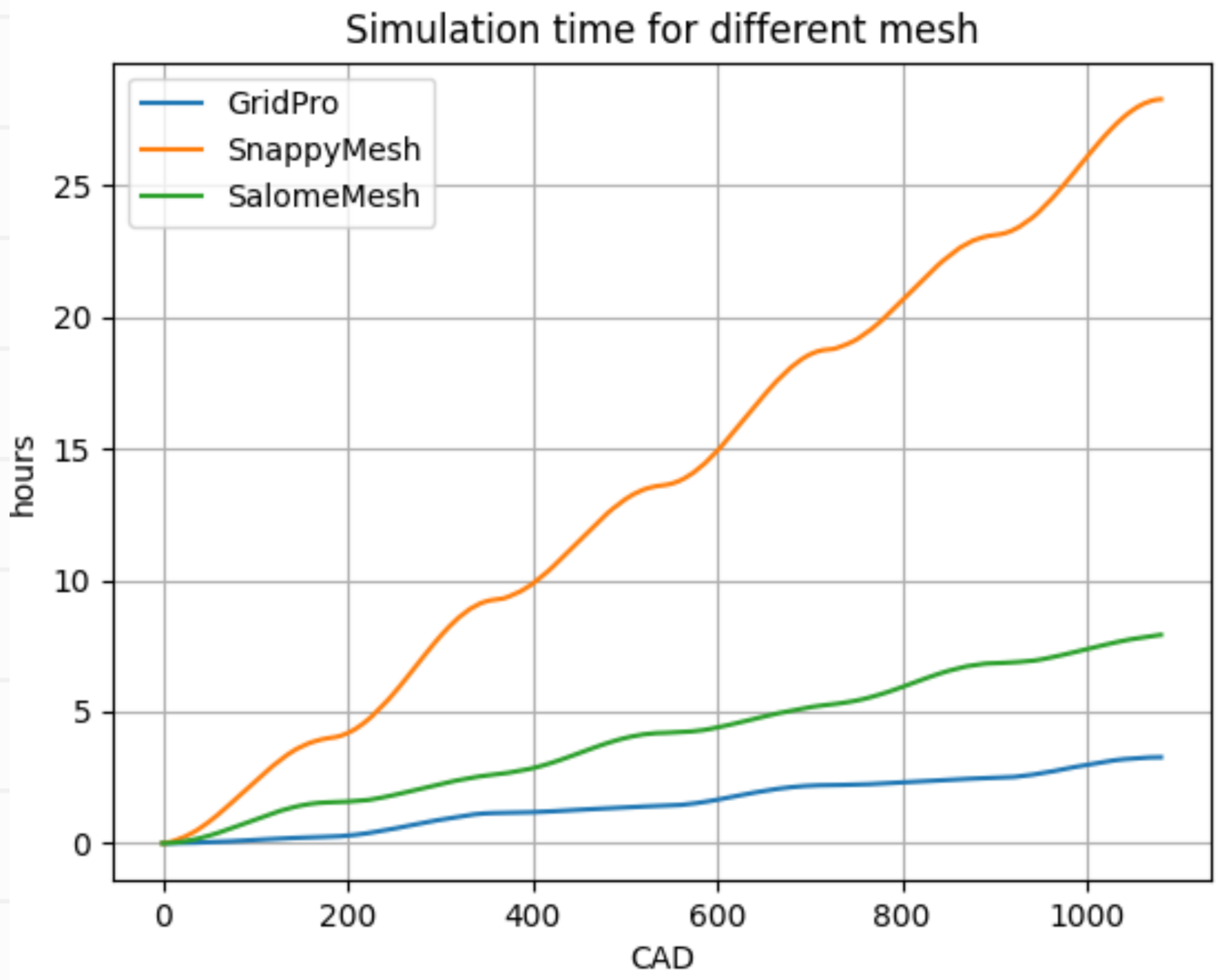
Structured hex grids solve 6–27× faster across published studies. The mesh pays for itself before the solver finishes.

6× — Medical & Biological Eng. & Computing, 2010 | 14× — Springer MBEC, 2010 | 27× — Ghaffari et al., Computers in Biology and Medicine, 2017 (cerebral artery CFD)

All Hex meshes are Not created EQUAL



Mesh Quality



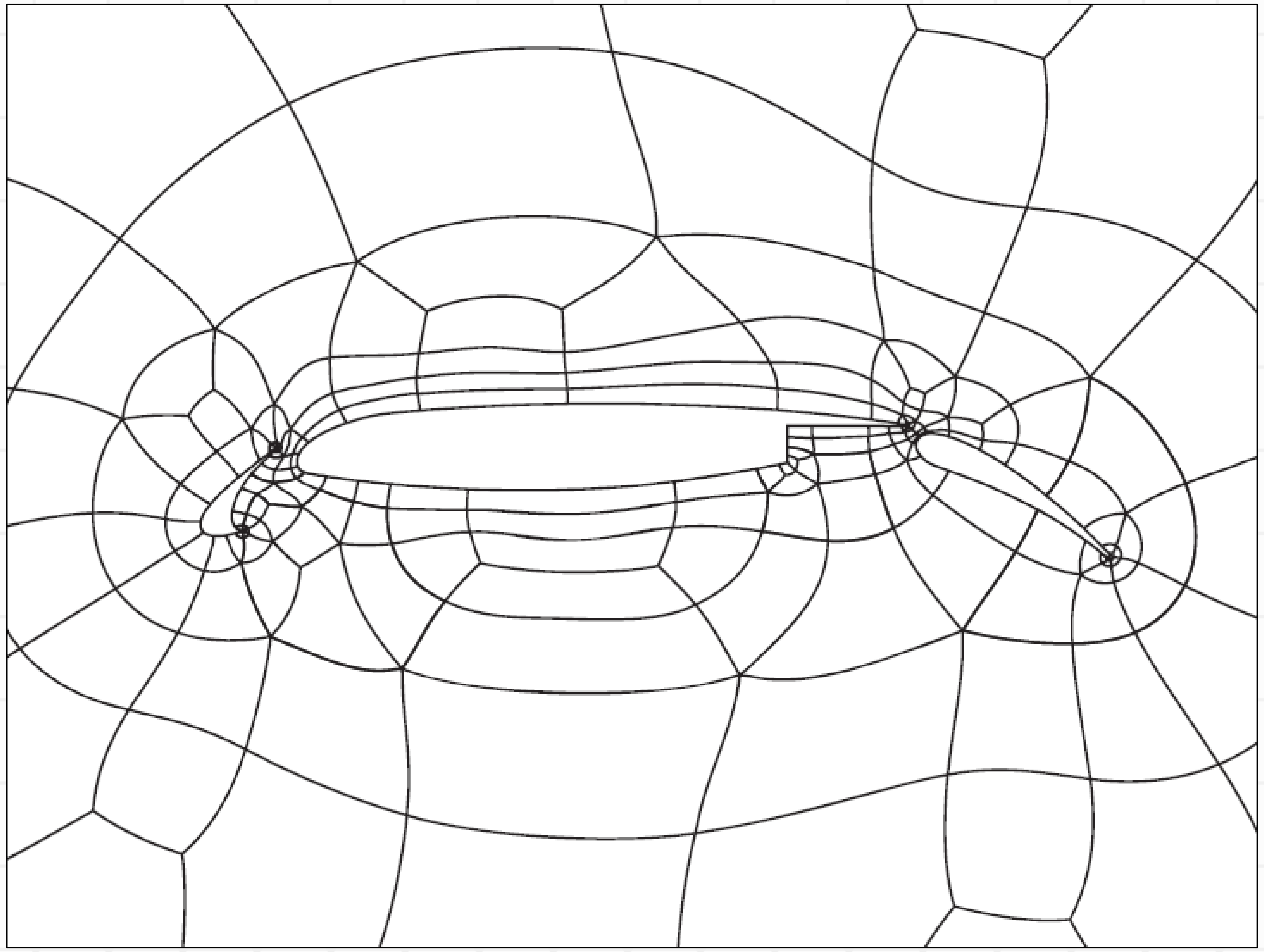
Mesh making tool	Mesh cells	Mesh quality
Salome grid	308,000	Non-orthogonal faces
SnappyHexMesh	1,503,000	1 Skew face, Concave cells and low interpolation weight faces
GridPro	451,000-652,000	Ok

*"But **structured** meshing is too hard."*

That used to be true and still is if you are using traditional multi-block Technologies.

