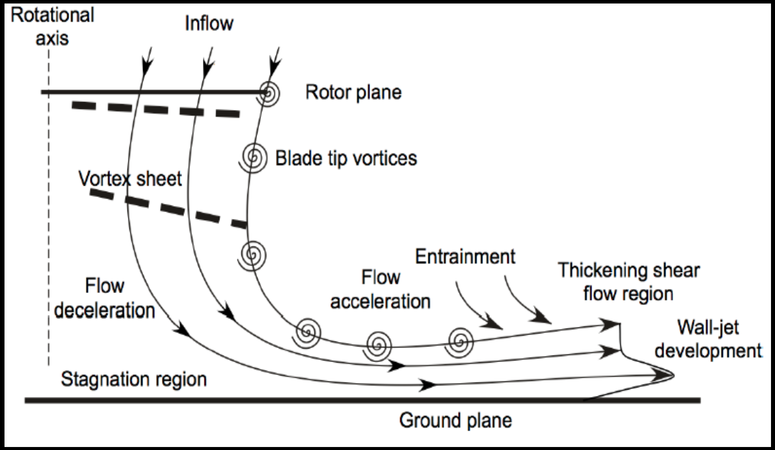
Student Poster Summary Presentation

High Fidelity Vorticity Generation and Preservation in Ground Effect



Schematic showing the flow near ground below the rotor

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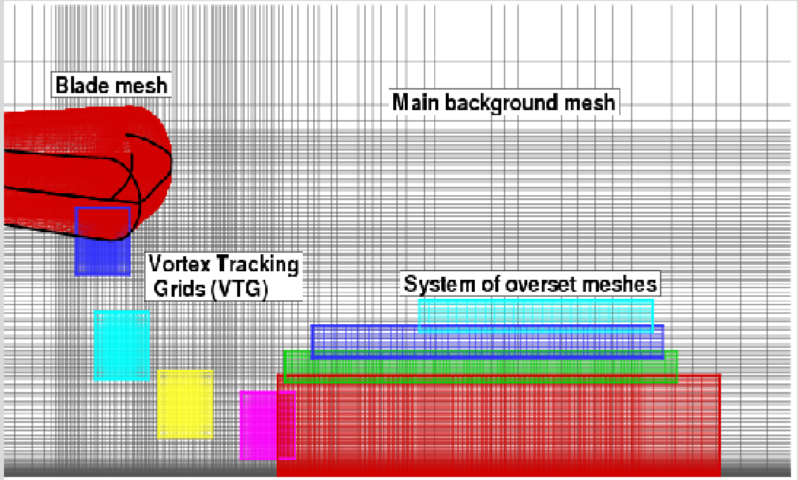
11th Symposium Overset Composite Grids and Solution
October 15-18, 2012 Dayton, Ohio

Brief Overview

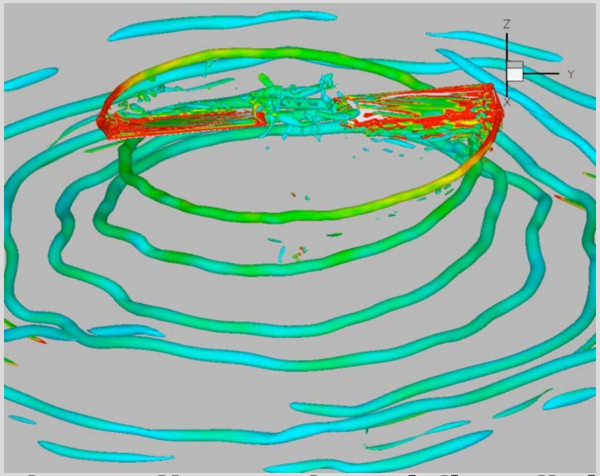
- **Motivation - Brownout phenomenon**
  - **Helicopters operating in ground effect entrain dust particles leading to formation of large dust clouds**
  - **Poor visibility leads to loss of situational awareness**
  - **Blade erosion and mechanical wear**
- **Objectives - Focus on understanding the interaction of rotor wake with ground**
  - **Preserve vortices for a long time to capture interaction with ground**
  - **Resolve boundary layer and turbulence at the ground**
  - **Capture time averaged jet-like boundary layer in ground-effect and predict unsteady wake induced velocity field**
- **Technical Approach**
  - **Unsteady RANS solver UMTURNS used for CFD modeling**
  - **Use of multiple overset grids in areas of interest to preserve vorticity and lower computational costs**

