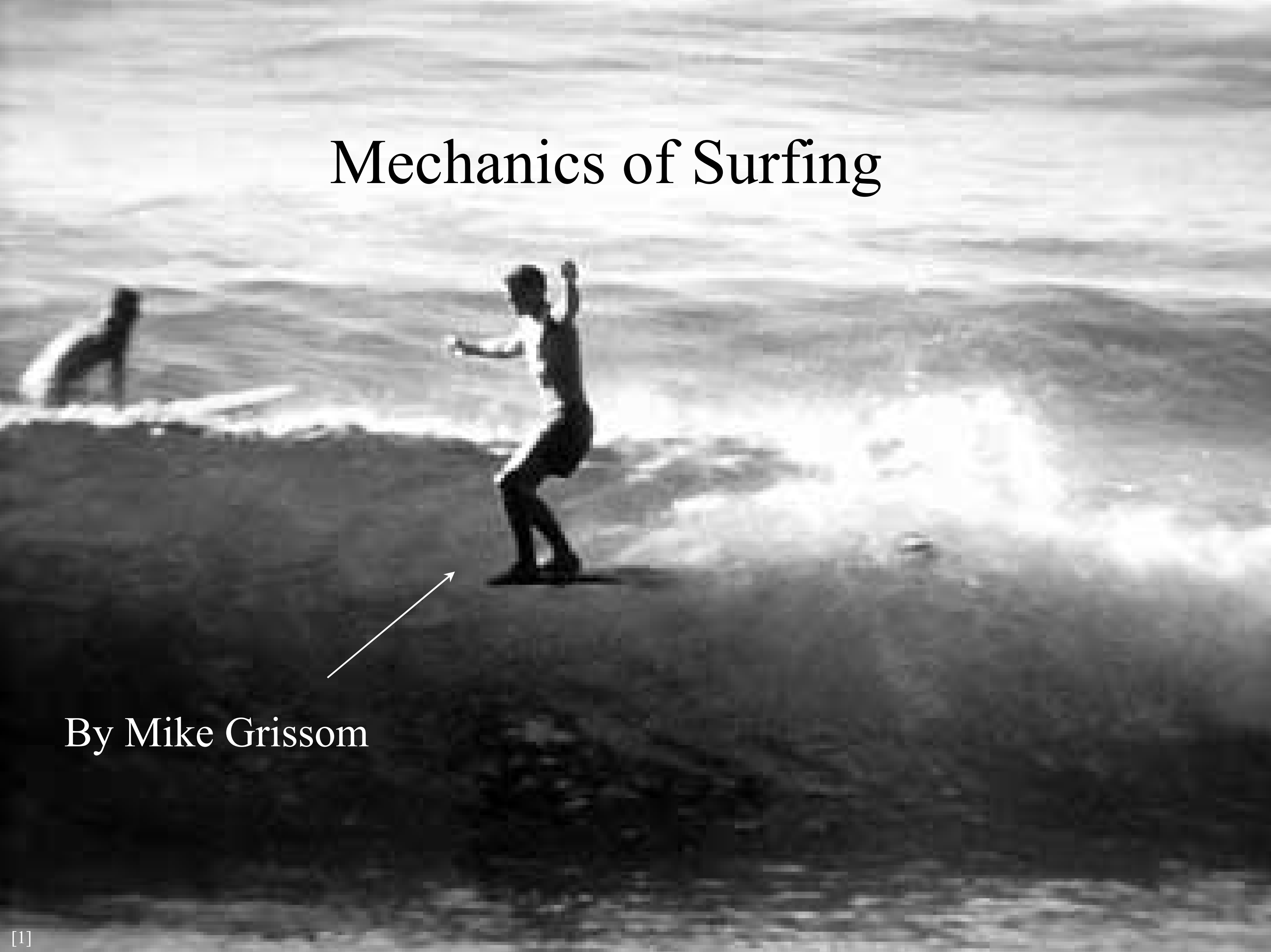
Mechanics of Surfing



By Mike Grissom

[1]

Apparatus


[2]

Longboard	Shortboard
- 9'0 or longer	-length ~ height of surfer
- more volume	- less volume
- more mass (~18 lbs)	- less mass (~6 lbs)
- more planing surface	- less planing surface


[3]

Same density!

