Drag Reduction by Trailing Edge Tabs on a Square Based Bluff Body with a Stationary Ground Plane

Scott Sawyer

Faculty Advisor: Dr. Jin Tso

AEROSPACE ENGINEERING

CAL POLY • SAN LUIS OBISPO

Overview

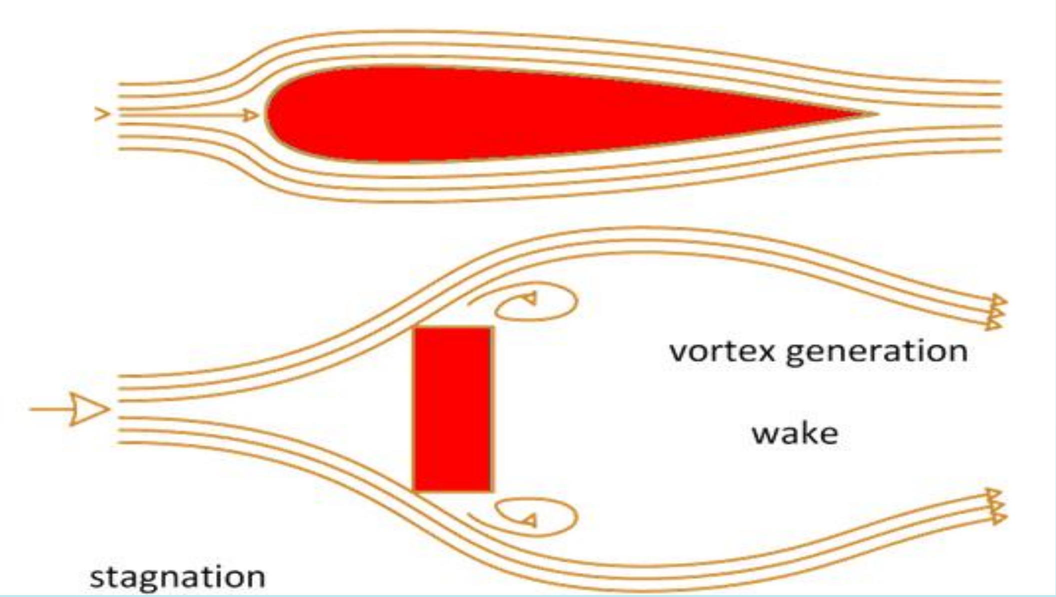
- Project Goals
- Bluff Body
  - Background
- Ground Effect
  - Background
  - Testing
- Previous Work
- Experimental Apparatus
- Testing Results

Project Goals

- To investigate drag reduction via trailing edge tabular devices on a square based bluff body in ground effect
- Compare base pressures in a bounded flow to previous work performed in unbounded flow
- Compare results of drag reduction devices in and out of bounded flow

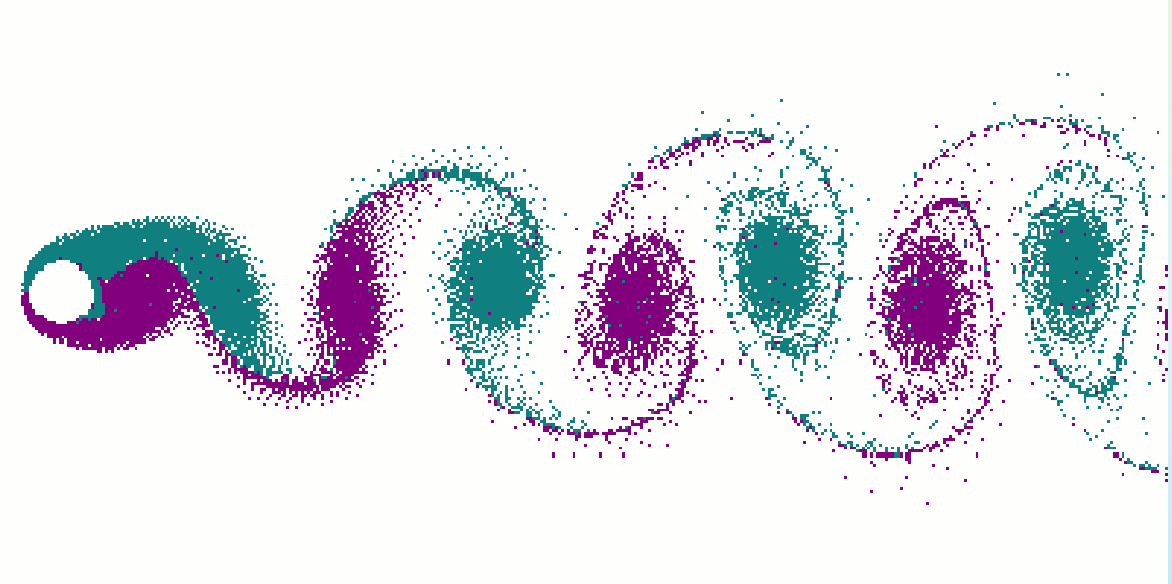
Bluff Body Basics

- A bluff body contains a large base region perpendicular to the airflow
    - Resulting separation of flow generates vortices, creating a low pressure region behind the vehicle and increasing overall aerodynamic drag
- Drag force is dominated by pressure drag in comparison to viscous drag