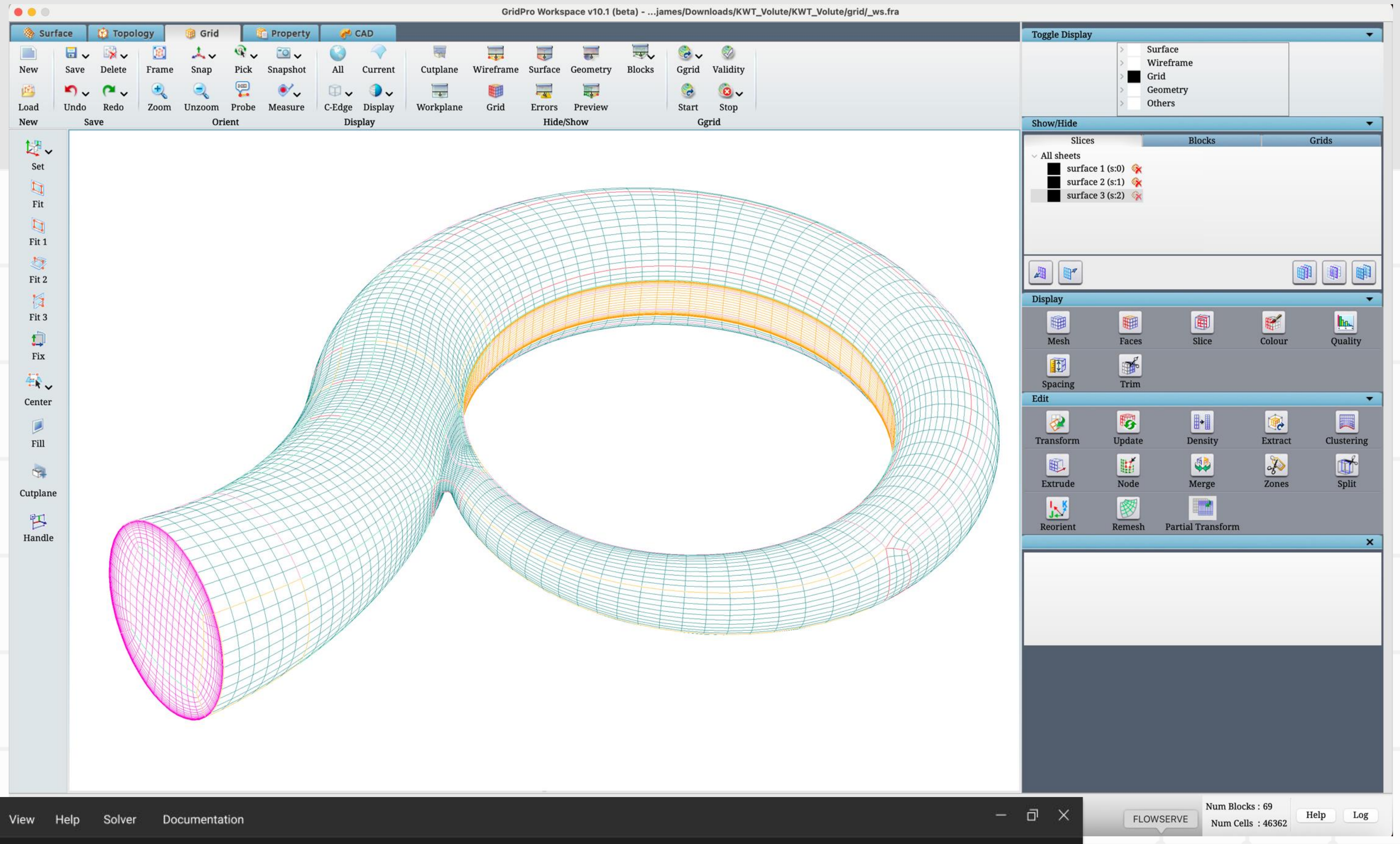
The Solution

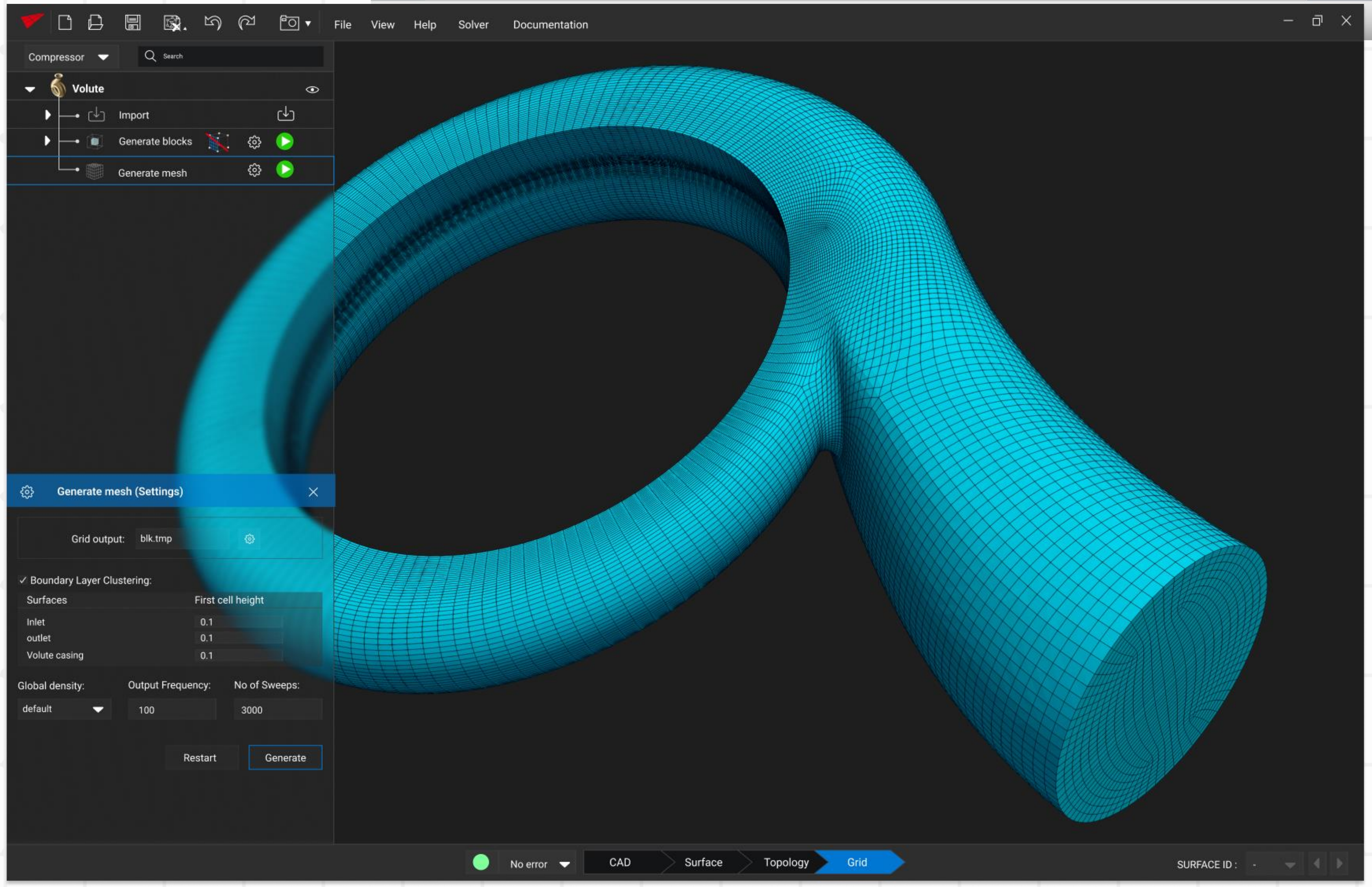
GridPro — Topology-First Structured Meshing + CAESES Automation



WHAT is GridPro ?

