

VG100: INTRODUCTION TO ENGINEERING

Fan Aerodynamics

Dr. Qiang Zhang



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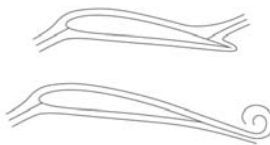
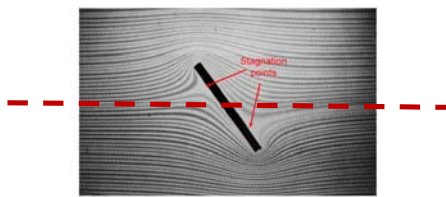
Preview

- Coanda Effect
- Boundary layers
- Friction Drag
- Flow Separation
- Fan aerodynamics
- Core project & Follow-up project



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a **frictionless fluid** stream meets a stationary body

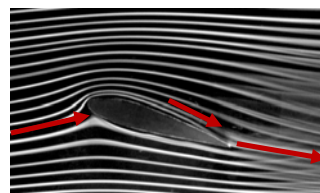


"Kutta Condition"
the fluid over the top and bottom will meet up at the trailing edge



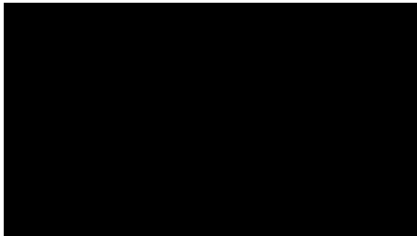
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a **real fluid** stream meets an airfoil



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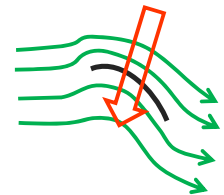
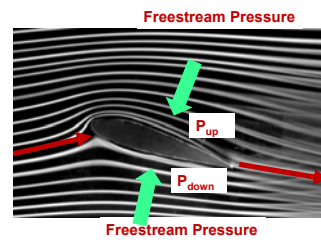
Harvard Natural Sciences Lecture Demonstrations



Can you explain the Coanda Effect ?

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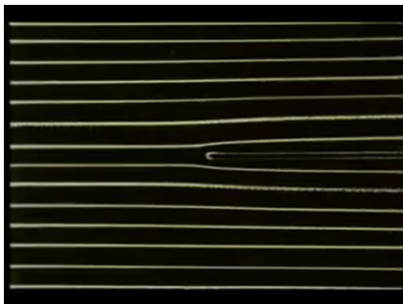
A **real fluid** stream meets an airfoil



➤ the Newton's 3rd law of motion

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“Boundary layer” & Friction Drag



Where is the highest friction force located?

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“Boundary layer”

Two Type of Boundary Layers: Laminar vs Turbulent



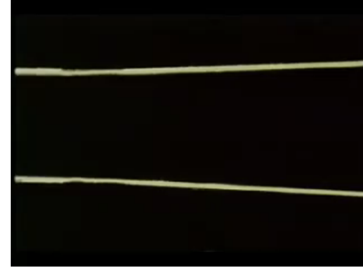
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“Turbulence”



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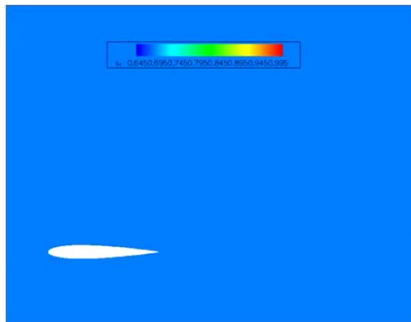
“Boundary layer” Separation



What kind of problem with flow separation?

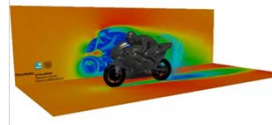
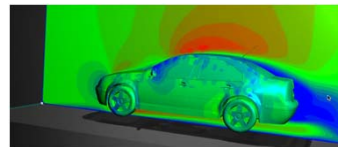
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Boundary layer separation and Entropy generation

