
Computational Fluid Dynamics

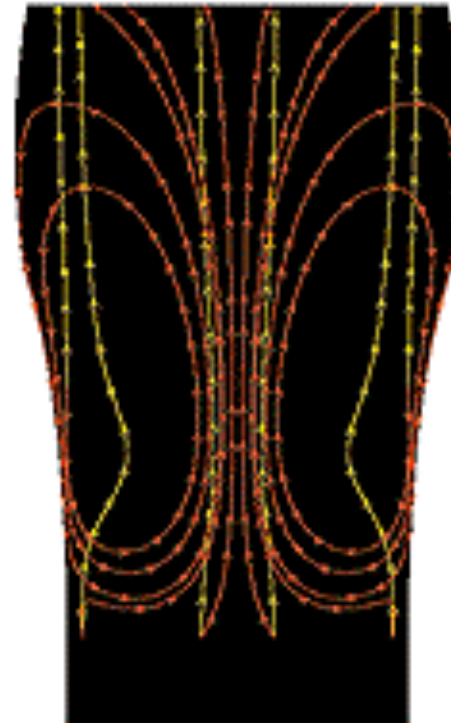


A perfect pint

Red lines = small bubbles, <0.05 mm diameter

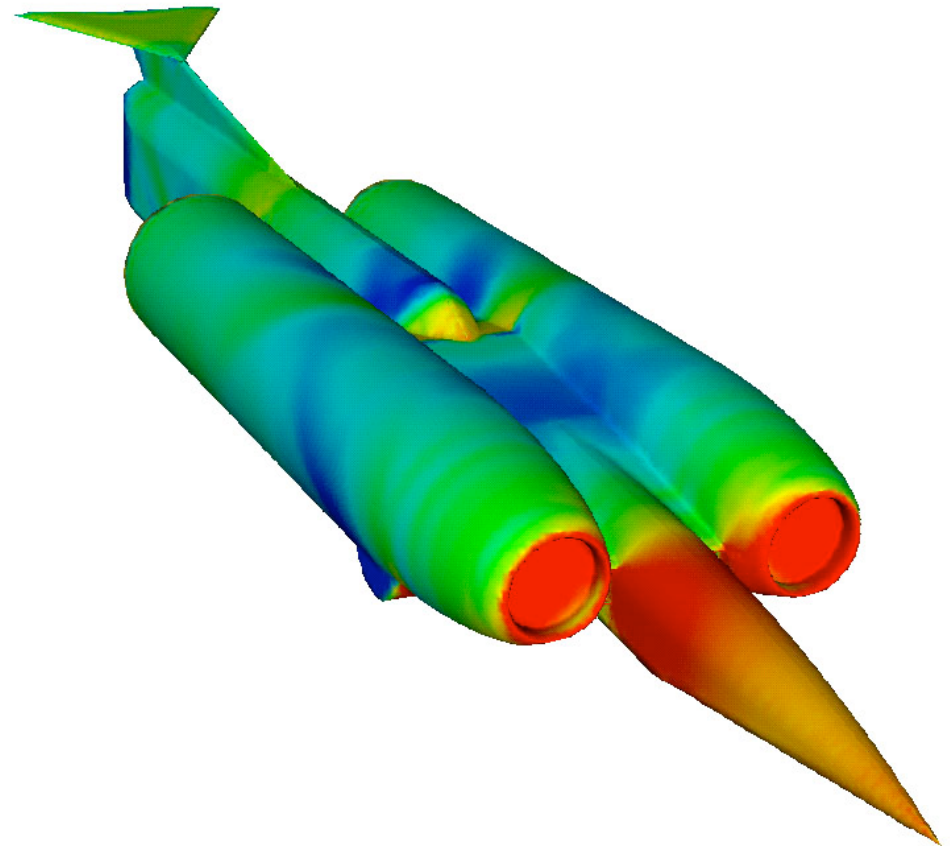
Yellow lines = larger bubbles

White lines = pathlines of fluid flow



What is Computational Fluid Dynamics?