- **A Specialized Meshing software for Automating Structured hexahedral meshes**
  - Topology Based Grid generator
  - Features semi-automatic and automatic blocking capabilities
  - Advanced Dynamic Boundary Conforming Smoother
  - Fully Customizable for Specialized Workflows
  - Powerful Python based API for Scripting
  - Fully Automated blocking workflows for
    - Blades
    - Volutes
    - Propellers
    - Wind Turbines

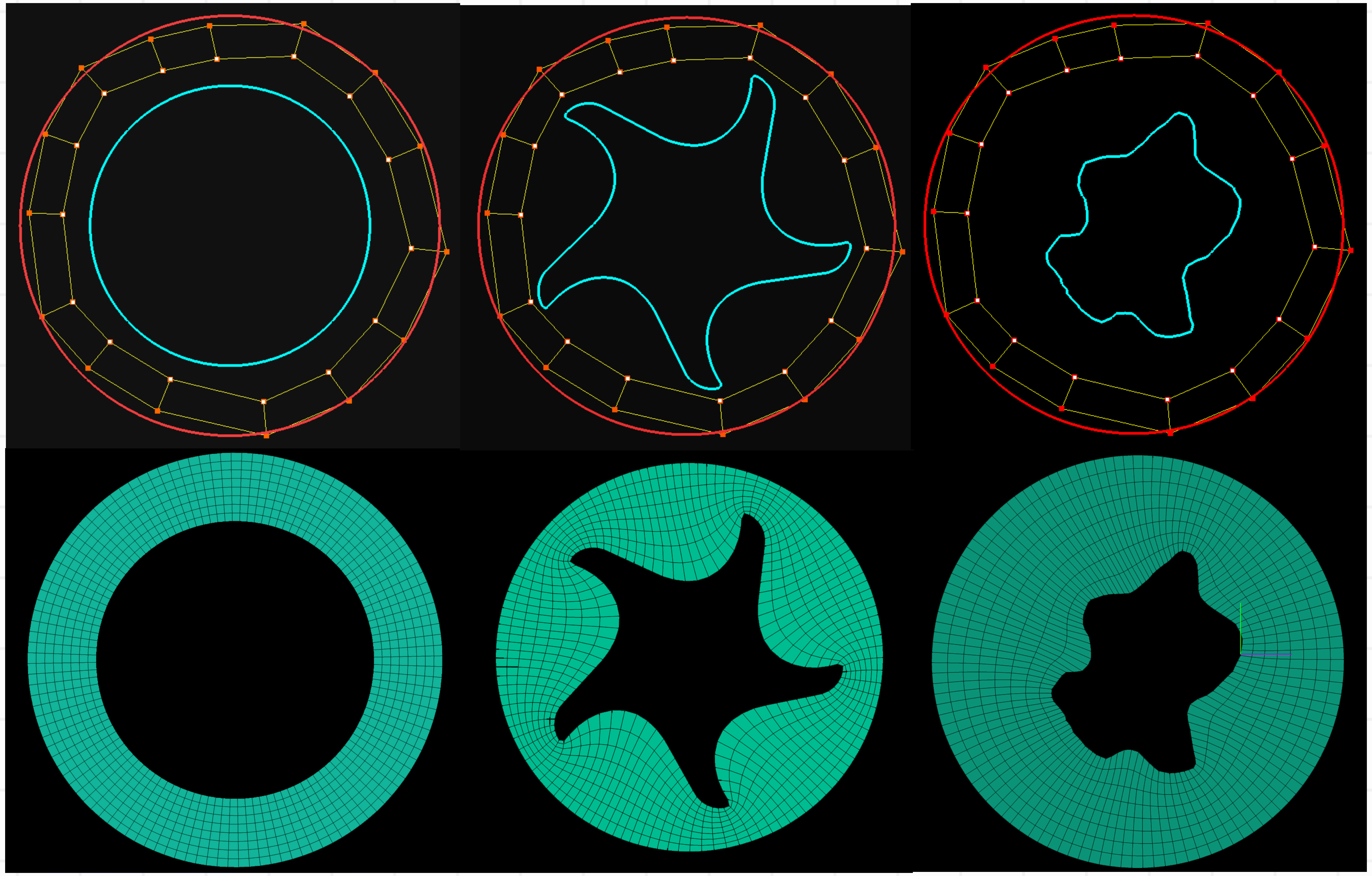




Topology-First Approach

“GridPro separates the mesh generation problem into two distinct steps: first define the topological block structure (connectivity), then let the smoother find the optimal node placement. This separation is what makes GridPro uniquely powerful for complex geometries.”

- ✓ Block topology defines how the computational space maps to physical space
- ✓ Topology is independent of geometry detail — same topology handles design variants
- ✓ Block decomposition adapts to arbitrary complexity:



Multi-Objective Smoothing Algorithm

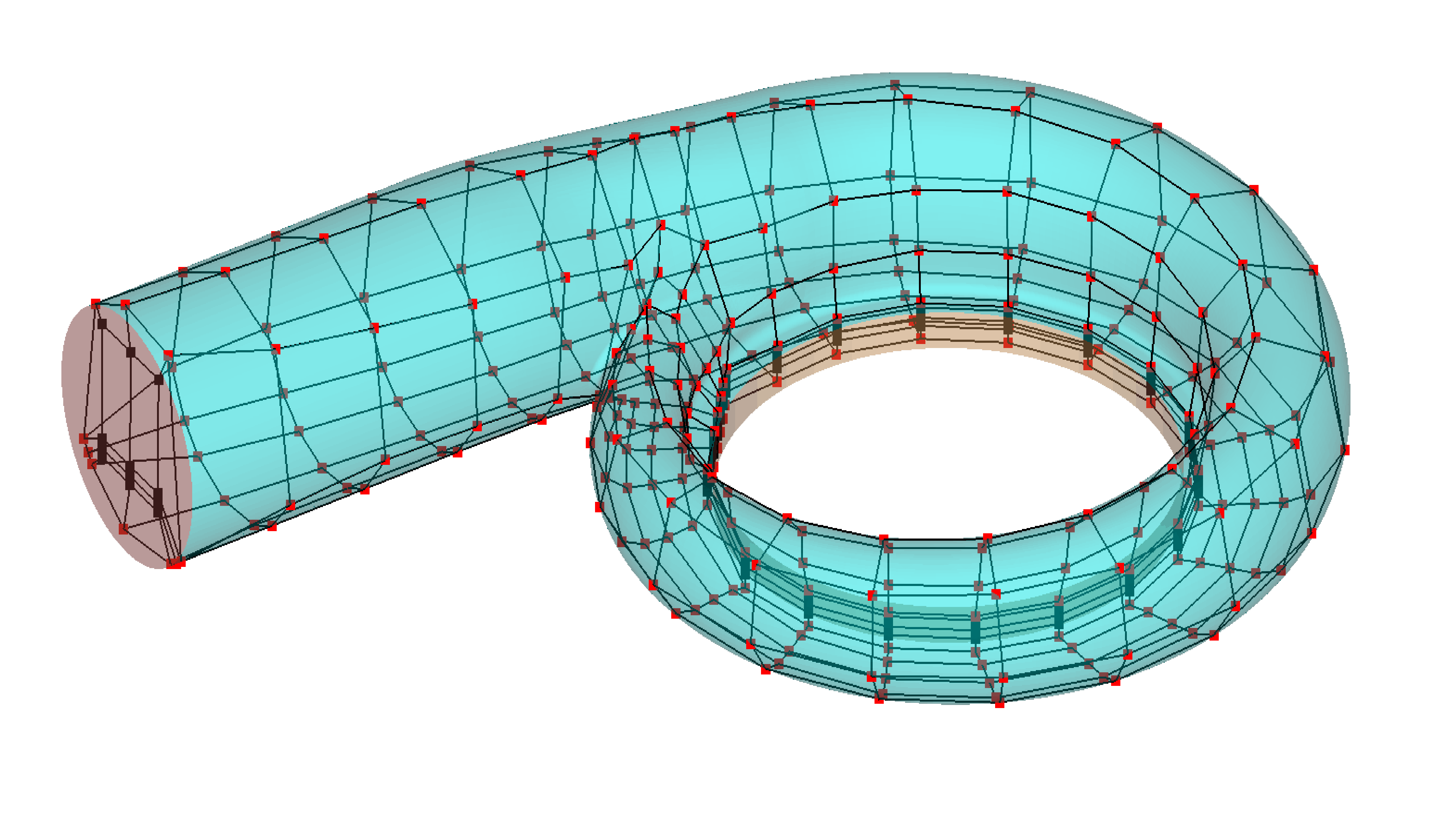
"GridPro's smoother simultaneously optimizes orthogonality, smoothness, and clustering — producing meshes where the face normal naturally aligns with the cell-center vector, eliminating the non-orthogonal corrections that plague unstructured solvers."

