High-order mesh generation for CFD solvers

M. Turner, **D. Moxey**, S. Sherwin, J. Peiró
Department of Aeronautics, Imperial College London

DiPaRT 2015 Annual Meeting, Bristol, UK
17th November 2015

Overview

- Motivation
- The spectral/*hp* element method
- Challenges: mesh generation
- Some results
- Conclusions

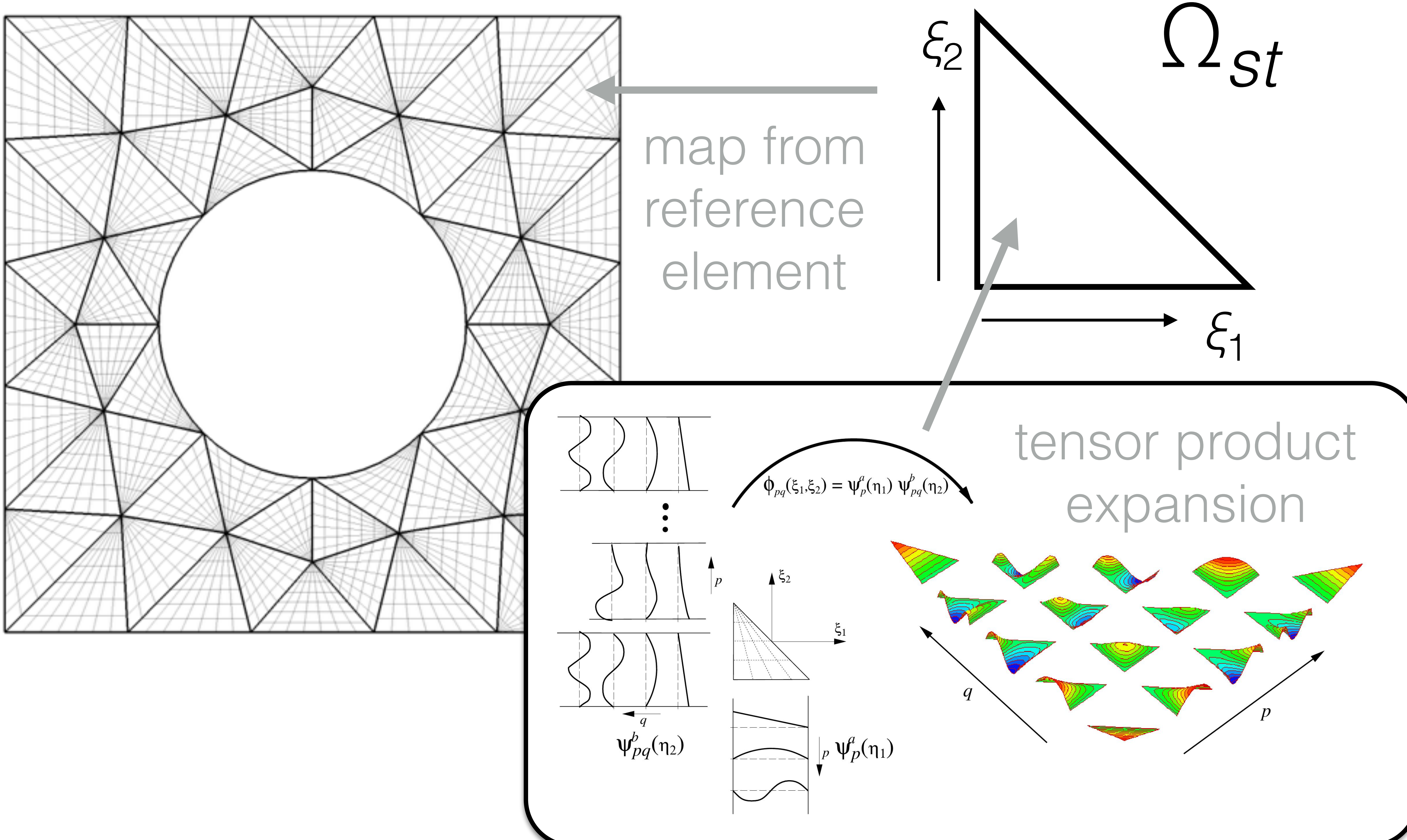
Motivation

Primary research goal is to investigate challenging external aerodynamics cases:

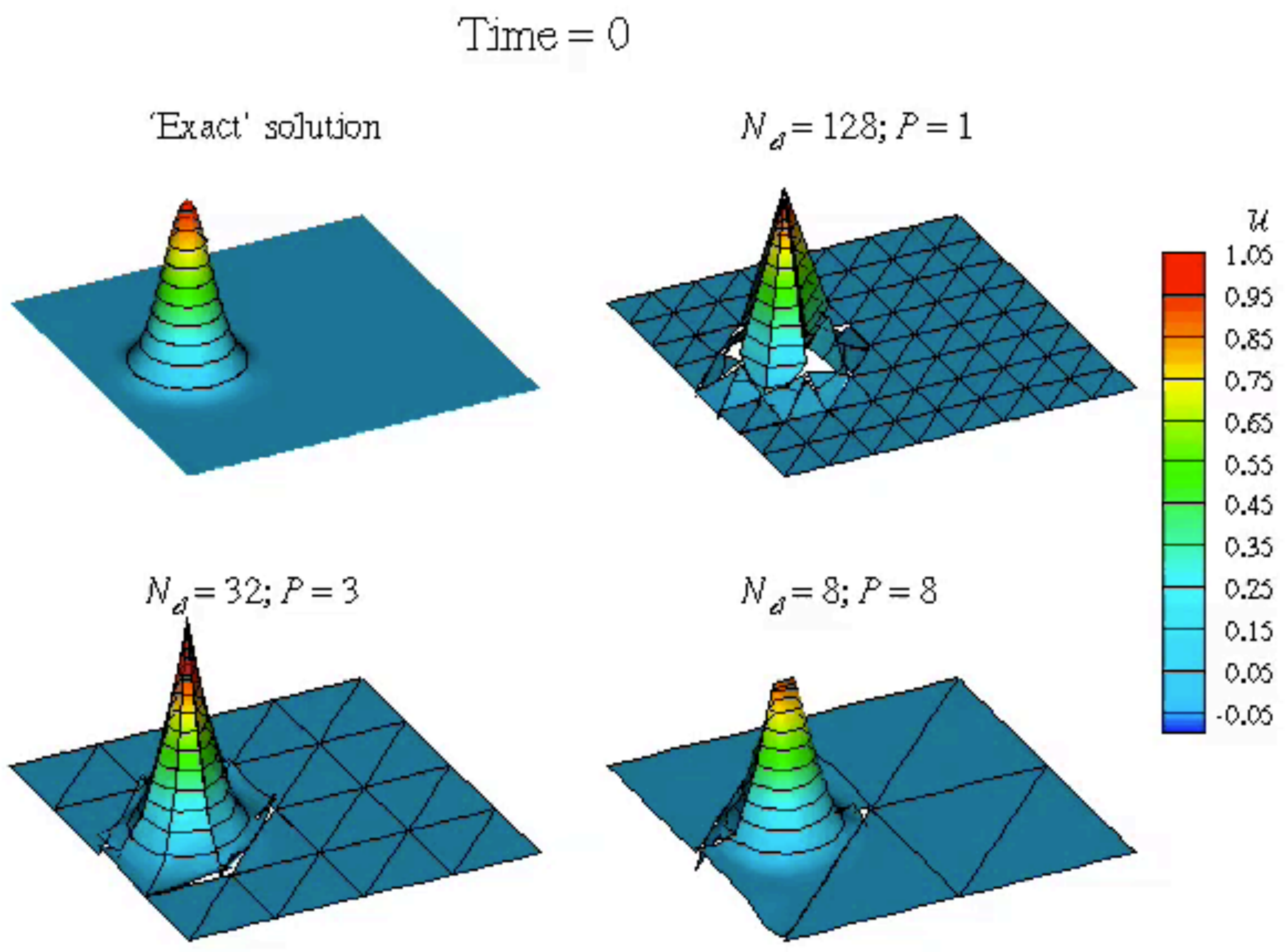
- High Reynolds numbers
- Complex three-dimensional geometries
- Large resolution requirements
- Transient dynamics

Using high-order spectral/*hp* element method

Spectral/*hp* element method



Why high-order methods?



Rotation of Gaussian bump in linear advection equation

Why high-order methods?

- Very good numerical properties: should therefore be better at tracking long-time transient structures

- Discrete operators are dense and have rich structure: computationally efficient & scale well

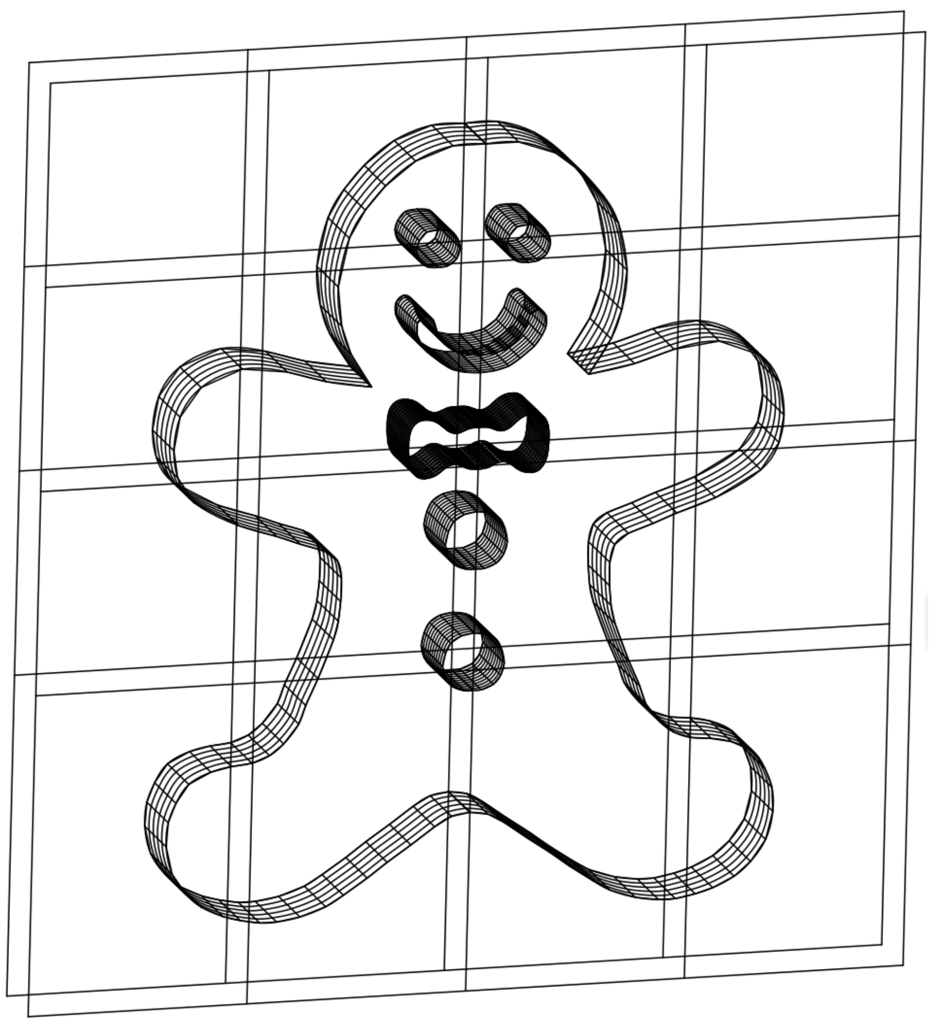
but...

