MAE 189 Capstone Design

Team 8: Aerodynamics Predictor

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Project Sponsor: Professor Johnson

Ashton

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Ashton

Project Overview

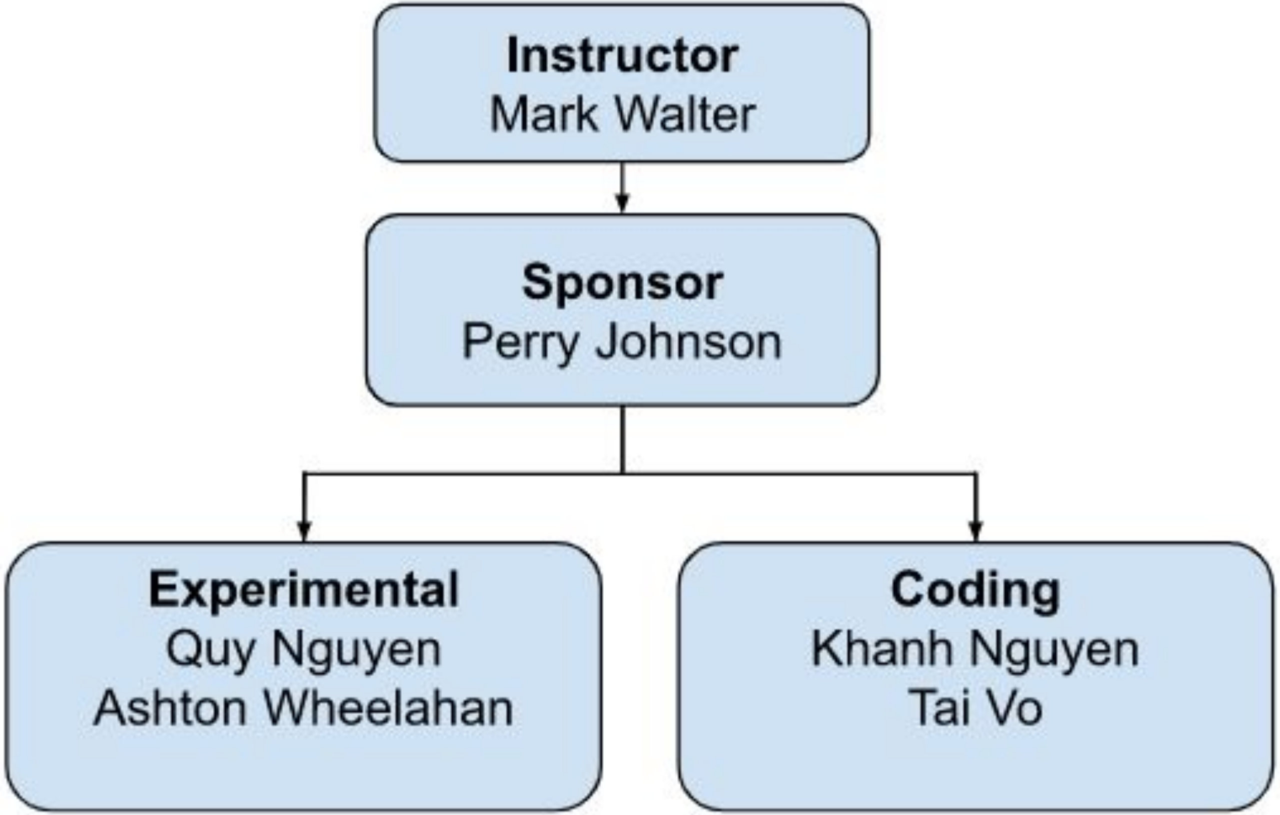
- Validate and verify the predictive capabilities of the program XFOIL through experimentation with wind tunnel testing

- Validate the the lift and drag calculations of a 2D airfoil

- A determination of the TRL of XFOIL with supporting evidence and documentation

Ashton

Team Structure



Ashton

Design Attributes

- Objectives
  - Must be able to validate and verify our predictions to show the technical readiness level of XFoil
  - Must compare real world experiments to program predictions to mathematical predictions
- Constraints
  - Testing 3D airfoils against a 2D program
  - Not all results are perfect representations

Ashton

Design Attributes

- Functions
  - Must have comparable data: Coefficient of lift and drag
  - Validated through pre existing math
- Means
  - Testing 3 airfoils in wind tunnels and preliminary data
  - Validating through basic shapes

Ashton

Requirements

- Test multiple airfoils shape through experimentation with the wind tunnel
  - NACA 0012, NACA 0015, NACA 0021
- Observe and compare coefficient of lift and drag with results from XFOIL
- Compare results to mathematical equations
  - Flat plate and cylinder

