

# Week of 3/26

- In lab
  - 4<sup>th</sup> instrumentation lab on Spectral Analysis and LabView
  - Preparation: Read Spectral Analysis section of manual
  - Homework on website, due at start of lab.
- Next Class
  - *This Wednesday (3/28) on Fracture Toughness Testing*

# The Rest of Course...

Week of 3/26	Ex. 7 class (Mon.) Ex. 5 class (Wed.)	Instrumentation Lab 4
Week of 4/2	- <i>No class</i> -	Experiment 5 Experiment 7
Week of 4/9	- <i>No class</i> -	Instrumentation Lab 5
Week of 4/16	- <i>No class</i> -	Experiment 7 Experiment 5
Week of 4/23	Last class (Mon.)	- <i>No lab</i> -
Week of 4/30	Final exam (Mon.)	- <i>No lab</i> -

# Experiments 5 and 7

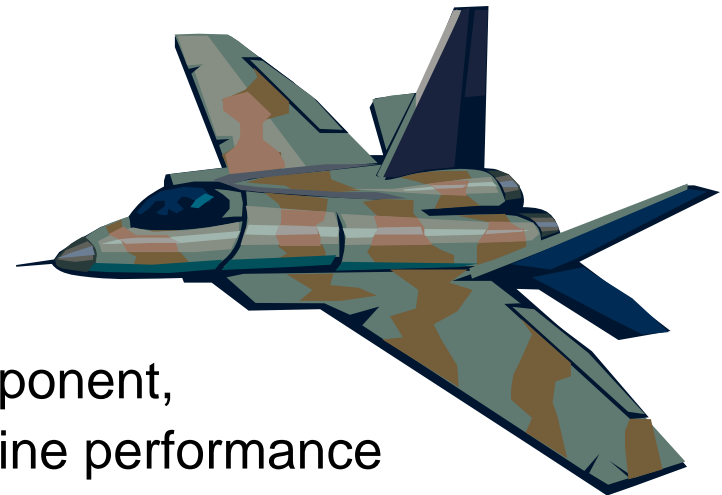
- Experiment 5 takes place in 127 Norris
- Experiment 7 takes place in the Stability Tunnel
- Visiting times are much more restricted
  - Will be part of Friday and/or Monday prior to test
  - Times to be posted on web
- Have pre-defined goals.

# Aerodynamic Testing

1. Why do we do aerodynamic testing?
  2. What is measured?
  3. Where do people test?
  4. What conditions do you test at?
  5. How is a test actually performed?
  6. Experiment 7
- Ocean vehicles and devices go through closely analogous testing using towing tanks, water and wind tunnels.

# 1. Aerodynamic Testing – Why?

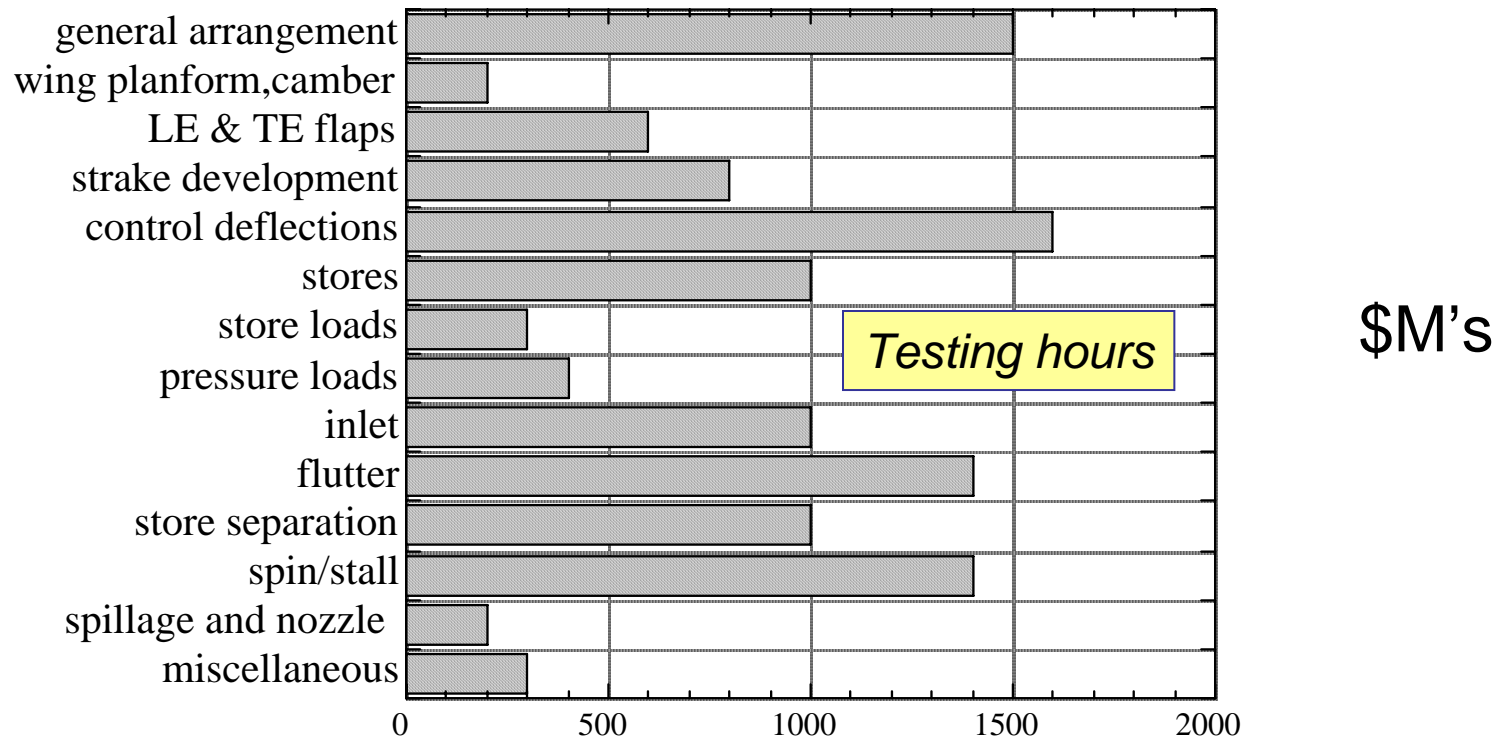
- Fundamental component of developing new aerodynamic vehicle and hardware designs
  - Prediction
    - To develop design
    - To initially evaluate design
  - Wind Tunnel Testing
    - To evaluate design
    - To confirm (or not) predictions
    - Testing of sub-component, component, whole vehicle models to determine performance
    - Obtaining performance data for control systems
  - Flight Testing