- Lots of specialised knowledge required

- One big challenge: mesh generation

High-order mesh generation

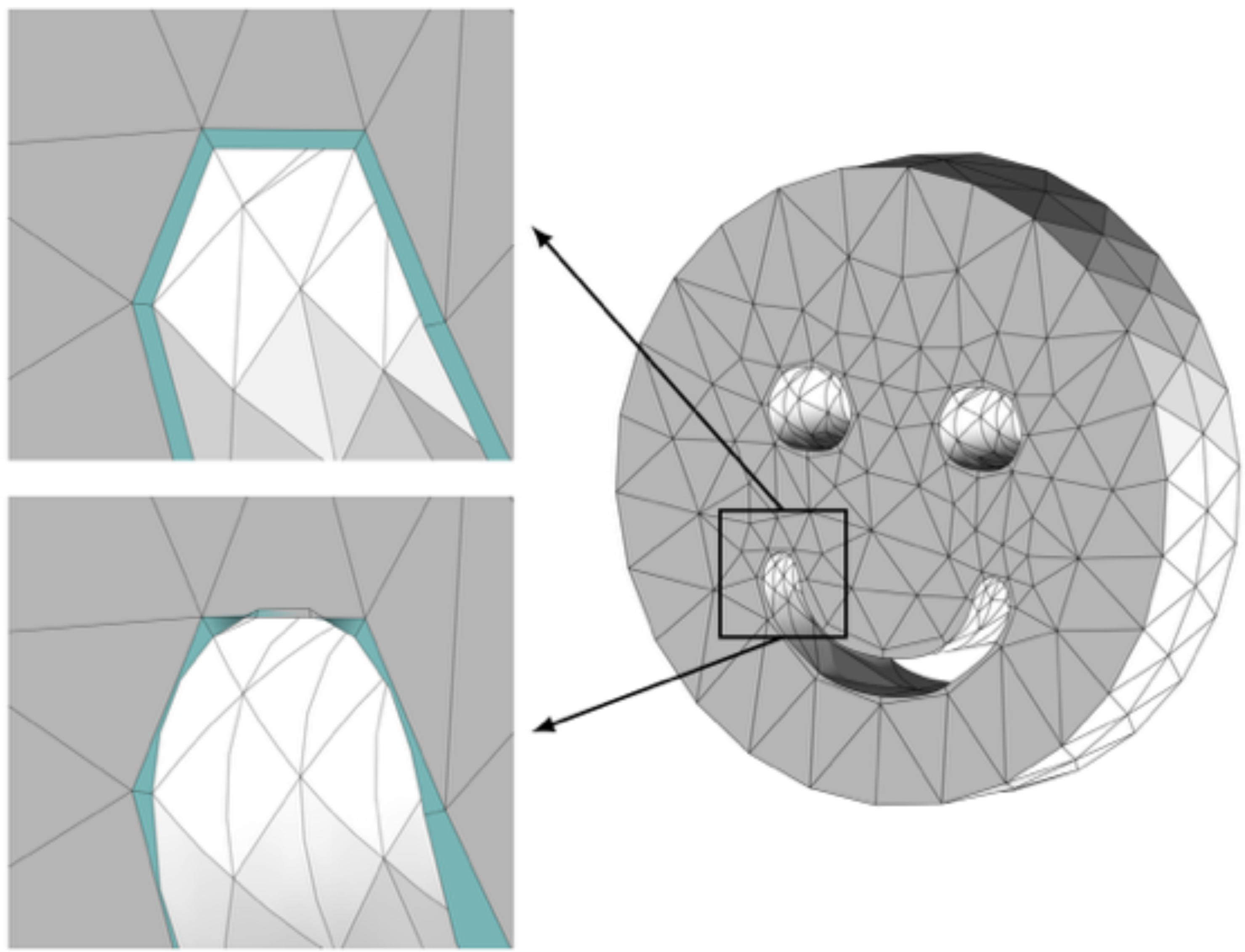
(in theory)



B-Rep

High-order mesh generation

Curving coarse meshes leads to invalid elements
Most existing MG packages cannot deal with this

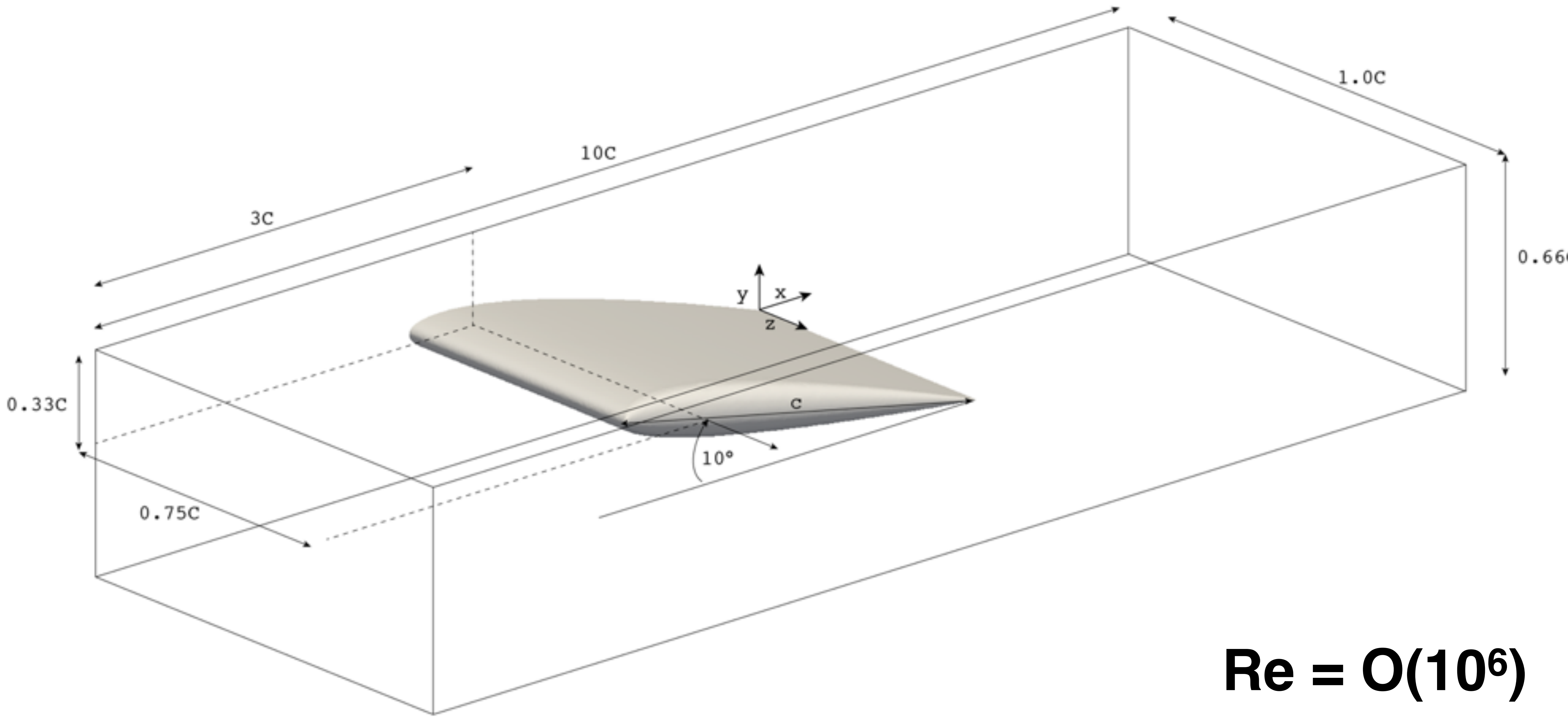


MG pipeline to date

For complex geometries:

- Use commercial mesh generator for coarse straight-sided mesh (prism boundary, tet interior)
- Manipulate the mesh to make it high order
- Try to fix broken elements
- Pray