Statics

<u>Archimedes' Principle</u> - *The buoyant force is equal to the weight of the displaced fluid*

- If object is less dense than fluid → $W_{\text{displaced fluid}} = W_{\text{object}}$

<u>Equilibrium</u> (with surfer lying prone on board)

Longboard

- greater surface area, volume → water displaced is mostly at the surface

-Surfboard remains at the surface of the water

Shortboard

-less surface area, volume → must sink deeper to displace enough water

-Surfboard is a few inches below surface

Quick Calculation

$V_{longboard} \approx 74{,}000\ cm^3$

$\rho_{ocean\ water} \approx 1\ g/cm^3$

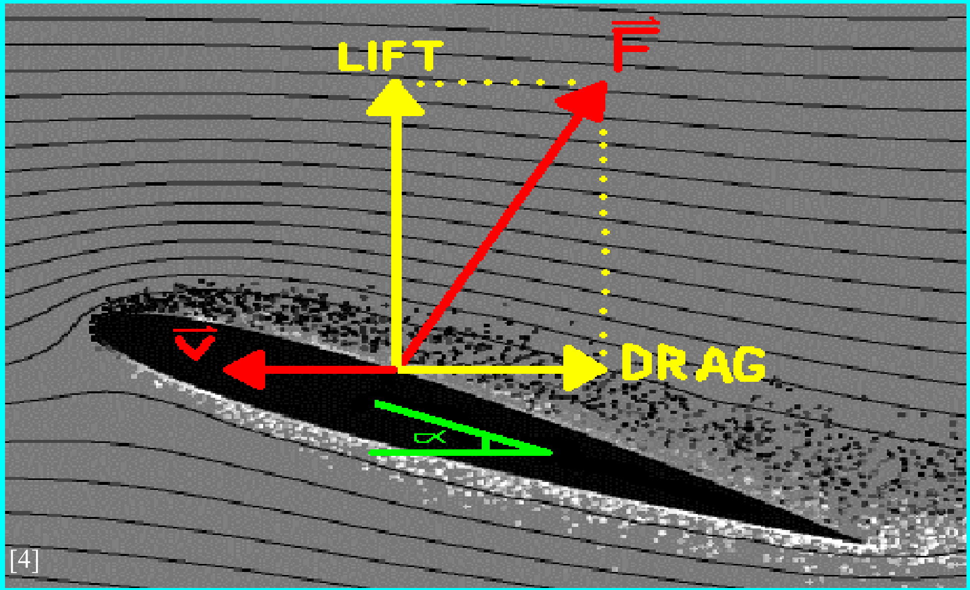
If board was totally submerged it would displace 74,000 g = 165 lbs of water!

→ It will float average human

→ Shortboards won’t!!!

Basic Concepts

Lift – Forces acting perpendicular to the motion
Angle of Attack – Angle between chord length of the foil and velocity
Drag - Forces acting in the direction opposite the motion