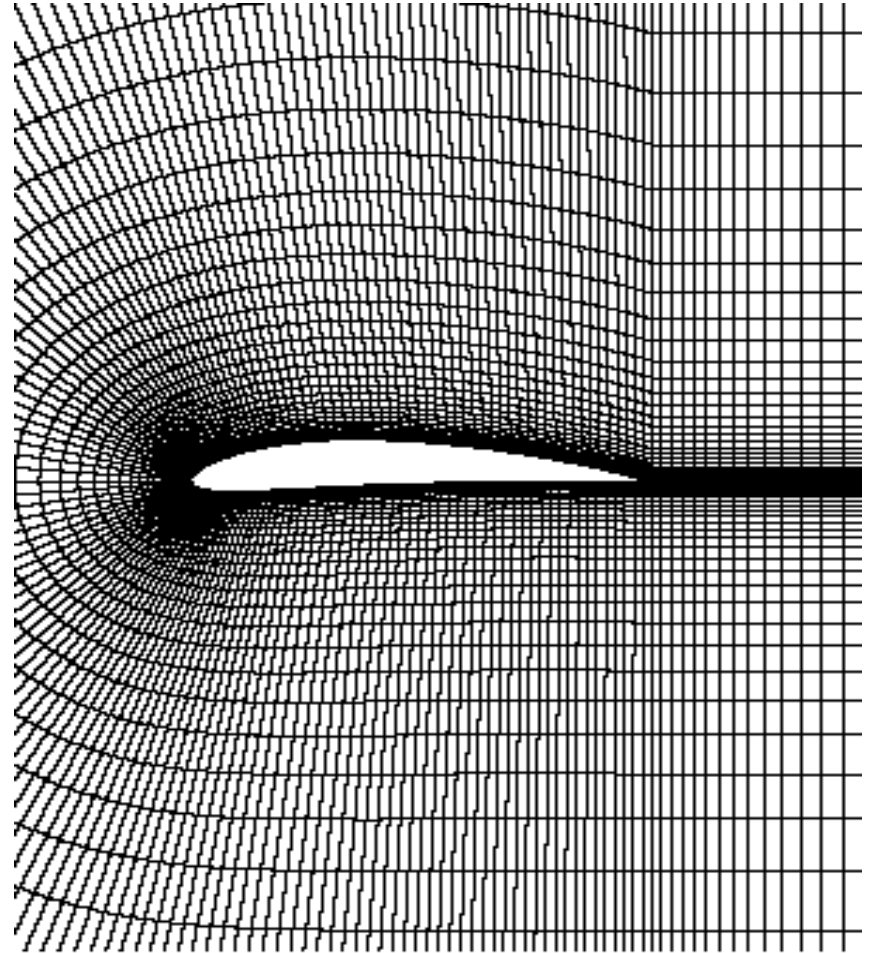
- Solves P.D.E.s (continuity eqn, etc) as large algebraic system on discrete domain
- Predicts
 - Fluid flow
 - Heat & mass transfer
 - Phase changes
 - Chemical reactions
 - Stress/deformation



CFD-Generated Pressure Gradient
of THRUST SSC

Method

1. Define Geometry
2. Divide the Fluid's Volume into Discrete Cells (Mesh)
3. Pick Solution Method
4. Set Boundary Conditions
5. Solve as Steady or Transient
6. Produce Visualization & Analyze



Solution Methods

1. Finite-difference (Eulerian)

- Simplest
- Taylor's series approximations at discrete points on the mesh

2. Finite-element

- Developed for solid analysis (like COSMOS)
- Not extensively used for CFD
- Piecewise polynomials on local elements