# How big a deal is wind tunnel testing?



F-16

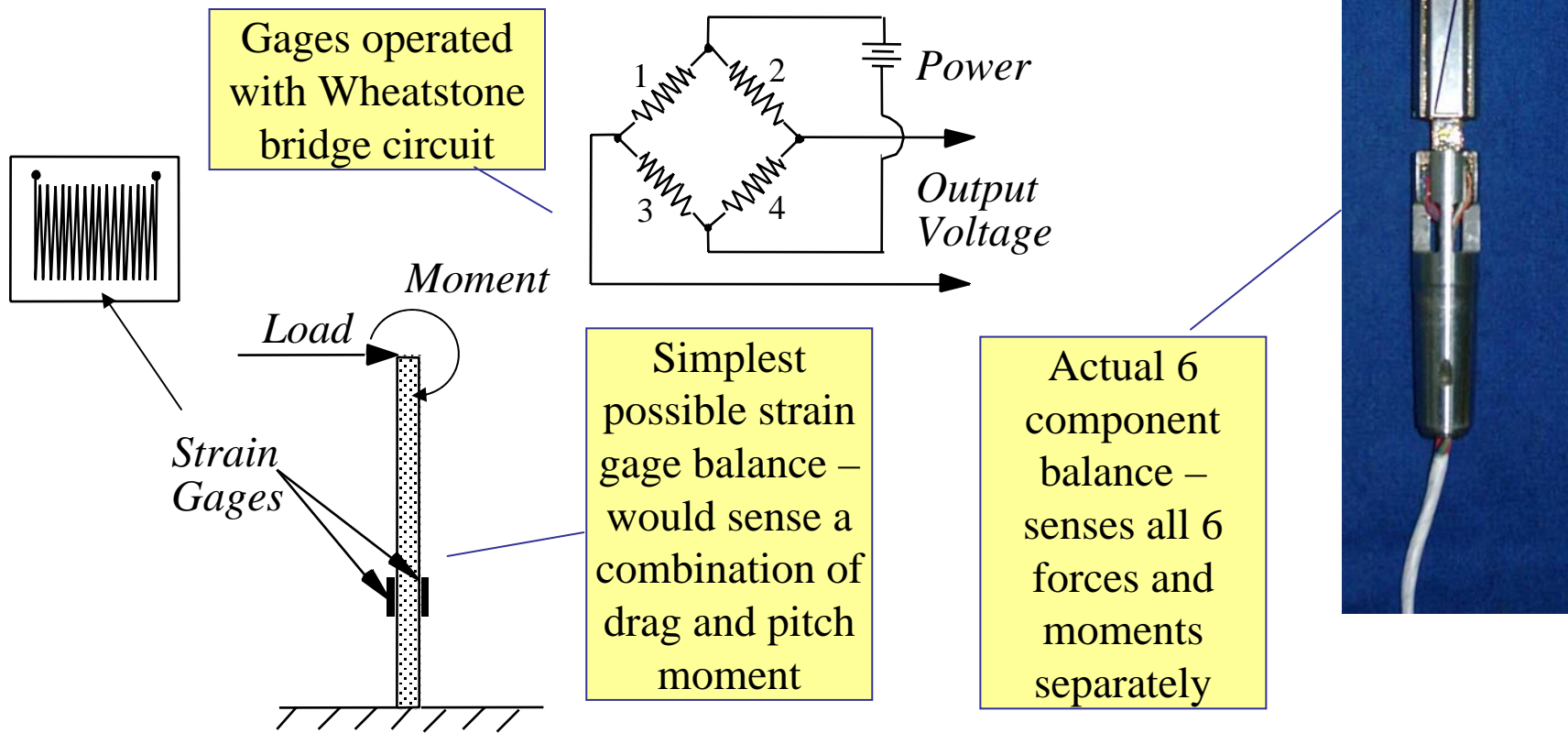


## 2. What is measured?

- Mostly forces and moments
  - Since these are what matters to the vehicle performance
  - Since these are the data needed to define the airplane control system
- Flow diagnostics
  - When forces and moments aren't behaving as expected, or to confirm expected behavior

# Measuring forces and moments

Strain gage balance. Model mounted on the end of a beam. Deflection /twist/bending of beam sensed by strain gages, and then used to infer forces and moments



# Flow diagnostics

- Flow visualization (smoke, oil-flow, tufts)
- LDV, Hot-wire velocity/turbulence measurements
- Mean surface pressure measurements using taps
- Pitot static traverses to look at wake, flow patterns

# 3. Where do you test?

In a Wind Tunnel...