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Key Design Decisions

Option 1 - Use medium size wind tunnels in ELF

- Unable to use due to instrumental failure

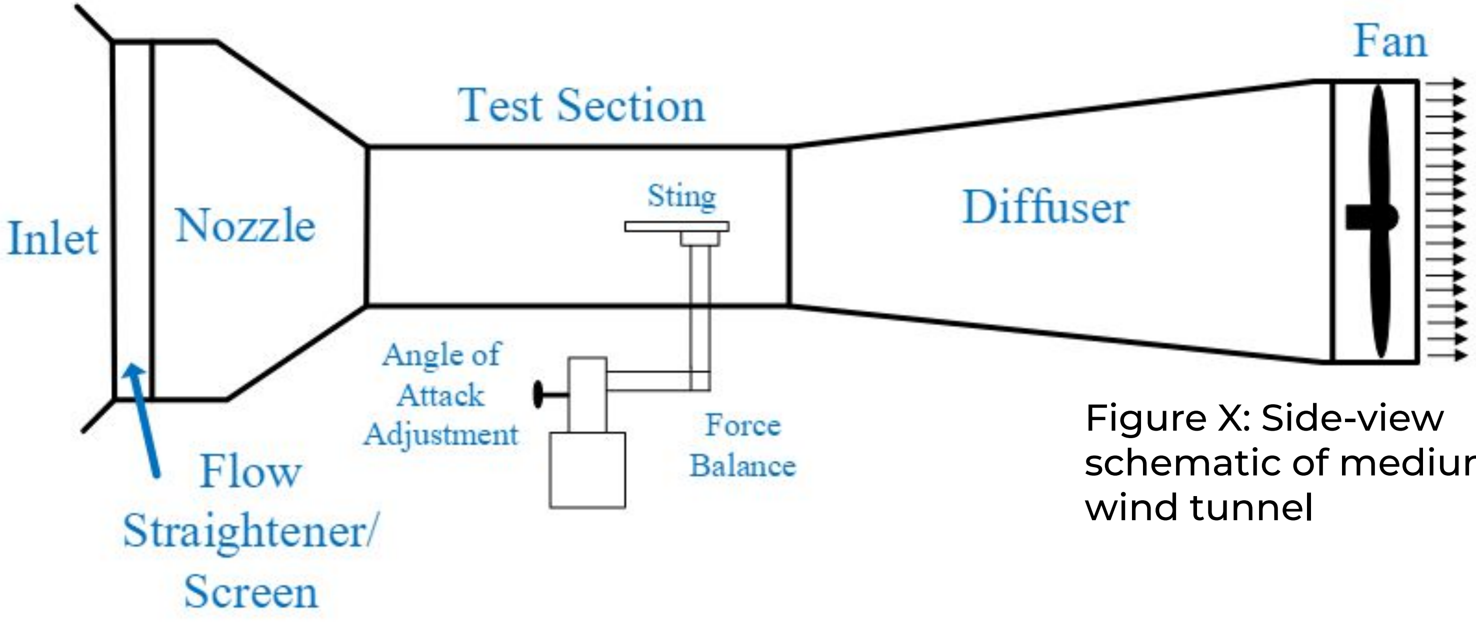

Figure X: Side-view schematic of medium wind tunnel

Quy

Option 1 - Use medium size wind tunnels in ELF

Quy

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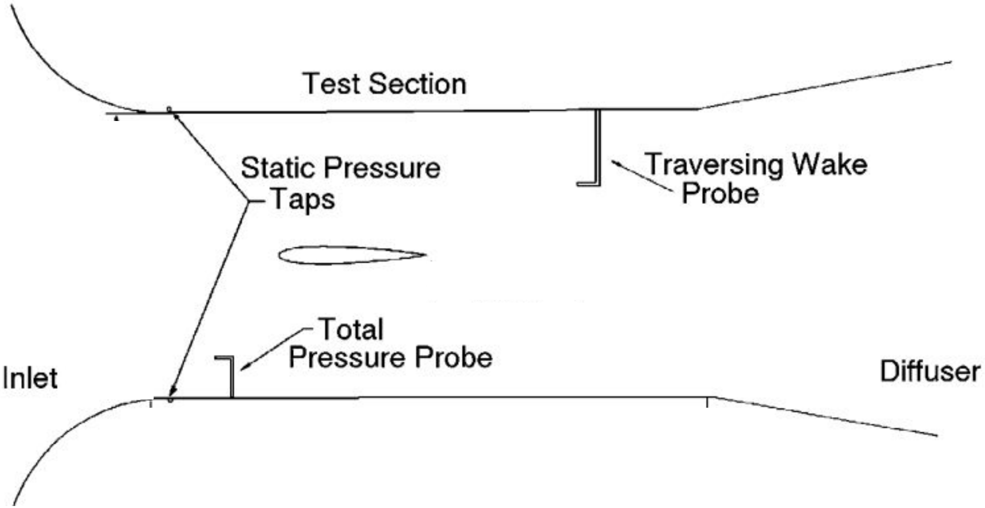
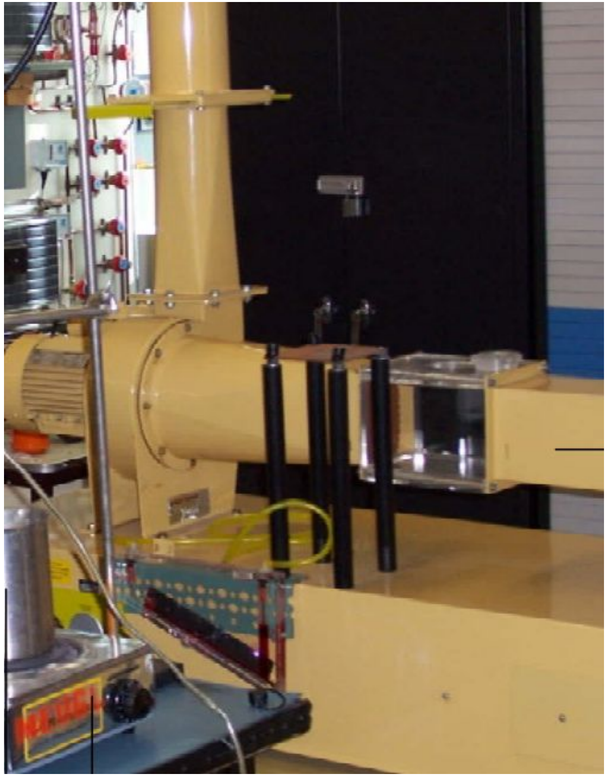
Option 2 - Use small wind tunnels in ET

- Results are prone to inaccuracy due to extraneous variables





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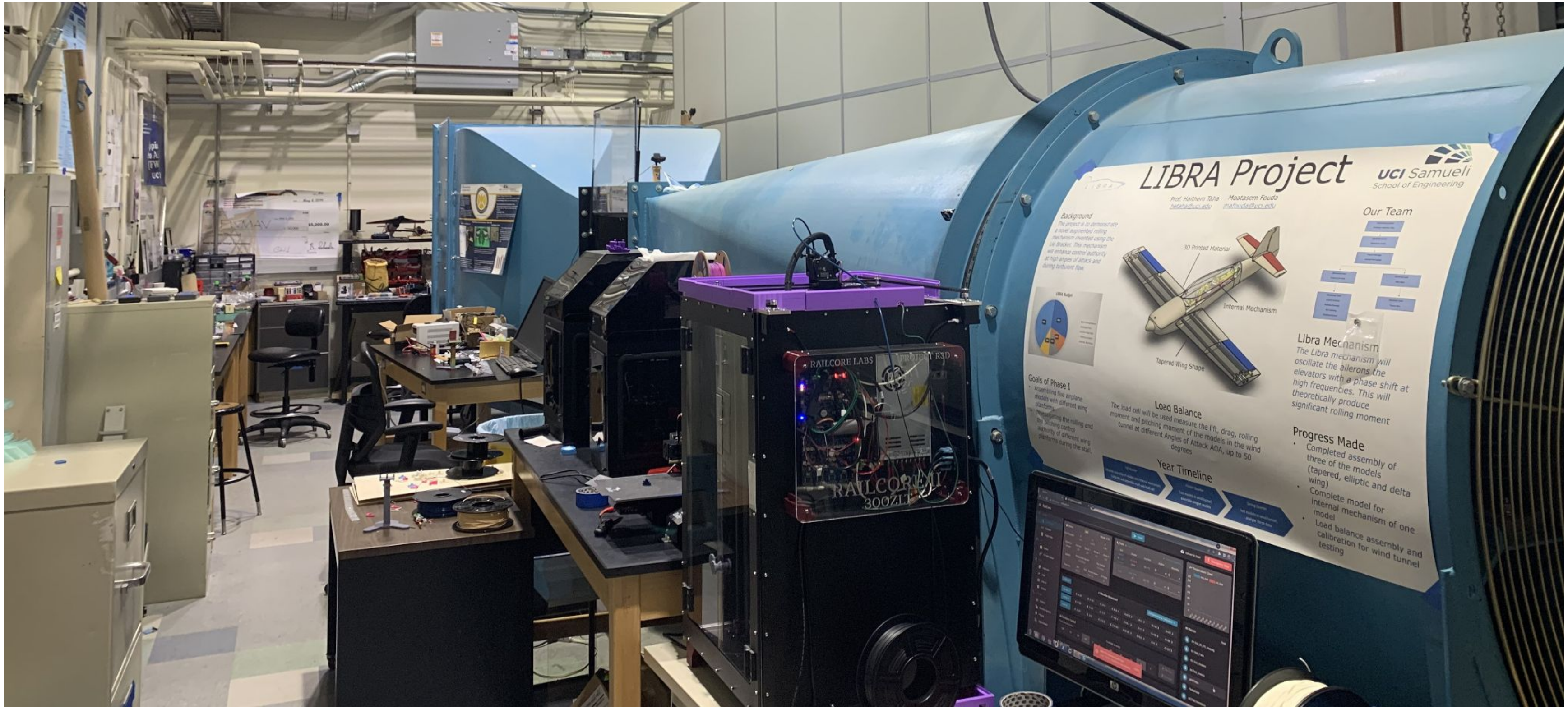
Option 3 - Shadow grad students in the big wind tunnel