Vortex Creation

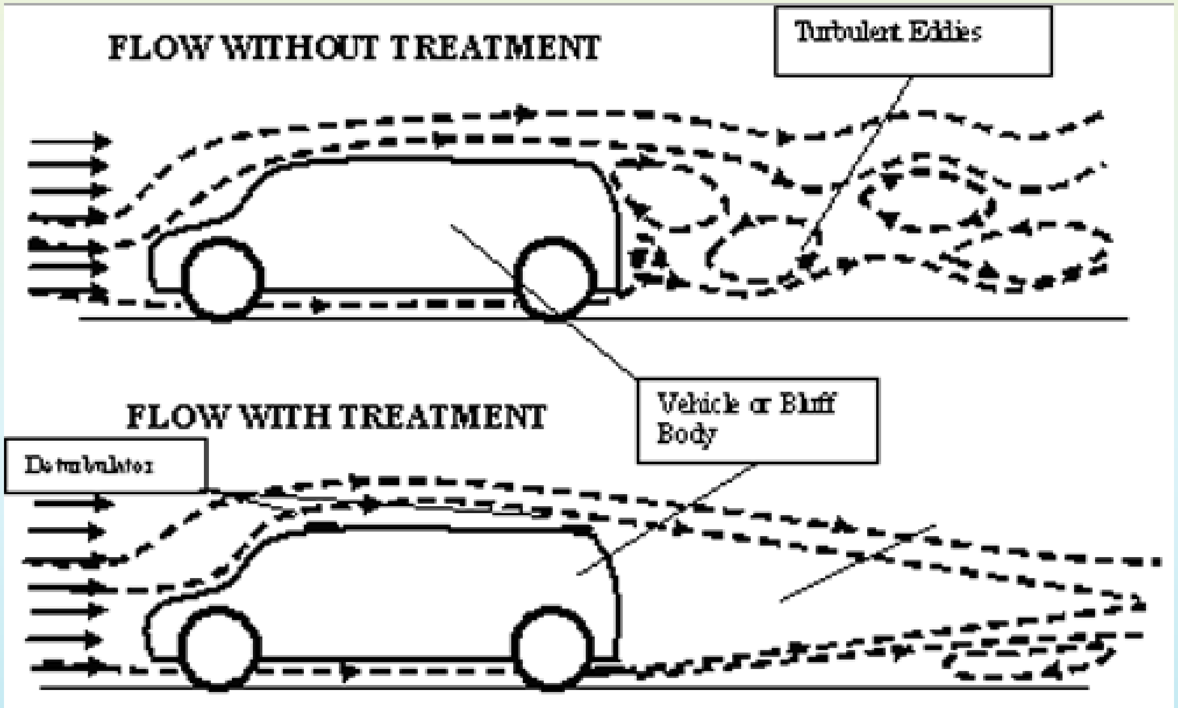
- The trailing edge creates an instantaneous separation of flow, resulting in the formation of an unstable shear layer
- This shear layer will roll into a vortex on both the top and bottom surfaces, forming a Karmen vortex sheet



Applications

• Real world application include aircraft, submarines and automobiles

  • This effect can most commonly be seen on large transport automobiles, buses, and tractor trailers

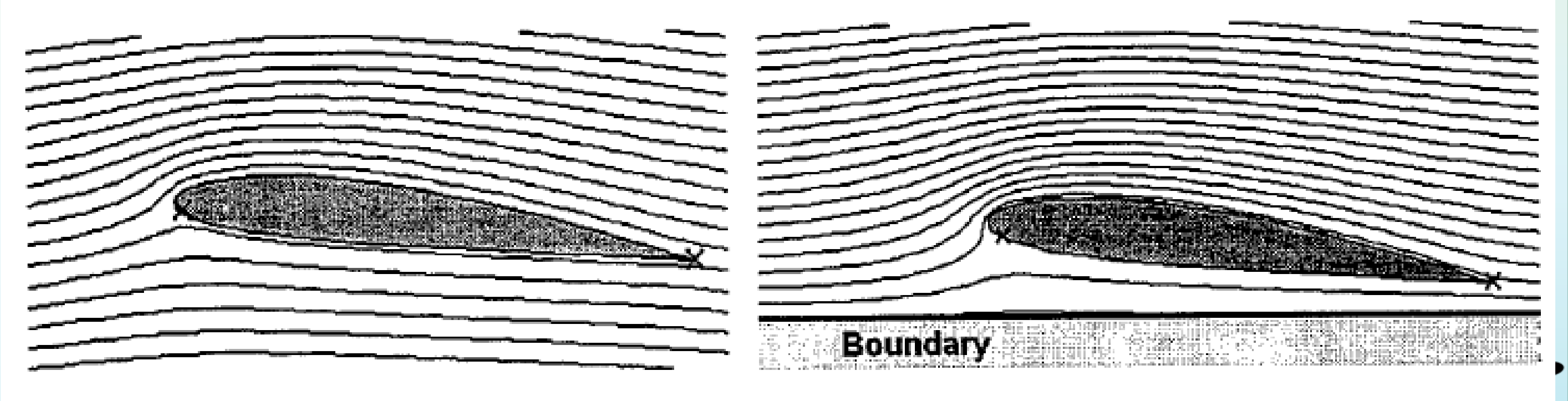


Bluff Body Drag Reduction

- For a large tractor trailer, as much as 70% of fuel consumption can be attributed to aerodynamic drag, depending on speed
  - A major cause of this is the bluff shape of the trailer
- Passive drag devices can be used to control and minimize this drag, which results in lower fuel consumption, and greater profits for the company