- Government
  - NASA (Langley, Ames, Glenn)
  - AEDC (TN)
- Commercial
  - Boeing (12')
  - DTW
- Universities
  - VT (6'), ODU, MD (11')...
- Europe
  - QinetiQ (5m), DNW (8m)



0 to 80m/s, 6' x 6'  
M=0 to 0.25

## 4. What conditions do you test at?

### Aerodynamic Similarity

- The equations governing aerodynamics dictate that the form of the flow depends on a series of non-dimensional parameters of which the most important are

– Reynolds number =  $UL/\nu$

– Mach number =  $U/c$

Size of device

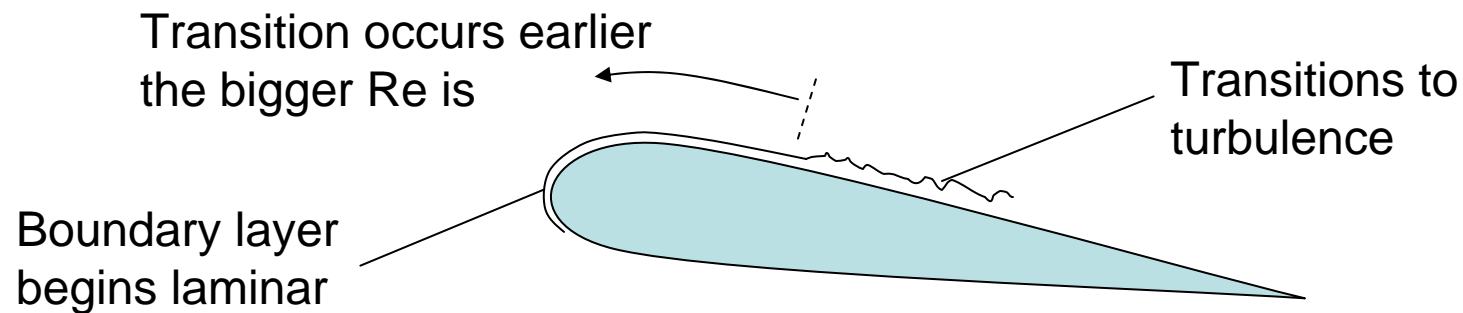
Flow speed

Kinematic viscosity

Speed of sound

# Reynolds Number

- Controls how important viscous effects are (big  $Re$  = small viscous effects)



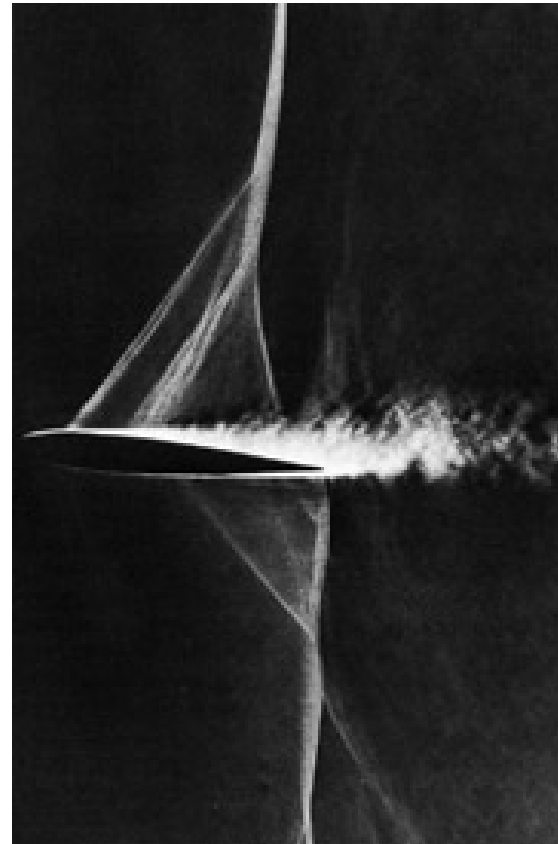
Turbulent boundary layers create more friction but much less likely to stall

- So, Reynolds number influences the flow through the boundary layer
- Boundary layers control the drag and critical things like the stall behavior.

# Mach number

- Controls how important compressibility effects are

At transonic and supersonic speeds compressibility effects result in the generation of shock and other waves. These will likely dominate the aerodynamics.



# Aerodynamic Simulation

- Ideally, a wind tunnel test at the same  $Re$  and  $M$  experienced by a full scale vehicle we would have the same flow (ignoring the effects of the walls and any imperfections).
- In most circumstances this can't be done
  - If you are testing in air at standard conditions, you need to test at the full flight speed to reproduce the Mach number (i.e. this fixes  $U$ )
  - Unless your model is full scale (?), this means you will be testing at much lower Reynolds number.

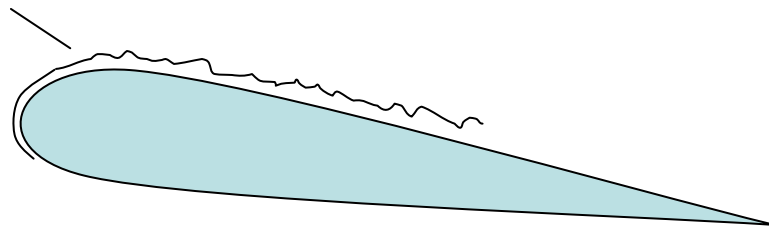
$$Re = UL/\nu$$

$$M = U/c$$

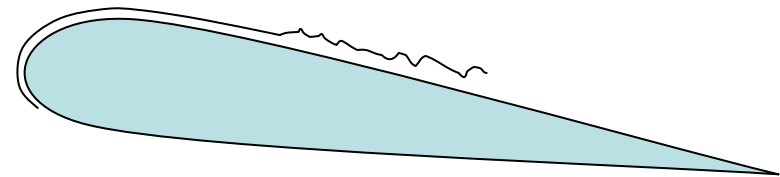
# Transition fixing

- To reproduce the effects of a high Re at a low Re, we use transition fixing:

Transition



High Re (full scale)

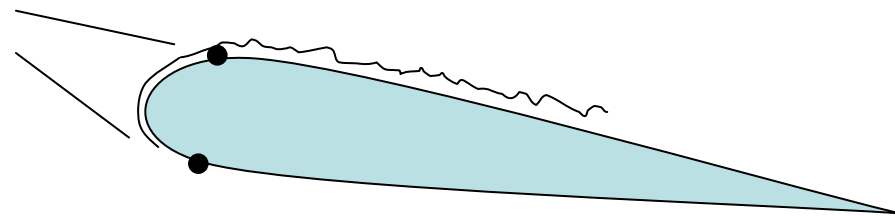


Low Re (wind tunnel)

'Boundary layer trip' causes early transition simulating high Re flow.