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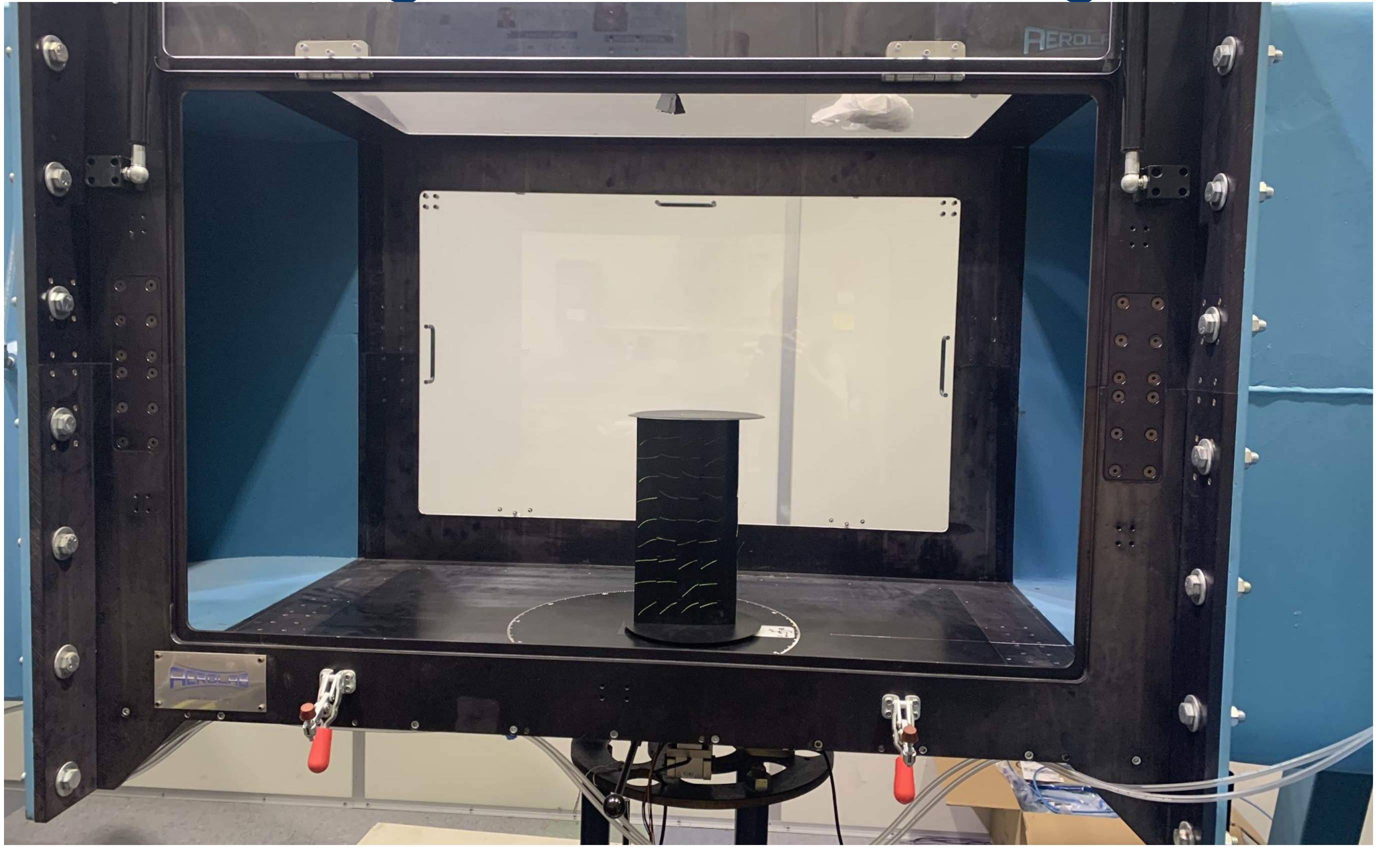
Option 3 - Shadow grad students in the big wind tunnel



Quy

Key Design Decisions - Verification

- Showing that XFoil works with basic shapes
- Testing flat plate and circle
- Used a very thin airfoil to show Boundary Layers
- Blausius solution gives flat plate drag at a given reynolds number

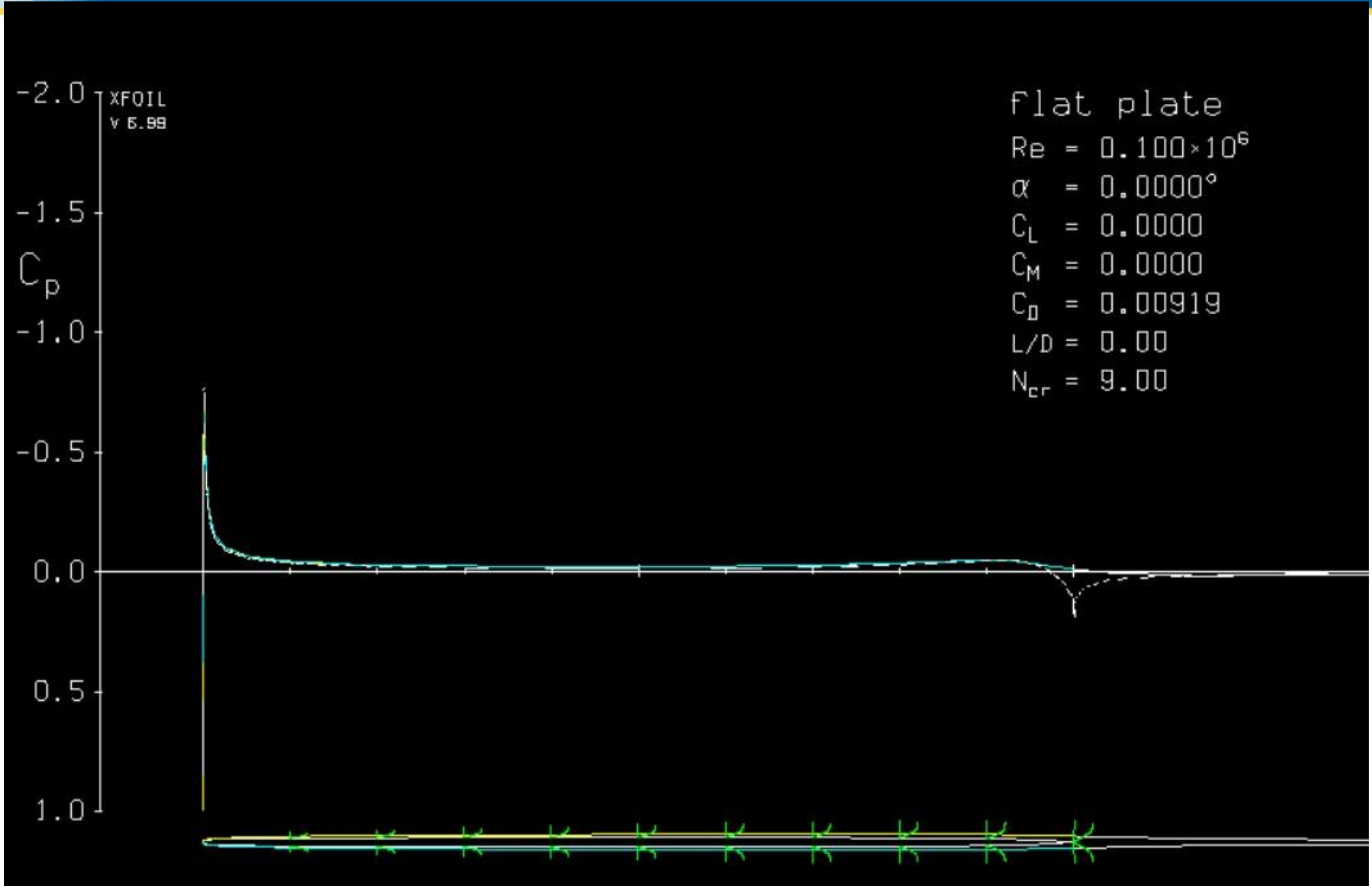
Khanh

Limitation of XFOIL

- According to multiple academic writings,
  - XFOIl is limited on:
    - **Flow Separation (non-converging flow)**
    - Instant trassional period between laminar and turbulent flow
    - Empirical formulation to predict coefficient of drag.