Bounded vs. Unbounded

- In aircraft aerodynamics, the majority of the airflow can be considered “unbounded”
  - However, in a bounded case, the boundary creates an alteration of the flow field by preventing the expansion of the streamlines
  - For aircraft, this can lead to an increase in lift and a decrease in drag

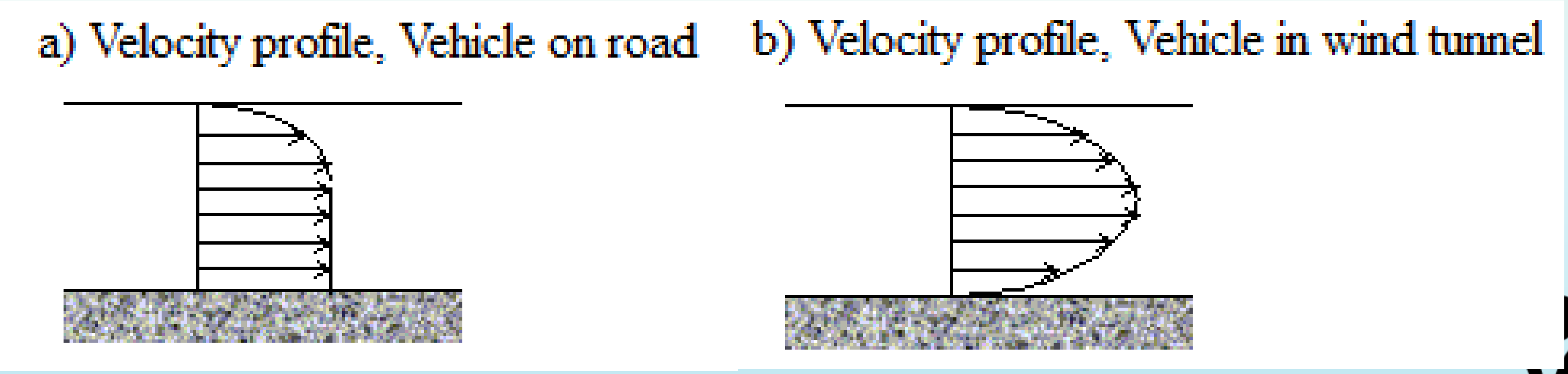


Ground Effect

- Aircraft experience ground effect most often during takeoff and landing
- For automobiles, the ground is constantly having an effect on the overall aerodynamics of the vehicle
  - High performance racing vehicles (Formula 1, Indy) have tried to utilize this effect to increase downforce
  - Wing in Ground Effect Vehicles (WIGS) have been built and tested

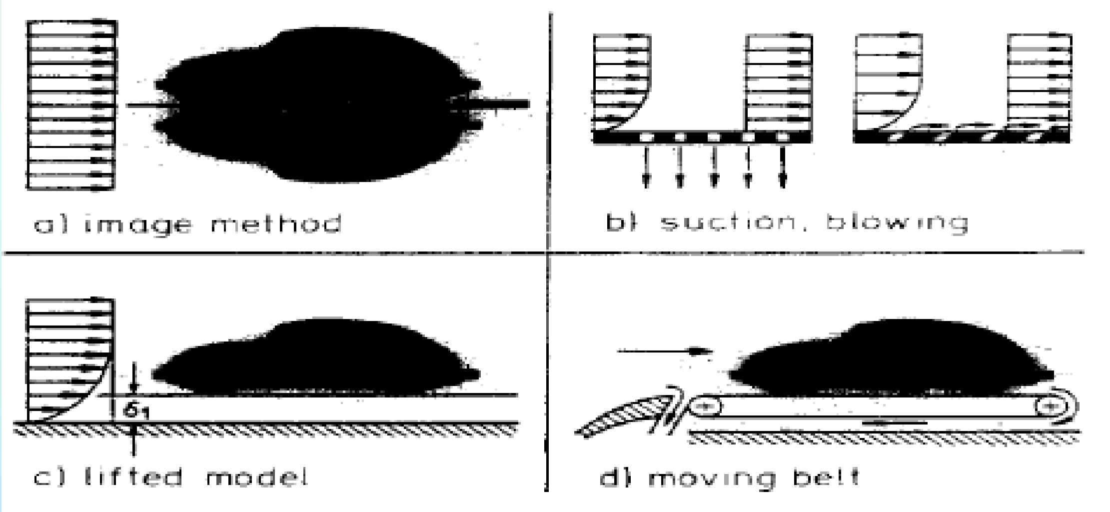
Modeling Ground Effects

- Presence of ground plays an important role in flow characteristics
- Depending on height above the ground, flow circulation is created in bounded airflow
- In a wind tunnel, because the air is moving in relation to the object, a boundary layer is formed that does not depict the real situation