Results

Three different rotor heights (h/R = 0.5, 1.0 and 1.5) above ground modeled with a laboratory scale rotor operating at M = 0.08 and Re = 32,400

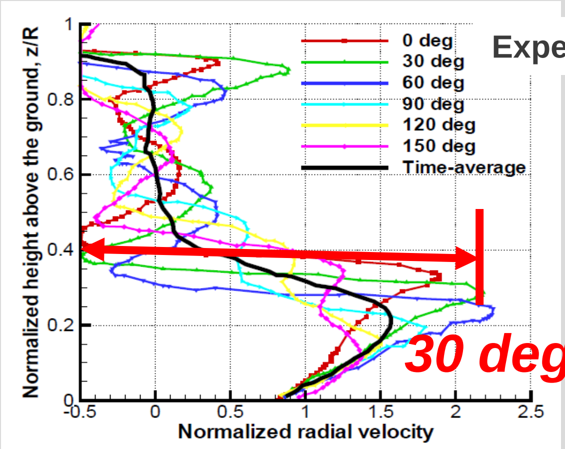


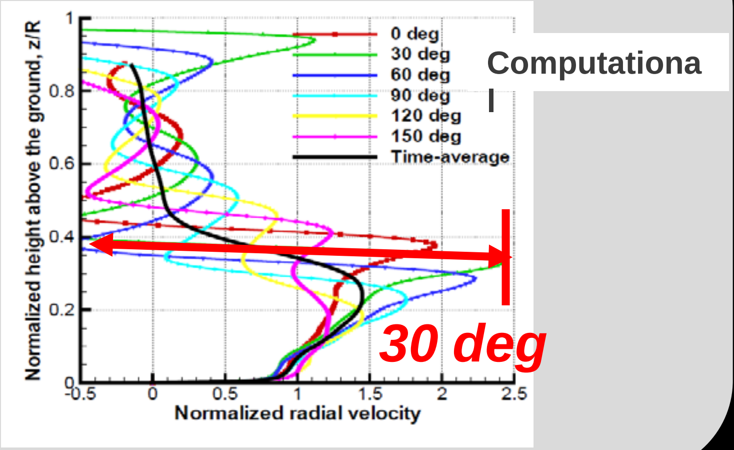
Overset mesh system



Three dimensional flowfield visualized by q-criterion

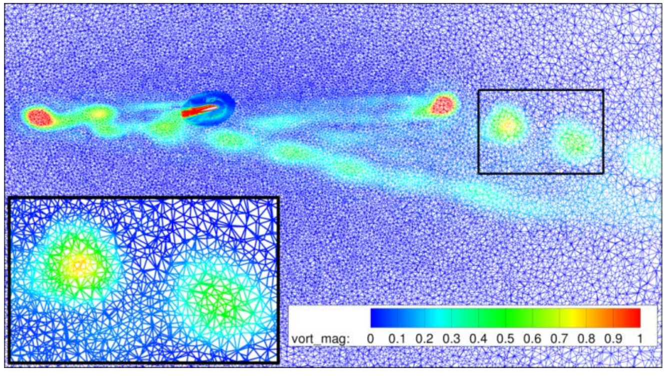
Quantitative validation of radial velocity profiles