NACA 0012 wing tip

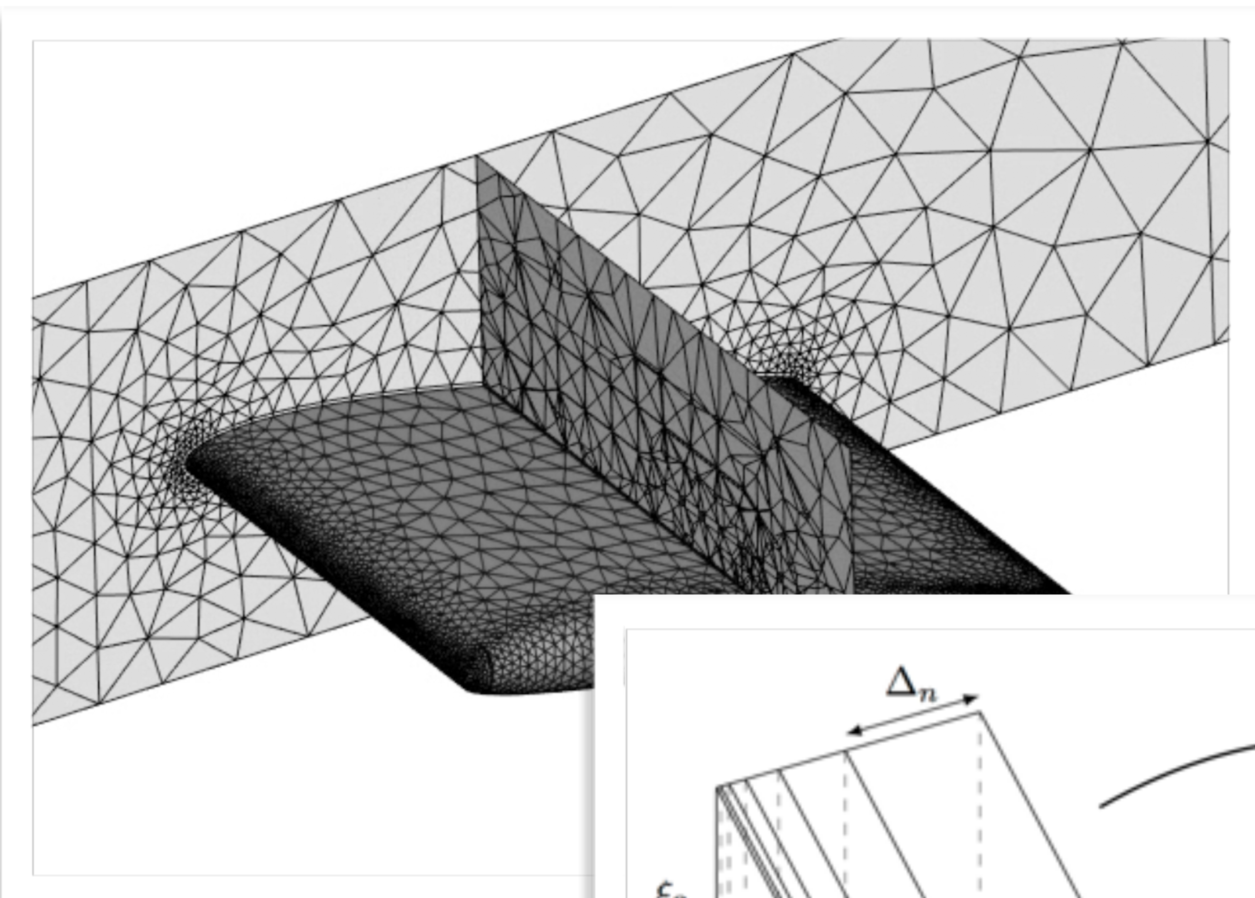


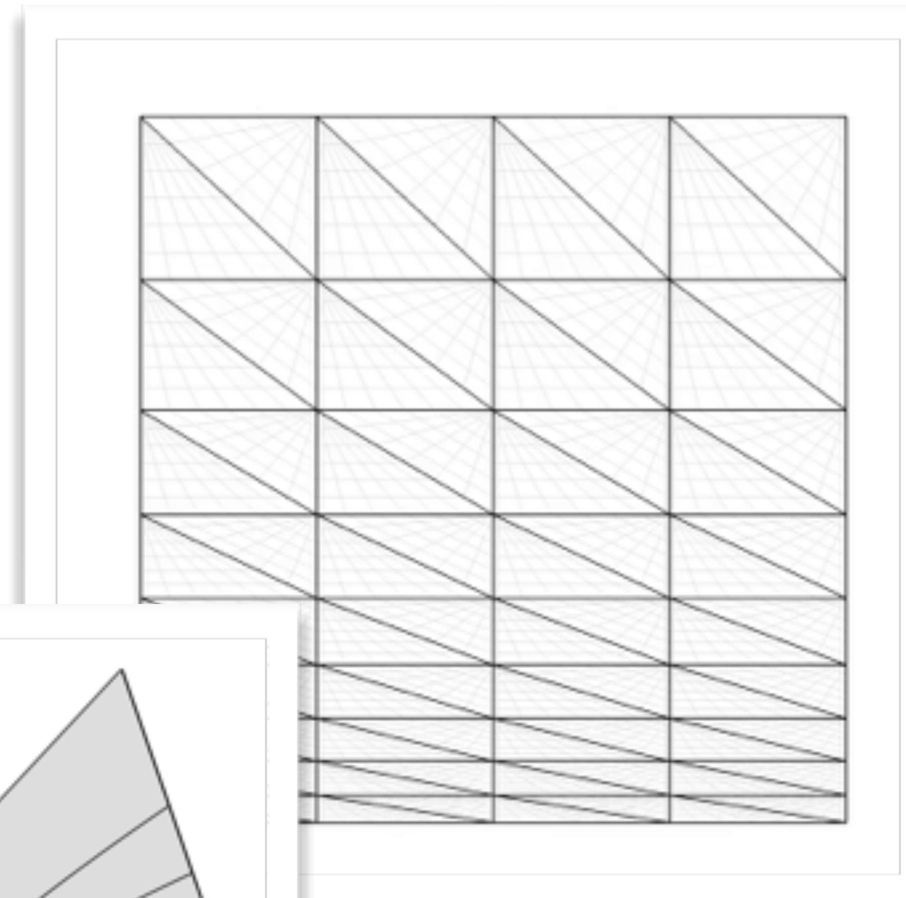
Re = O(10^6)

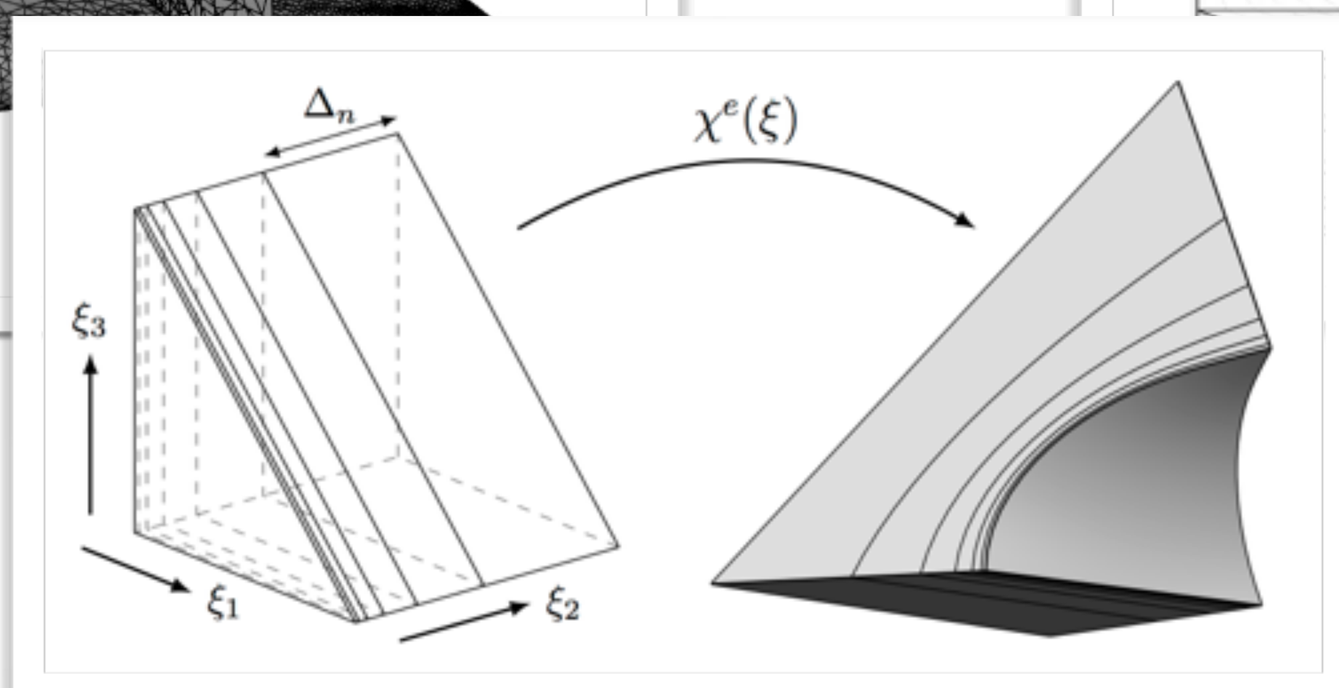
Strong wingtip vortex difficult to capture with RANS

Existing workflow

Linear mesh from Star-CCM+ → Convert to high-order → Output high order mesh

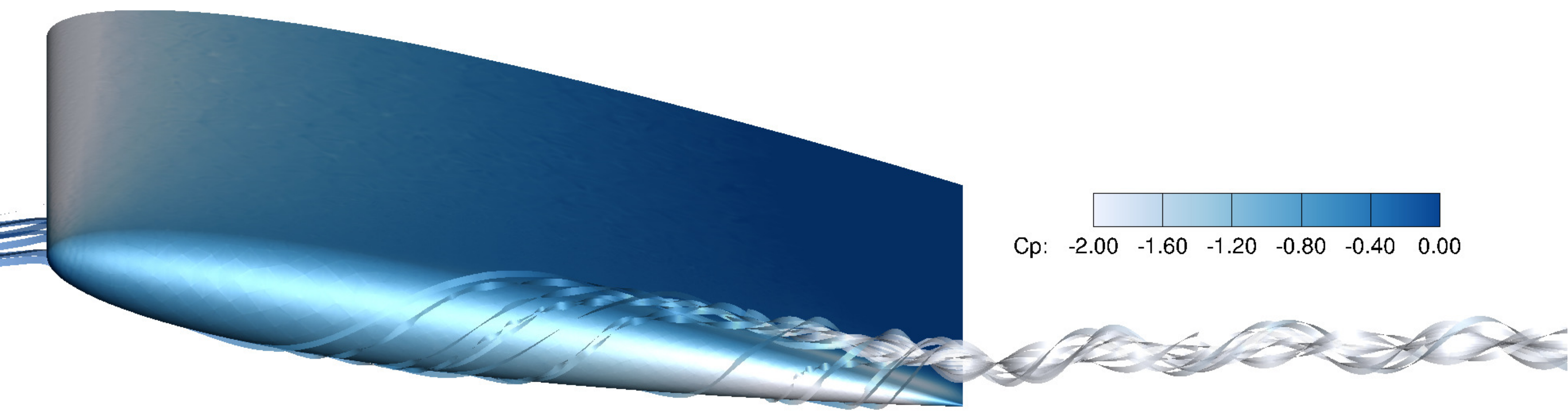






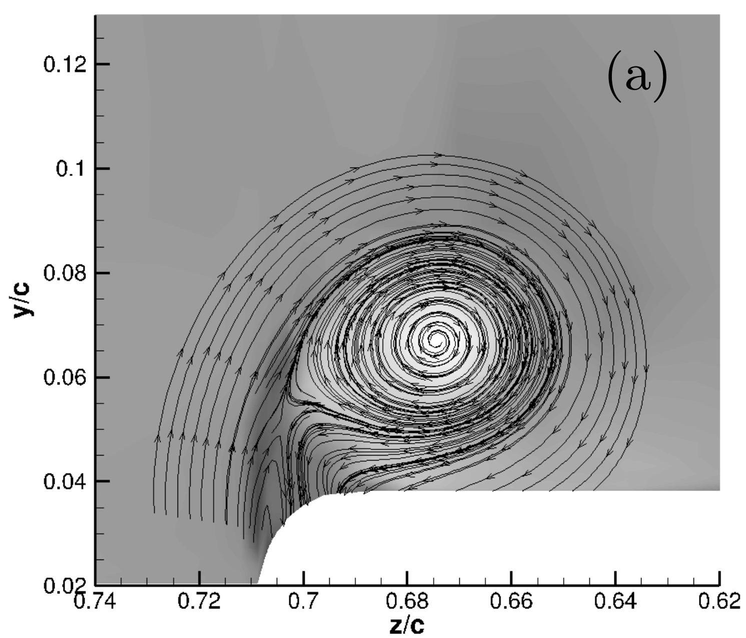
NACA 0012 example

- Simulations at Re = 1.2m
- Highly unsteady, vortex dominated
- SVV-LES formulation of incompressible NS

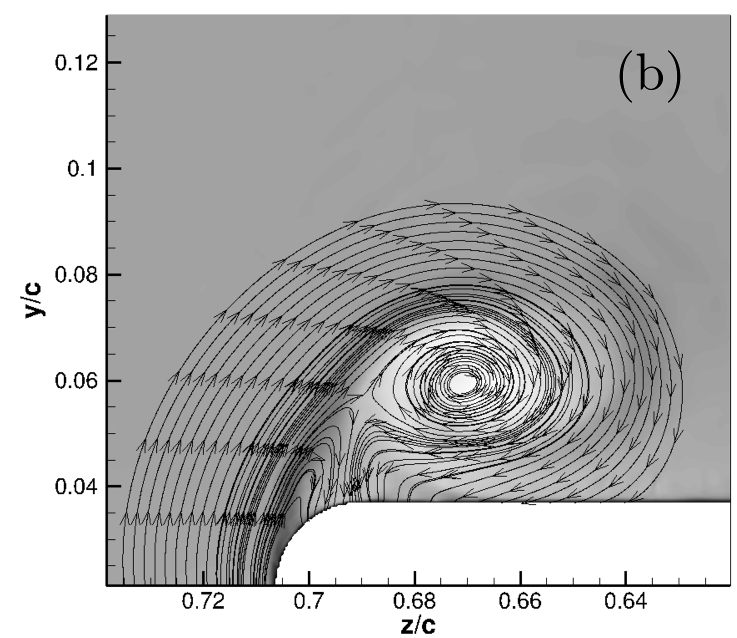


Lombard, Moxey, Hoessler, Dhandapani, Taylor and Sherwin
to appear in AIAA J. (2015)