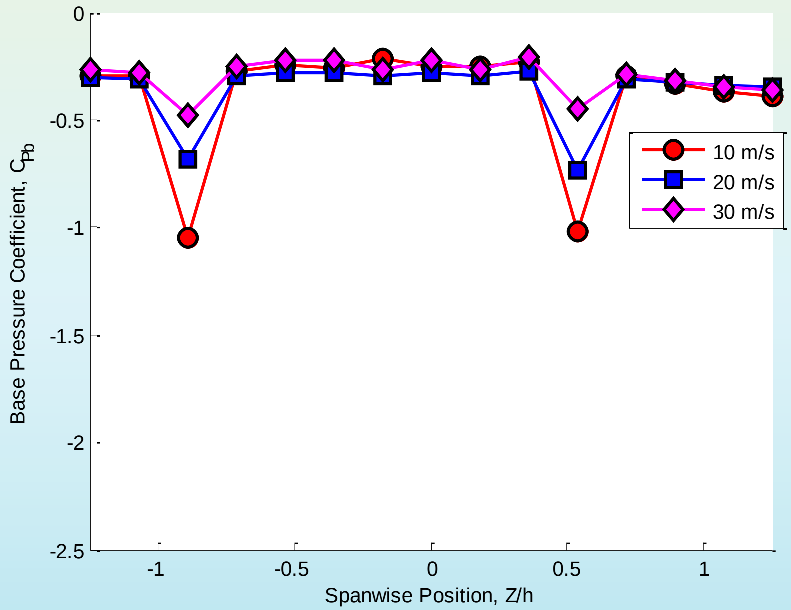
Modeling Ground Effect

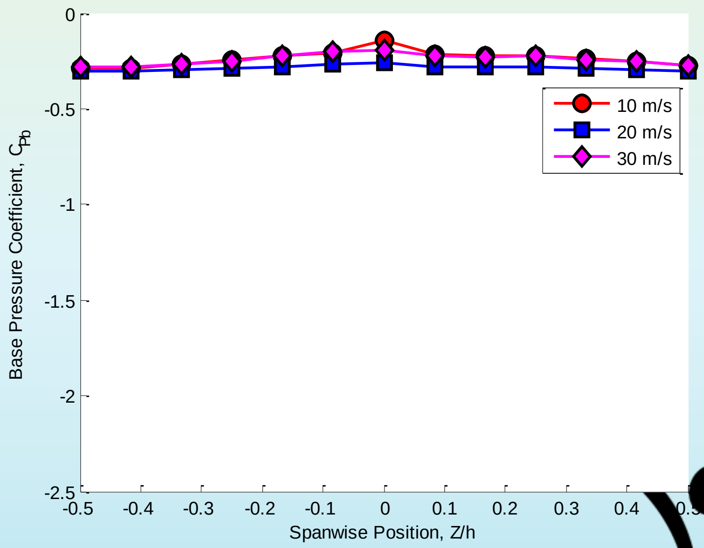
- Mimicking real world bounded flow phenomena in a wind tunnel presents difficult challenges
  - Money, complexity, and space
- Lifted model is the easiest test setup and provides realistic results for larger ground clearances
- Moving belt is most accurate, but is complex and costly



Previous Work at Cal Poly

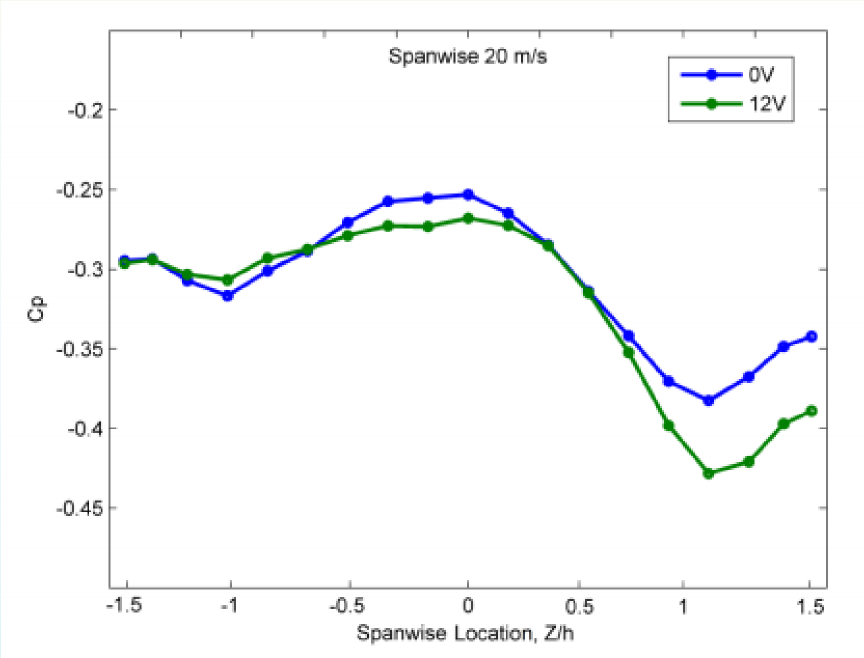
- Jarred Pinn found a large drag reduction by adding tabs to each side of the model
- Reported a 36% increase in base pressure with the addition of tabs
  - Attributed the attenuation of vortex shedding to this large drag decrease



