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An Adaptive Mesh Refinement (AMR) Strategy For Static & Dynamic Overset Unstructured Meshes

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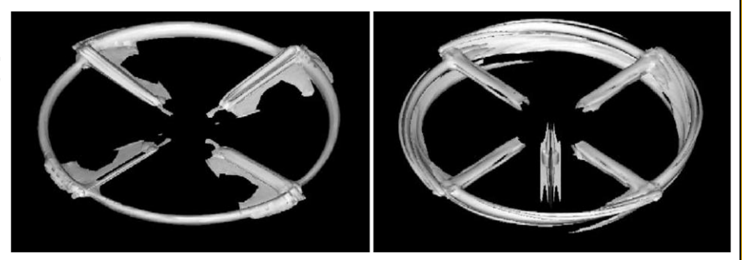
Overview

Why use Mesh Adaptation?
- No need to tailor mesh to flow phenomena
- Capture wake physics without coupling with a hybrid code

Anisotropic Adaptation
- Can accurately capture tip vortices

Refinement capability within FUN3D
- Feature and adjoint-based anisotropic AMR for unstructured tetrahedral meshes
- Previously used in non-overset cases with no indicator to capture vortices and wake structures

Previous AMR efforts in Rotorcraft
- Overset methods
  - Background mesh is adapted
  - Hover conditions – Canonne et. al.
  - Structured near-body – Duque et. al.
- Non-overset and sliding mesh approaches
- Adaptation in body-fixed frame



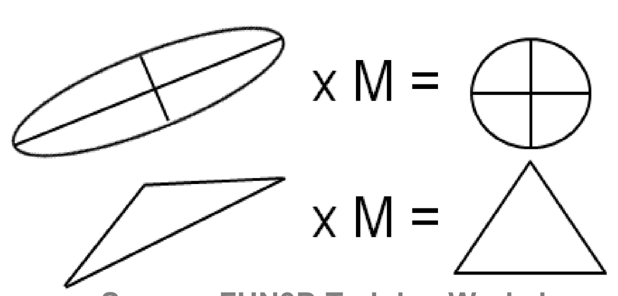
Unadapted (left) and adapted (right) iso-vorticity surfaces of a rotor in hover

Source: Canonne, E., Benoit, C., and G. Jeanfaivre. "Cylindrical mesh adaptation for isolated rotors in hover", *Aerospace Science and Technology*, Vol. 8, No. 1, Jan. 2004

Overset Adaptation Technique

What is unique about this?
- Overset method (SUGGAR++) using single unstructured RANS solver (FUN3D)
- Anisotropic AMR with vorticity-based indicator
- Adaptation performed in intertial reference frame

Parallelized Adaptation Mechanics
- Node insertion and movement
- Edge swap and collapse
- Iteratively satisfies anisotropic metric M