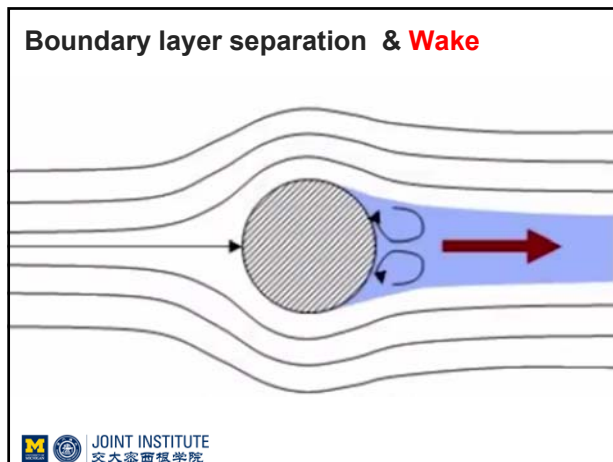


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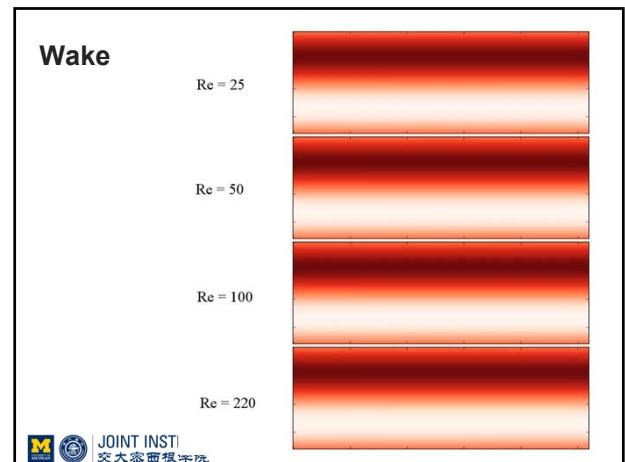
Boundary layer separation & Wake



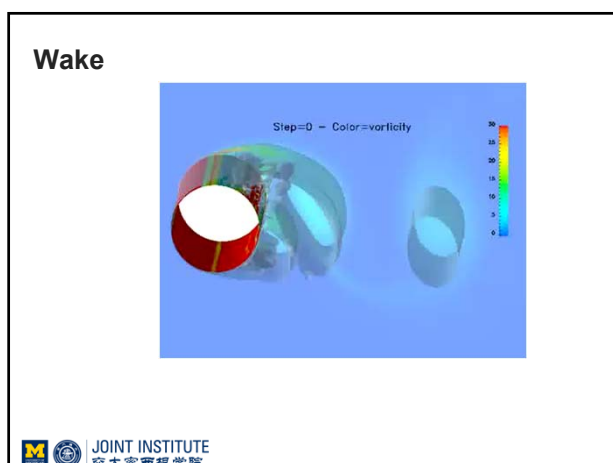
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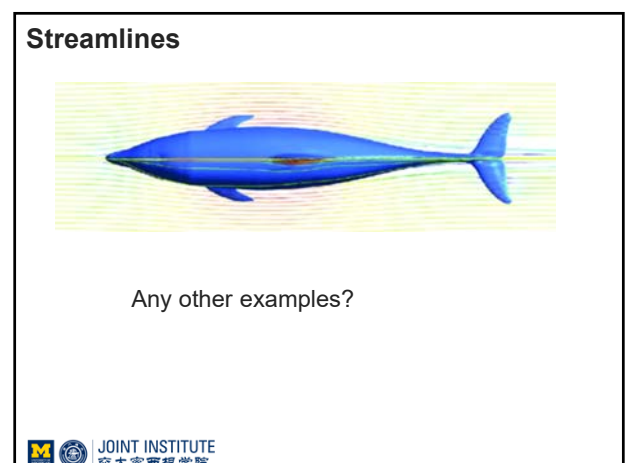
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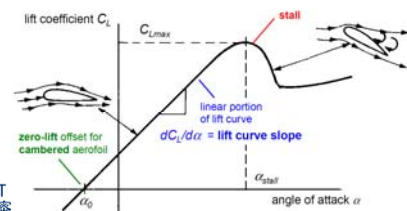
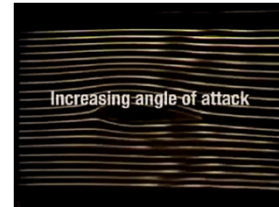
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A Homework

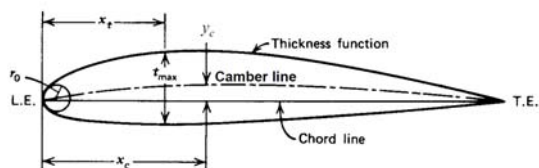


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Stall



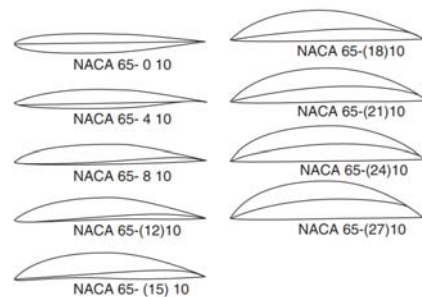
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- Note the rounded leading edge and sharp trailing edge
- Chord line: straight line joining leading and trailing edges
- Camber line: average of upper and lower surface
 - For a symmetrical section, the camber line = the chord line
- Angle of incidence (also called angle of attack)
 - Angle between chord line and direction of travel