Sources of Drag in Surfing

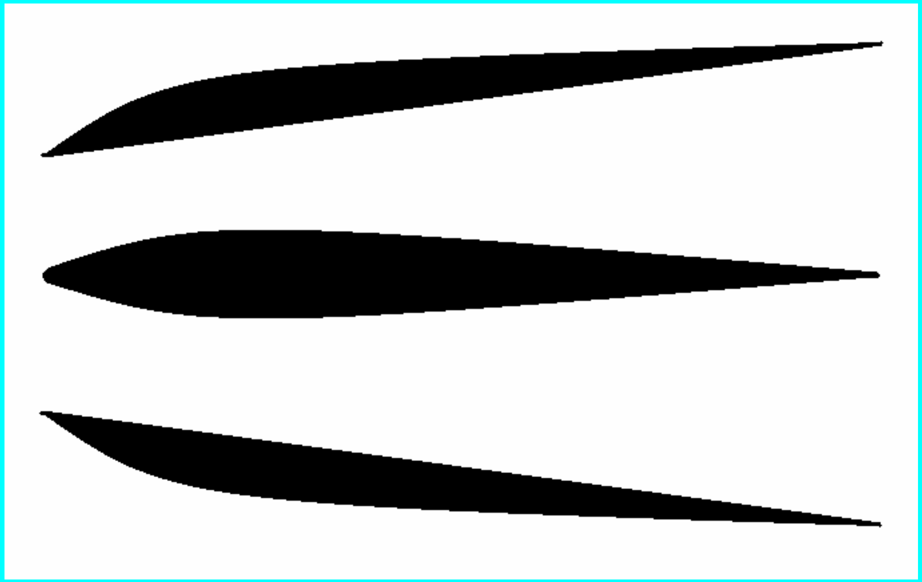
1. Skin Friction Drag – collision of board with water molecules (boundary layer)
2. Form (Pressure) Drag – shape of board
3. Wave-making Drag – momentum given to waves from board
4. Spray-making Drag – same as above

Bernoulli’s Principle

In steady fluid flow, a change in pressure is associated with a change in velocity.