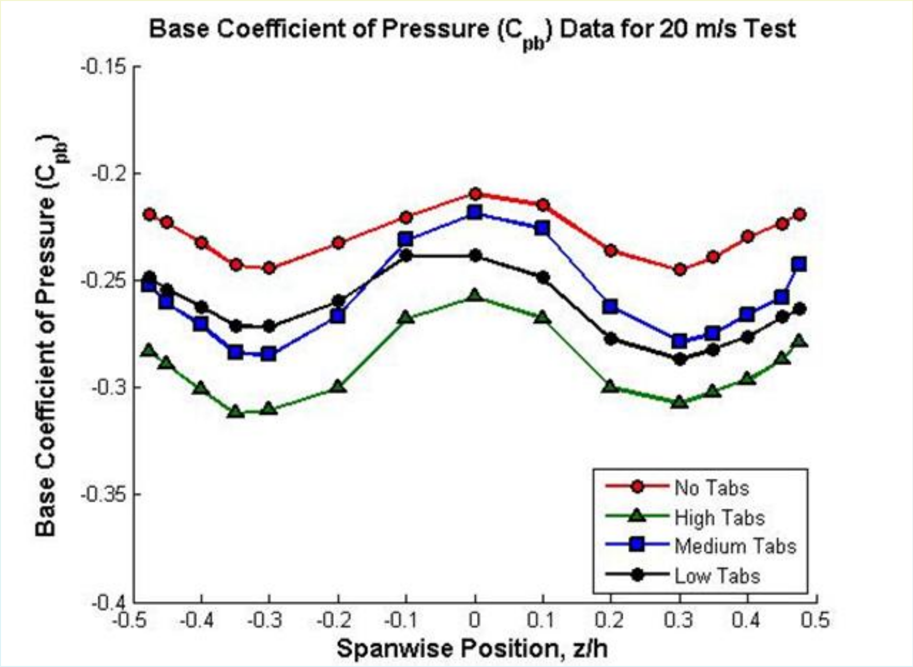


Previous Work Cont.

- Ethan Erlhoff investigated active drag reduction for 3D bluff bodies via distributed forcing
- Baseline model pressures contradicted Pinn
- Concluded that while drag was decreased with forcing, it was not efficient energy wise



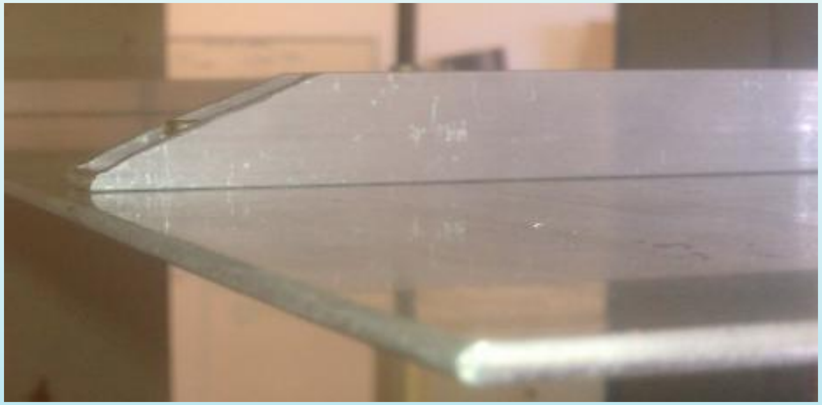
Previous Work Cont.



- Barker reported drag increase of a 3D bluff body with tabs for vortex attenuation, over the untabbed version
- Trailing edge tabs were ineffective at decreasing base pressure drag, and larger tabs created lower base pressures

Experimental Apparatus

- 3’ X 3.5’ aluminum ground plane installed from wind tunnel ceiling
- 6” flap at the trailing edge
  - Controls stagnation point
- Full adjustability allows for testing at all ground clearance heights
- Structural support was added as a result of initial testing
- Rounded leading edge to prevent separation



Ground Plane Installation

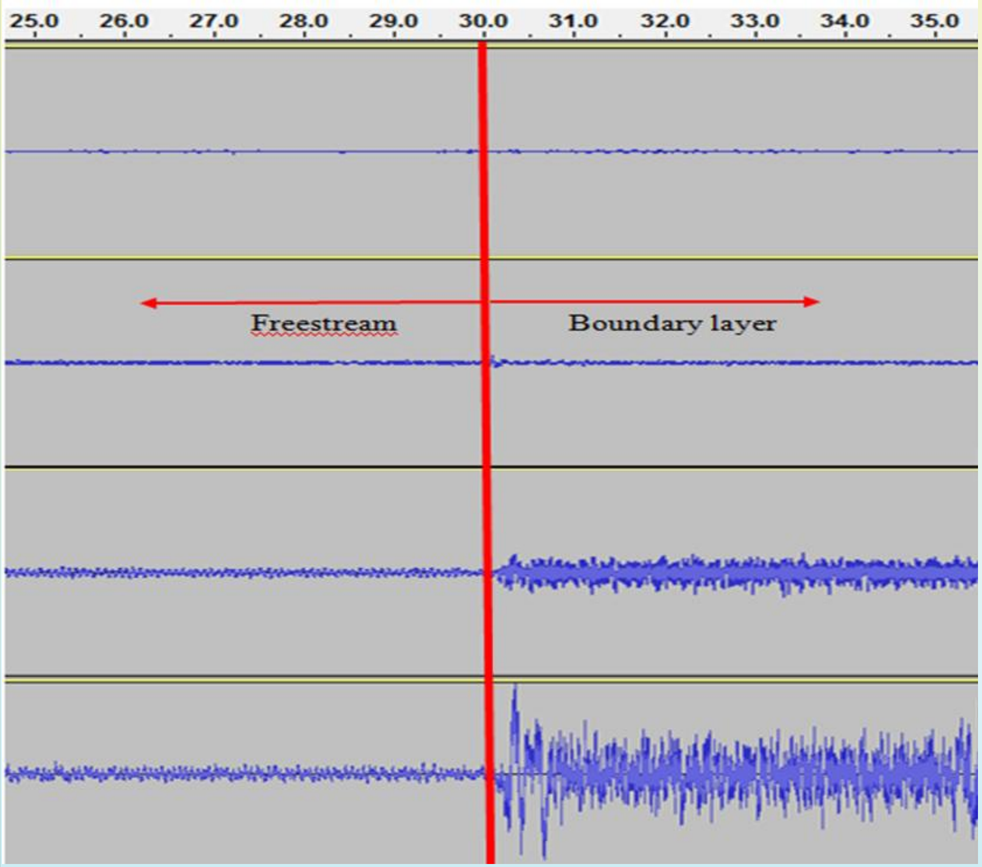
- Ground plane lowered from wind tunnel ceiling
  - No interference with sting balance or strut

