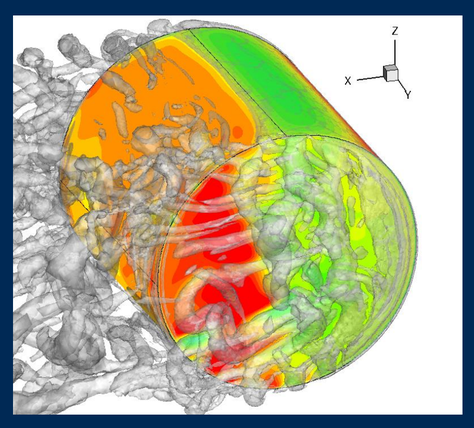
Coupled Aerodynamics and Dynamics of Bluff Bodies



Applications

• Numerous applications in commercial, private, and military use: aerial firefighting, air drops, pilot training, crane operations, and sling loads.

Challenges

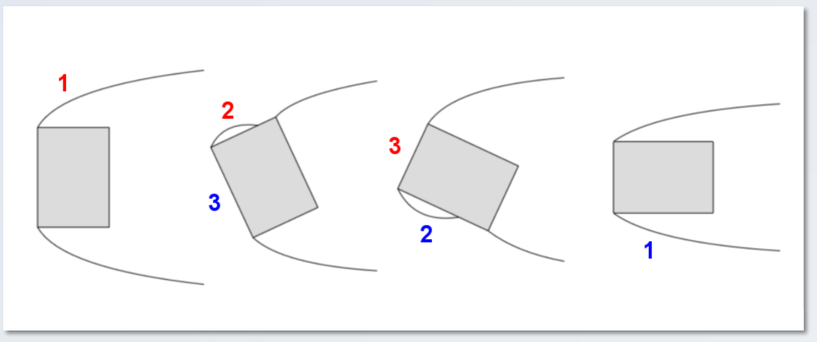
• Aerodynamics: separated wake, unsteady flow, vortex shedding, 3D flow, reattachment, rotor wakes

• Dynamics: coupled helicopter/load motion, tether dynamics, difficult-to-measure system parameters

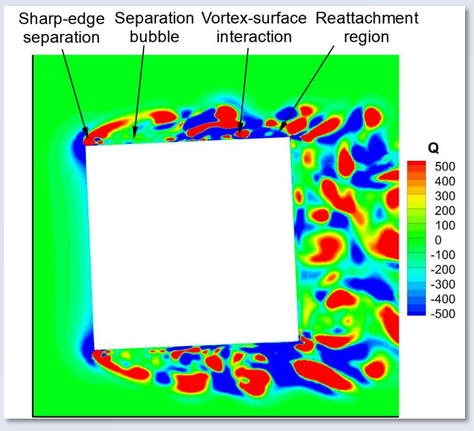
Physics

Approach:

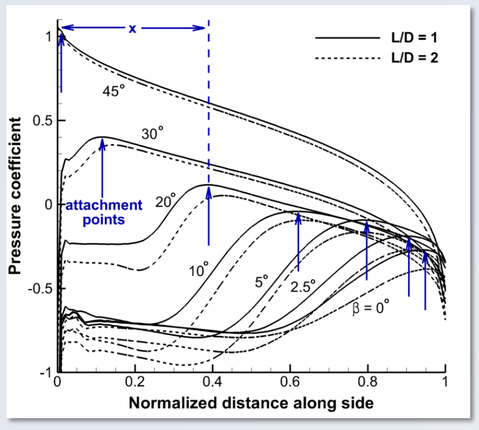
- Develop an understanding of the important aerodynamic phenomena in 3D bluff body flows.
- Apply this understanding to improve flight performance and stability predictions.



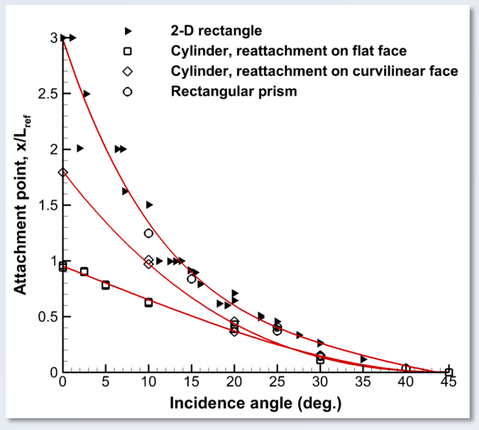
Typical shear layer behaviors: 1) Fully Separated flow, 2) Reattaching flow, and 3) fully attached flow.



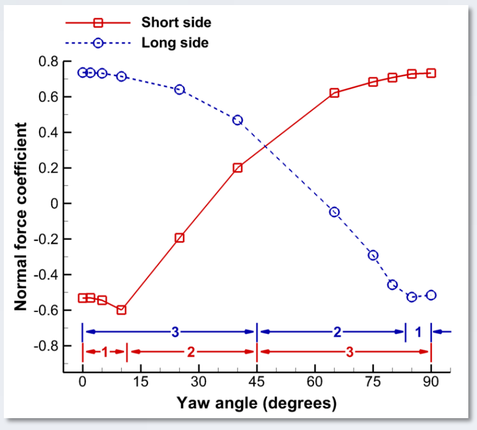
Top-down view of cylinder with L/D = 1. Unsteady reattachment may be intermittent, with vortices periodically impinging on the surface.