Assumptions: Laminar, incompressible, inviscid flow

Ex. Pipes, airplane wings, surfboard fins



← Asymmetric Side Fin

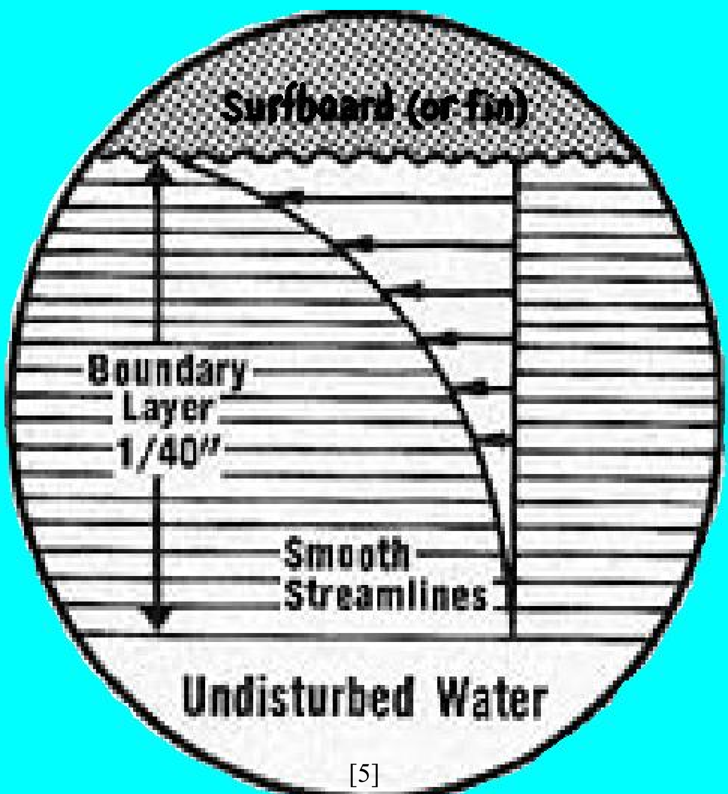
← Symmetric Center Fin

← Asymmetric Side Fin

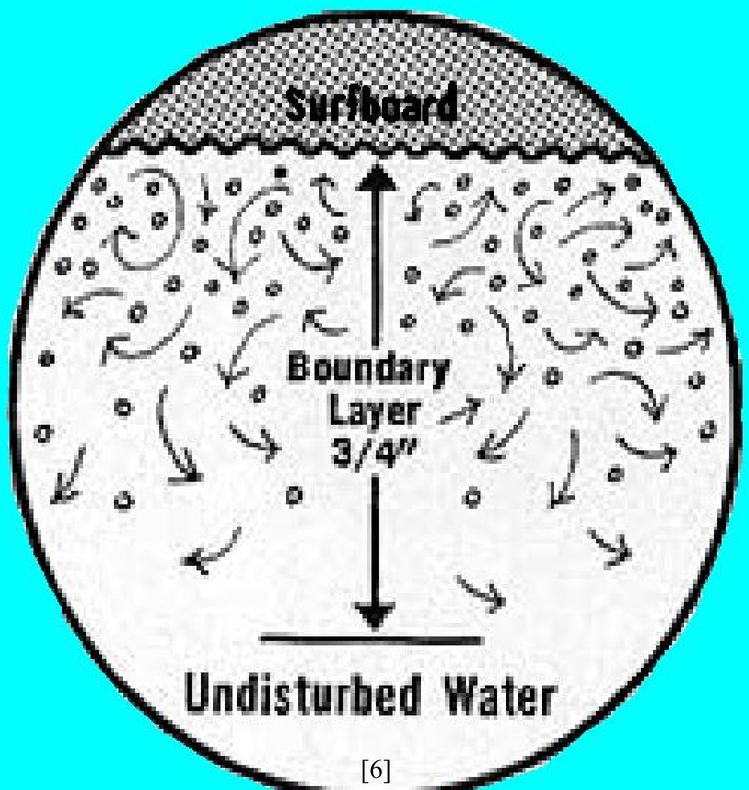
Boundary Layer

- Thickness varies → velocity, wetted length, and type of flow
- Skin friction drag is greater for turbulent boundary layer
- Transition from laminar to turbulent takes place in first few inches!