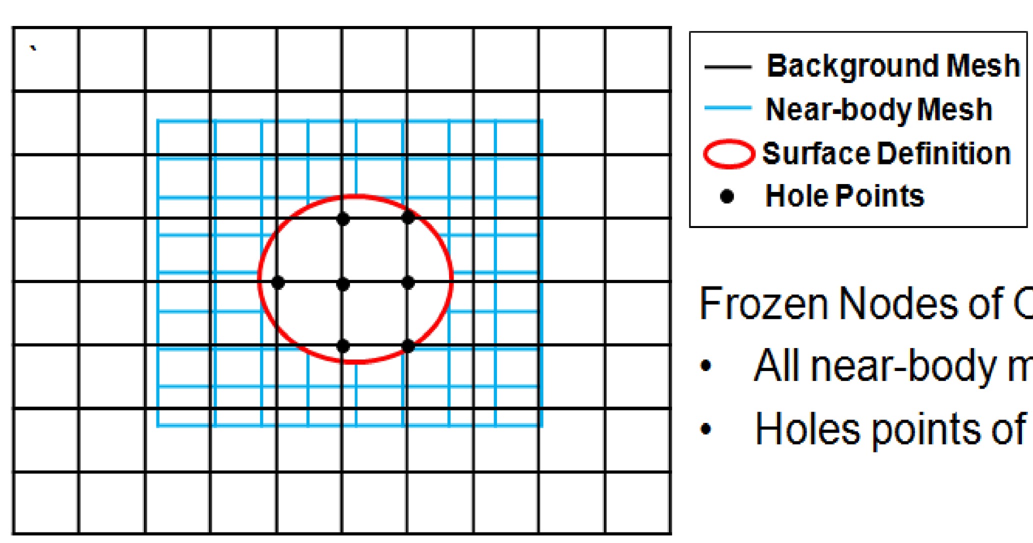


Source: FUN3D Training Workshop Manual, NASA LaRC, Apr. 2010

Overset AMR Strategy
- AMR restricted only to background mesh
- Performed at intervals to capture unsteady wake's evolution

Adaptation Indicator

$$|\omega| \times (\text{edge length})^{1.0}$$

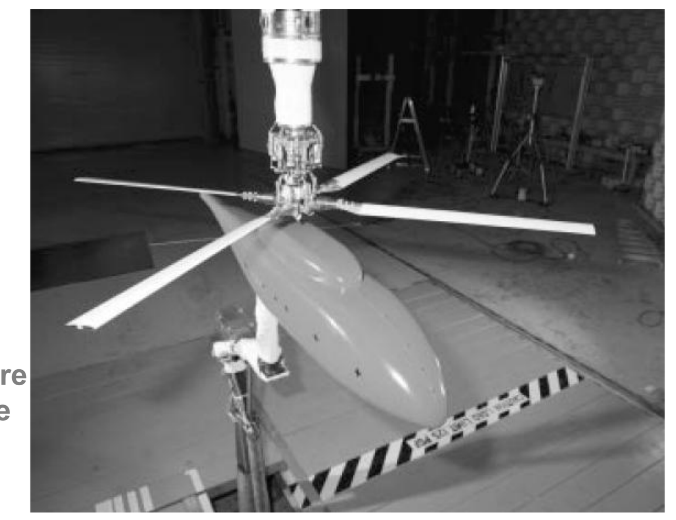


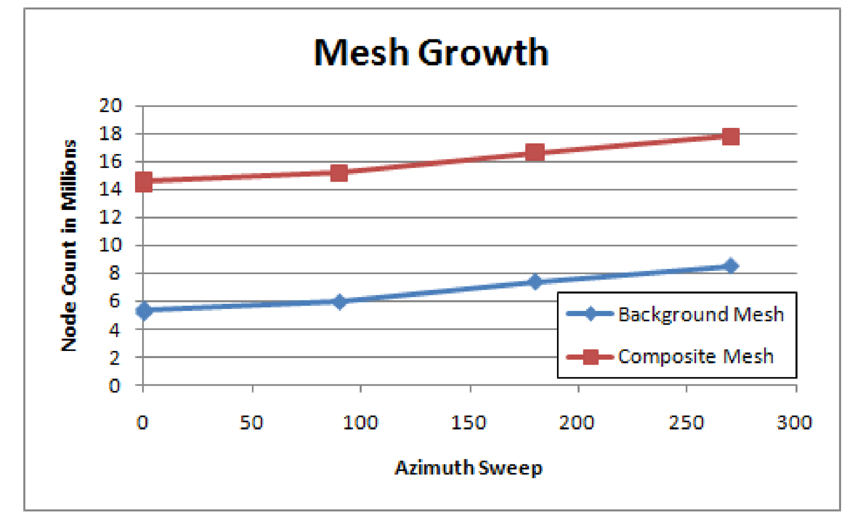
Frozen Nodes of Overset AMR:
- All near-body mesh nodes
- Holes points of background mesh