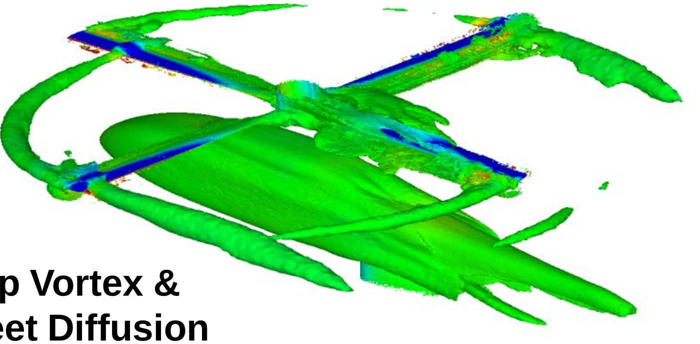




Overset Grid Adaptation: More than Just Pretty Pictures

- We want CFD to be accurate!!
- Combine benefits of overset methods with grid adaptation to simulate complex flows accurately





Tip Vortex & Sheet Diffusion

- Improvements noted from this effort
  - Captured vortex-fuselage impingement
  - Improved wake character in bluff bodies
- Current research questions:
  - Can we make grid adaptation more robust?
  - Adapt to vehicle drag?

Rajiv Shenoy
Advisor: Prof. M.J. Smith
October 16, 2012

The End of Orphans as We Know It?

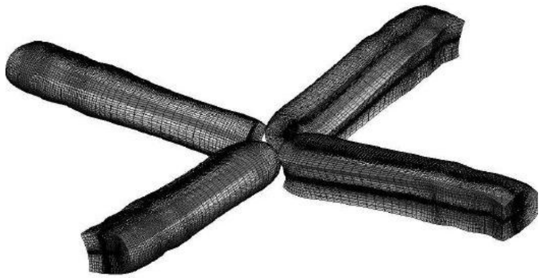
Eliot Quon, Ph.D. Candidate, Georgia Tech (Advisor: Prof. Marilyn J. Smith)

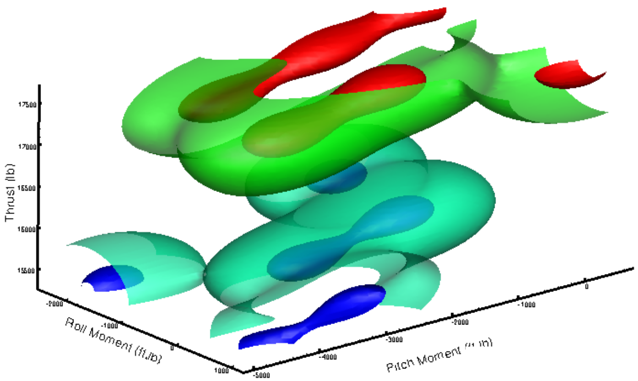
- The Problem
  - **Reduced accuracy** in **overset CFD** simulations despite use of high-order numerical schemes
  - **"*Orphan*" points** where data transfer is necessary
- The State of the Art
  - Conduct donor-receptor search (where orphans are formed)
  - Use **linear** mapping and interpolation techniques
- Advancements to the State of the Art
  - **Elimination of orphans** using clouds of interpolation points
  - Make **highly accurate interpolation and extrapolation** possible, using **advanced higher-order data transfer strategies**, with relaxed requirements on overlapping meshes
  - Other applications: hybrid CFD, CFD/CSD coupling, grid adaption, ALE schemes

Flying Towards Overset CFD/CSD Trim

- Problem Description:
  - Rotorcraft simulations are expensive
  - Largest cost: Trimming
- Coupling Types:
  - Loose Coupling
    - Data Exchanged: Periodically
    - Trimmer: Autopilot
  - Tight Coupling
    - Data Exchanged: Each Timestep
    - Trimmer: Kriging-based