E.g.

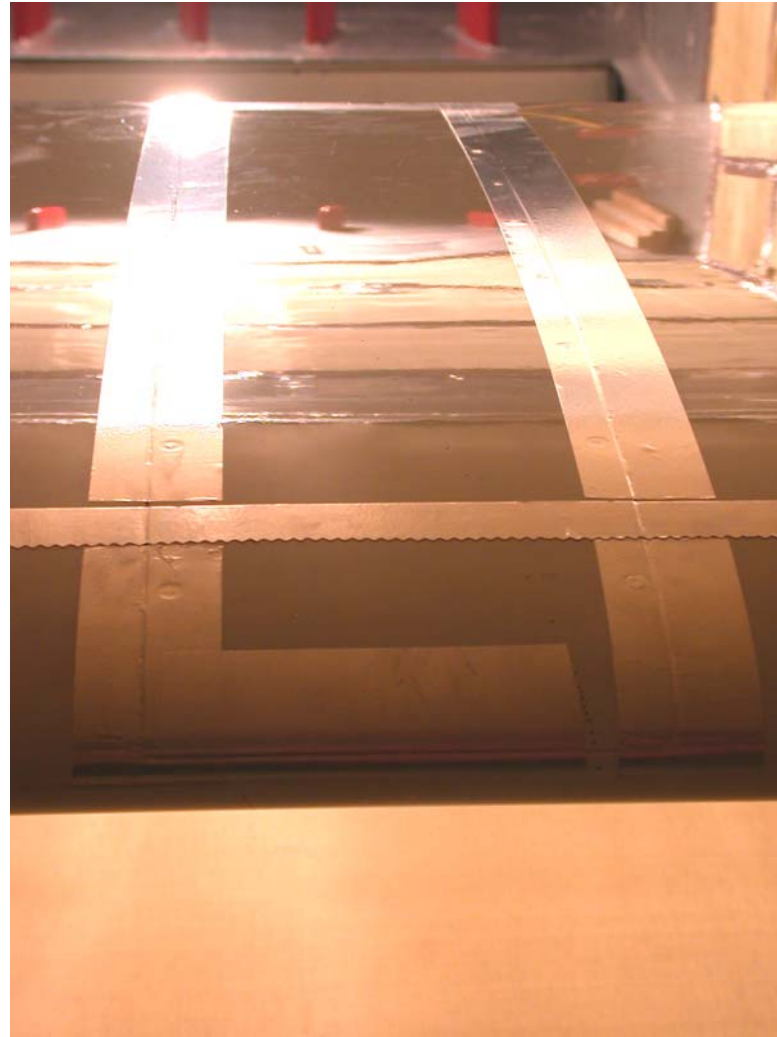
- Serrated tape
- Wire across airfoil span
- Sandpaper strip



Low Re with transition fixing

# Serrated Tape Trip

3' chord airfoil in  
the VT Stability  
tunnel



← Trailing edge

Serrated tape at  
10% chord with  
serrations facing  
forward to trip  
boundary layer

← Leading edge

# 5. How is a test performed?

- Tests are *very* expensive so planning/organization is critical to minimize tunnel time
  - Begin with clear goals for the test (often set by mgmt)
  - Investigate the facility and the quality of its flow, the model(s) to be used and their characteristics, the instrumentation. Models often to be built.
  - Make a minute-by-minute run schedule that defines exactly what will be done and when to meet the goals
  - Make theoretical ‘Pretest Estimates’ of the quantities to be measured.
  - Execute the test with max efficiency, comparing measurements with pretest estimates as the test proceeds to catch measurement problems

# Experiment 7

- Educational goal: To provide as realistic as possible experience of an aerodynamic test

Logbook  
preparation

- The goals for the test
- Investigate the facility and the quality of its flow, the model(s) to be used and their characteristics, the instrumentation
- Make a minute-by-minute run schedule that defines exactly what will be done and when to meet the goals
- Make theoretical ‘Pretest Estimates’ of the quantities to be measured.
- Execute the test with max efficiency, comparing measurements with pretest estimates as the test proceeds to catch measurement problems

# Goals (predetermined by mgmt)

- Determine the...
    - lift curve slope
    - angle of attack for zero lift
    - maximum lift coefficient
    - aerodynamic center
    - nature of the pitching moment curve "break" near stall
    - zero lift drag
    - drag due to lift performance relative to the 0% and 100% polars
- ...of a Clark Y rectangular wing. Also perform flow diagnostics (flow vis)

THESE ARE AMBITIOUS – YOU WILL NEED TO BE WELL ORGANIZED

# Facility

## Virginia Tech Stability Wind Tunnel

Detailed information on this facility, the quality of its flow can be found at

[www.aoe.vt.edu/research/facilities/stab/](http://www.aoe.vt.edu/research/facilities/stab/)

Facility is operated independently and performs educational, research and commercial testing.



