

High Fidelity Approaches For Simulation of Wind Energy Aerodynamics

Deploying the ASC NW Code Base to Supporting the DOE Wind Energy Atmosphere 2 electron (A2e) Strategic Plan

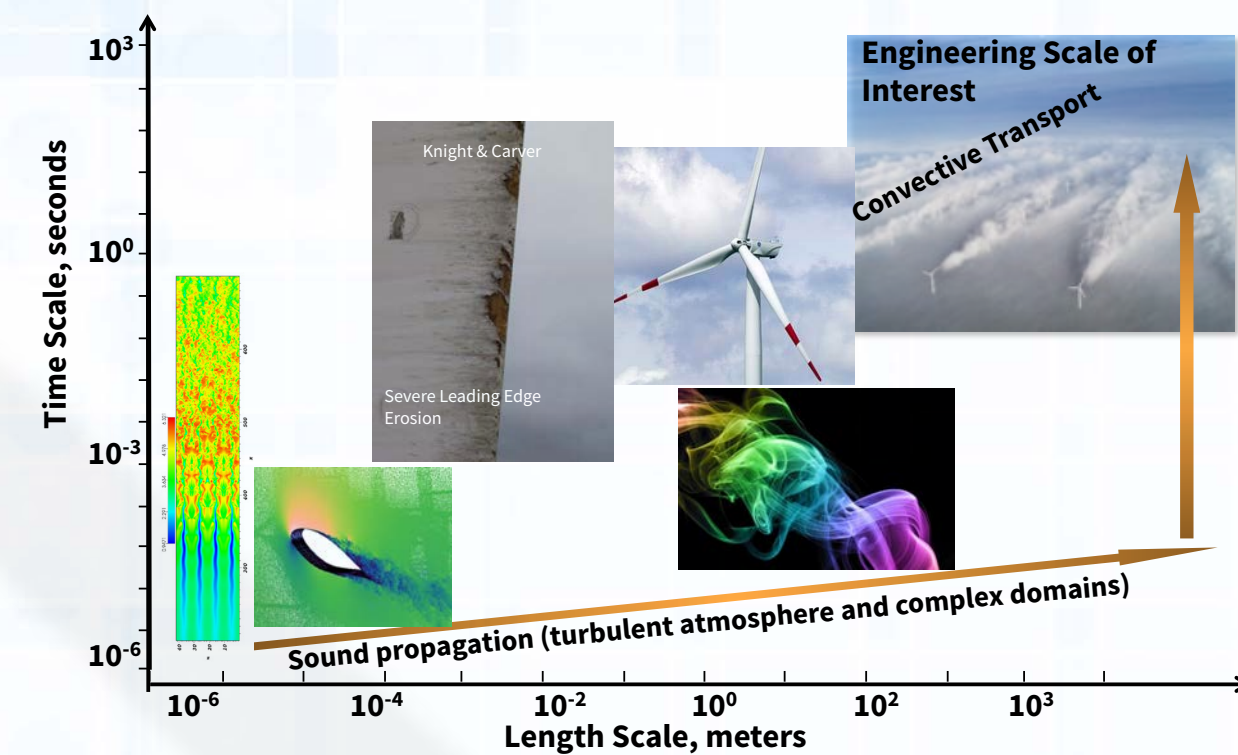
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Matt Barone, Aerosciences

Challenge: Wind Energy Physics Spans Vast Time and Length Scales

Physics driving the engineering scale of interest is unaffordable to resolve

Objectives:

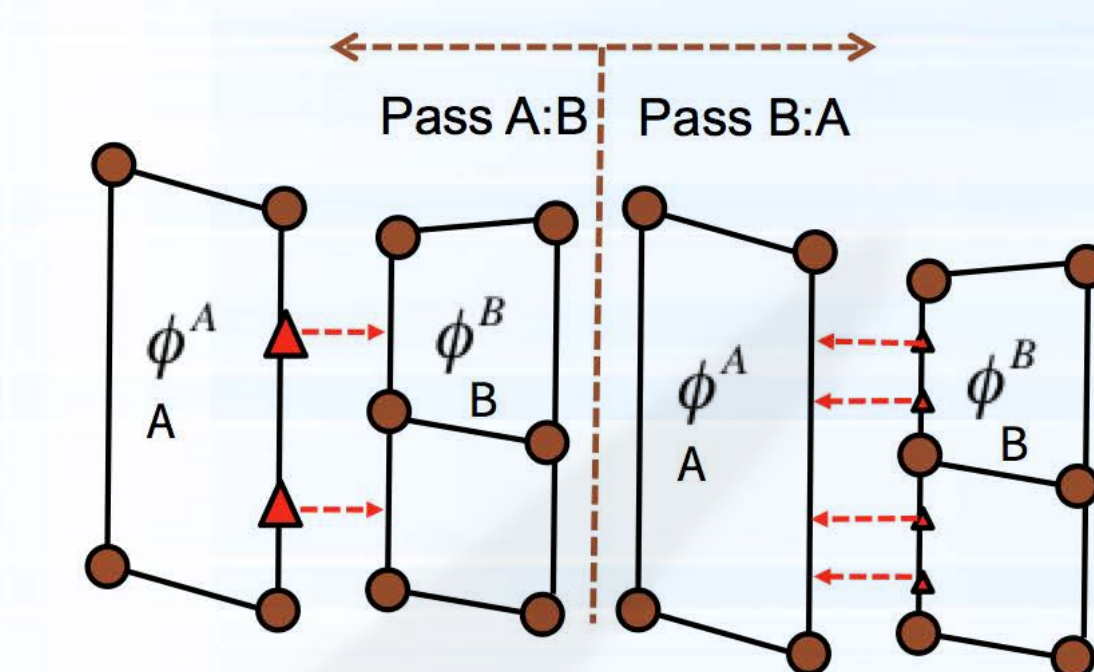
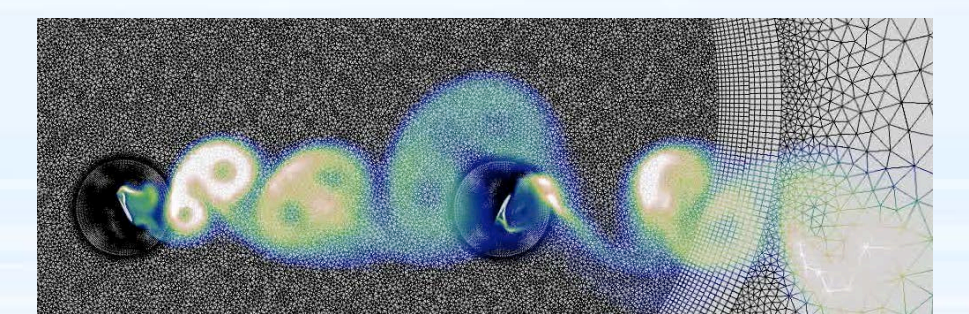
- Drive turbulence model and HPC innovation
- Drive model development
- Deploy HPC developed SNL tools to support Scaled Wind Farm Technology (SWIFT) facility needs
- Foster partnerships with NREL and academia