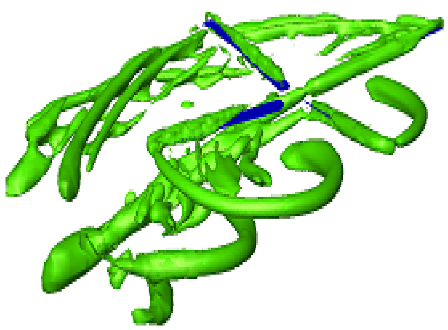
[1]





[2]

[3]



Nic Reveles

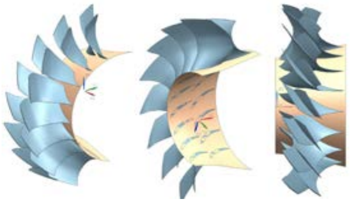
General Axisymmetric Solver for Turbomachinery

University of Cincinnati

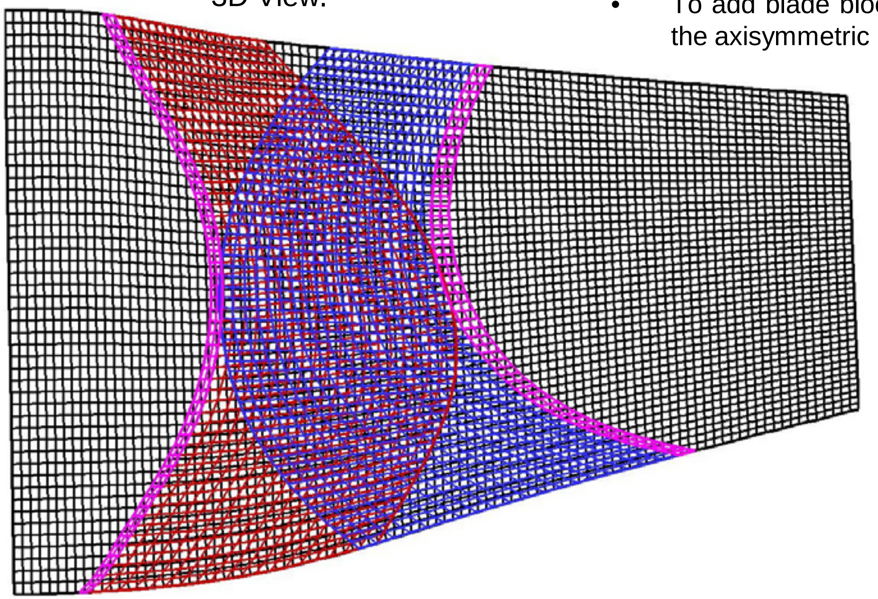
Gas Turbine Simulation Laboratory
School of Aerospace Systems

Kiran Siddappaji, Marshall Galbraith and Robert D. Knapke
Advisor: Dr. Mark G. Turner
University of Cincinnati

Partial Tandem Blade configuration



3D View.