✓ Elliptic smoothing with source terms for boundary orthogonality control

✓ Cell-quality-aware redistribution: worst cells improved without degrading neighbors

✓ Anisotropic clustering for boundary layers, wakes, and shear layers

✓ Result: near-zero non-orthogonality and skewness across the entire domain



Direct CFD Consequences of GridPro Mesh Quality

Near-zero non-orthogonality → implicit diffusion scheme is exact → no correction iterations needed

Low skewness → face interpolation hits the right location → accurate convective fluxes

Aligned aspect ratio → boundary layer resolved with minimal cells → correct wall shear stress & y+

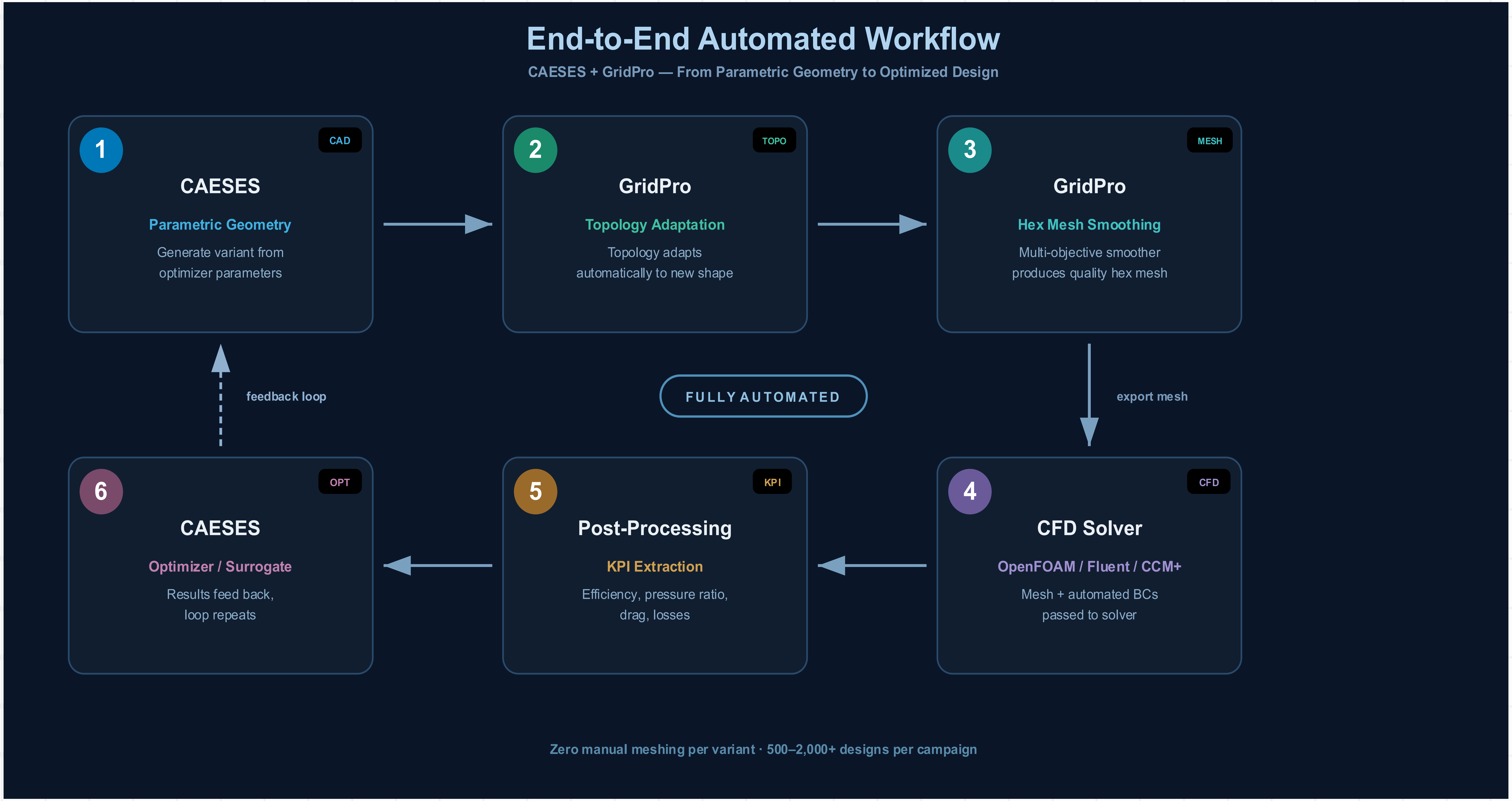
Smooth cell transitions → monotonic truncation error → reliable Richardson extrapolation for GCI

No degenerate cells → robust CFL behavior → larger time steps → faster transient simulations

Net effect: fewer cells, faster convergence, more accurate results — simultaneously

End-to-End Automated Workflow

CAESES Parametric Geometry → GridPro Topology Adaptation → CFD Solve → Feedback



Six steps, fully automated. CAESES drives geometry, GridPro handles meshing, solver runs hands-free, results feed back. Zero manual intervention per variant.

Parametric Geometry Morphing Engine (PGME)

“GridPro's PGME uses RBF-based morphing to deform the mesh for every design variant — without full regeneration. The topology and quality are preserved while the mesh conforms to CAESES geometry updates. Per-variant meshing drops from minutes to seconds.”