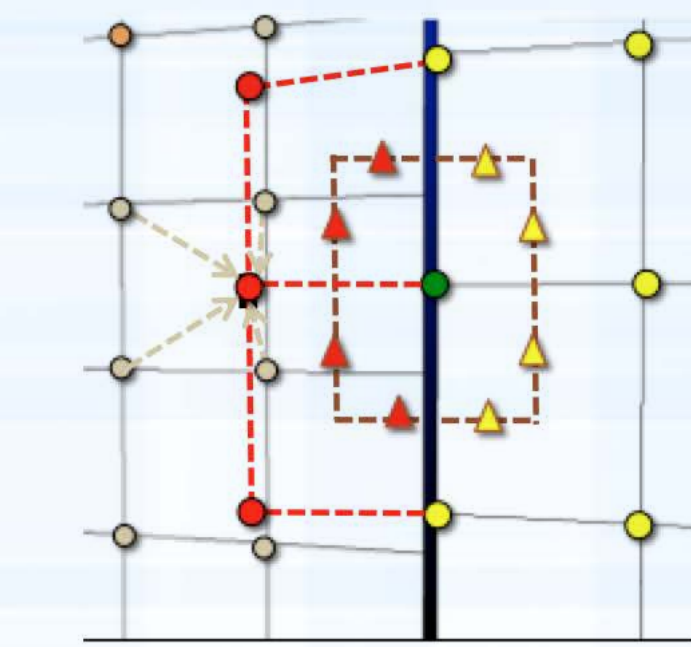
Advanced Sliding Mesh Technology

Wind energy applications require moving mesh (rotation) via either dynamic re-mesh, sliding mesh or overset

Investment in *verified* sliding mesh with non-conformal flux reconstruction



DG flux reconstruction approach at non-conformal mesh (Domino, 2008, 2014)



Extension of Halo (Stejil, 2008) and extrusion (Blades, 2006) procedure(s) to low Mach (Domino, 2013)



Leveraging ASCR, SNL LDRD, and NW NNSA ASC Investments in Generalized Unstructured, Low Dissipation Methods

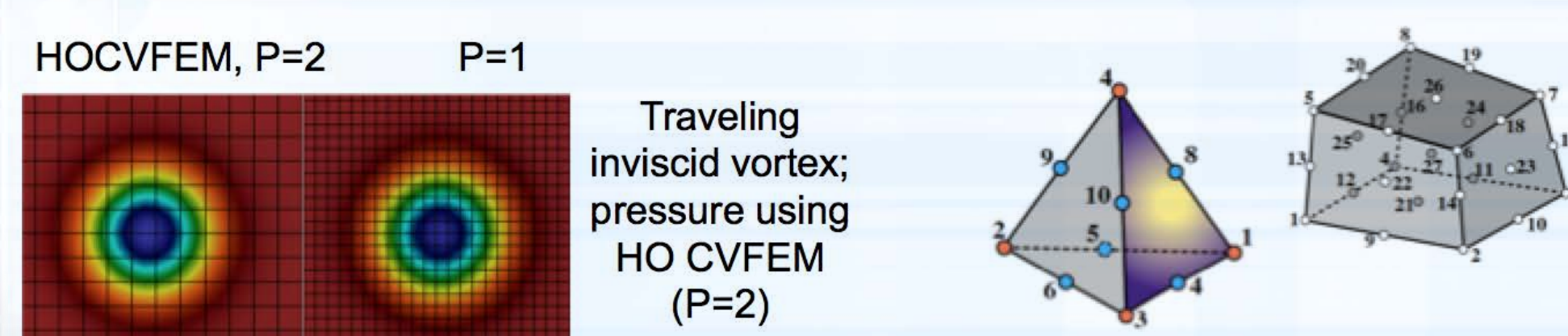
Geometric complexity drives generalized unstructured, low Mach, low dissipation schemes suitable for Large Eddy Simulation (LES)

Logos: ASCR, LDRD, ASC, Nalu low Mach

Simulations: XTF Facility; inset downward Propellant burn, Re ~1e6 VAWT, FLAME Facility, Re 45K backstep, h-Adaptivity, 1.6 km section of Angel Fire, NM

Low Order vs. Higher Order Discretizations

Goal: Implement third order low Mach CVFEM scheme (P=2) and compare timings between P=1 and P=2