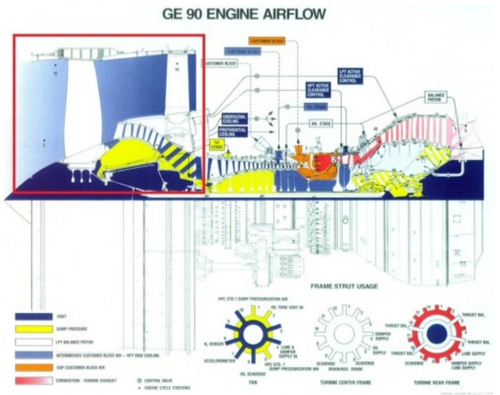


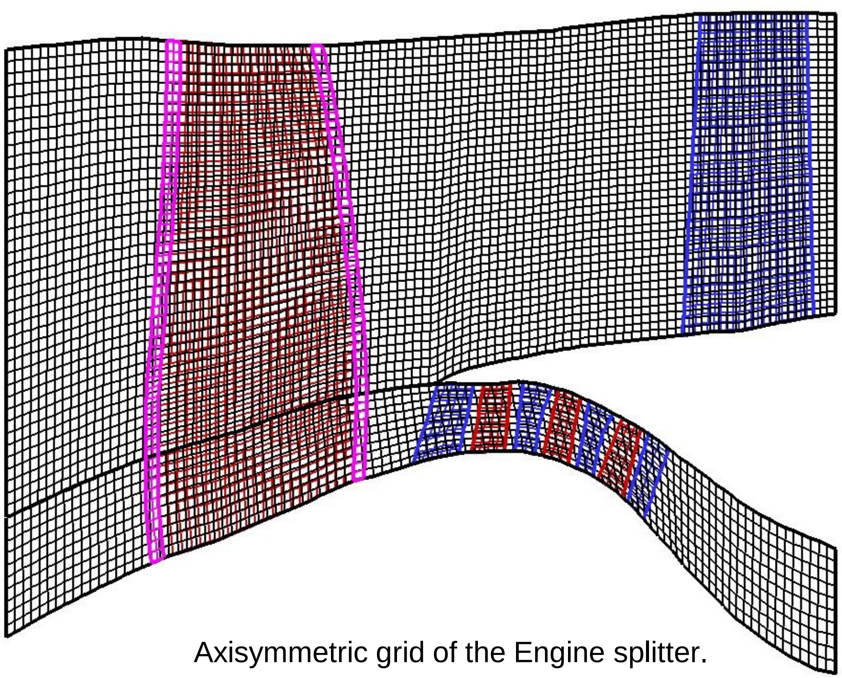
Axisymmetric grid of the partial tandem blade configuration.

Objectives:

- To create an axisymmetric grid for complicated geometries through structured meshes.
- To develop a general axisymmetric solver by modifying an existing Discontinuous Galerkin (DG) Chimera solver[1] developed at GTSL, University of Cincinnati.
- To add blade blockage factor and source terms into the axisymmetric equations in the cylindrical system.

GE 90[2] Engine Splitter





Axisymmetric grid of the Engine splitter.

Advantages of DG-Chimera:

- A stencil which is dependent only on its current cell and its immediate neighbors.
- Eliminates the need for a large interpolation stencil required for inter grid communication.
- Fringe points are not needed to maintain the interior stencil across artificial grid boundaries.[1]

Axisymmetric Governing Equations:

Cylindrical System -

b	=	Blockage	θ	=	Tangential
x	=	Axial	ρ	=	Density
r	=	Radial	u_x	=	Axial velocity
E	=	Internal Energy	u_r	=	Radial velocity
H	=	Total Enthalpy	u_θ	=	Tangential velocity
P	=	Pressure	ru_θ	=	Angular momentum

Continuity:

$$\frac{\partial}{\partial t}(b\rho) + \frac{\partial}{\partial x}(b\rho u_x) + \frac{1}{r}\frac{\partial}{\partial r}(rb\rho u_r) = 0$$

Axial Momentum:

$$\frac{\partial}{\partial t}(b\rho u_x) + \frac{\partial}{\partial x}(b\rho u_x u_x) + \frac{1}{r}\frac{\partial}{\partial r}(rb\rho u_x u_r) = -\frac{\partial bP}{\partial x}$$

Radial Momentum:

$$\frac{\partial}{\partial t}(b\rho u_r) + \frac{\partial}{\partial x}(b\rho u_r u_x) + \frac{1}{r}\frac{\partial}{\partial r}(rb\rho u_r u_r) = -\frac{\partial bP}{\partial r} + \frac{b\rho u_\theta^2}{r}$$

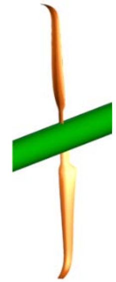
Angular Momentum:

$$\frac{\partial}{\partial t}(b\rho r u_\theta) + \frac{\partial}{\partial x}(b\rho r u_\theta u_x) + \frac{1}{r}\frac{\partial}{\partial r}(rb\rho r u_\theta u_r) = 0$$