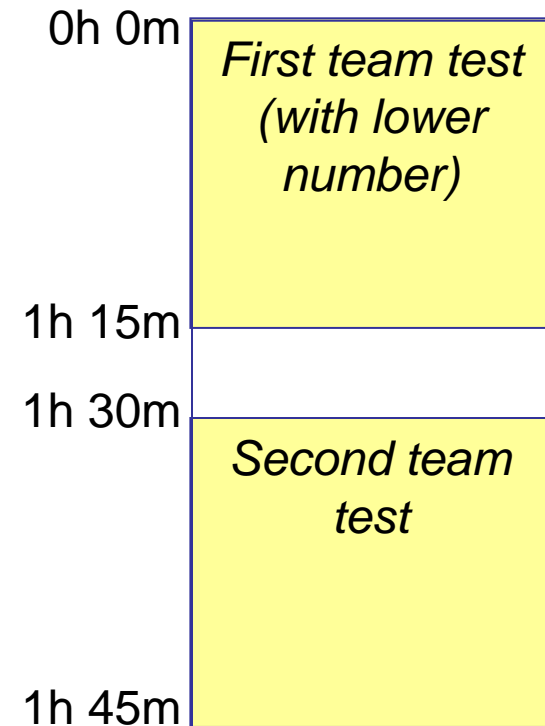
0 to 80m/s, 6' x 6'

M=0 to 0.25

# Scheduling

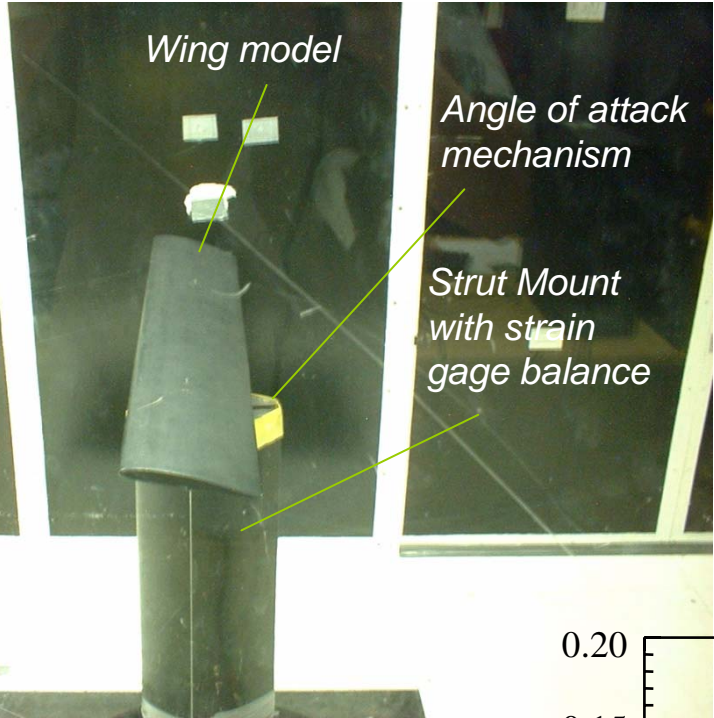
- Two teams are scheduled to use the wind tunnel during each 2 hour 45 minute period.
- The first team (with the lowest number) starts their test at the beginning of the lab period and has 1 hour 15 minutes to complete all their work and return the facility to its original state
- The second team has 1 hour and 15 minutes to compete their test which will start 1 hour 30 minutes into the scheduled lab period