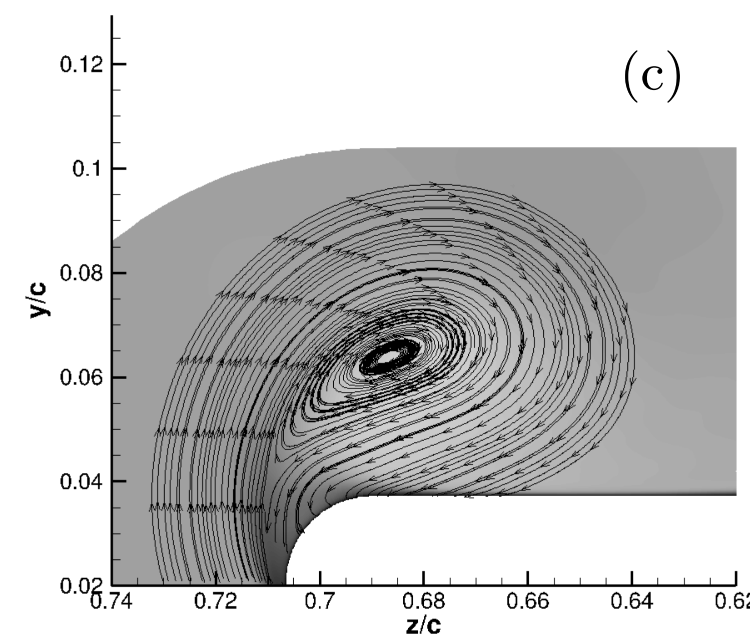
NACA 0012 example



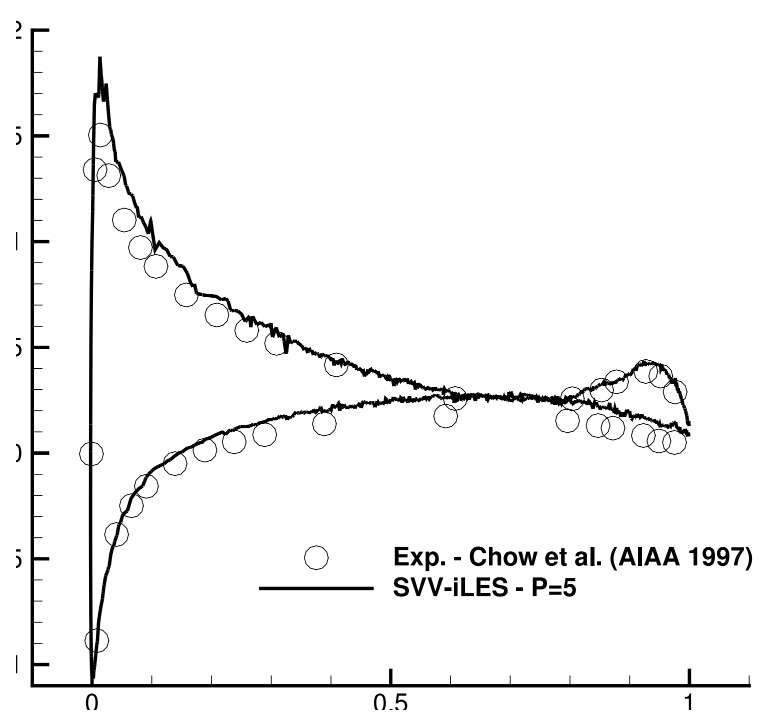
Exp.