Laminar



Turbulent



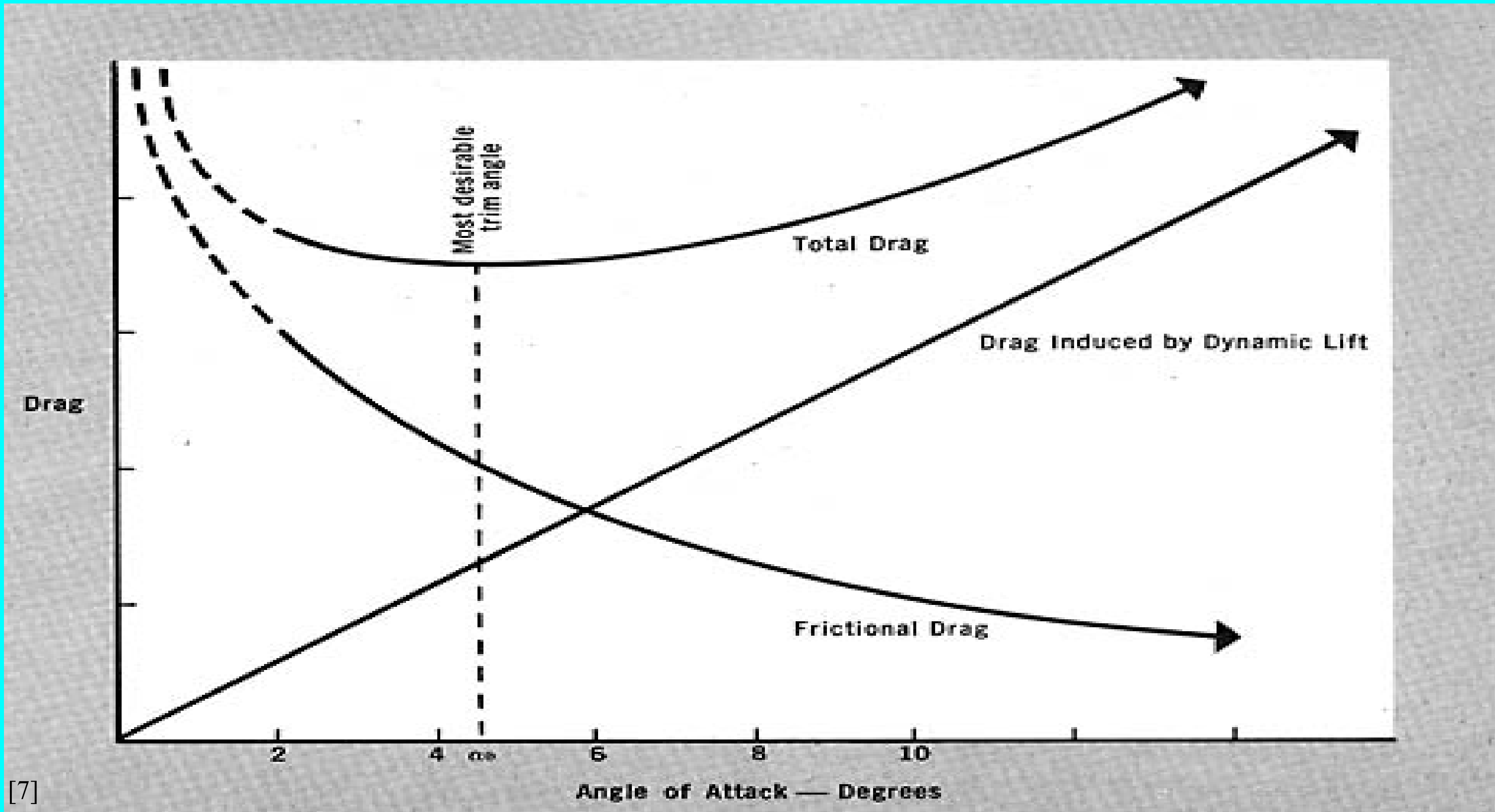
Planing Watercraft

For maximum speed – what's the best angle of attack?

Too much → lots of form drag

Too little → lots of skin friction drag

Best Angle of Attack ~ 4.2°



Paddling & Catching a Wave

- Surfer must accelerate to wave velocity using a combination of paddling and gravity

<u>Longboard</u>

- More flotation → Greater paddling velocity → Catch waves earlier, before they crest.