Periodic flow past a square timings

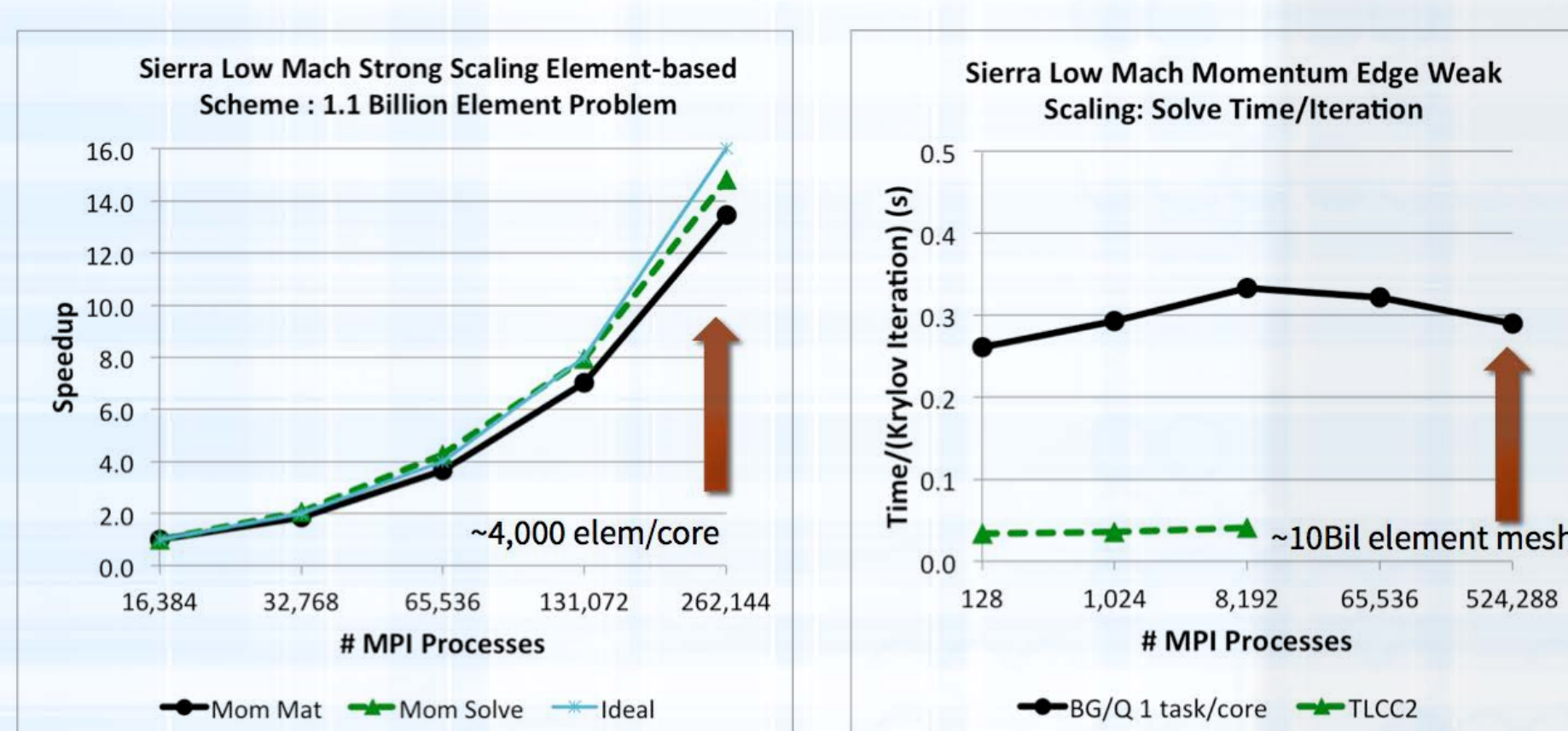
	Momentum		Continuity	
	P=1	P=2	P=1	P=2
Assemble (s)	268	304	123	153
Solve (s)	259	341	420	900
Linear It (av)	5.3	6.0	6.1	19