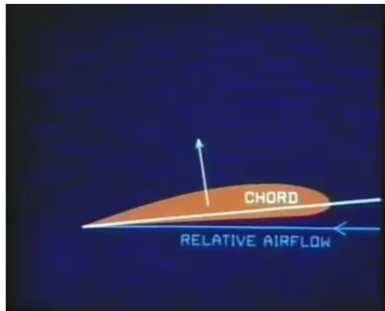
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NACA AIRFOILS



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Life and Drag around an airfoil



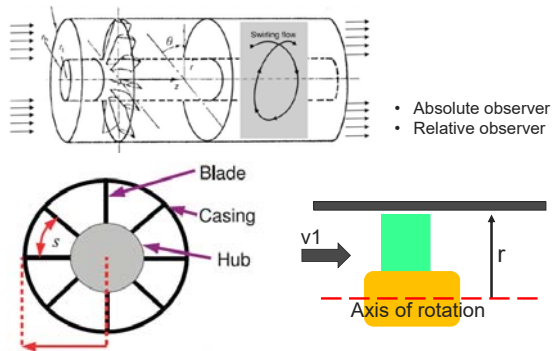
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A Propeller



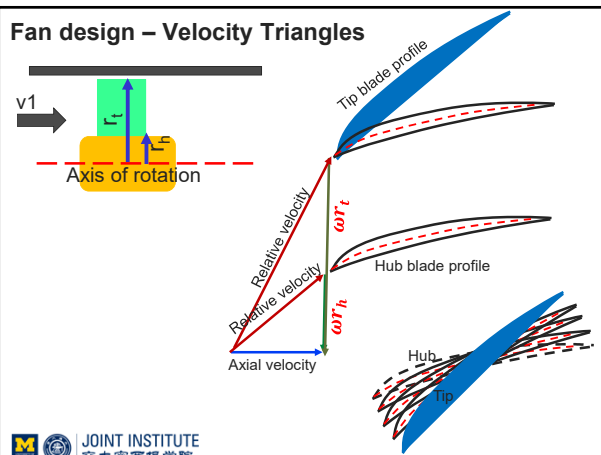
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Fan design – Relative Frames

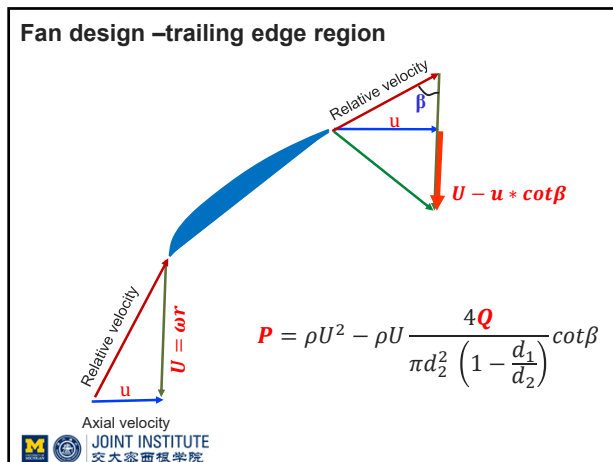


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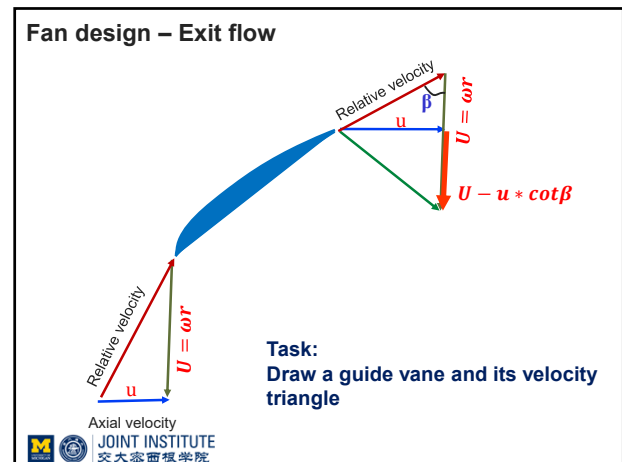
Fan design – Velocity Triangles