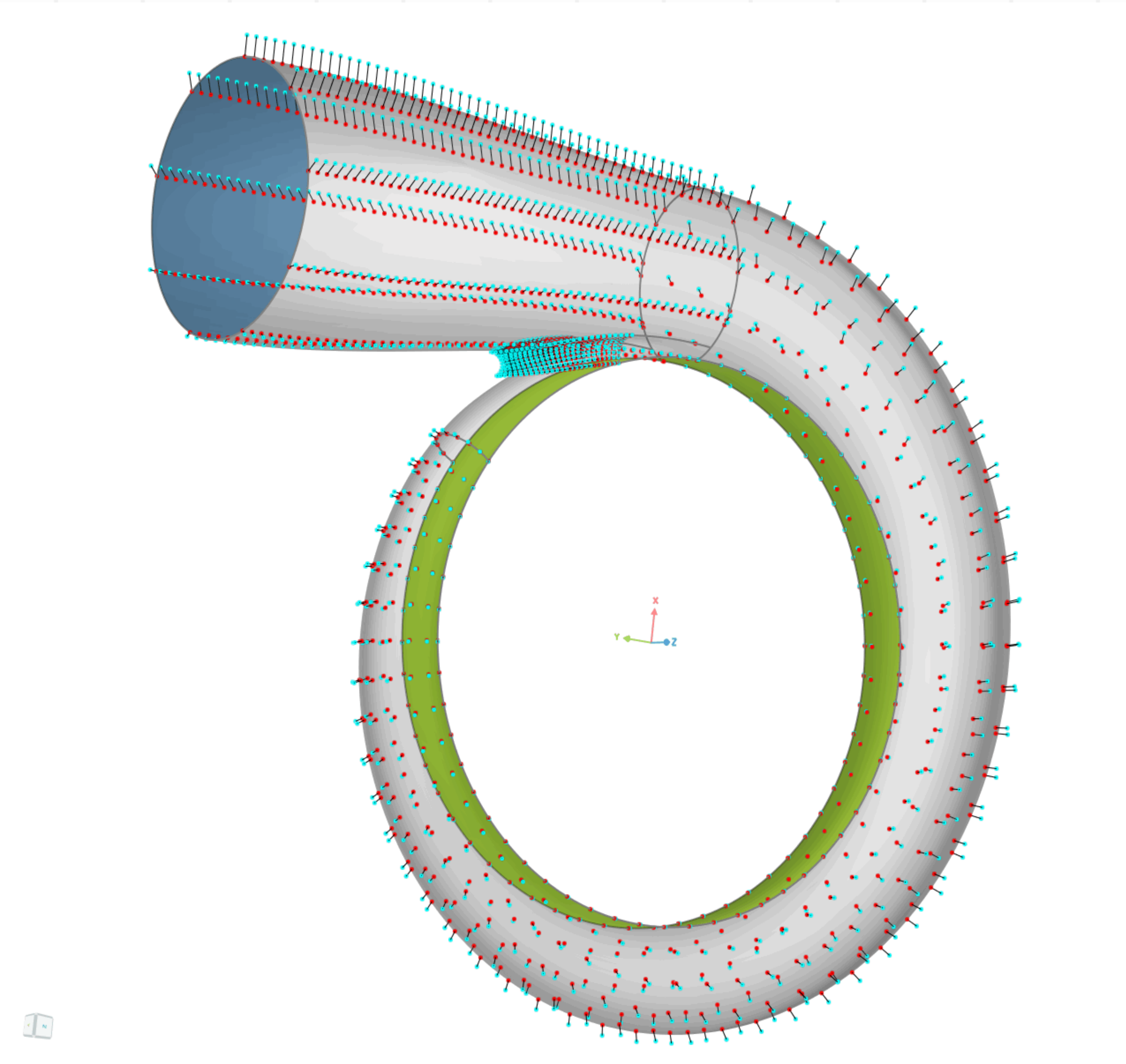
✓ PGME intelligently maps point clouds to initial blocks, then morphs block and vertex positions for each variant

✓ RBF interpolation deforms the blocks based on surface displacement

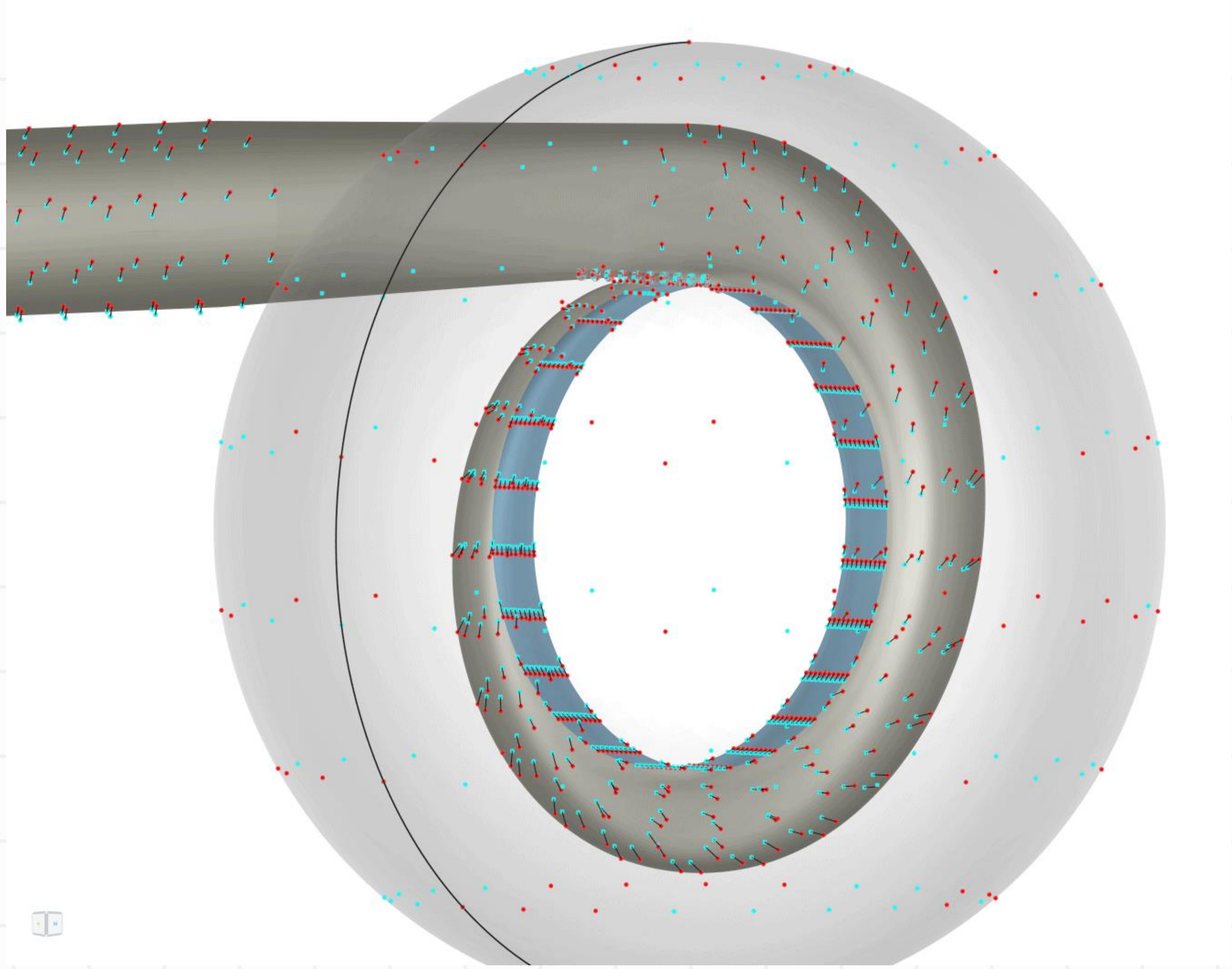
✓ Mesh quality preserved: orthogonality and smoothness degrade minimally across variants