Method of Manufactured Solutions, 3rd order demonstrated

- Conclusion:**
- Assembly time is okay
 - Invest in new solver/precond. approaches
 - Ongoing ASC project

Scalability: low Mach, Implicit Pressure-Projection

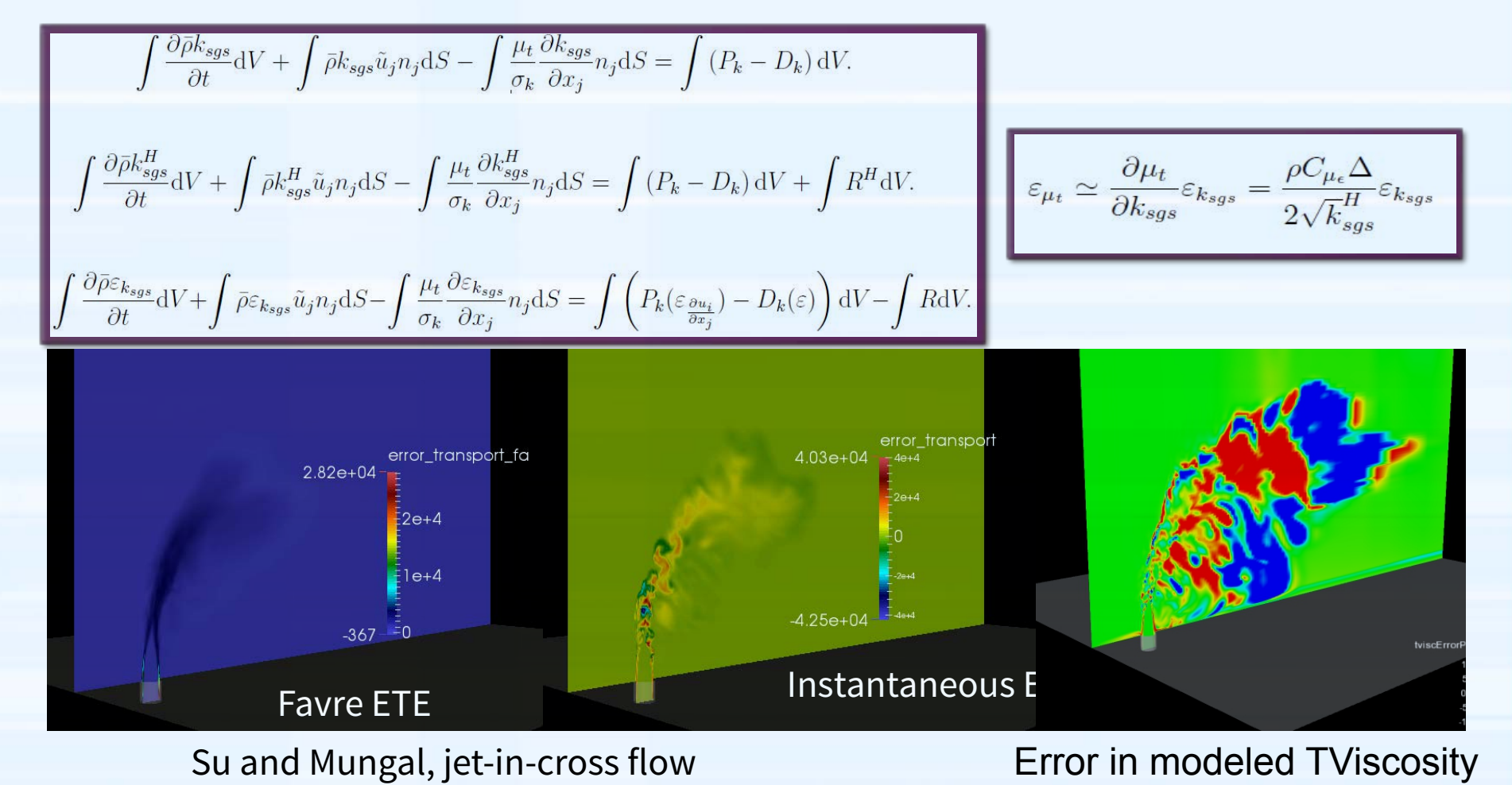
- Q:** Do our algorithms demonstrate scalability in the weak and strong sense?
- A:** Yes, on today's capability class machines (SNL Next Generation Platform investments STK, Trilinos and kokkos)