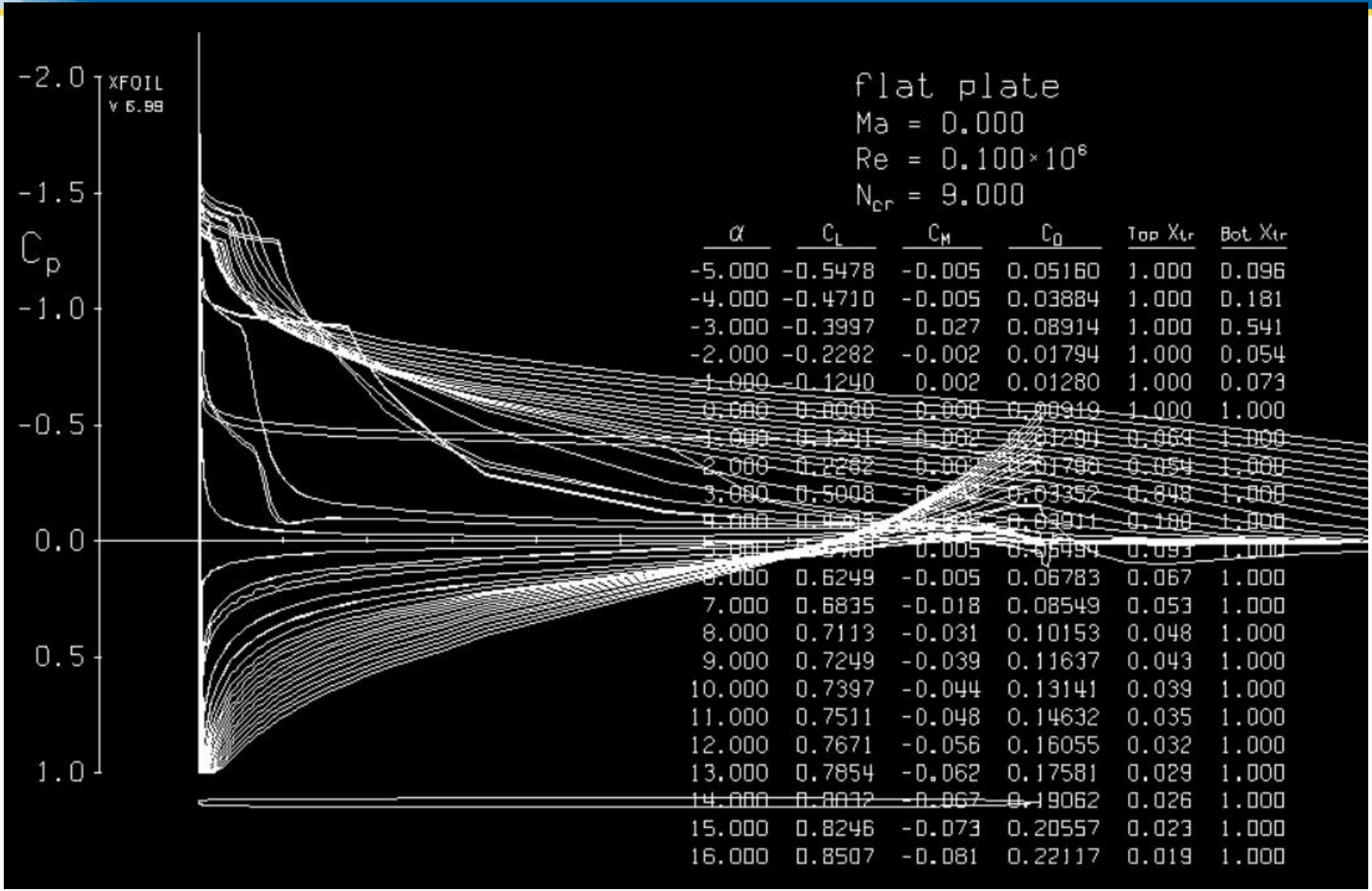
Khanh

Flat Plate: Viscous



Khanh

Flat Plate: Viscous



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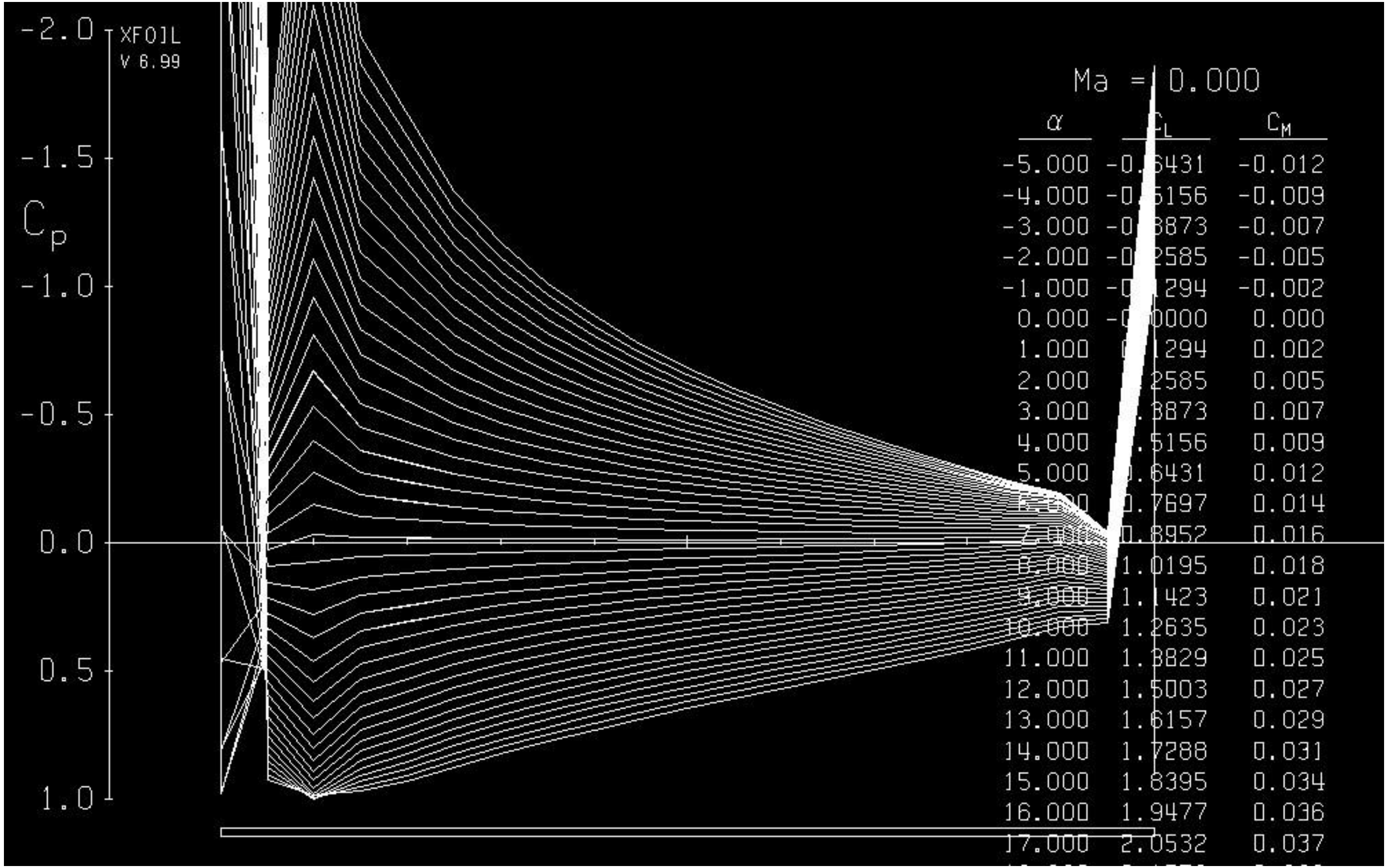
Flat Plate: Inviscid