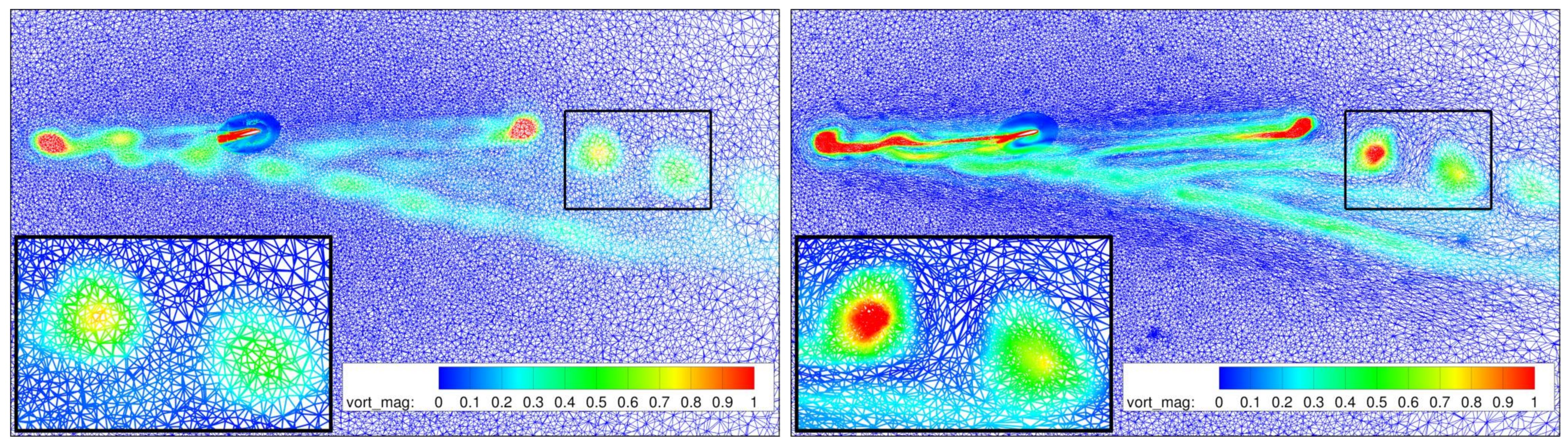
Rotor-Fuselage Configuration: ROBIN

Generic rotor-fuselage (NASA)
- Rotorcraft CFD validation case
- Unsteady pressure data correlation desired
- CFD does not model complex rotor hub

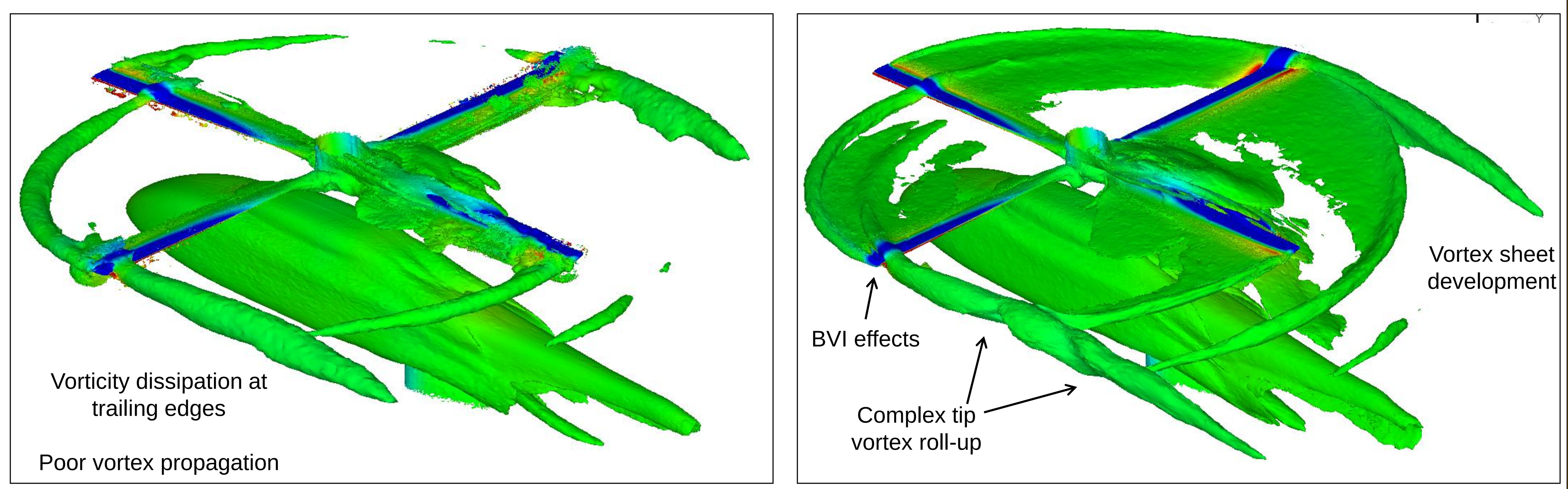
Source: (left) Mineck, R.E. and S.A. Gorton, "Steady and Periodic Pressure Measurements on a Generic Fuselage Model in Presence of a Rotor", *NASA/TM-2000-210286*, Jun. 2000