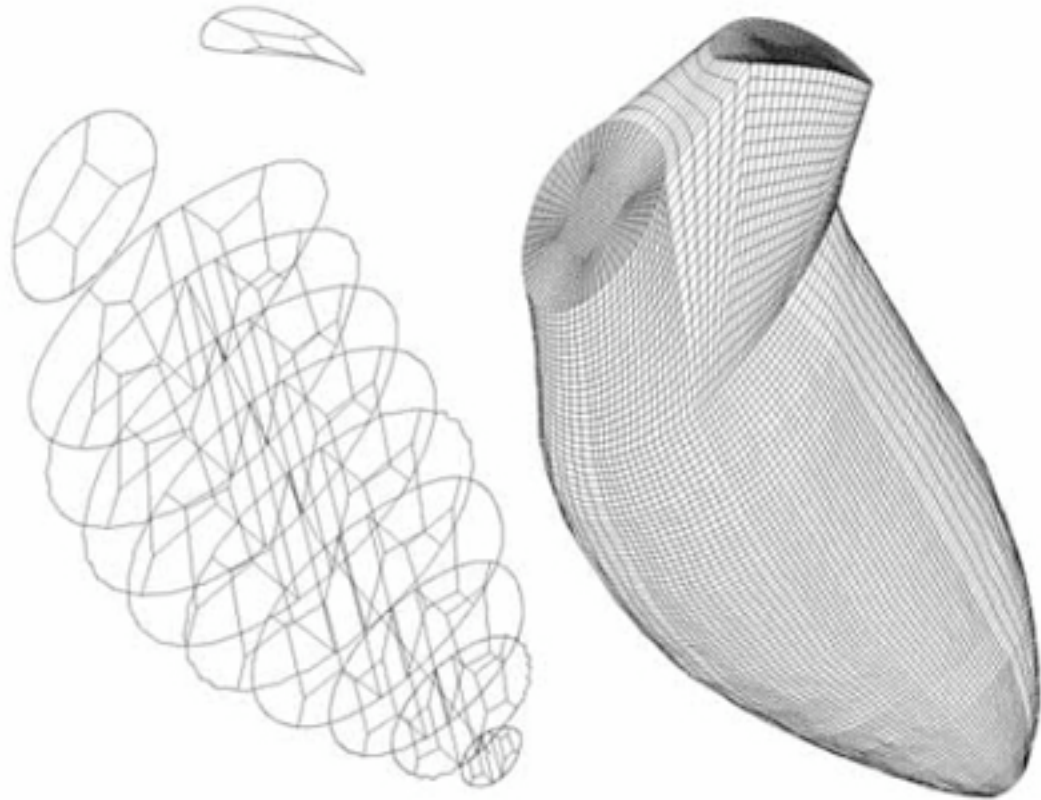
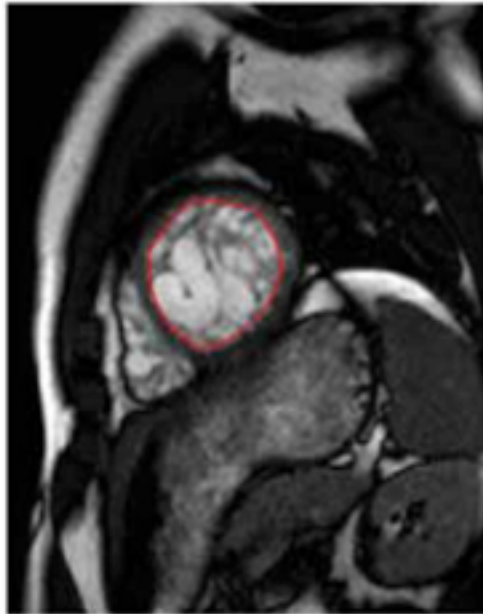
Solution Methods

3. Spectral

- Replaces unknowns w/ Fourier series
- Uses eqns for entire flow area, not local approximations