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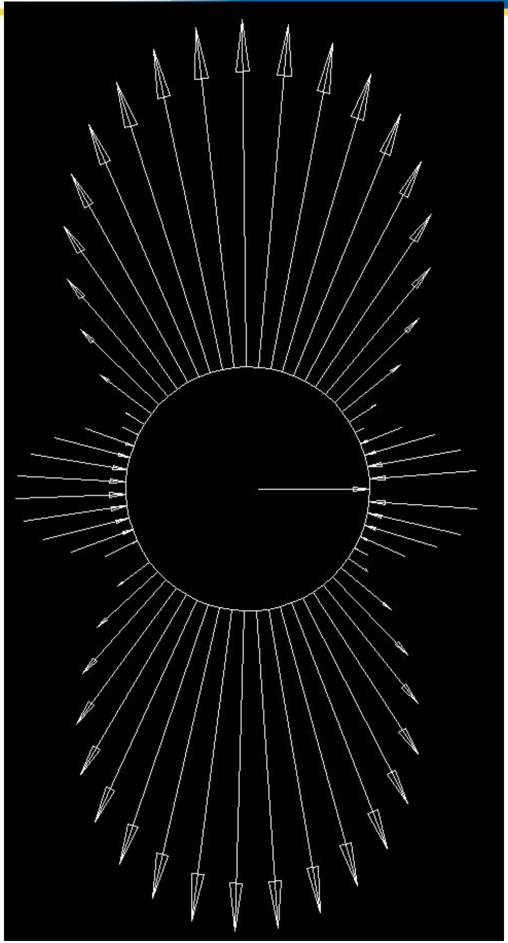
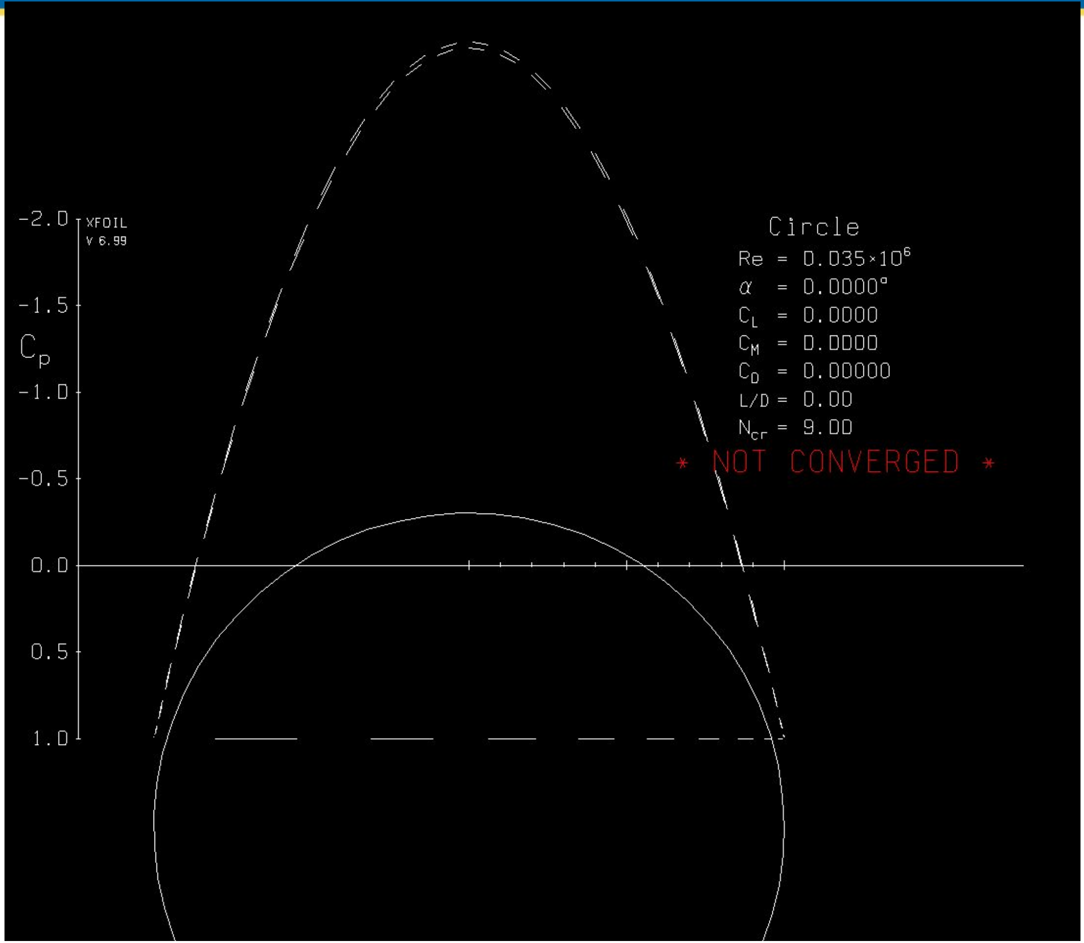
Circle - Pressure Vectors





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Key Equations

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Name of Formula	Formula
Room Pressure in Pascals	$p_{pa} = \frac{0.00348}{T} * (p - 0.003796 * R_h * e_s$
Change in Pressure	$\Delta P = P_o - p_{ts} = \frac{1}{2}\rho V_{ts}^2$
Normalized Velocity	$V_{normalize} = \frac{V}{25}$
Relative Humidity	$p = \rho RT$
% Error Formula	$\% Error = \frac{Experimental - Actual}{Actual} * 100$
Normalized Dynamic Pressure	$q_{normalize} = \frac{q}{q_{max}}$
Normalized Stagnation Pressure	$p_{stag\ normalize} = \frac{p_{stag}}{p_{max\ stag}}$

Inches of water to pascals conversion	$\Delta p_{pa} = \Delta p_{inch/water} * 248.84$
Velocity of pitot tube	$V_{pitot} = \sqrt{\frac{2*q_{Tunnel\ Tap}}{1.22}}$
Dynamic Pressure	$\Delta p = \frac{1}{2}\rho V_\infty^2$
Drag Coefficient	$C_D \equiv \frac{F_a - F_{a,0}}{\frac{1}{2}\rho V_\infty^2 A_f}$ or $C_D \equiv \left\| \frac{Fz}{\frac{Dynamic\ Pressure*\pi*0.075^2}{4}} \right\|$
Reynold's Number	$Re = \frac{\rho v L}{\mu}$