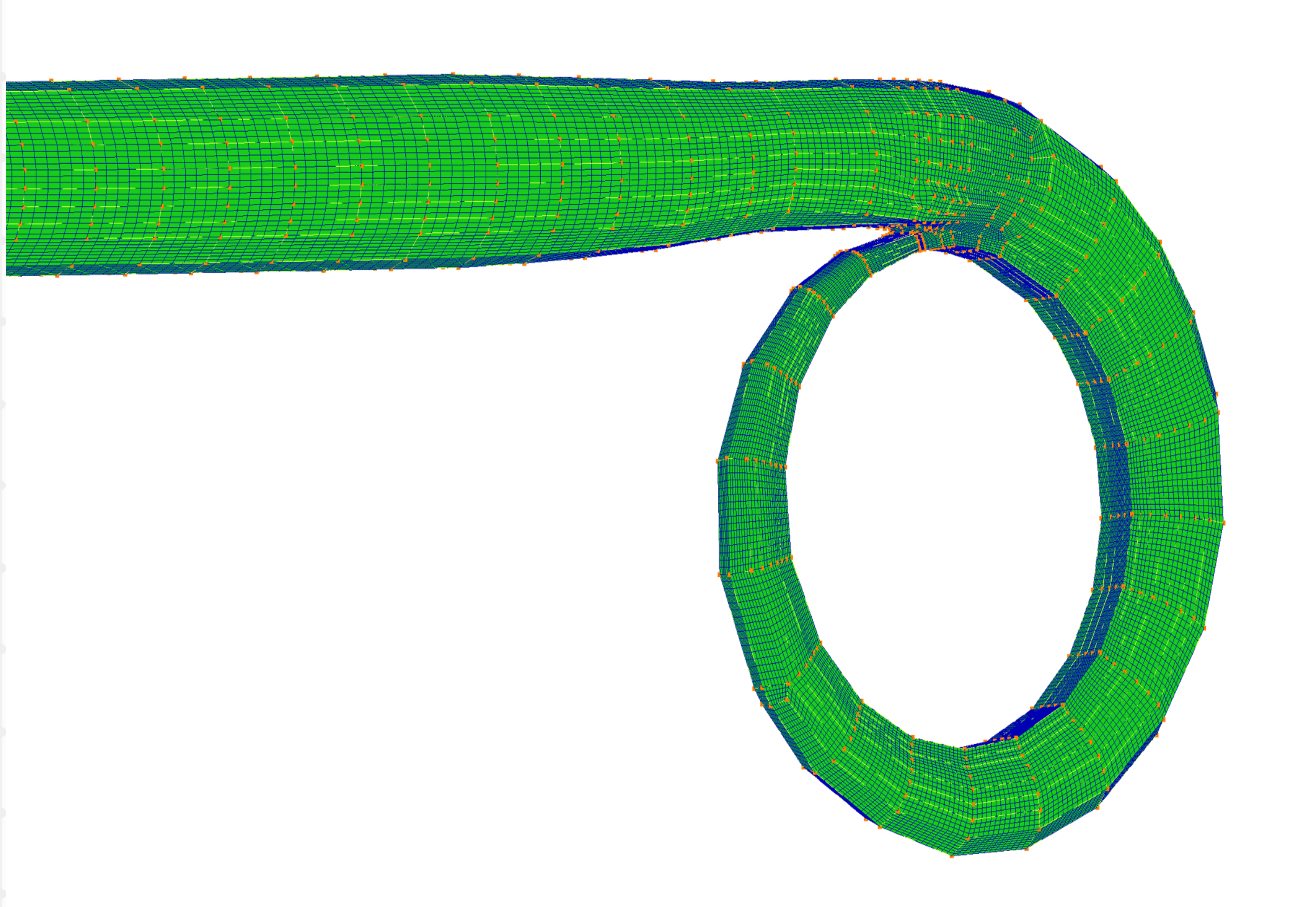
✓ < 1% failure rate — most scenarios achieve 100% success across all design variants