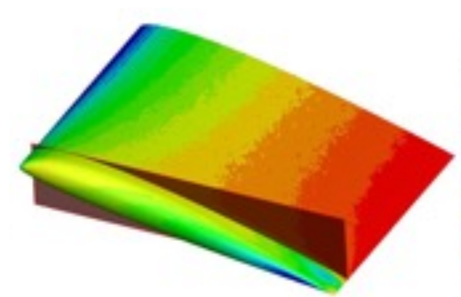


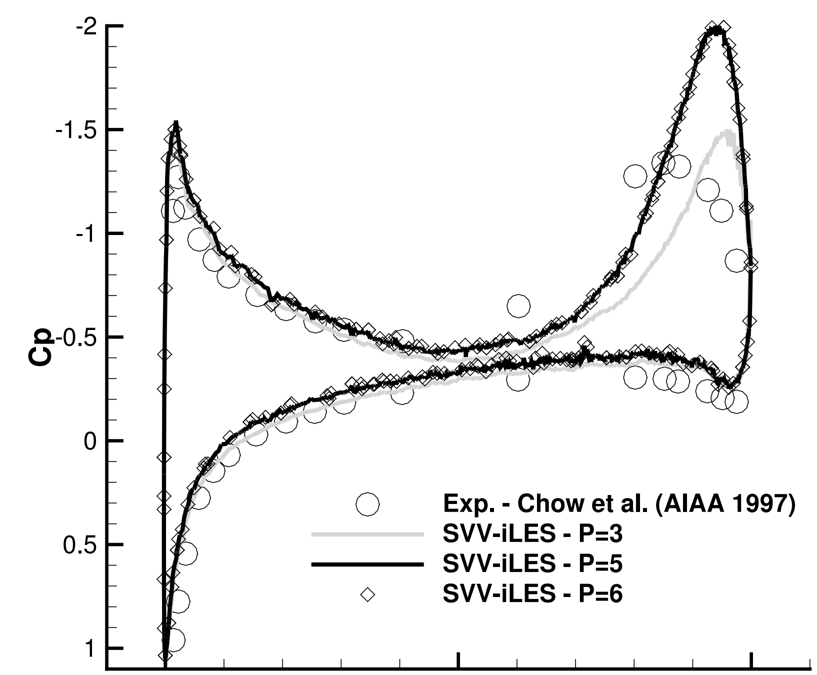
Nektar



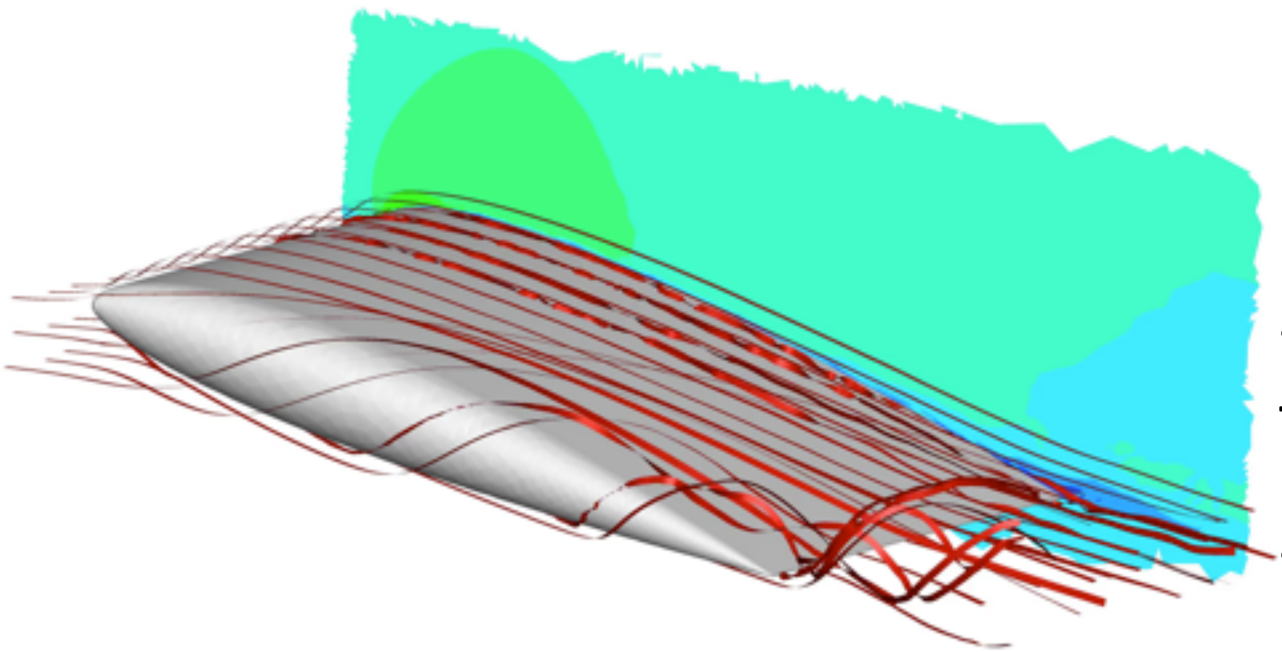
LES. Uzun

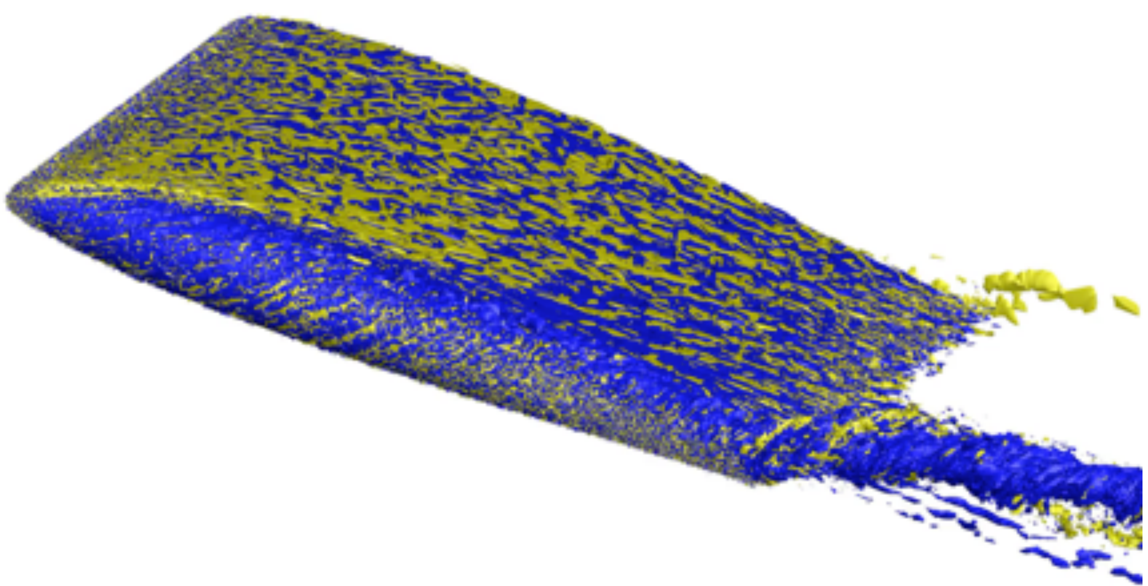


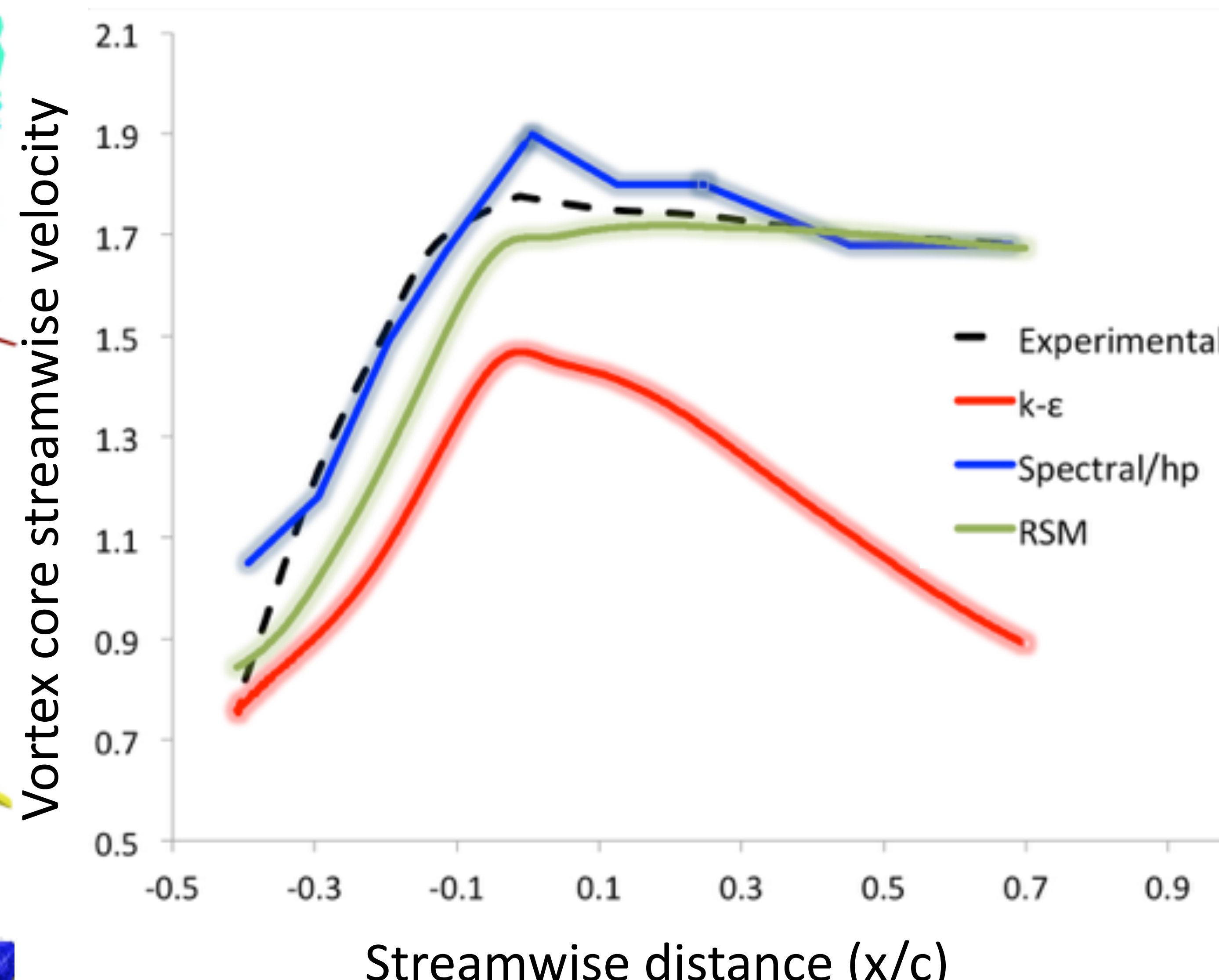




NACA 0012 example

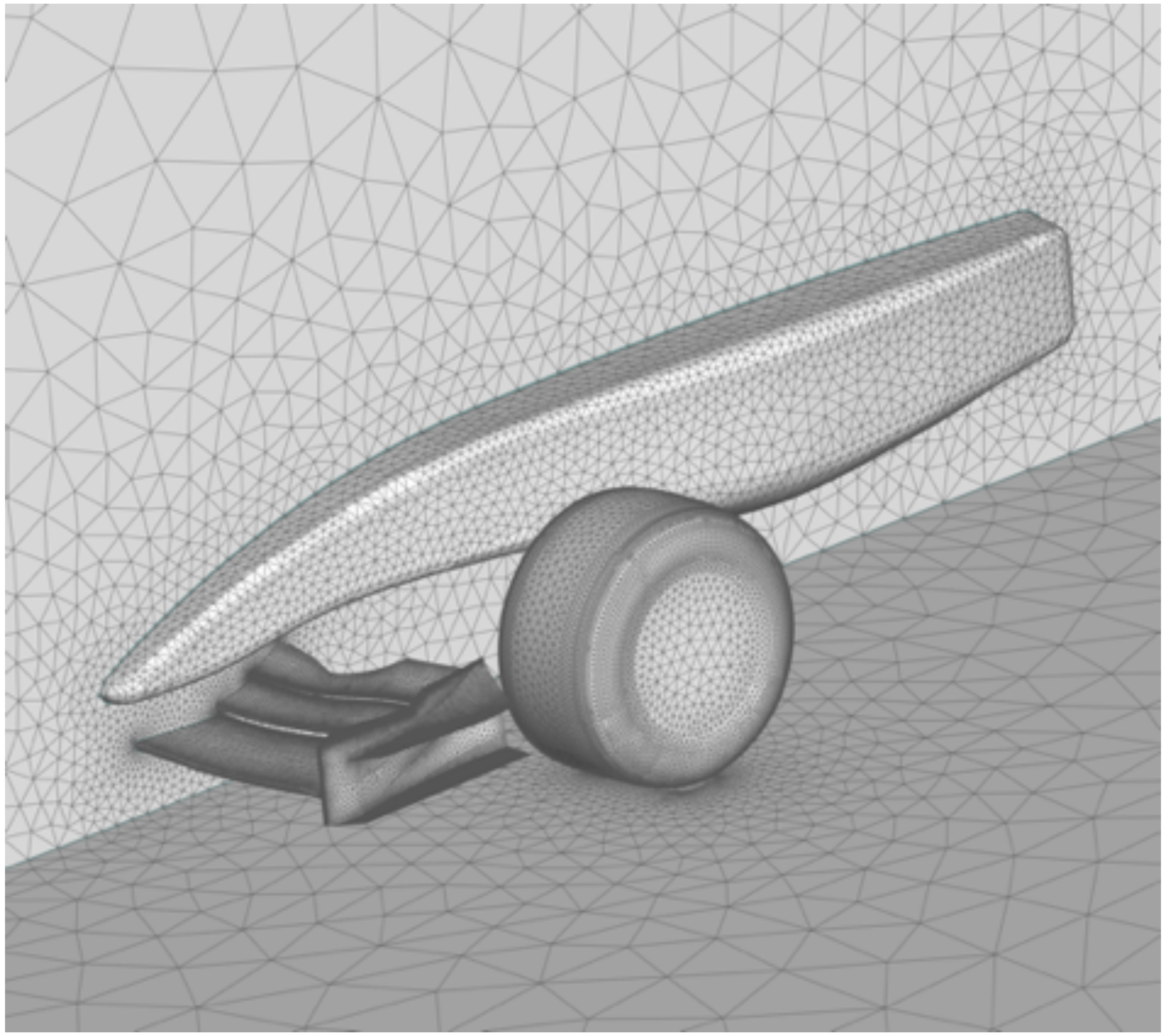


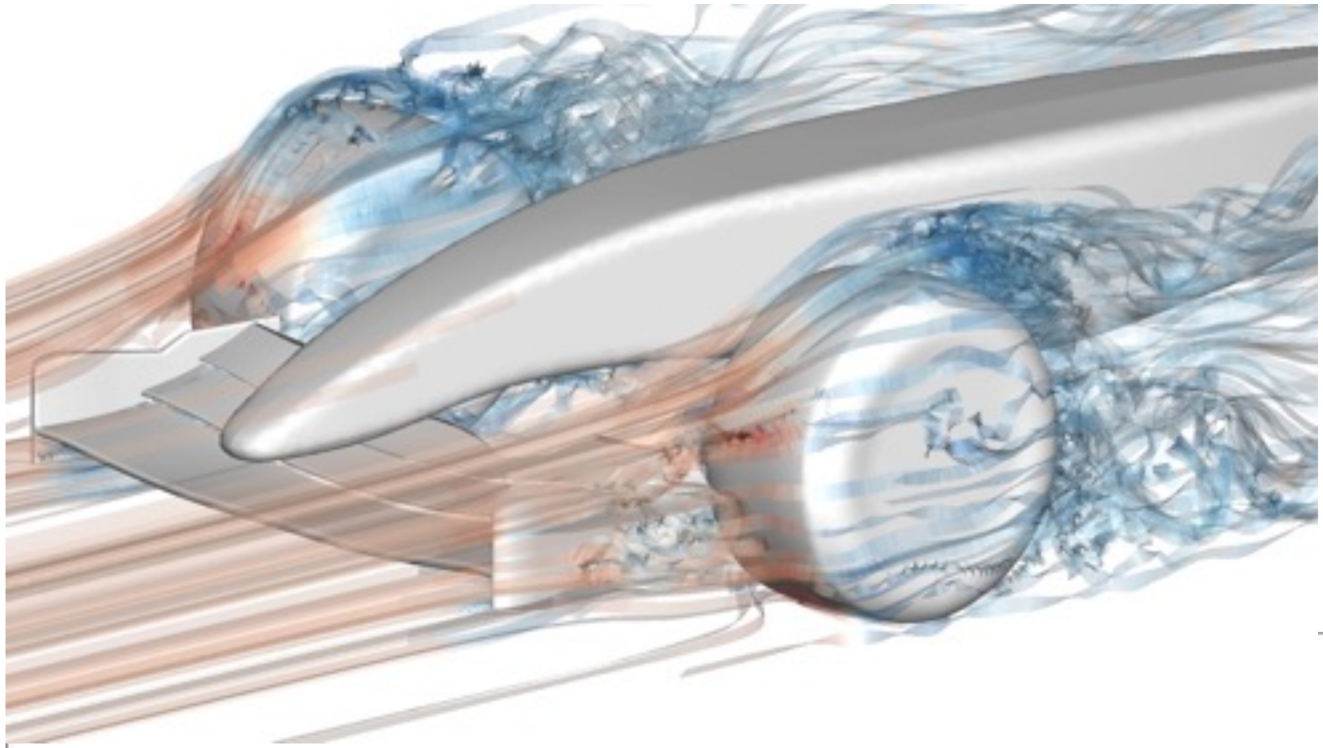


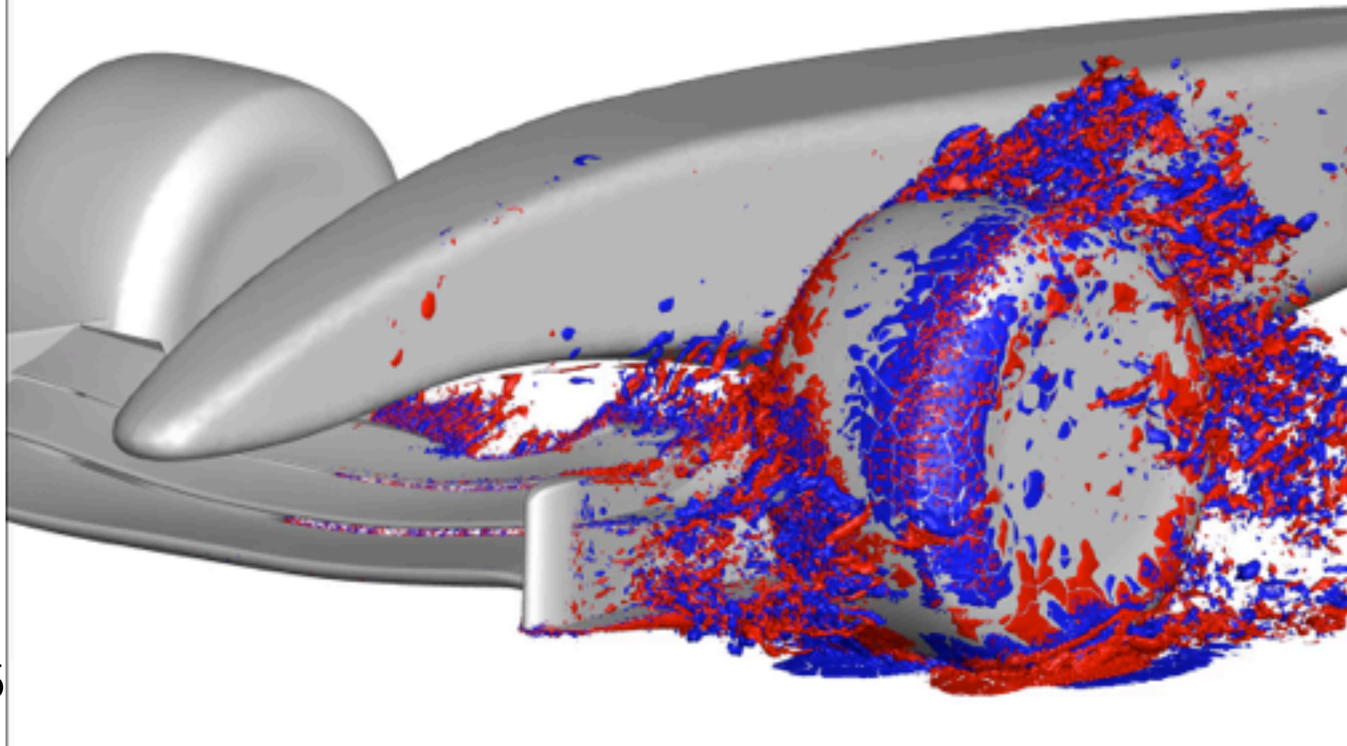