Prediction of fully implicit low Mach turbulent round jet (Sequoia) Lin et al. Parallel Processing Letters, 2014

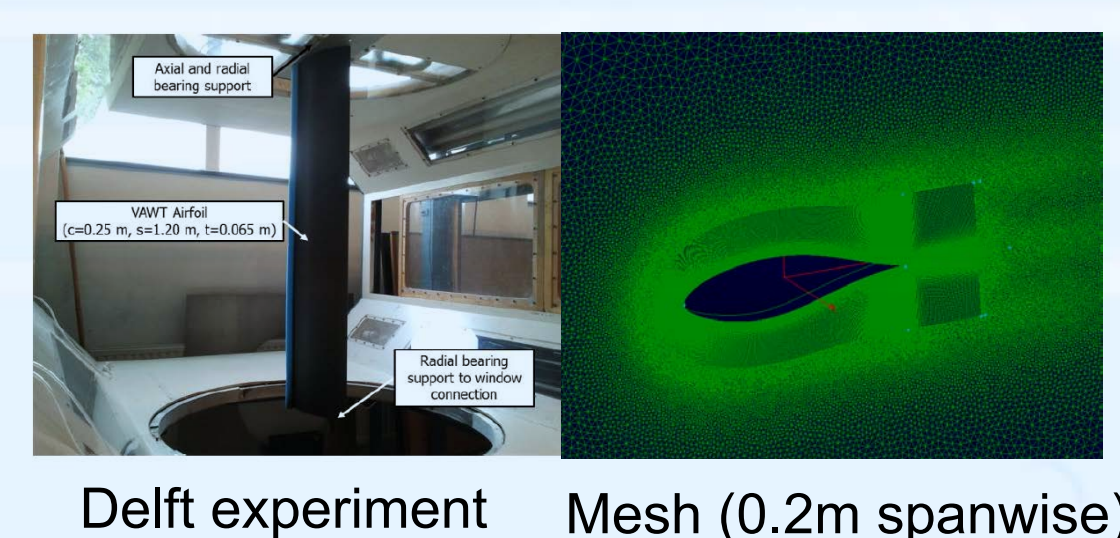
But where to place the mesh?

In most cases, we do not need to refine the mesh everywhere in the domain; local adaption can be critical not only for minimizing numerical error, however, assisting the user in mesh density placement