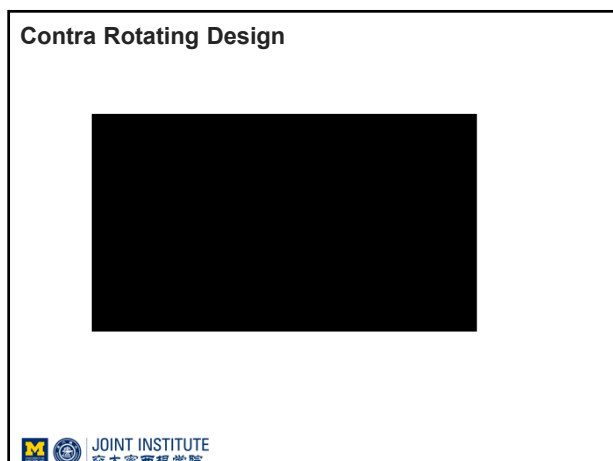
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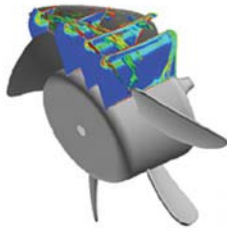


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Ducted or Ductless



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Tip Vortex

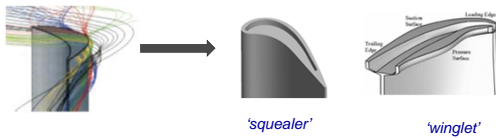


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Tip Vortex

A story in my previous turbine research

Blade tip design :



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Tip Research

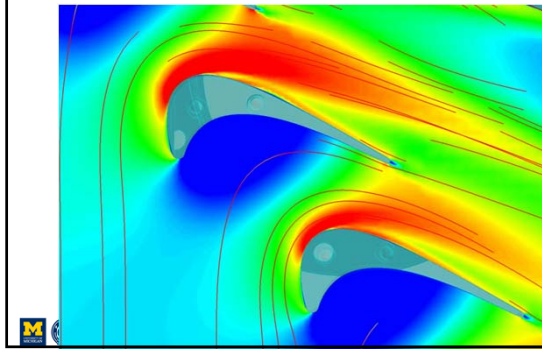
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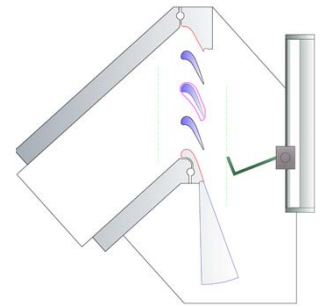
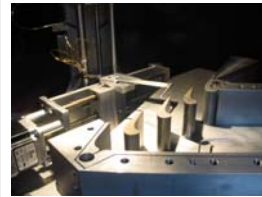
Tip Research

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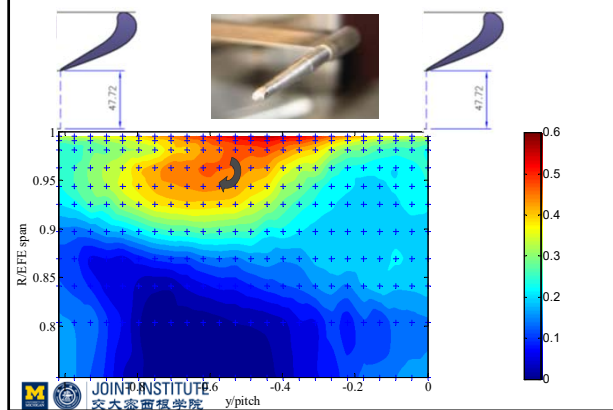
Exit loss measurement



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Cp Loss coefficient contour



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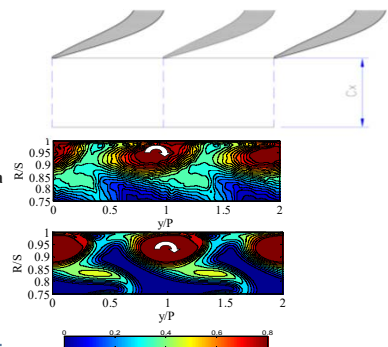
Some Sample Measurement Data