4. Finite-volume

- Most common in commercial, research apps
- Volume of cells – extra flexibility

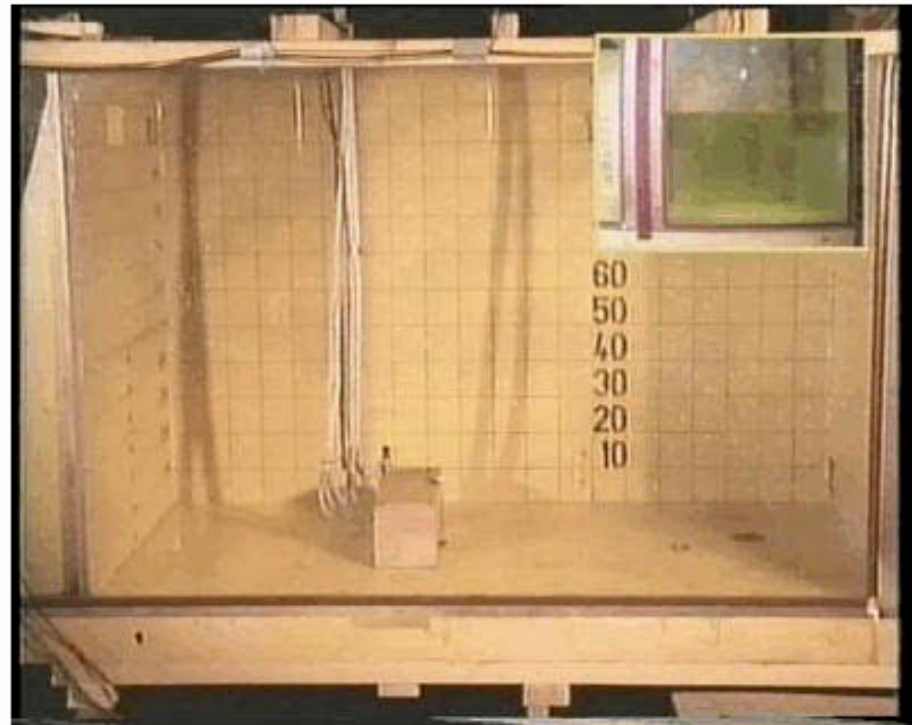
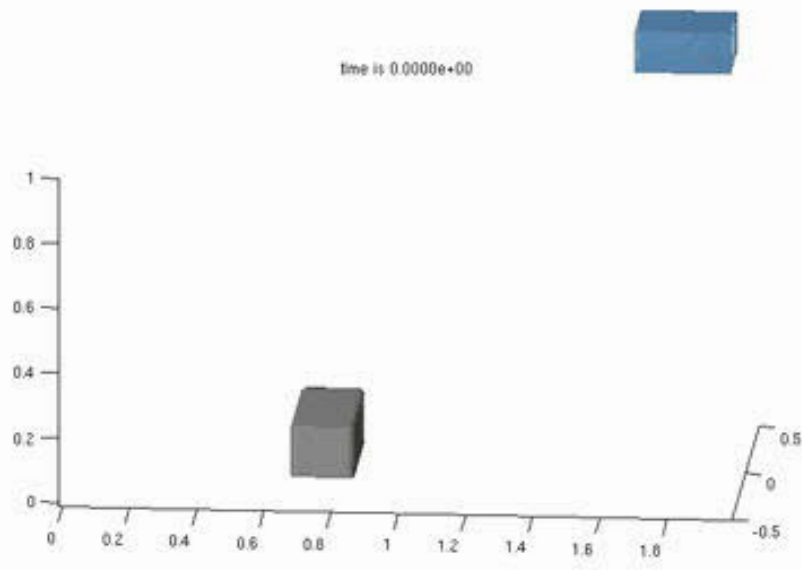


A grid developed to model the heart using from MRI.

Why CFD isn't perfect

- Model error & Uncertainty
- Discretization error
- Iteration/Convergence Error
- Round-off errors
- Application Uncertainties
- User errors
- Code errors

CFD and Lab Simulation



CFD vs Wind Tunnel - Round I

CFD

- Computed at scale
- Done wherever computing power possible
- Sample any quantity at any point
- Simulate internal flows

WIND TUNNELS

- Scaling issues – Reynolds & Mach #'s
- Geographical availability
- Limited sampling options
- Not designed for internal flows (e.g. building ventilation)