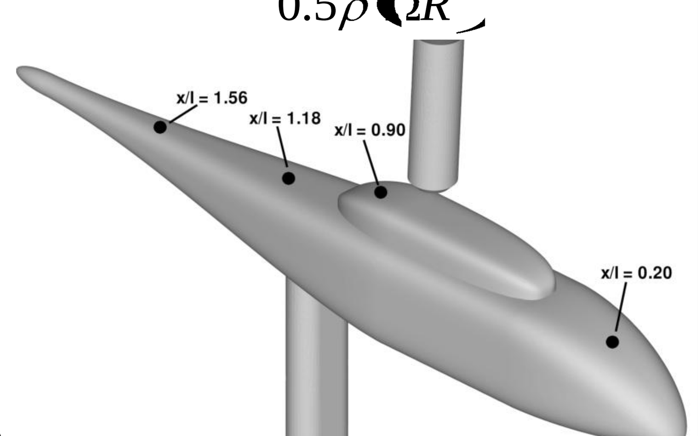


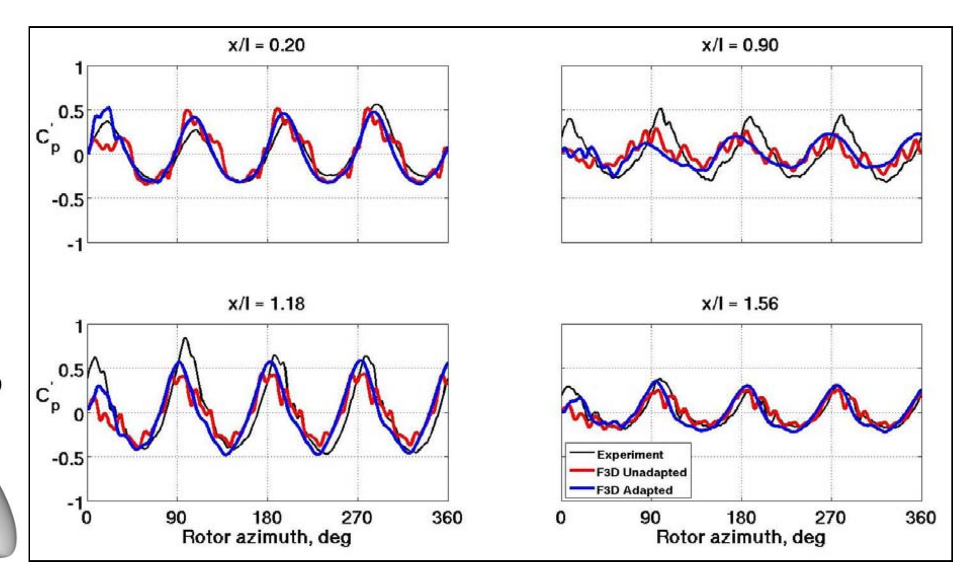
Unadapted (left) and Adapted (right) Mesh Contours at r/R = 0.56 (retreating side)