Time from  
start of lab  
period  
↓

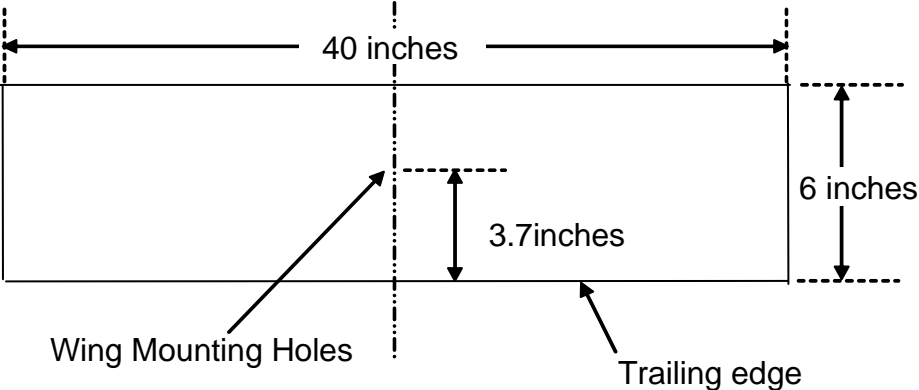


*WIND TUNNEL OPERATOR WILL BE PRESENT TO OPERATE FACILITY  
AND INSTRUMENTATION*

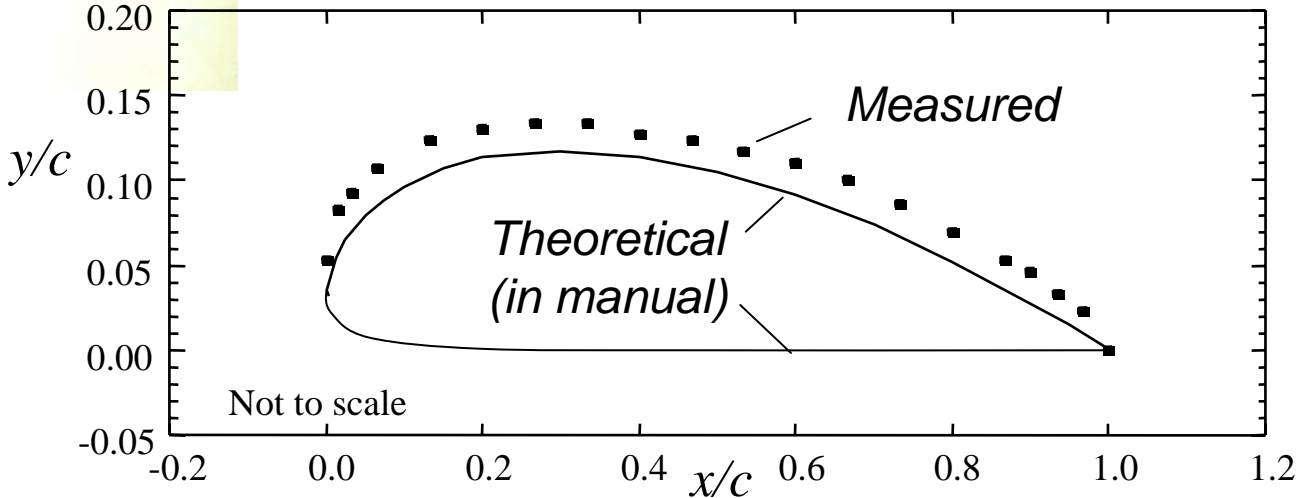
# Model



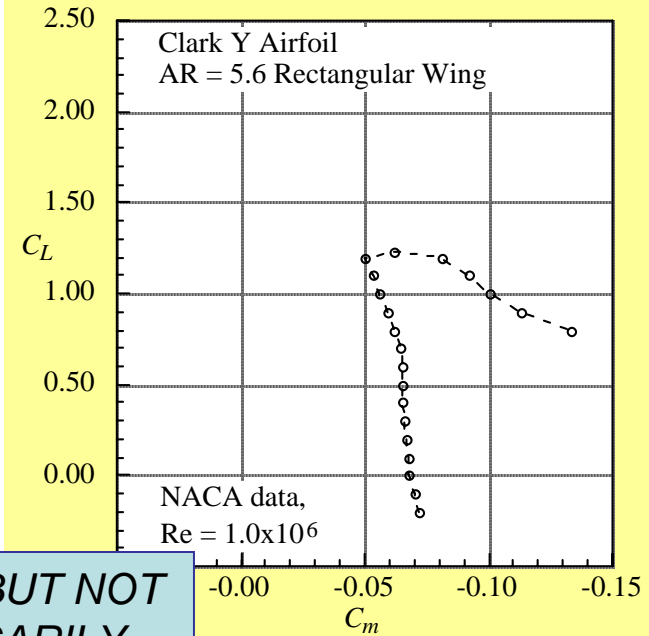
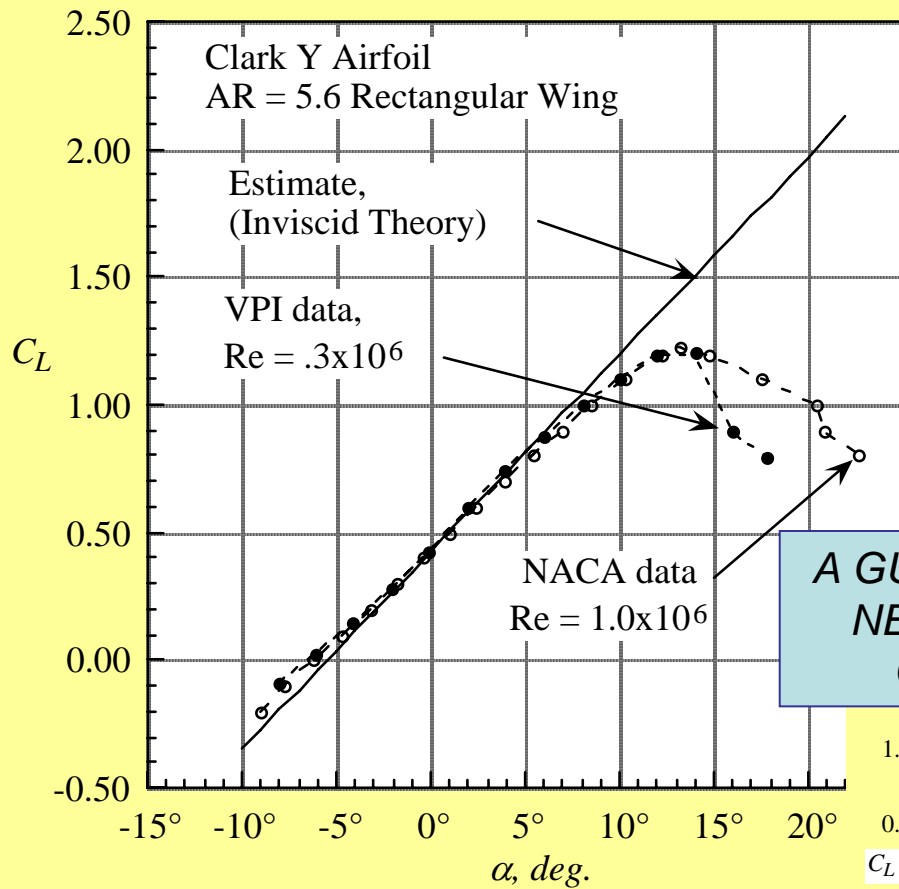
Nominal Planform