CFD vs Wind Tunnel - Round II

CFD

- Often takes longer to produce final results
- Cannot predict chaotic turbulence
- Inaccurate for laminar to turbulent transitions
- Only solves what it's given
- Requires huge amount of computing power

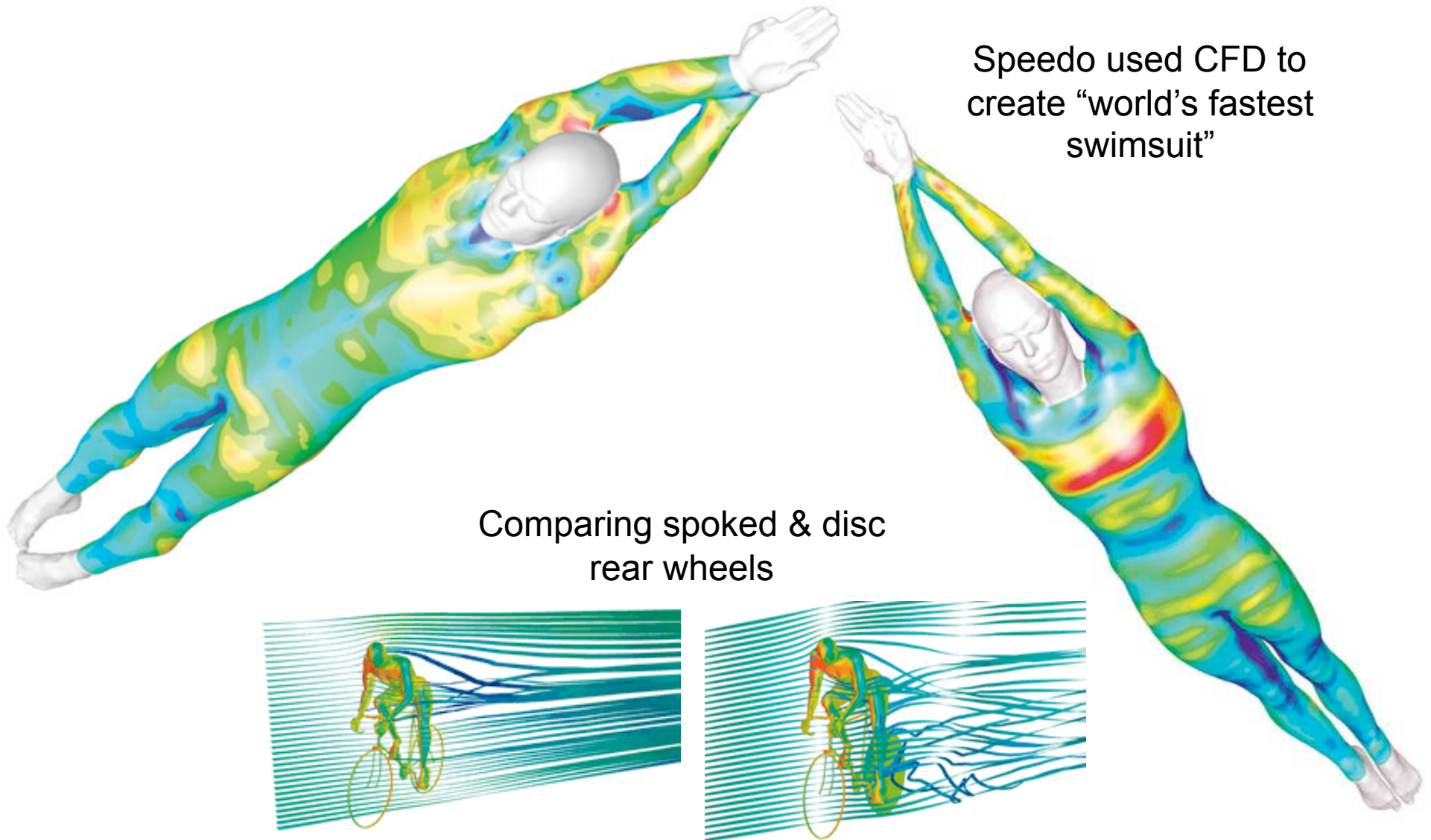
WIND TUNNELS

- Can be faster – esp. for small adjustments
- Immediate qualitative analysis
- Inherently 3-D
- Unsteady aero effects
- Unknown unknowns