Lombard, Moxey, Hoessler, Dhandapani, Taylor and Sherwin
to appear in AIAA J. (2015)

More complex geometries

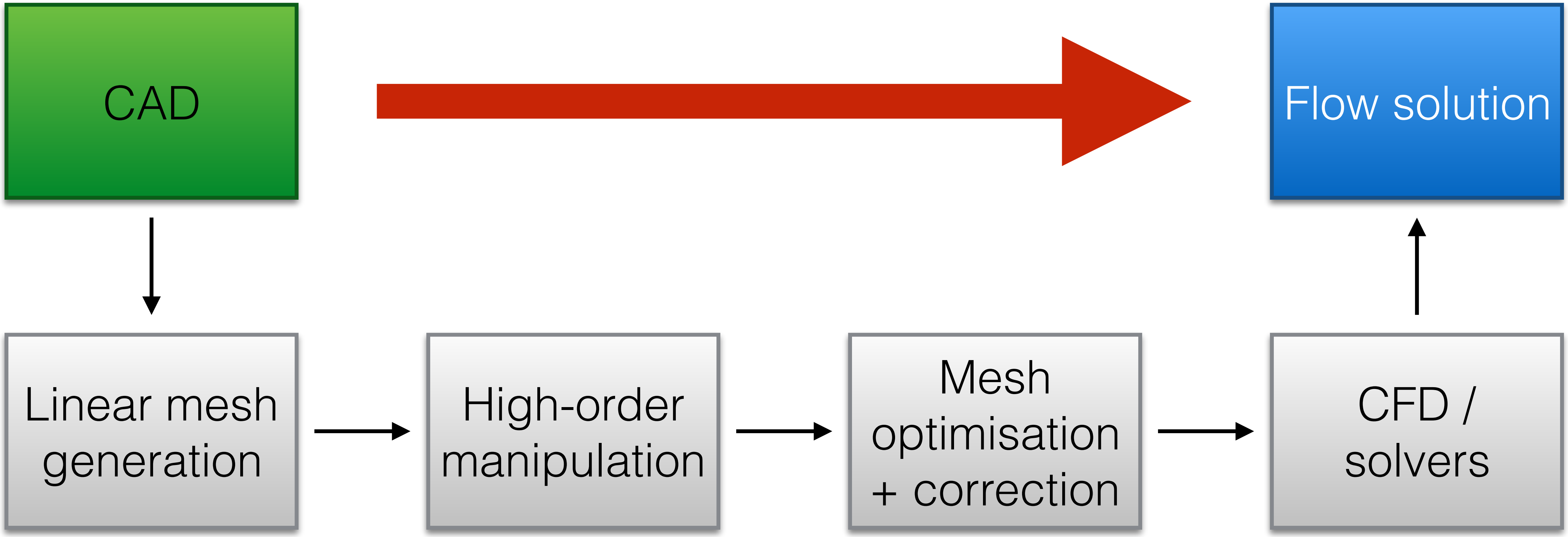




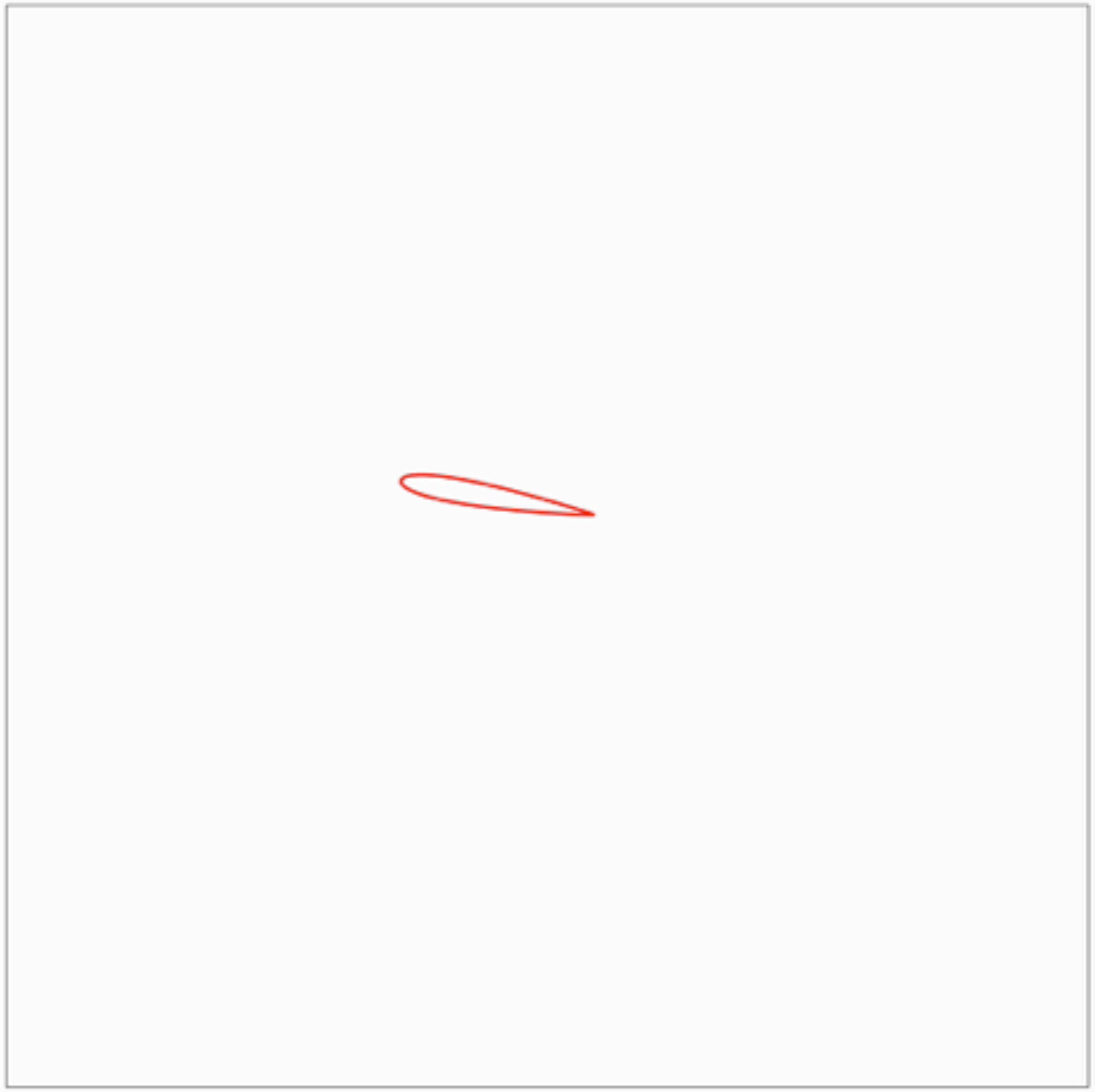


Towards a better MG solution

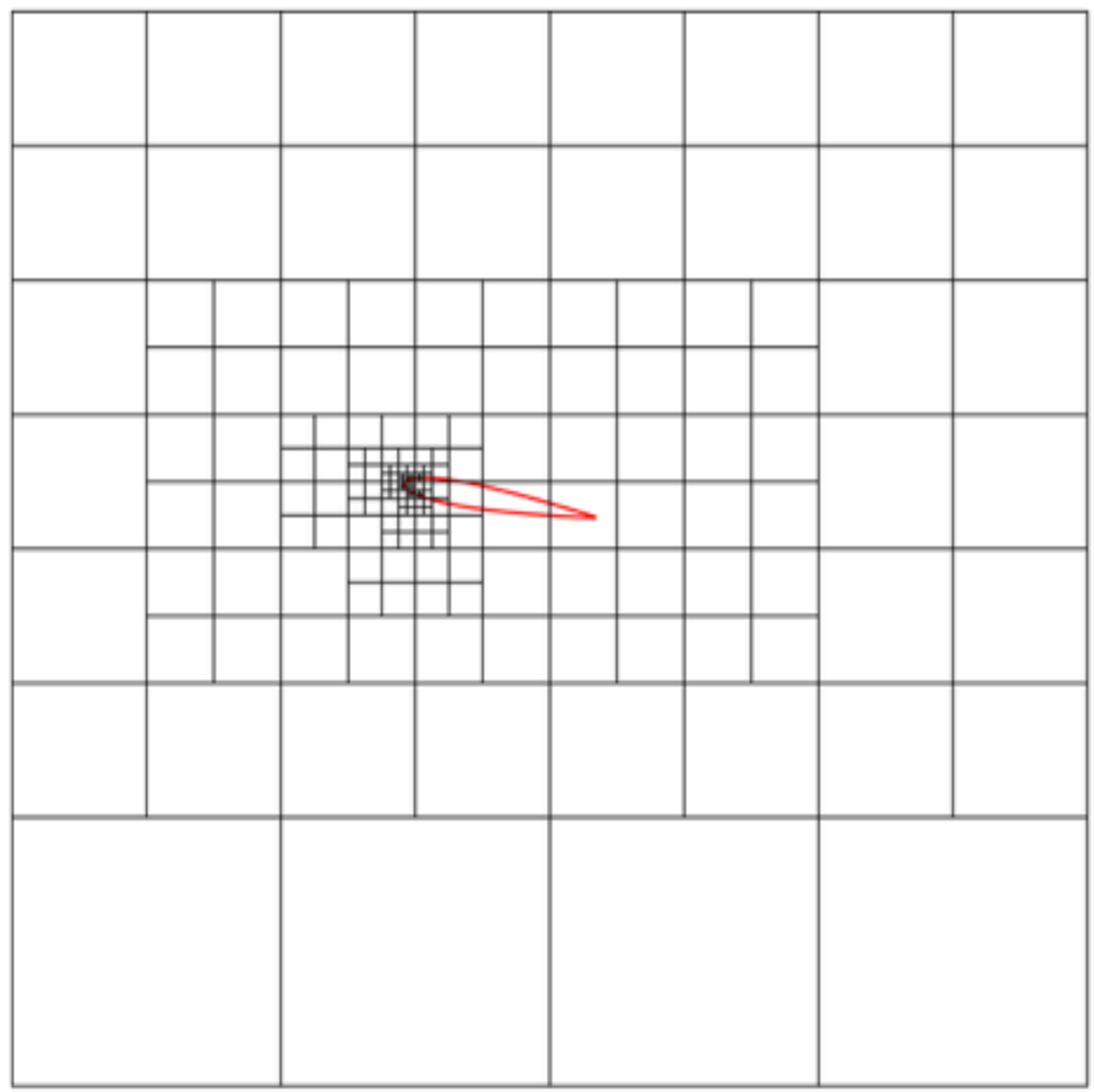
Single step process from CAD to flow solution
As few user parameters as possible