Stiffening Spars

Ground Plane

Support Rods

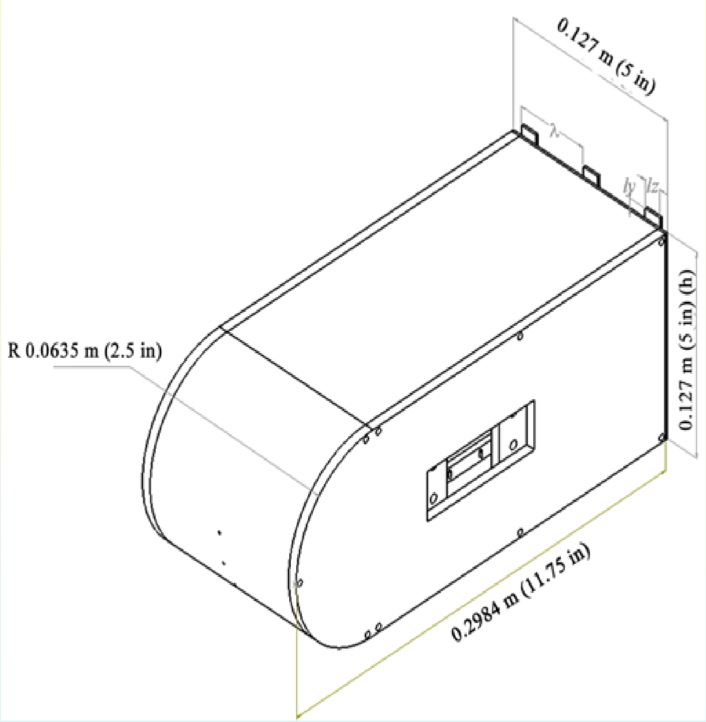
Ground Plane Validation

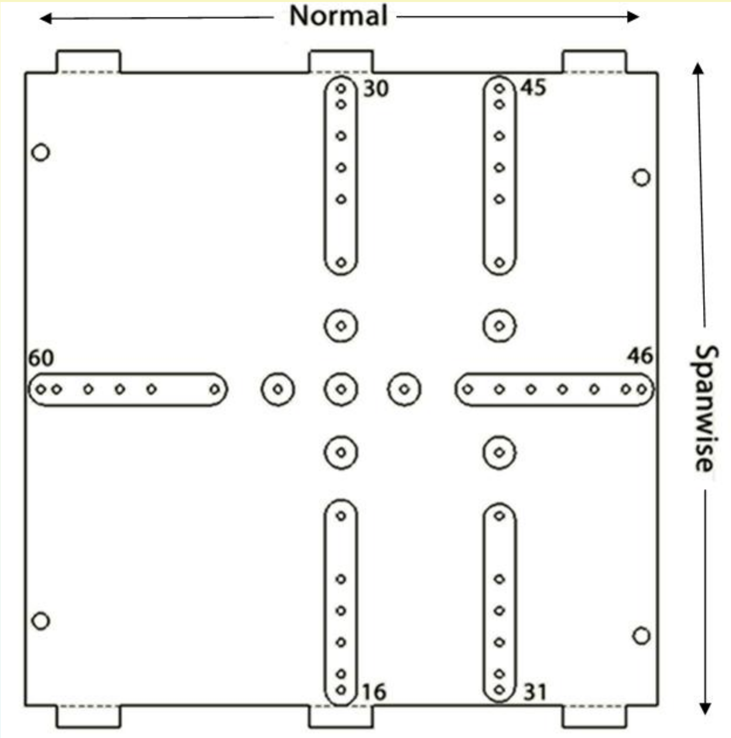


- Laminar boundary layer was present at 5 and 10 m/s
  - Turbulent at higher test velocities

Speed [m/s]	BL Thickness (Laminar) [mm]	BL Thk (Turb) [mm]
5	9.07E+00	3.11E+01
10	6.41E+00	2.71E+01
20	4.53E+00	2.36E+01
30	3.70E+00	2.17E+01