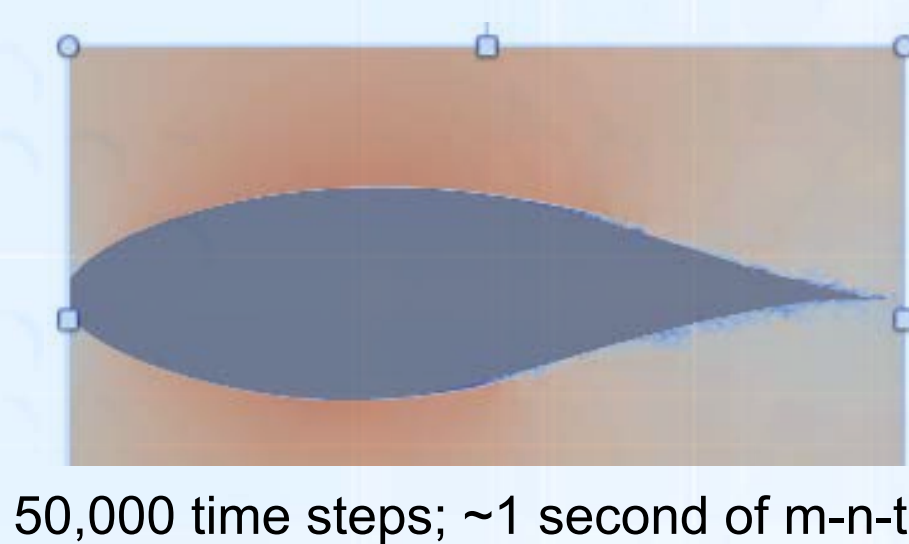
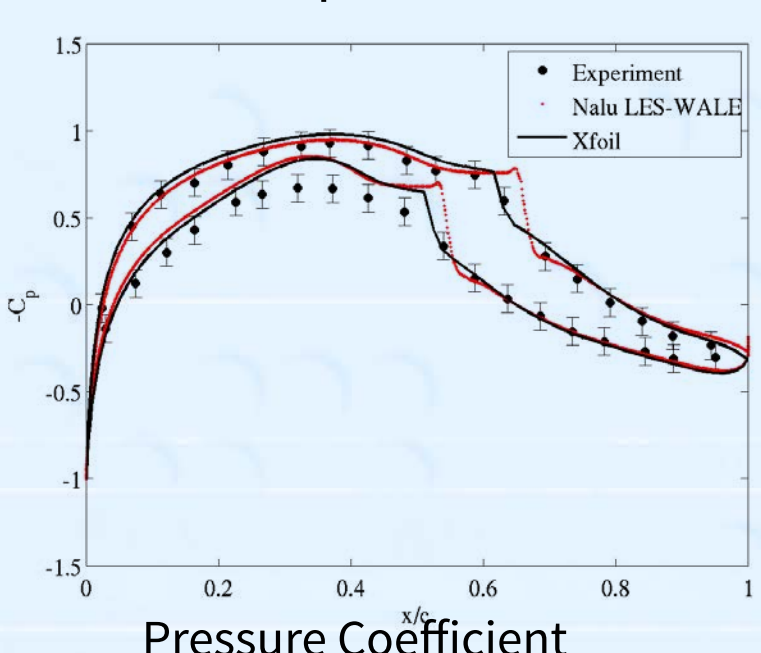


Wall Resolved LES of a Novel Vertical Axis Wind Turbine Airfoil Design (DOE Wind)

Goal: Wall Resolved LES (WRLES) using P=1 (soon, P=2) Control Volume Finite Element Method (CVFEM)



- Hybrid mesh topology; structured near-body hex mesh with tetrahedral far-field mesh (pyr transition) 55.8M elements; varying angle of attack
- $\Delta x^+ \sim 45$, $\Delta y^+ \sim 0.7$, $\Delta z^+ \sim 36$



Conclusion: Good prediction, however, how scalable is this to a full Vertical Axis Wind Turbine?

Nalu v1.0 BSD open source model: <https://github.com/spdomin/Nalu.git>

Logos: U.S. DEPARTMENT OF ENERGY, Sandia National Laboratories, Trilinos

Simulations: Heated turbulent back-step, 2D/3D periodic, 2D/3D sliding mesh, Multiphysics CHT, cold and reacting jets, Multiphysics Fluids/PMR/CHT battery fires

Strategic Partnerships with: UI, UI, UI, UI

Select Publications:

- "Towards extreme-scale simulations with next-generation Trilinos: a low Mach fluid application study", Parallel Processing Letters, 2014
- "A comparison between low-order and higher order low-Mach discretization approaches", Center for Turbulence Research Summer Proceedings, 2014
- "Parameter uncertainty in LES of Channel Flow", Physics of Fluids, 2015
- "Thermal runaway of lithium-ion batteries and hazards of abnormal thermal environments", 9th U.S. National Combustion Meeting, 2015