✓ Enables evaluation of 500–2,000+ variants per optimization campaign

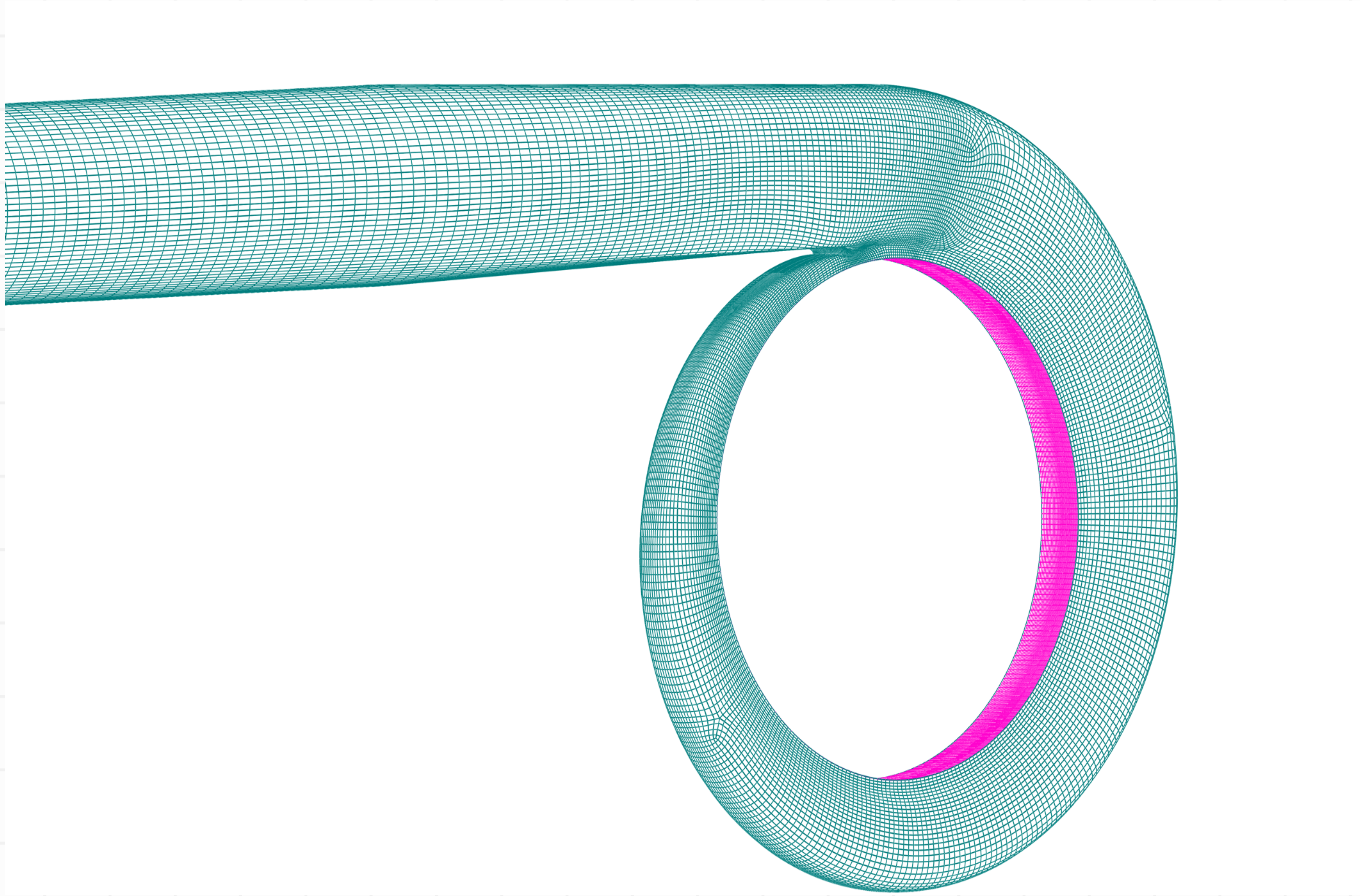


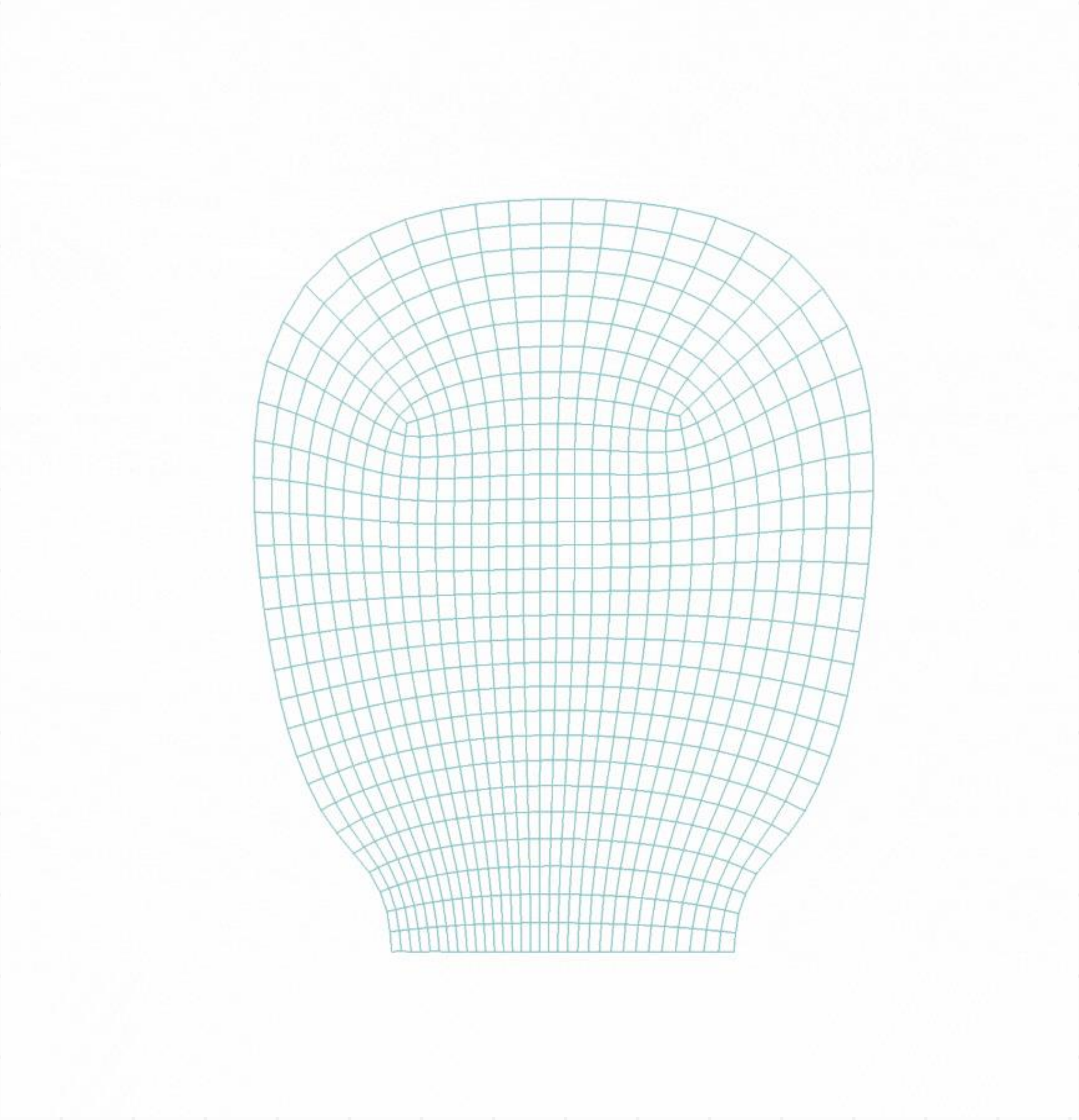
Parametric Geometry Morphing Engine (PGME)