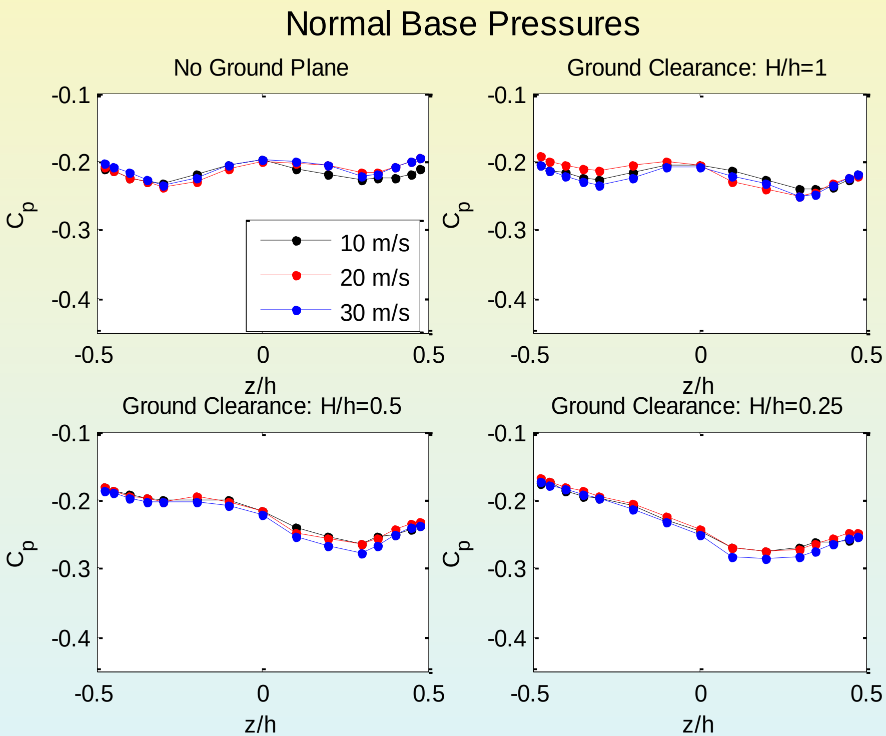
Bluff Body Model

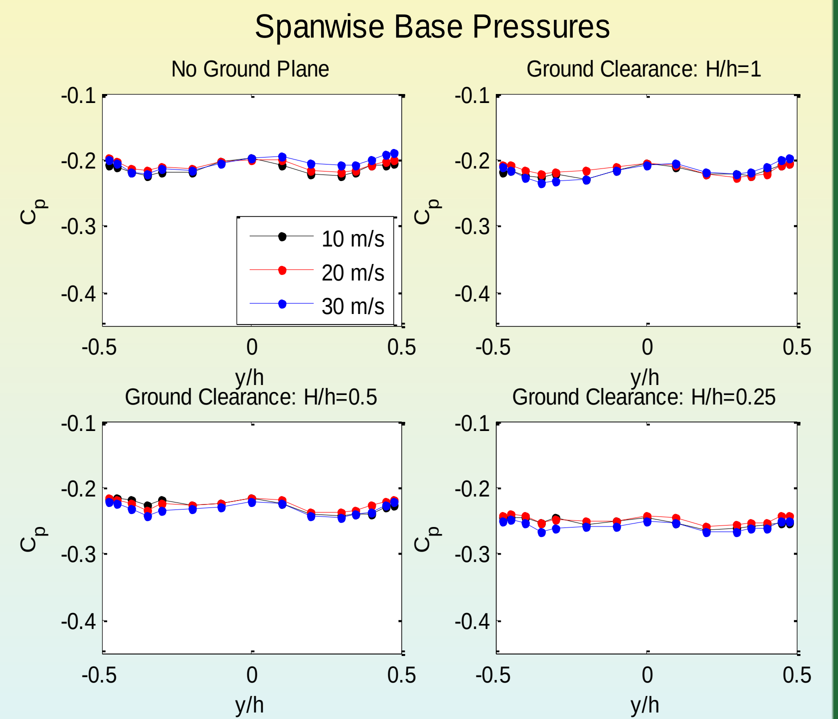




- Same model that Barker used in testing
  - Allows for direct comparisons of results
- Square base with 44 tapped pressure ports
- Utilized one row of ports on both the spanwise and normal directions
  - Limited by spacing in sting balance strut for tubing