Construct an octree

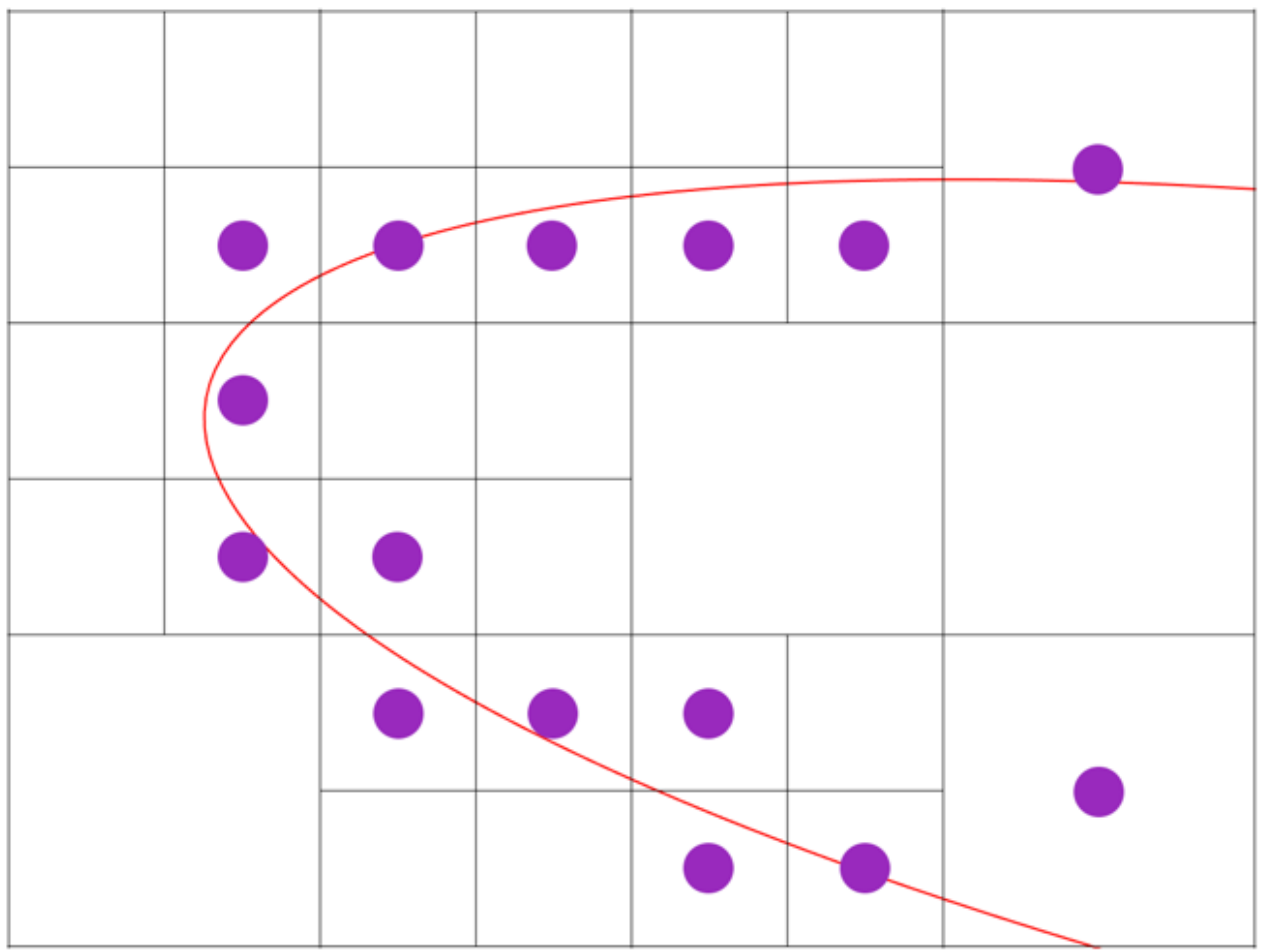


Smooth the octree

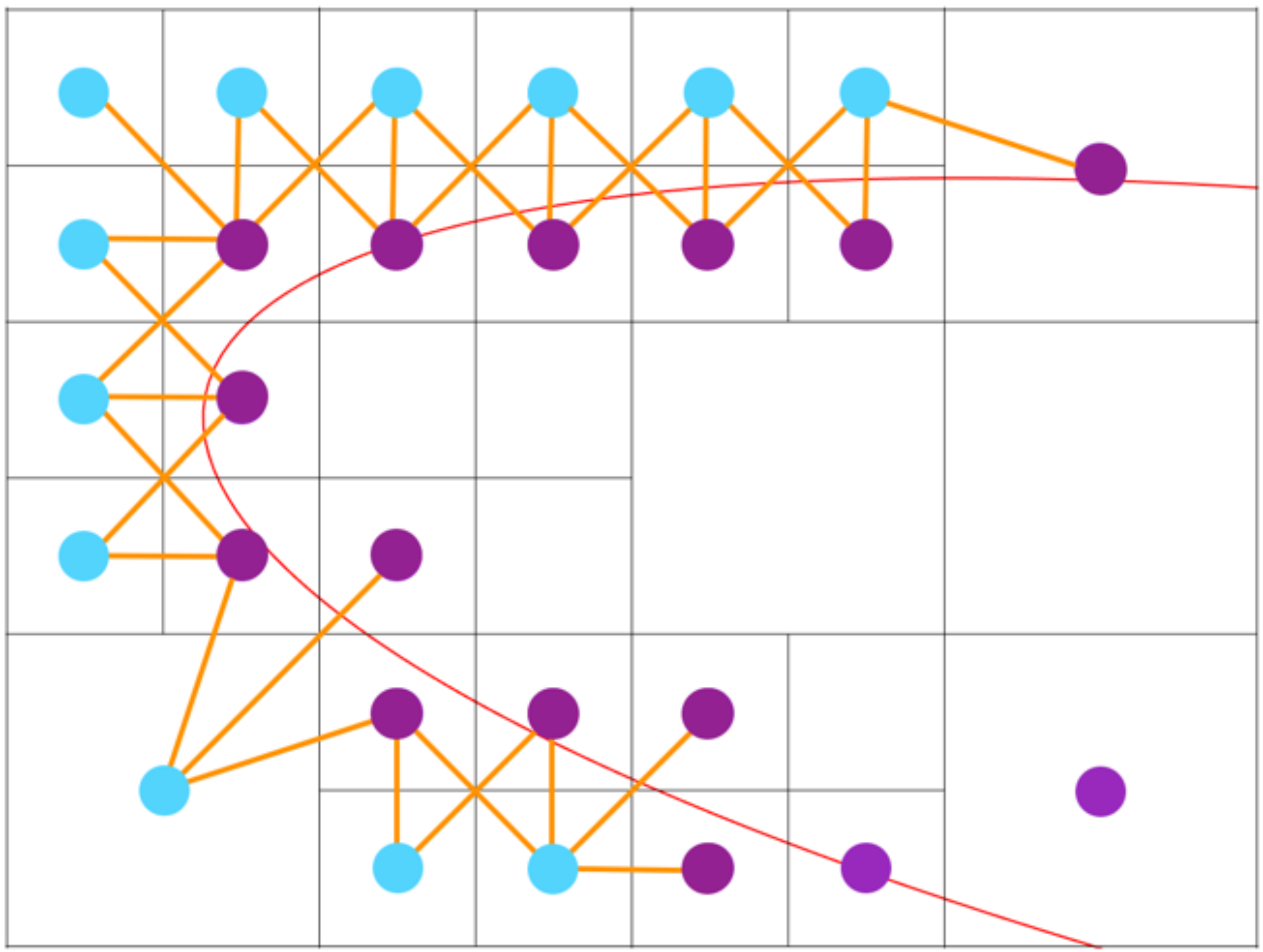


Relate geometry to mesh sizing

$$\delta(R)$$



Propagate mesh specification



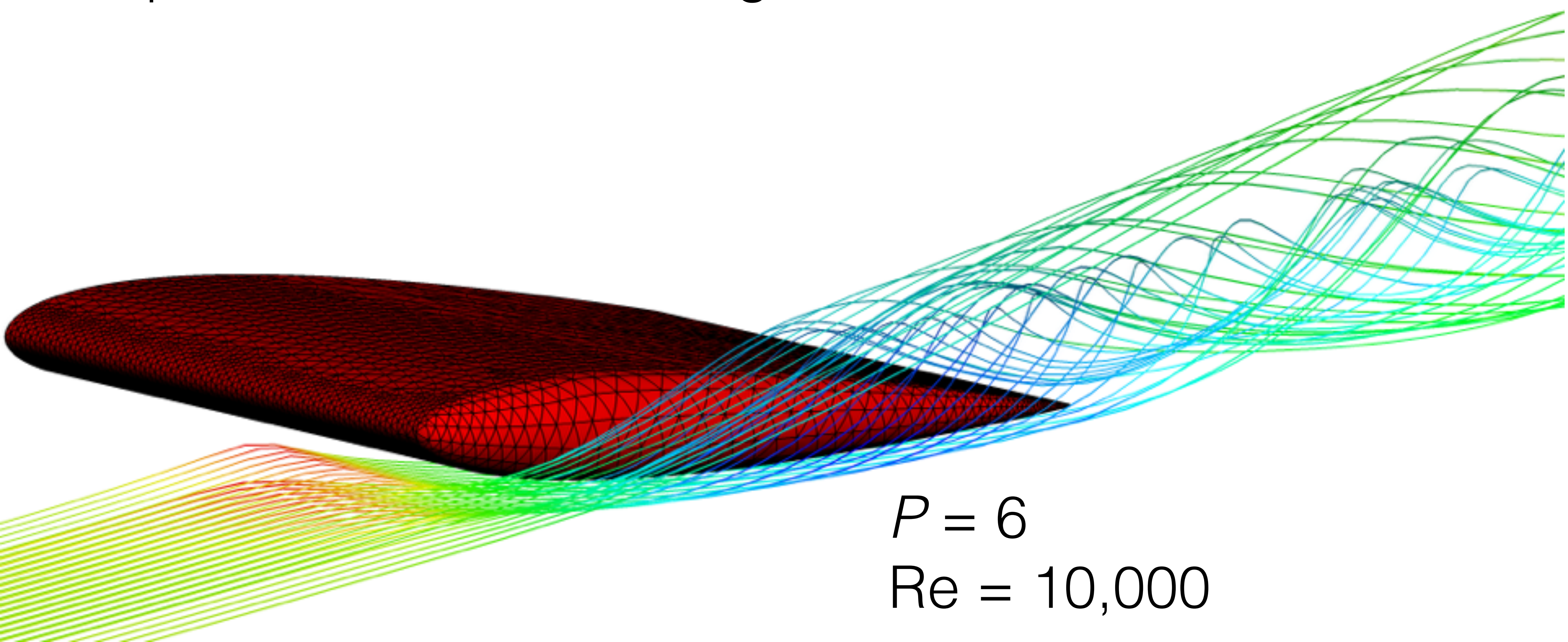
Our process

- OpenCascade for CAD handling
- Modified version of Triangle for surface meshing
- Modified version of TetGen for the interior volume
- Our own system for high-order manipulation
- Linear elastic PDE solver for mesh deformation