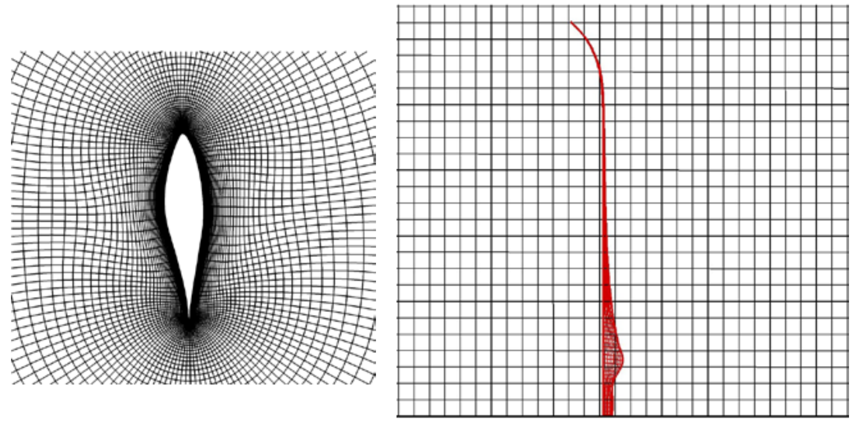
Energy:

$$\frac{\partial}{\partial t}(b\rho E) + \frac{\partial}{\partial x}(b\rho H u_x) + \frac{1}{r}\frac{\partial}{\partial r}(rb\rho H u_r) = 0$$

NREL[3] Wind Turbine with a Winglet[4]

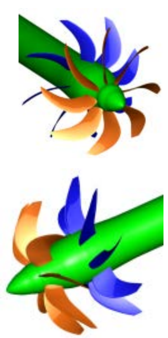


3D View.

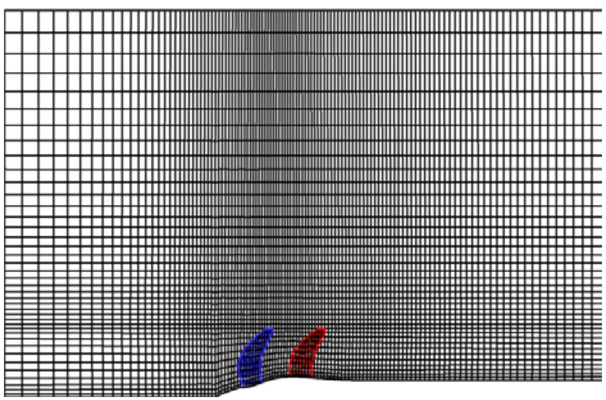


Axisymmetric grids of a 2 bladed NREL wind turbine with winglet and the tip airfoil.

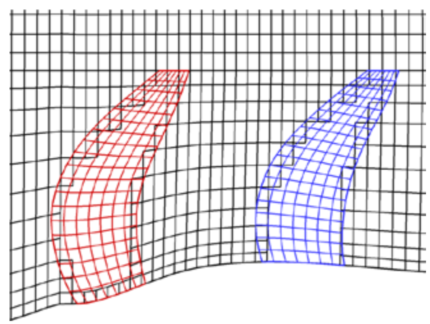
Open Rotor (NUMECA[5] design)



3D View.



Axisymmetric grid of the Open rotor.



Hole cutting done on the rotors.

Future Work:

- Completing the axisymmetric solver development.
- Creating 3 dimensional grid and solver for these complicated geometries in cylindrical system.
- Adding multiphase system solvers.