Model section

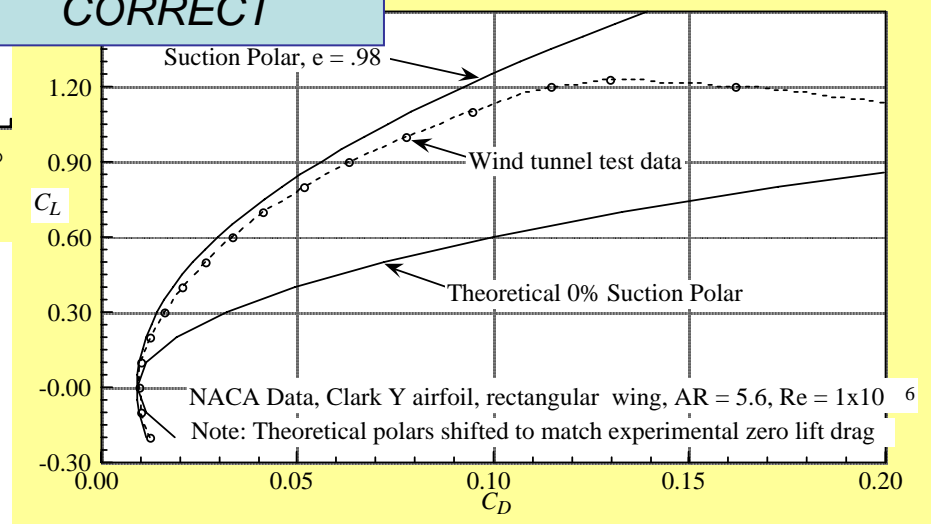


# Prior Data Available



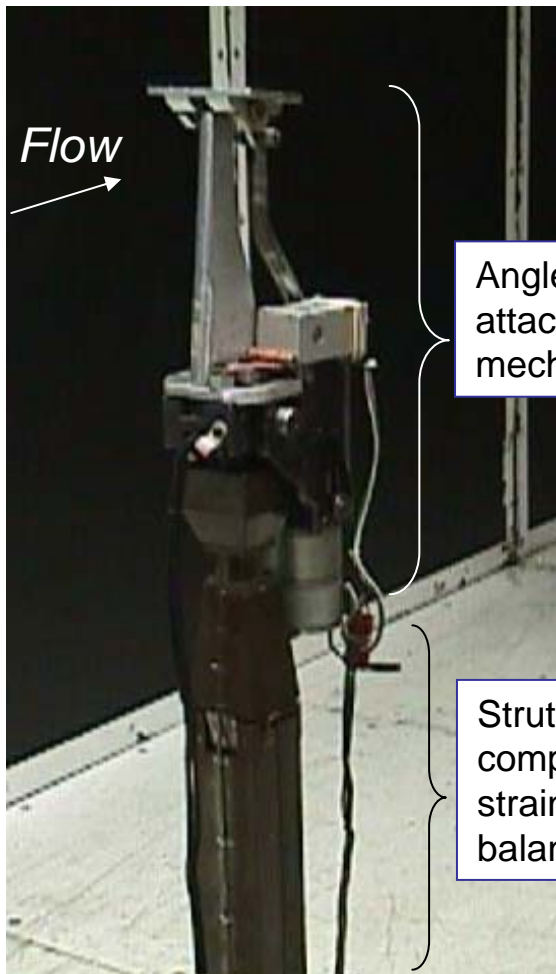
**A GUIDE BUT NOT NECESSARILY CORRECT**

**USEFUL FOR COMPARISON.  
NACA REPORT HYPERLINKED  
FROM MANUAL**

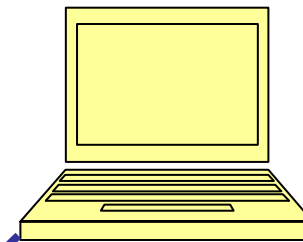
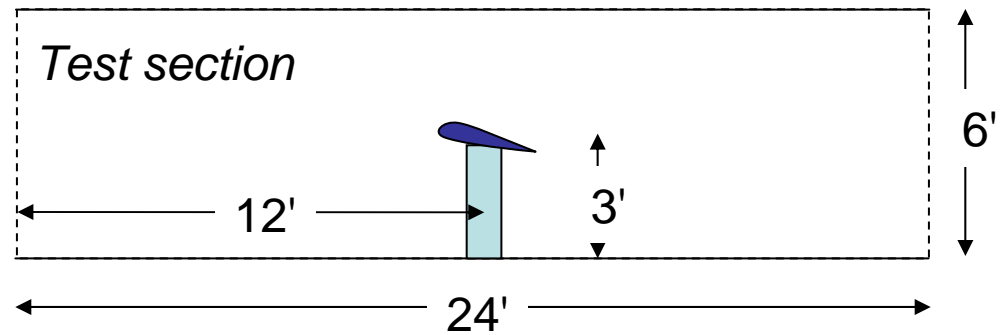