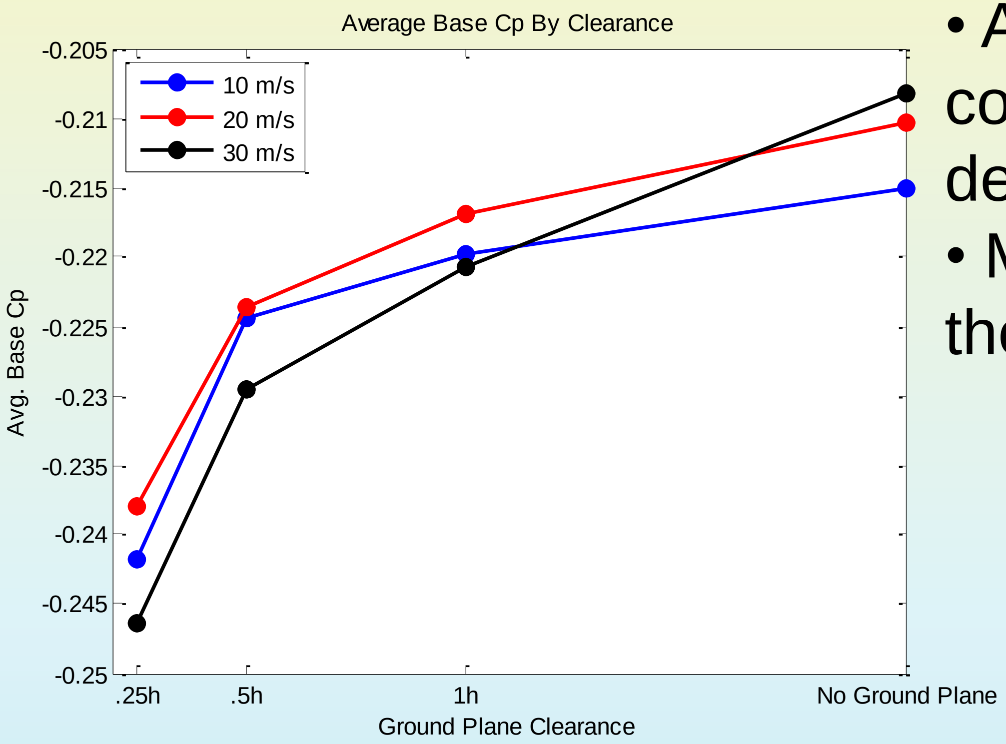
Testing Results





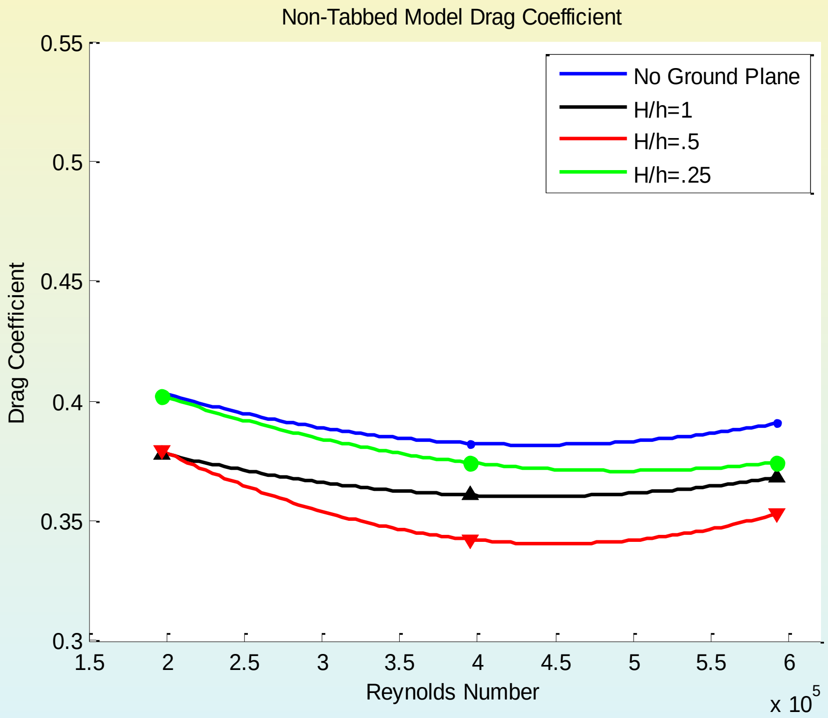
- Ground plane alters the flow field at the base of the model
    - Unbounded flow side experiences a large drop in Cp

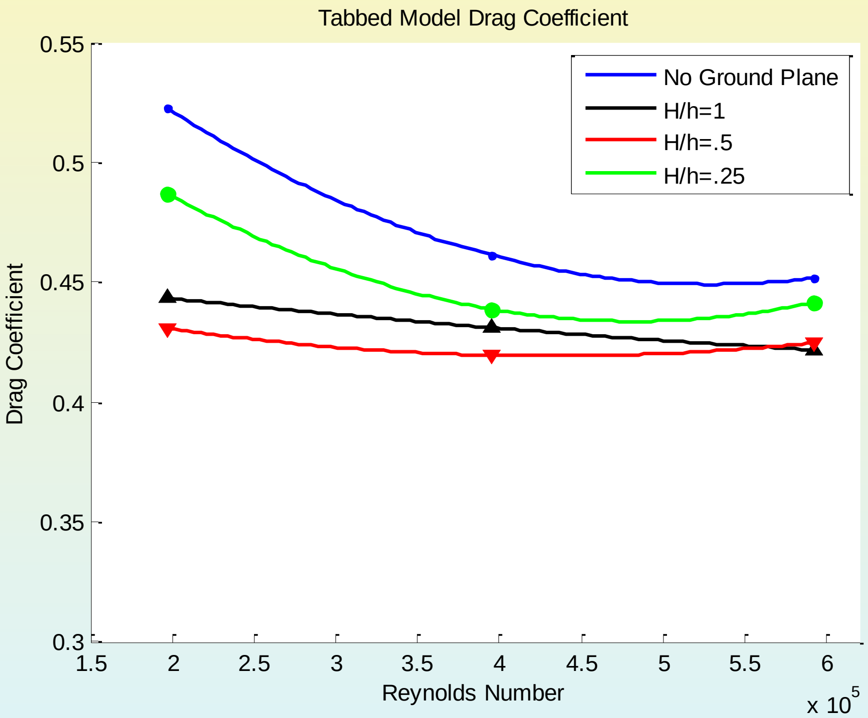
Testing Results



- Average base pressure coefficients drop with decreasing ground clearance
- Much greater decrease at the lowest ground clearance
  - Turbulent boundary layer effects

Drag Force





- Sting balance data inidicates the addition of trailing edge tabular devices actually increases overall drag force
- Drag decreases with decreasing ground clearance, up to a critical gap height

Questions?