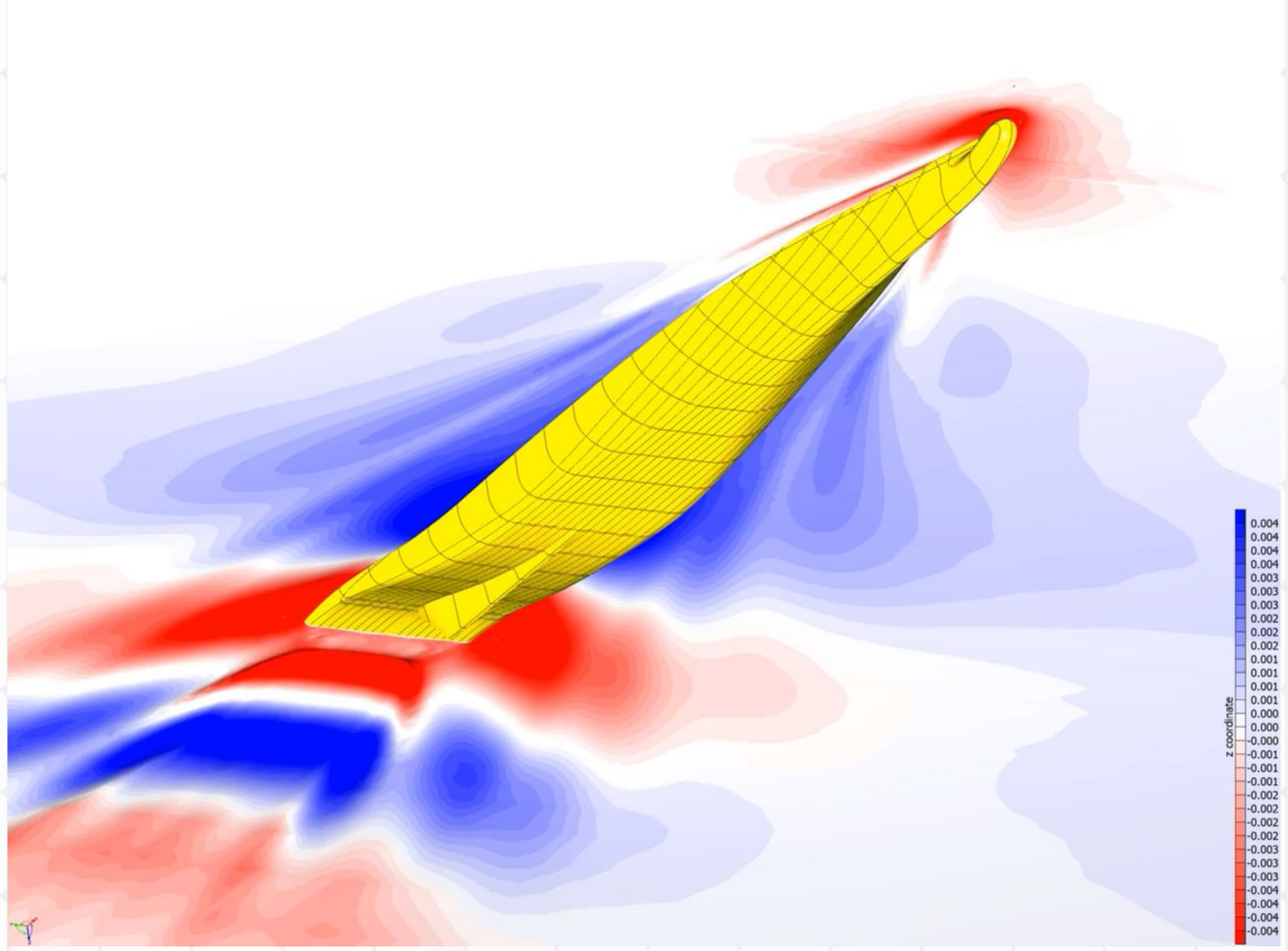
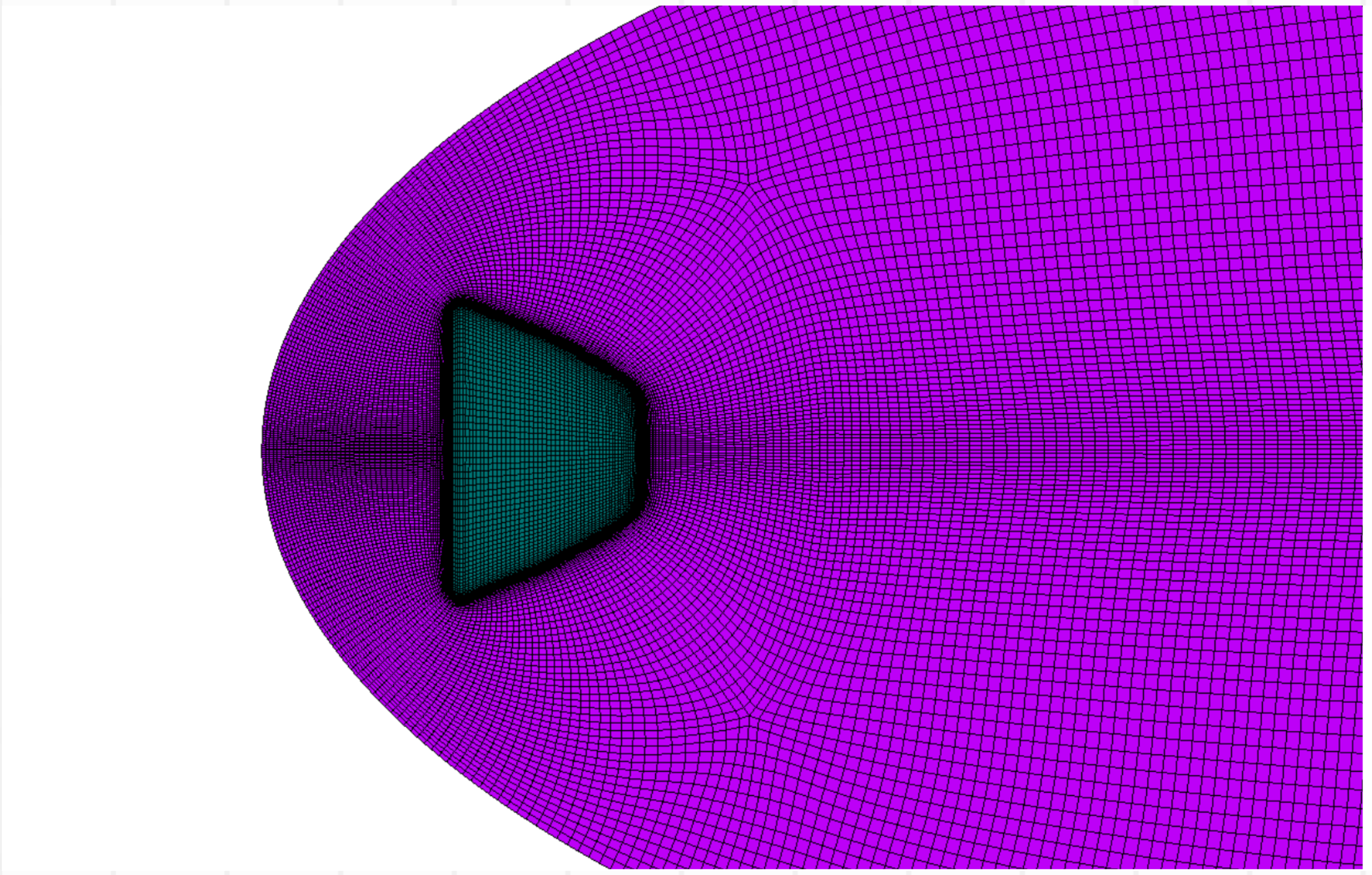
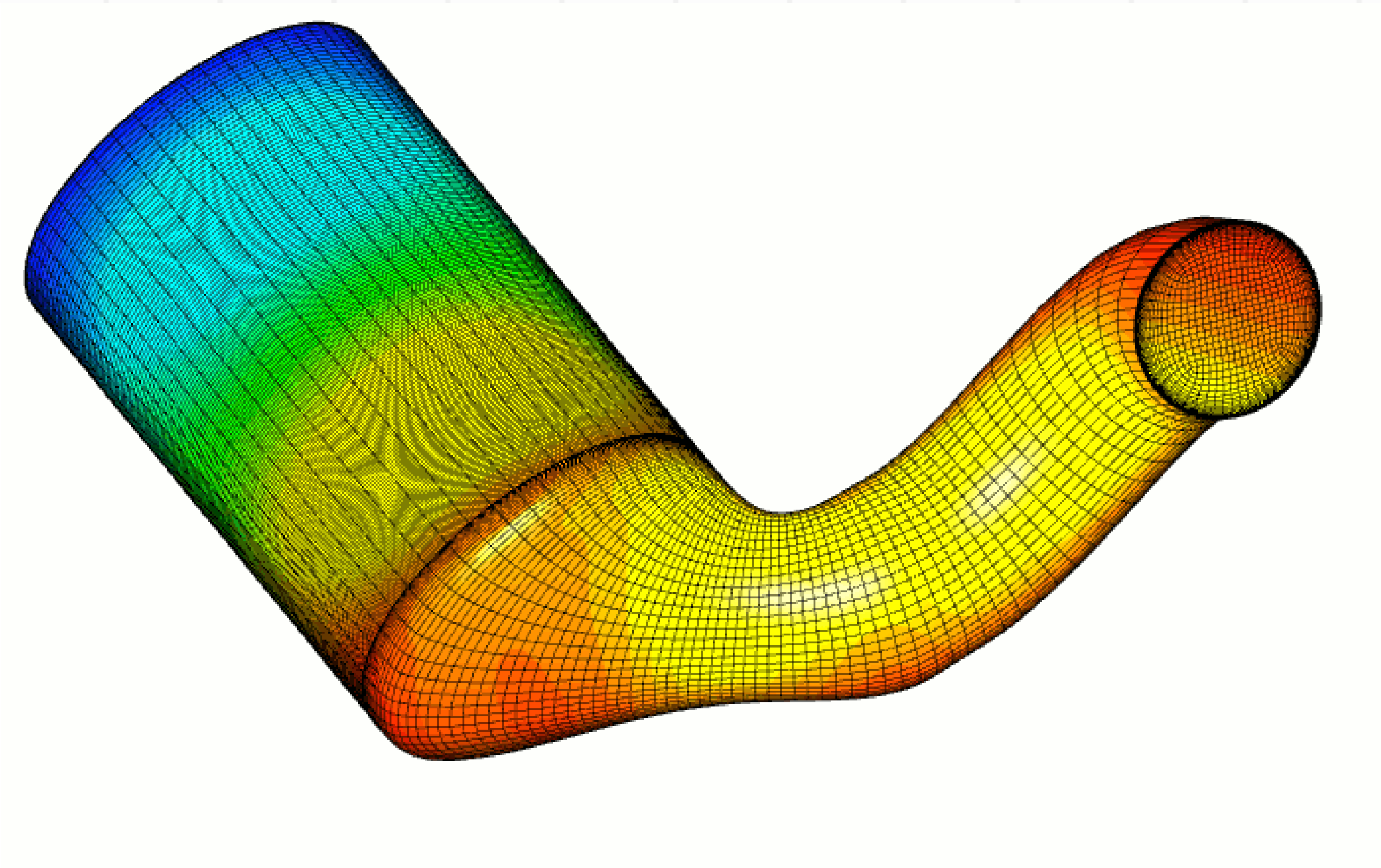
Parametric Geometry Morphing Engine (PGME)





GridPro and CAESES Success stories across industries




Key Takeaways

- Mesh quality is the #1 lever on CFD accuracy — garbage in, garbage out
- Structured hex meshes deliver 4–14× fewer cells and 6–27× less compute time
- GridPro's topology-first approach makes structured meshing practical for complex geometries
- CAESES + GridPro automation enables 500–2,000+ design variants per project
- The combination cuts design cycle time by 40–70% with predictions within 1–2% of experiment

The mesh is not a preprocessing step — it is the simulation.

Make it count.

Questions?

Let's talk about your geometry.

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