# Mounting / Instrumentation

*Model strut w/o shroud  
and model removed*

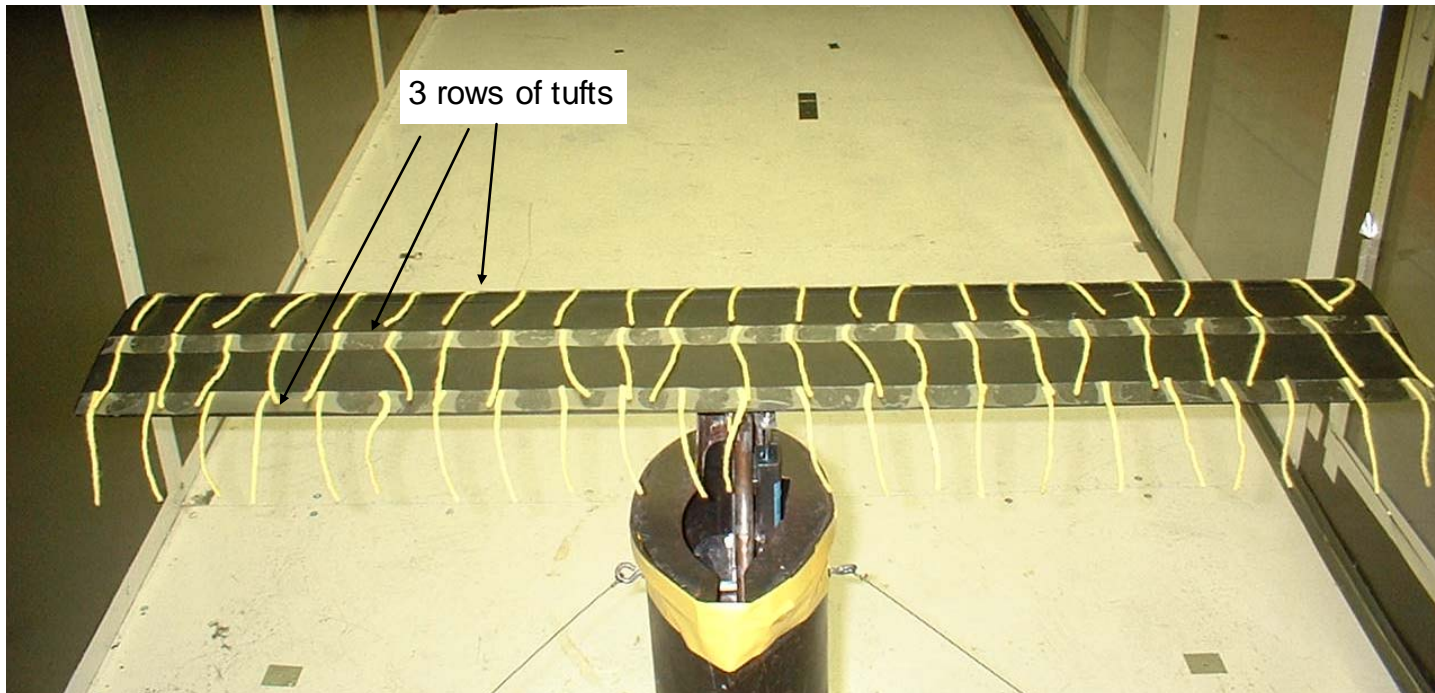


*Flow*

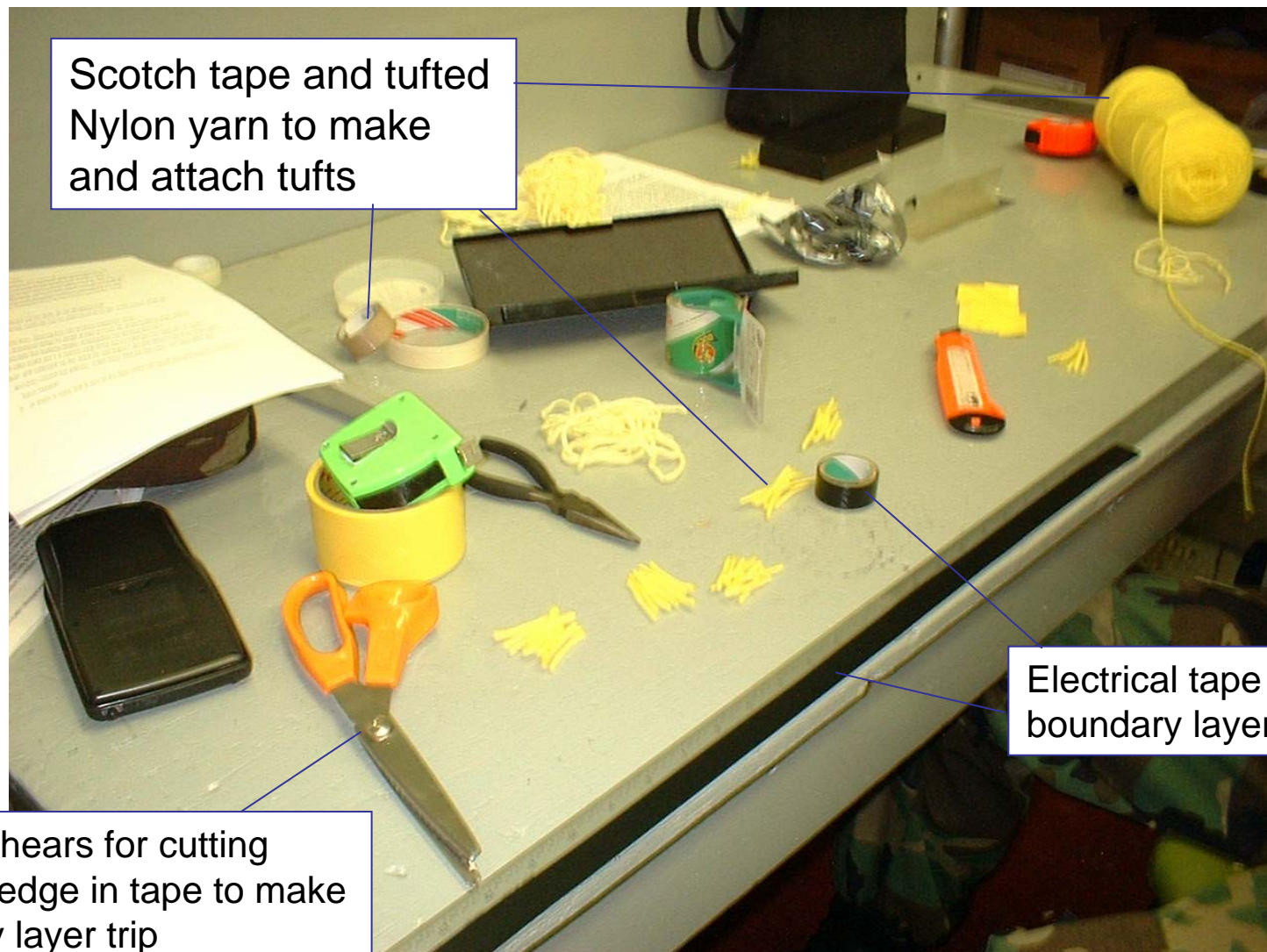


Computer running LabView controls angle of attack, measures 6 components of force and moment, reads wind tunnel Pitot Static, barometer and thermometer to get conditions.

# Flow Diagnostics (Tuft flow vis)



# Trip and flow vis. material



Scotch tape and tufted Nylon yarn to make and attach tufts

Pinking shears for cutting serrated edge in tape to make boundary layer trip

Electrical tape for boundary layer trip

# What you have to do...

- Read the manual carefully to understand the goals, and what is expected. Look over earlier data in manual. Add any goals of your own.
- Learn about the facility (on web), and instrumentation and model, **visit the tunnel**.
- Define a run schedule (what angles of attack, what speeds, trip/no trip, flow speeds), be prepared to make trip strips, tufts etc.
- Make pretest estimates - techniques and tools in manual (formulas, lifting line theory program)
- Run an organized and efficient test, be ready to tell the wind tunnel engineer what you want.

# Things To Ask When You Visit The Tunnel

- What range of angles of attack can actually be run?
- What maximum speed can be run?
- Is there any way of using the angle of attack system to maximize accuracy?
- What is the uncertainty on angle of attack?
- What is the uncertainty on the force and moments?
- Can we prepare (now) a trip or set of tufts ready for our test?
- How is the tunnel flow speed measured?
- Can we measure the model?
- Can we see the fan?

*GOOD LUCK!!*