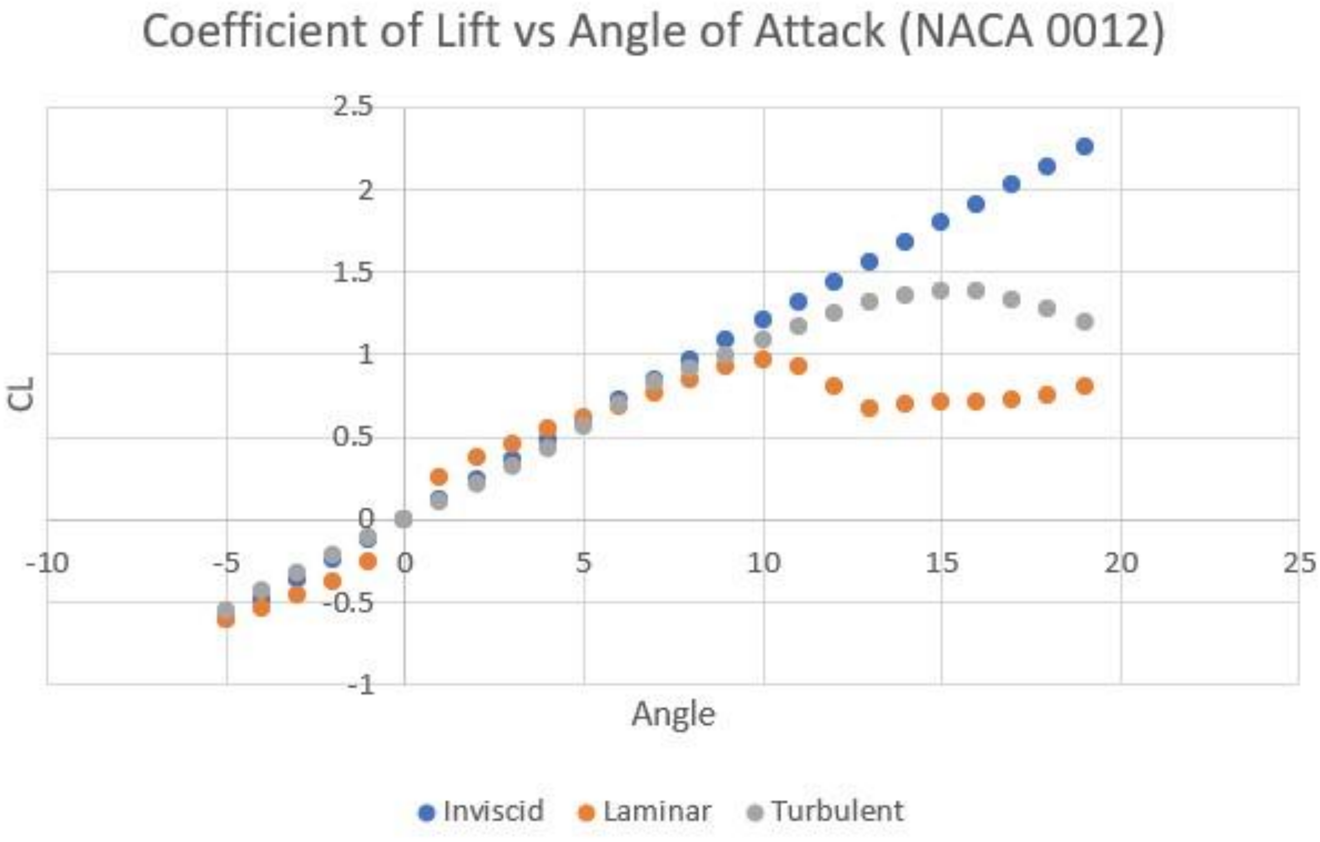
Khanh

Key Design Decisions - Validation

- Testing 3 airfoils - NACA 0012, NACA 0015, NACA 0021
- Reynolds number of ~64000 (15mph) to 130000 (30mph)
- Comparing experimental results to XFoil and math solutions