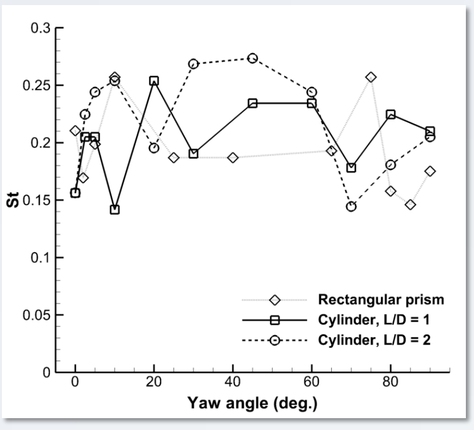
Reattachment causes sudden drastic changes in surface pressure. This figure depicts reattachment pressures for finite cylinders.



Reattachment distance depends on the geometry type: cylinder, rectangular prism, etc.



Local forces and moments on individual faces can be characterized by shear layer behavior.



Shedding is erratic and multimodal, but Strouhal numbers are typically in the range 0.15—0.3.

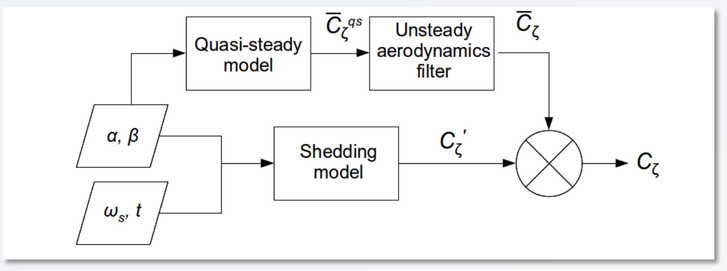
Reduced Order Modeling

Modeled aerodynamic phenomena:

- Nonlinear quasi-steady aerodynamics
- Turbulent vortex shedding
- Unsteady effects from body motion

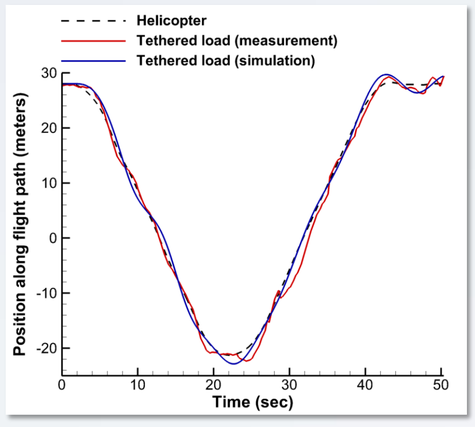
Computational cost:

- 5 orders of magnitude reduction relative to high-fidelity URANS.

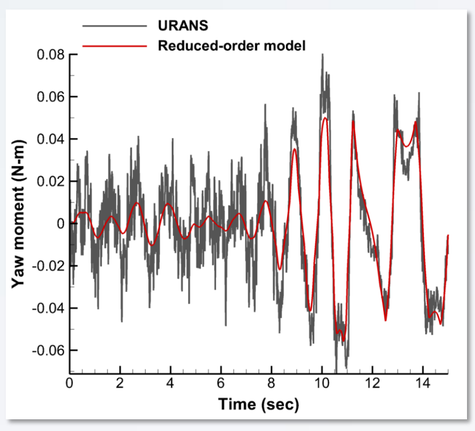


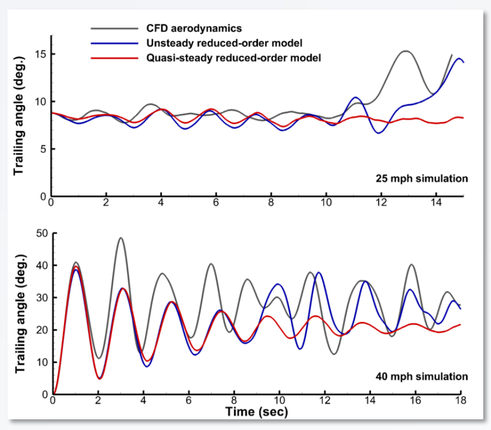
Reduced-order aerodynamic model flowchart illustrating how the important phenomena are incorporated.

Successful validation to date:

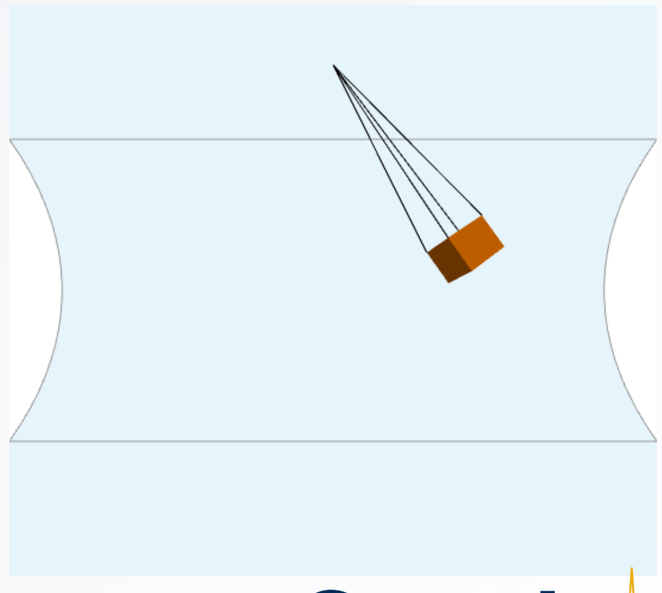


Validation with flight testing from the Georgia Tech UAV Research team. The reduced-order model has also been implemented into their simulation tool, GUST.





Validation against high-fidelity URANS/6-DoF simulations with FUN3D. The unsteady reduced-order model faithfully reproduces the aerodynamics and produces an accurate dynamic response.



Georgia Tech

Nonlinear Computational Aeroelasticity Lab