References:

1. Galbraith M., Orkwis D. P. and Benek A. J., *Chimera Overset Method with a Discontinuous Galerkin Discretization,* OGS2012-0014, Overset Composite Grids and Solution Technology Symposium, Dayton, Oct 2012.
2. http://ctr-sgi1.stanford.edu/CITS/ge90r.jpeg
3. Giguere P. and Selig M.S., *Design of a tapered and twisted NREL wind turbine*, NREL/SR-500-26173, Illinios, 1999.
4. Johansen J. and Sorensen N.N., *Aerodynamic investigation of winglets on Wind Turbine Blades using CFD*, Riso-R-1543, Riso National Laboratory, Denmark, 2006.
5. Open rotor, http://www.numeca.com/index.php?id=turbomachine

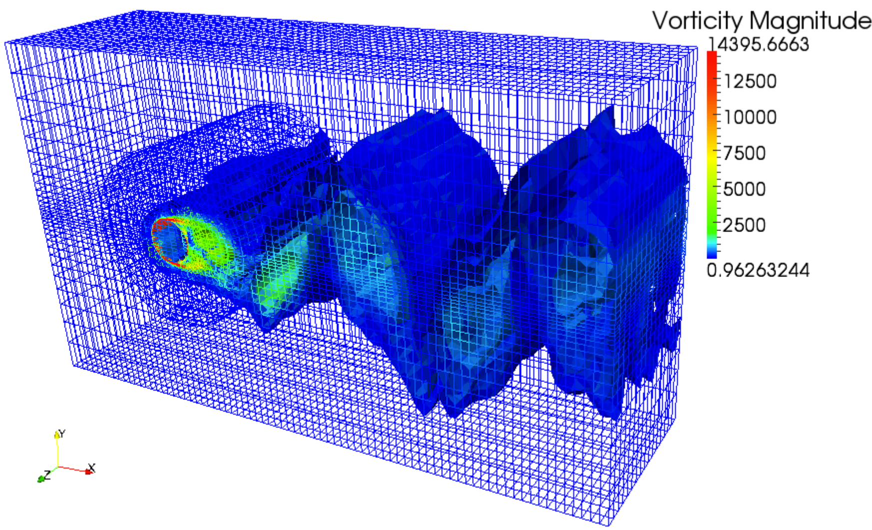
UNIVERSITY OF Cincinnati

Gas Turbine Simulation Laboratory
School of Aerospace Systems

Matt Laurita, Georgia Institute of Technology

"OverFOAM": Overset OpenFOAM for the Wind Energy Community

- Why OverFOAM?
  - Open source
  - International community of users
  - Free to customize and share
  - Leverages the flexibility of OpenFOAM by adding features of interest to wind energy research
  - Builds upon OpenFOAM's existing mesh motion / deformation capabilities
- How is it implemented
  - Incorporates Suggar++ and DiRTlib
  - C++ Class: oversetControl
    - Handles initialization, data, and communication with Suggar++ and DiRTlib
  - Class declaration and member functions compiled into a library
    - Library can be linked to an existing OpenFOAM solver during compilation or dynamically linked at runtime
    - Library implementation minimizes the number of lines of of code to be added to a solver to make it overset
  - Runtime parameters specified by an OpenFOAM dictionary: oversetDict



Applications of Overset Grids for CFD Analyses in the Penn State Applied Aerodynamics Research Group

James Coder

- Applied Aerodynamics - lift, drag, and pitching moment of both simple and complex geometries or configurations
  - Overset grids (OVERFLOW 2.1/2.2) are enabling technology
  - Comparisons with high-quality low-speed, low-turbulence wind tunnel
  - Development of new transition modeling capabilities in a CFD-compatible framework

- Example applications
  - Full aircraft geometries (AIAA Drag Prediction Workshop)
  - Sailplane wing/winglet combinations including transition effects
  - Airfoils with deployable Gurney flaps (MiTEs)
  - Multi-element natural laminar flow airfoils (Airfoils, Inc.)

Selected Examples

- MiTEs
  - Overset grids allow deformable geometry
  - Creative topology permits orphan-free solution
  - Studies netted much physical insight into the unsteady aerodynamic behavior
- Multi-element Natural Laminar Flow Airfoil
  - Fine-resolution O-grids on each element
  - XRAY hole cutting
  - Transitional analysis using PSU-developed amplification factor transport equation