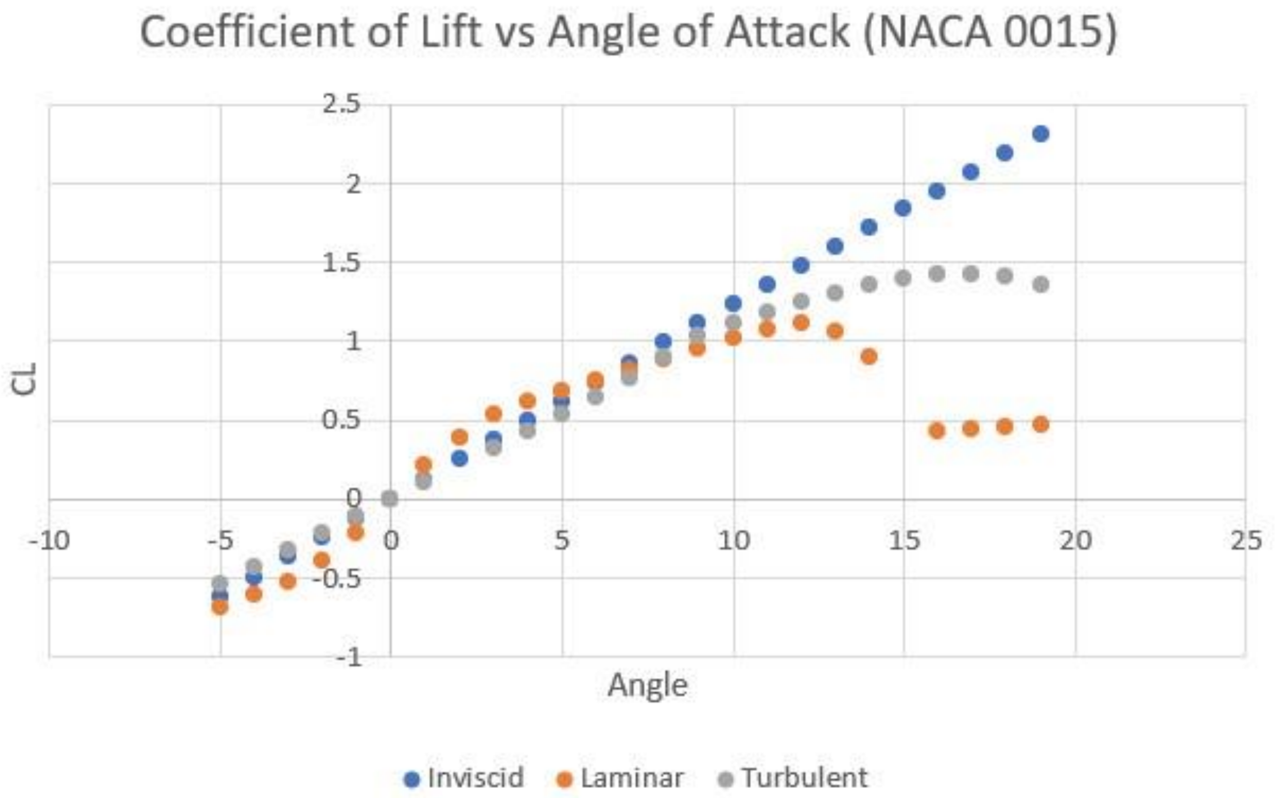
Tai

Coefficient of Lift vs Alpha



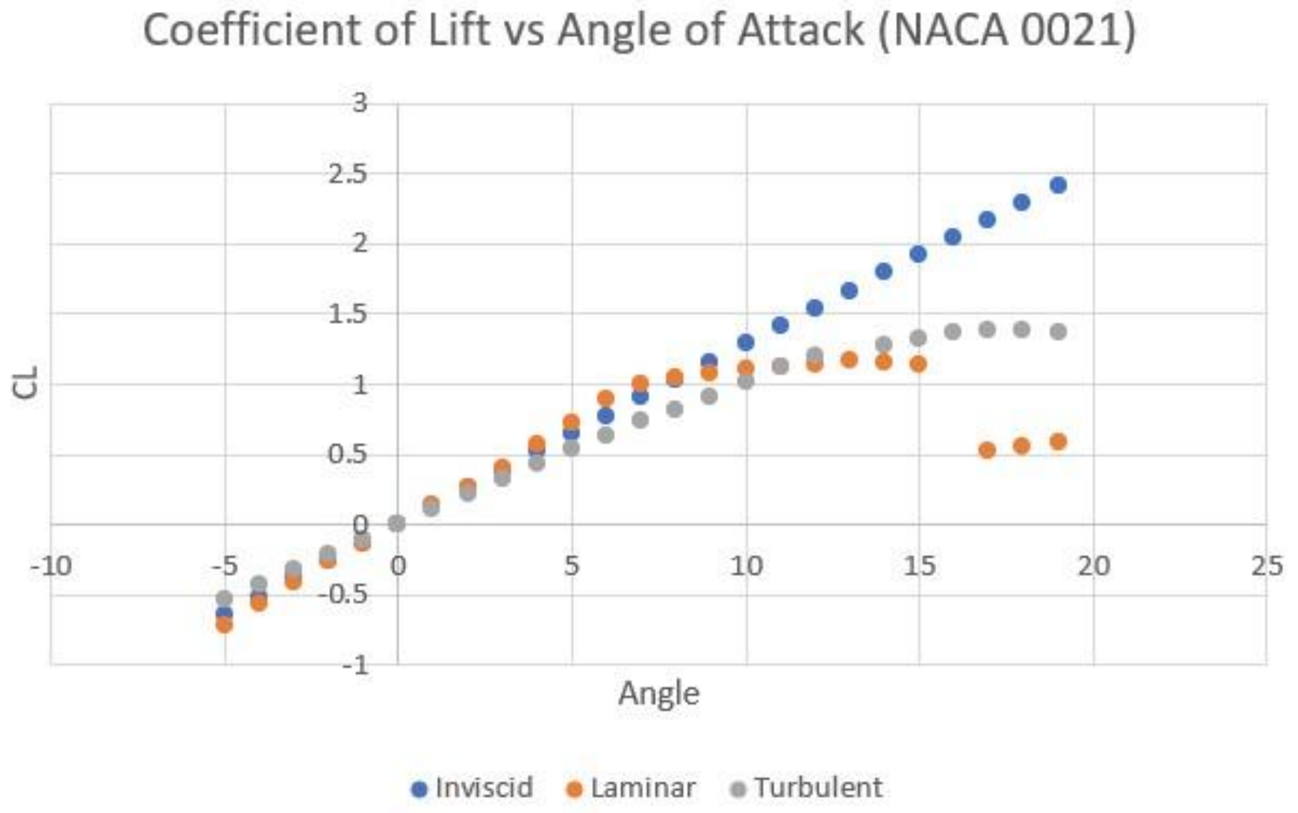
Tai

Coefficient of Lift vs Alpha



Tai

Coefficient of Lift vs Alpha



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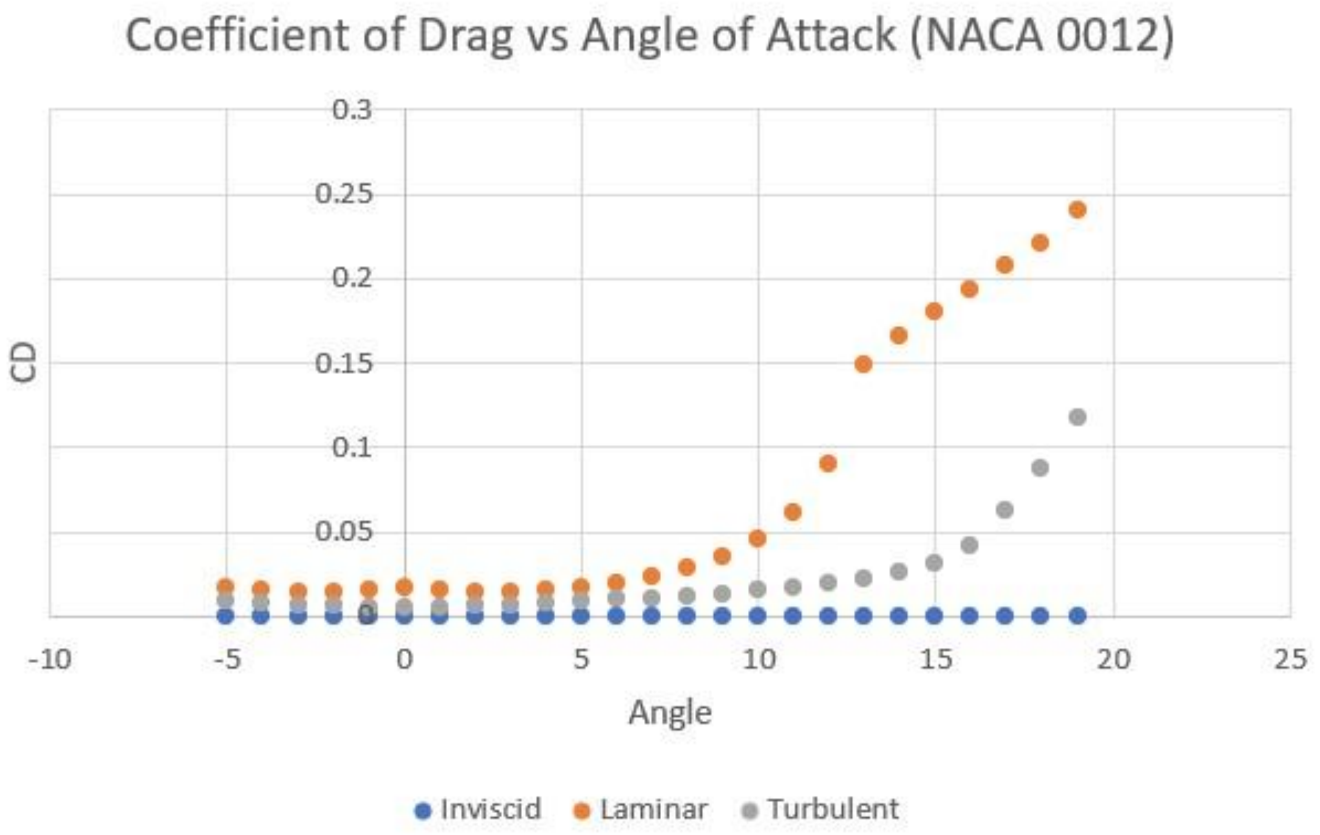
Coefficient of Drag vs Alpha



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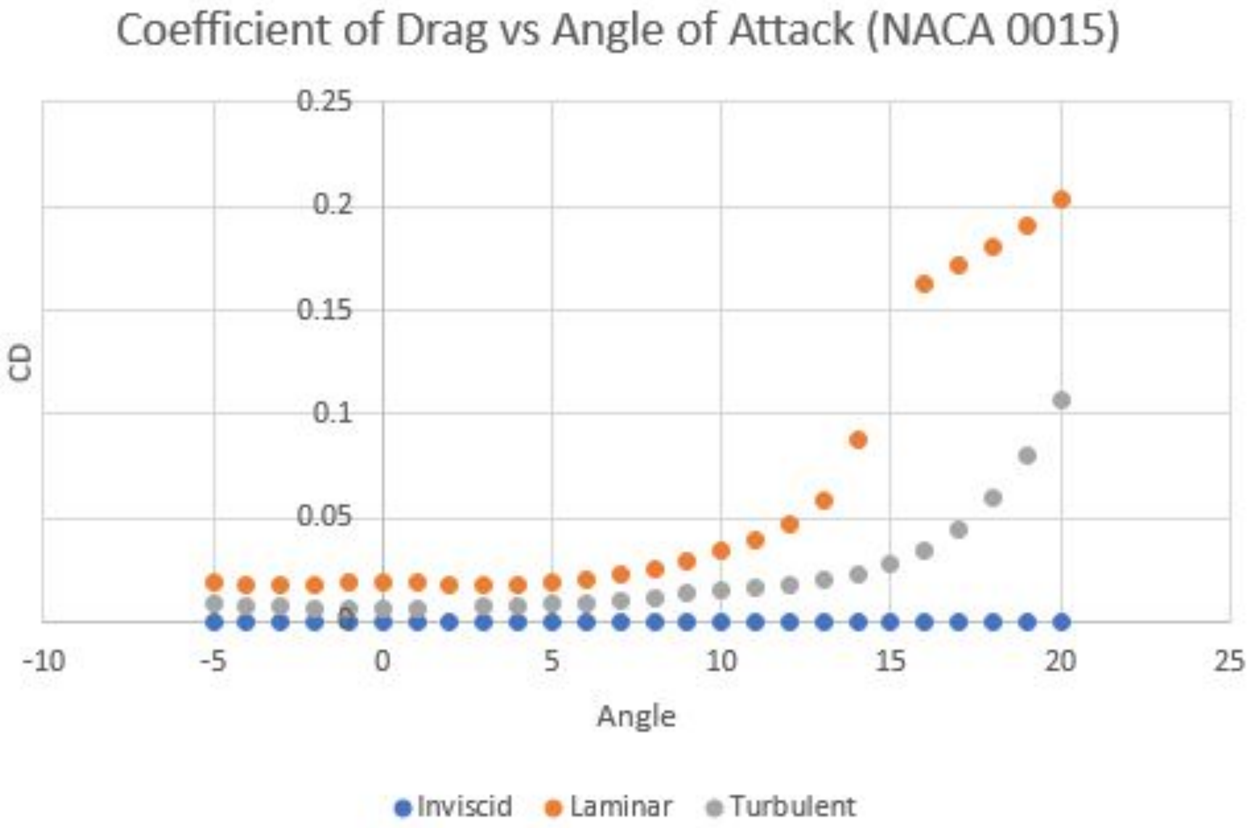
Coefficient of Drag vs Alpha