<u>Shortboard</u>

- Less flotation → Low paddling velocity
  → Depend on gravity

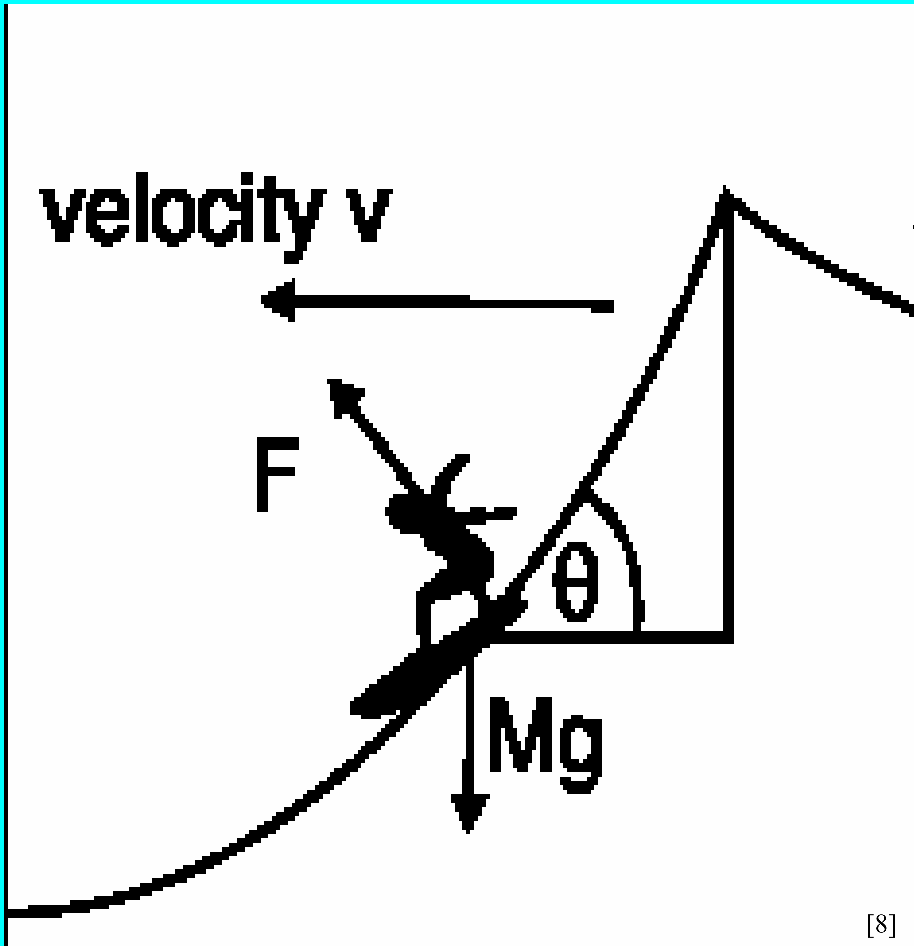
We know

$$F_H = F\sin\theta$$

$$F\cos\theta = Mg$$

So

→ $$F_H = Mg\tan\theta$$



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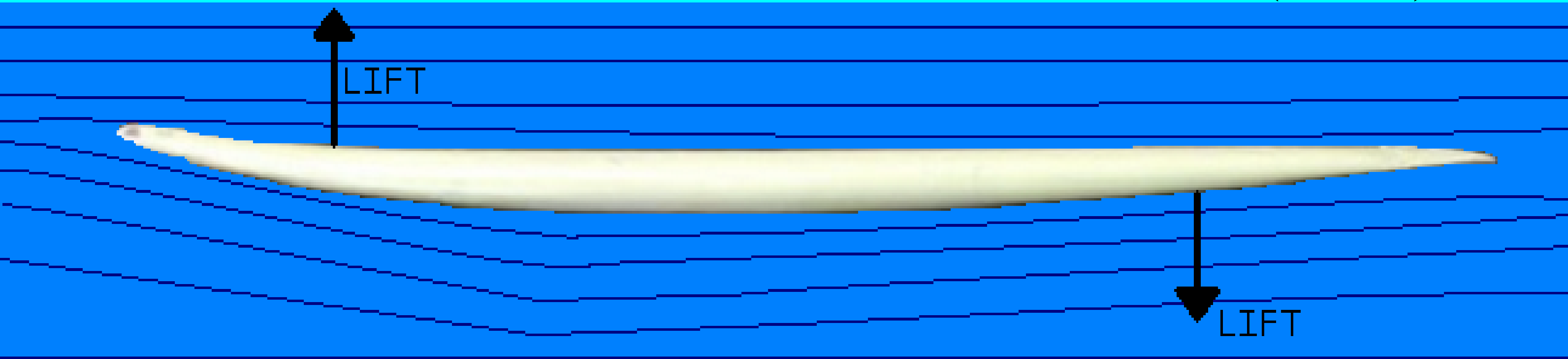
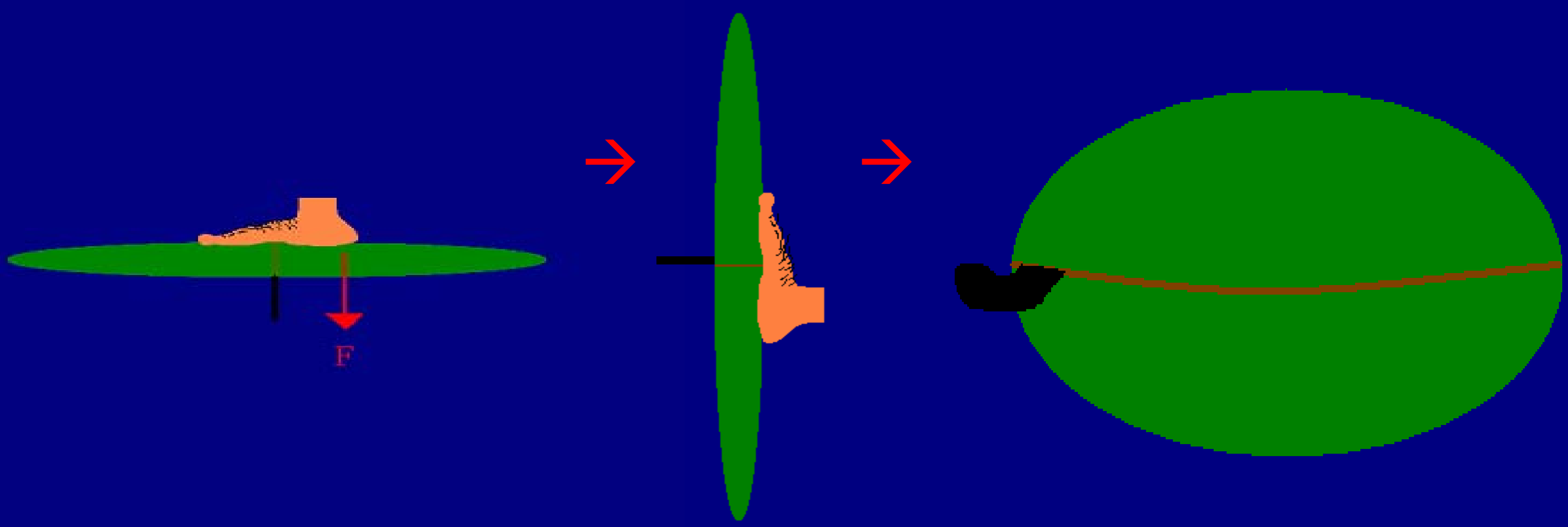
Turning