Loss coefficient

CP_0

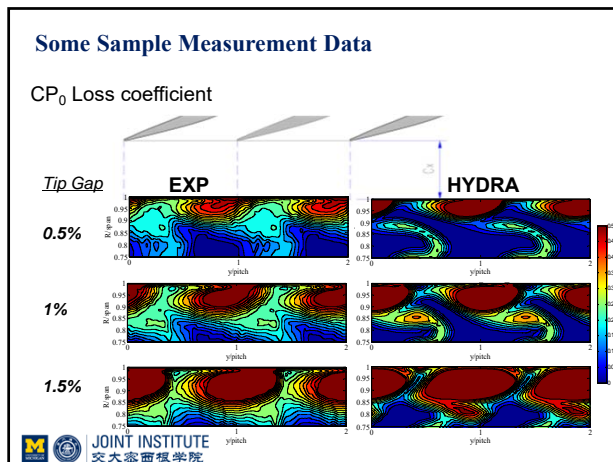
Experimental data

CFD

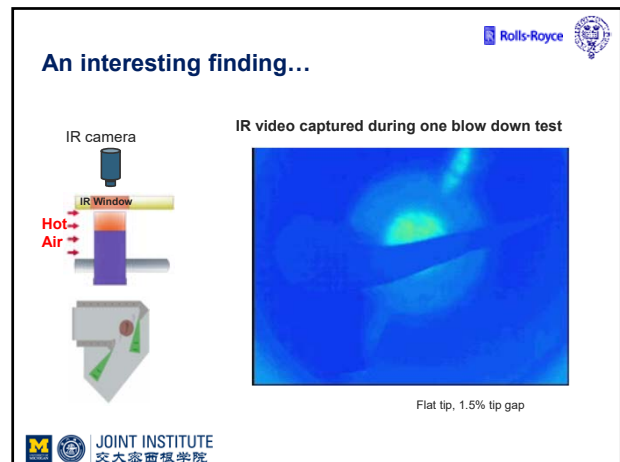


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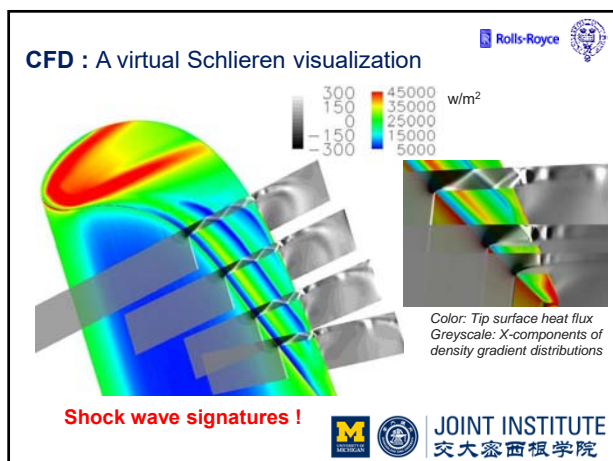
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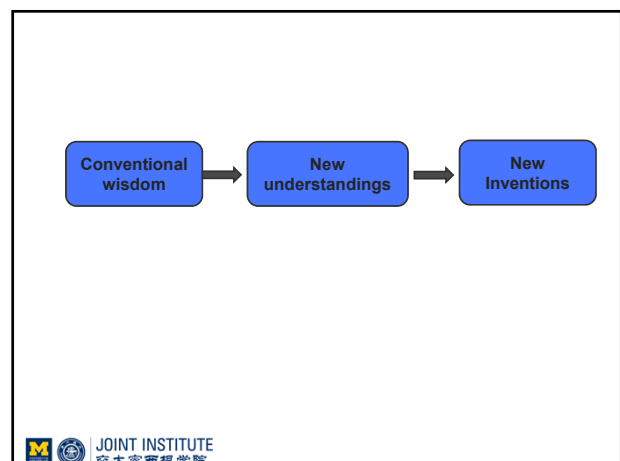
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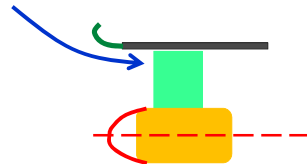
Ducted or Ductless

- Ducted fan can produce a lot more thrust (could be twice as much) than an open rotor of the same size.
- Other factors to consider?
 - ☐ Weight & money & Space.
 - ☐ Manufacturing tolerances
 - ☐ Duct...

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Some Possible Follow-up Project Ideas

- Better hub design?



- Discuss your other thoughts with me or TAs!

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Our core project

- Plan your follow-up project idea now
- Teamwork !
- Understanding !

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Follow-up Project Suggestions

- Suggest to focus on ONE Improvement per team
- What key physical principles are involved ?
- What new story can you tell? (not just some fancy design)
- Can your objective be achieved within the budget and time?
- What potential risks?

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Review

- Coanda Effect
- Boundary layers
- Friction Drag
- Flow Separation
- Fan aerodynamics
- Core project & Follow-up project