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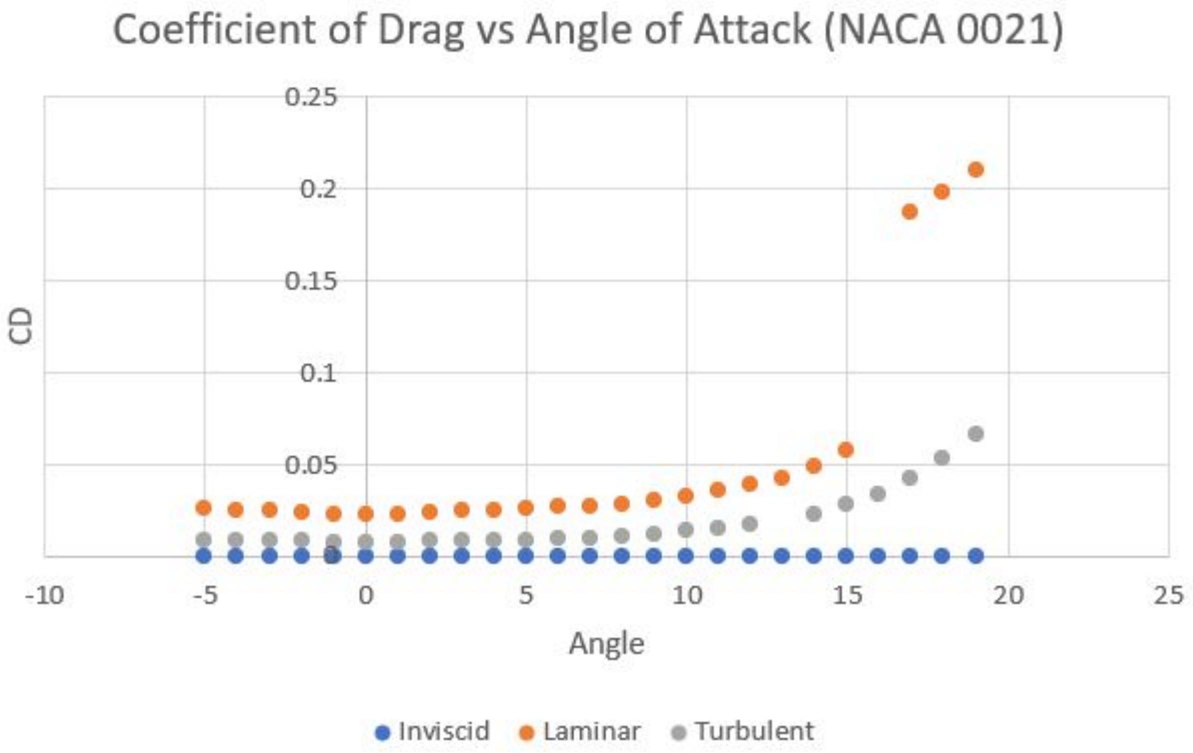
Coefficient of Drag vs Alpha



Tai

Project Schedule

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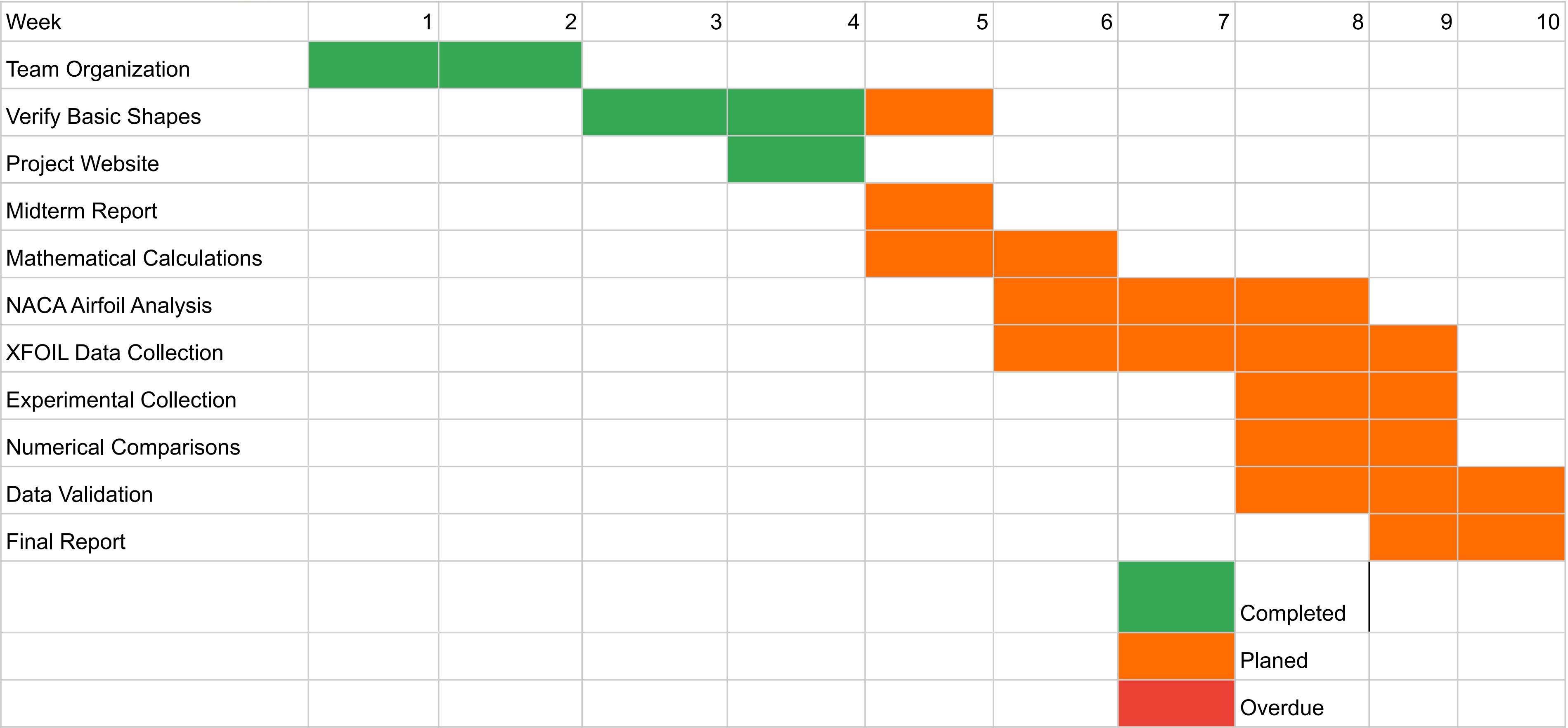

Khanh

Future Plan

- A good understanding of coding with XFOIL
- Data from wind tunnel experiment is still in progress
- Using the experimental data and translate it to needed values
  - Compare these coefficients with the results from XFOIL

Khanh

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Khanh

Thanks for listening!

Does anyone have any questions?

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