Change in direction → Need Lift!

Lift comes from: -changing the angle of attack

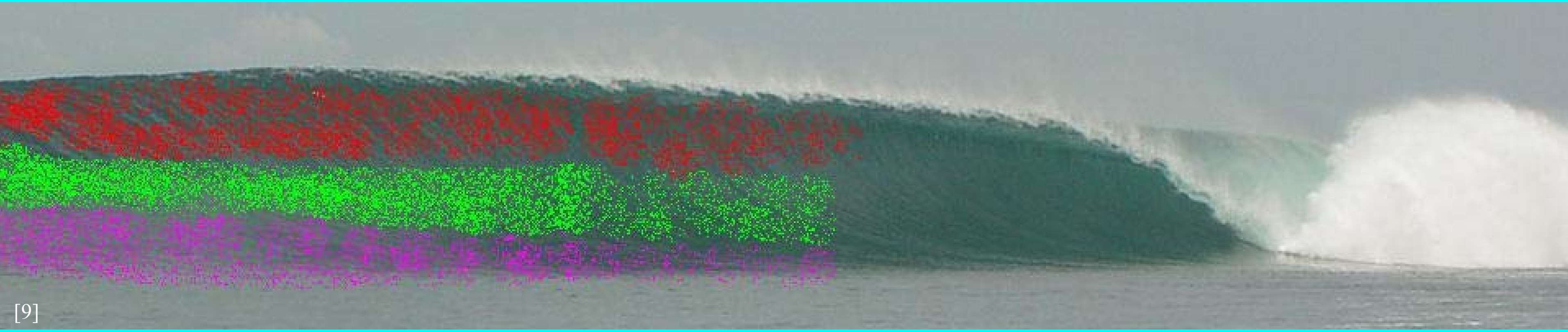
-the curved bottom surface of the board (rocker)





Walking on the Board

Recall $F_H = Mg\tan\theta$ → More energy where wave face is more vertical



Changing position of surfer allows - manipulation lift and drag forces!
- energy conversion!