Encapsulated inside Nektar++ spectral/*hp* element framework

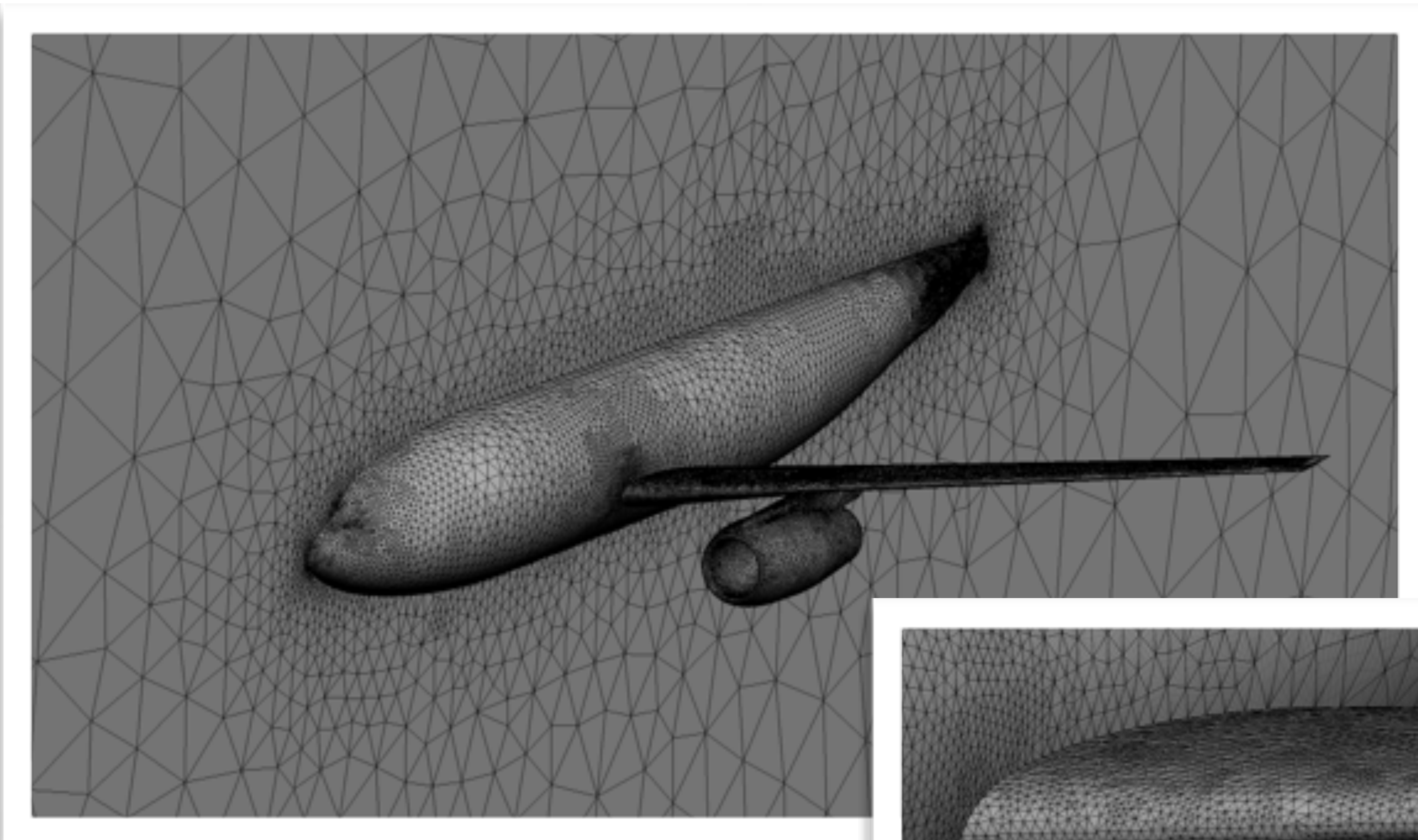
Result

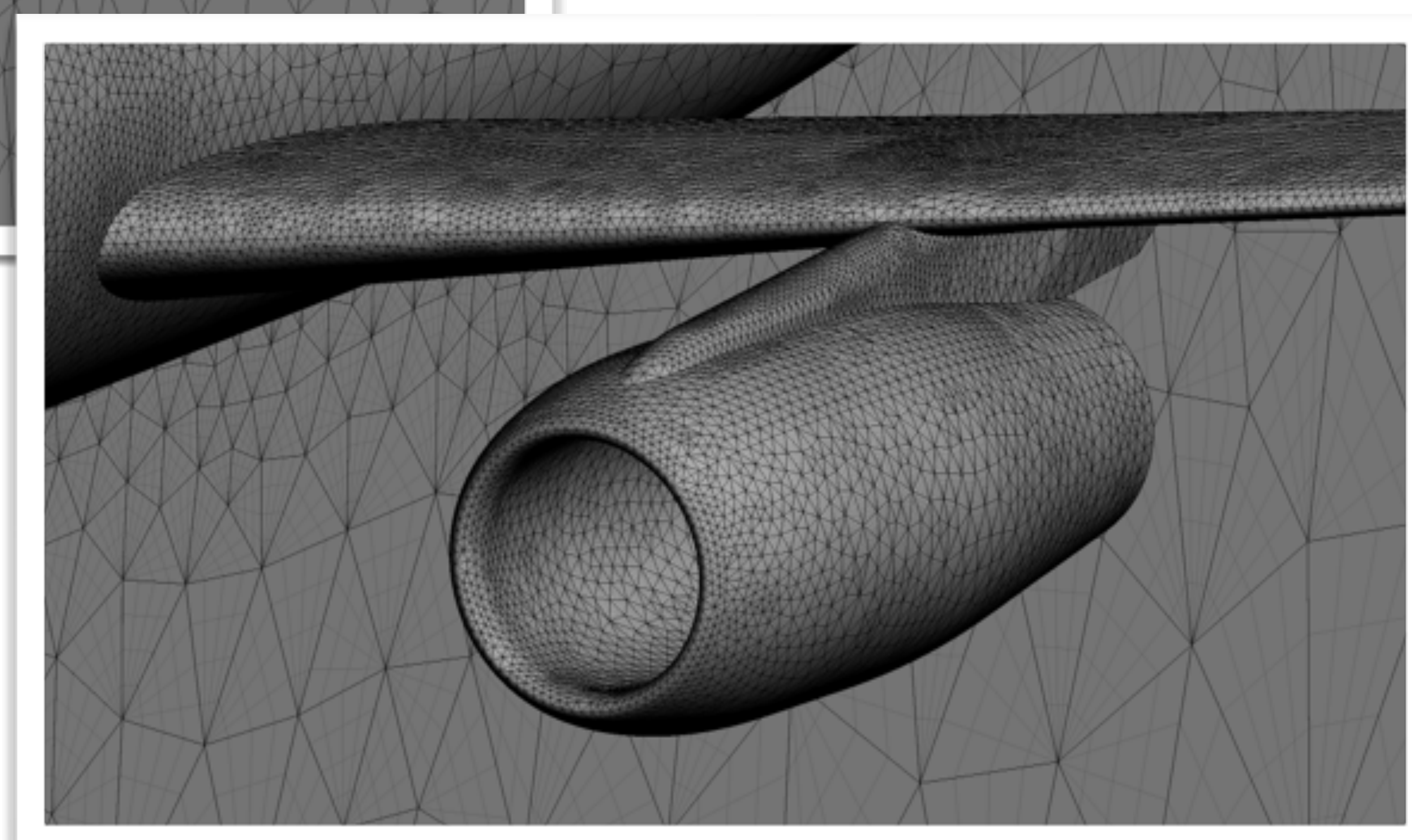
Without leaving Nektar++ and only 4 user parameters for meshing



$P = 6$
Re = 10,000

More complex geometries





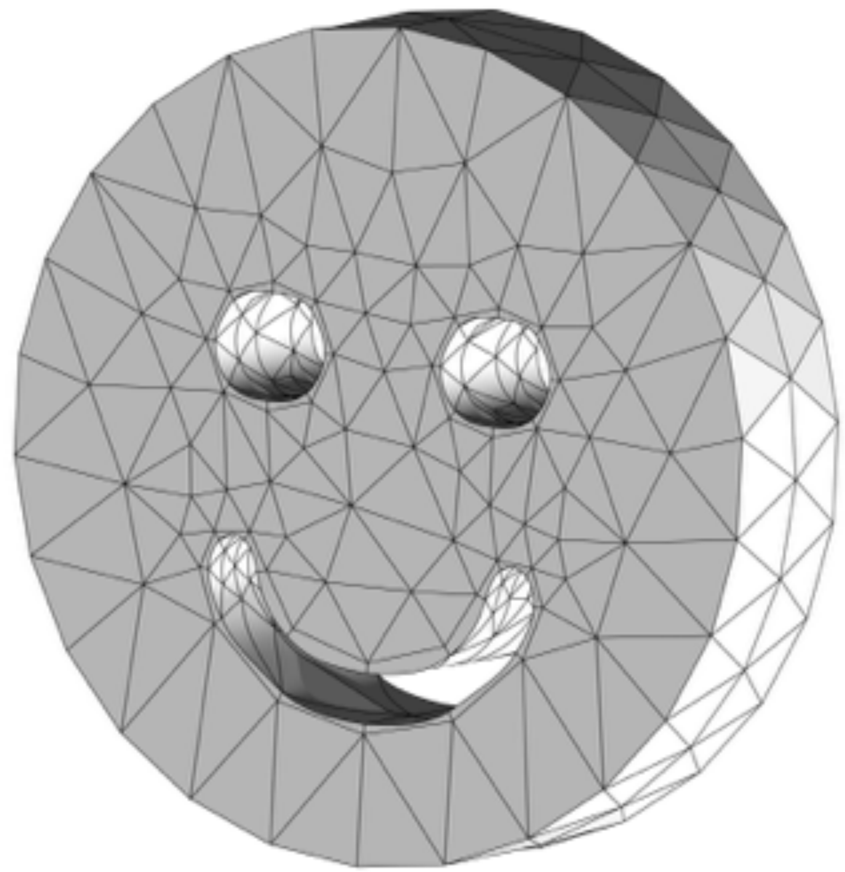
Nektar++ high-order framework

Framework for spectral(/hp) element method:

- Dimension independent, supports CG/DG/HDG
- Mixed elements (quads/tris, hexes, prisms, tets, pyramids) using hierarchical modal and classical nodal formulations
- Solvers for (in)compressible Navier-Stokes, advection-diffusion-reaction, shallow water equations, ...
- Parallelised with MPI, tested scaling up to ~10k cores

http://www.nektar.info/
nektar-users@imperial.ac.uk

Thanks for listening!



@davidmoxey

d.moxey@imperial.ac.uk

www.nektar.info