Unadapted (left) and Adapted (right) Iso-Vorticity Surfaces

$$C'_p = \frac{p - p_\infty}{0.5\rho(\Omega R)^2} \times 100$$



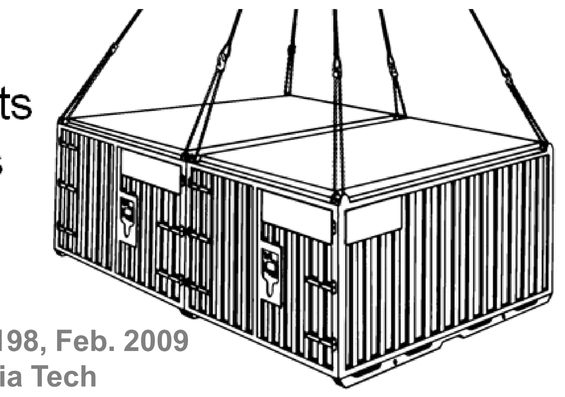


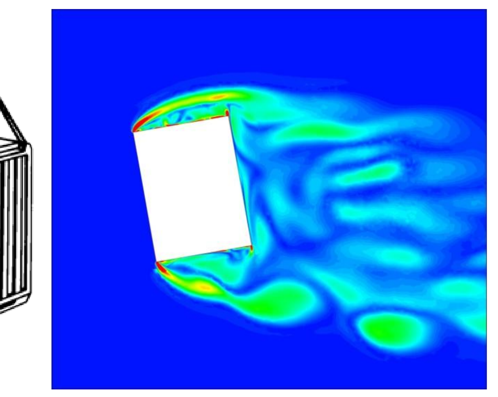
Unsteady pressure correlation
- Adaptation damps out high order oscillations
- Better magnitude agreement at empennage locations – x/l = 1.18 & 1.56
- Smooth pressure prediction at x/l = 0.90 due to accurate root vortices

Applications & Ongoing Research

Sling Loads

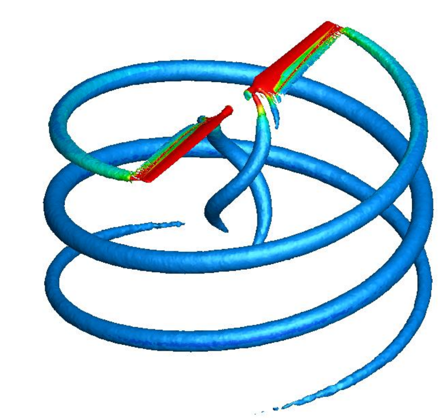
- Aerodynamic effects on dynamic modes
- Drag prediction





Source: (left) *US Army* FM 4-20.198, Feb. 2009
(right) B. Koukol, Georgia Tech

Wind Turbines

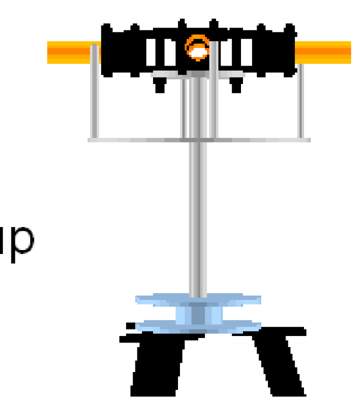


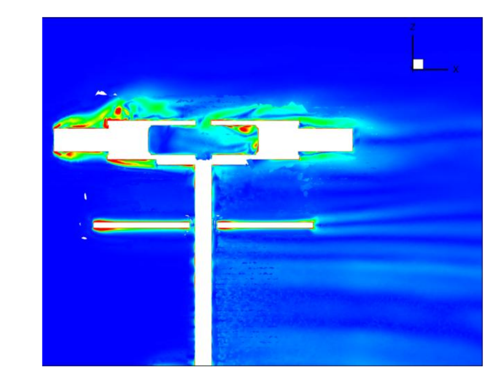
- Tower and nacelle contributions to wake
- Full configuration interactions

Source: (left) "Unsteady Aerodynamics Experiment Phase VI: Wind Tunnel Configurations and available Data Campaigns," *NREL/TP-500-29955*, Dec. 2001
(right) C.E. Lynch, Georgia Tech

Hub Drag

- Rotor-hub interaction
- Component drag buildup
- Assembly interactions





Current & Future Work

Source: Kenyon, R. and R.E. Brown, "Wake Dynamics and Rotor-Fuselage Aerodynamic Interactions." *Journal of the American Helicopter Society*, 54.1, 2009.

Capture longer wake-ages similar to VTM (left)

- Overset AMR process currently quite complex
- Integration of adaptation and overset capability
  - Effective communication between libraries
  - Increased efficiency and robustness
- Develop a time-dependent metric-based approach
  - Better accuracy in capturing unsteady features
  - Less sensitive to adaptation frequency

Advisor: Prof. Marilyn Smith
Collaborators: Eric Lynch, James Cook
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