Applications

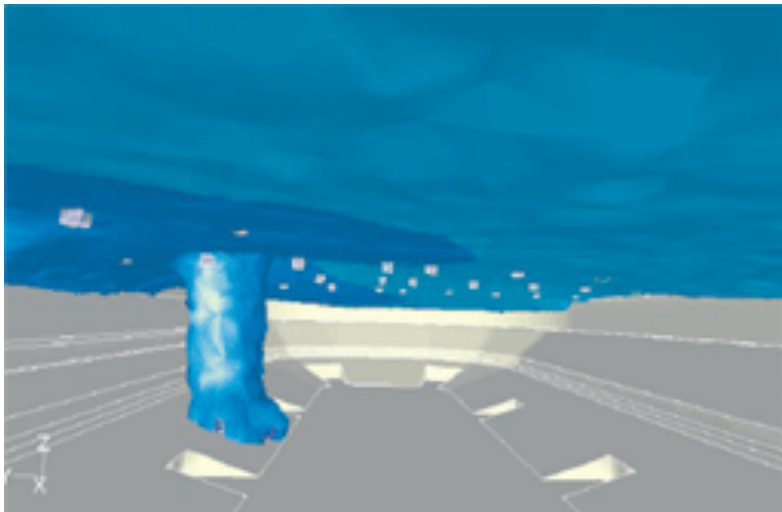
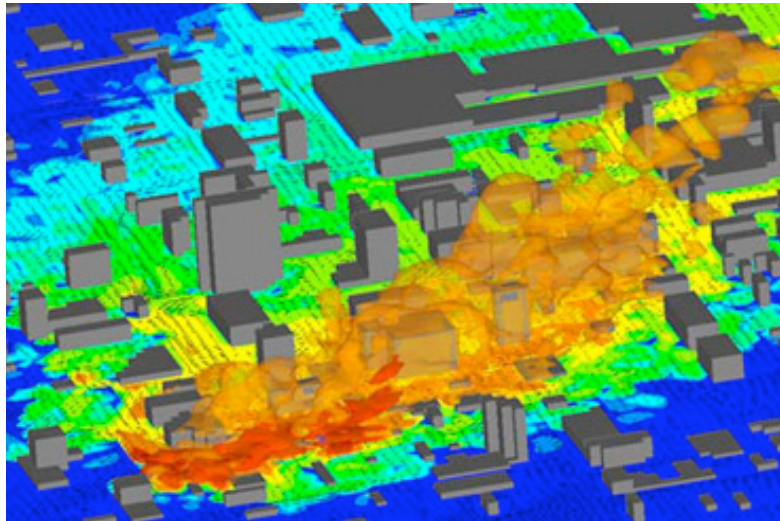
Aerospace	Aerodynamics, wing design, missiles, passenger cabin
Automotive	Internal combustion, underbody, passenger comfort
Biology	Study of insect and bird flight
Biomedical	Heart valves, blood flow, filters, inhalers
Building	Clean rooms, ventilation, heating and cooling
Civil Engineering	Design of bridges, building exteriors, large structures
Chemical Process	Static mixing, separation, reactions
Electrical	Equipment cooling
Environmental	Pollutant and effluent control, fire management, shore protection
Marine	Wind and wave loading, sloshing, propulsion
Mechanical	Pumps, fans, heat exchangers
Meteorology	Weather prediction
Oceanography	Flows in rivers, estuaries, oceans
Power Generation	Boilers, combustors, furnaces, pressure vessels, nuclear
Sports Equipment	Cycling helmets, swimming goggles, golf balls
Turbomachinery	Turbines, blade cooling, compressors, torque converters

Application – Sports



Application – Disaster Prediction

Large eddy dispersion simulation in an urban area



Fire scenario in
Budapest Sports
Arena