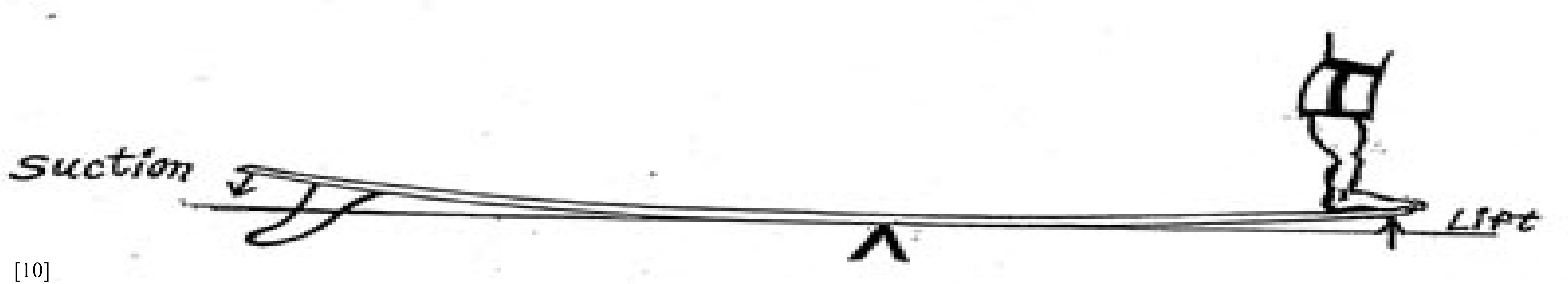
<u>Position</u> <u>Purpose</u>

Tail ---------- Increase drag - slow down – rise higher on face
Sharp turns

Middle ------ Least drag – speed up

Nose -------- Test your balancing skillz!!!!

Nose Riding



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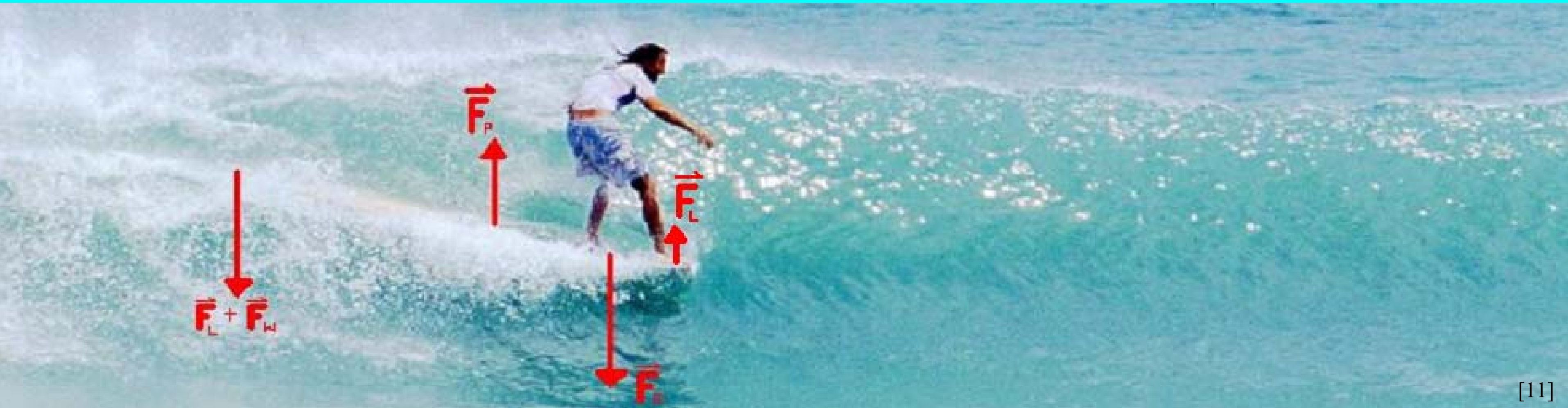
Very unstable dynamic equilibrium!!

One side of board is almost entirely in the wave face.

Weight of water, downward lift at tail necessary for forces to cancel.



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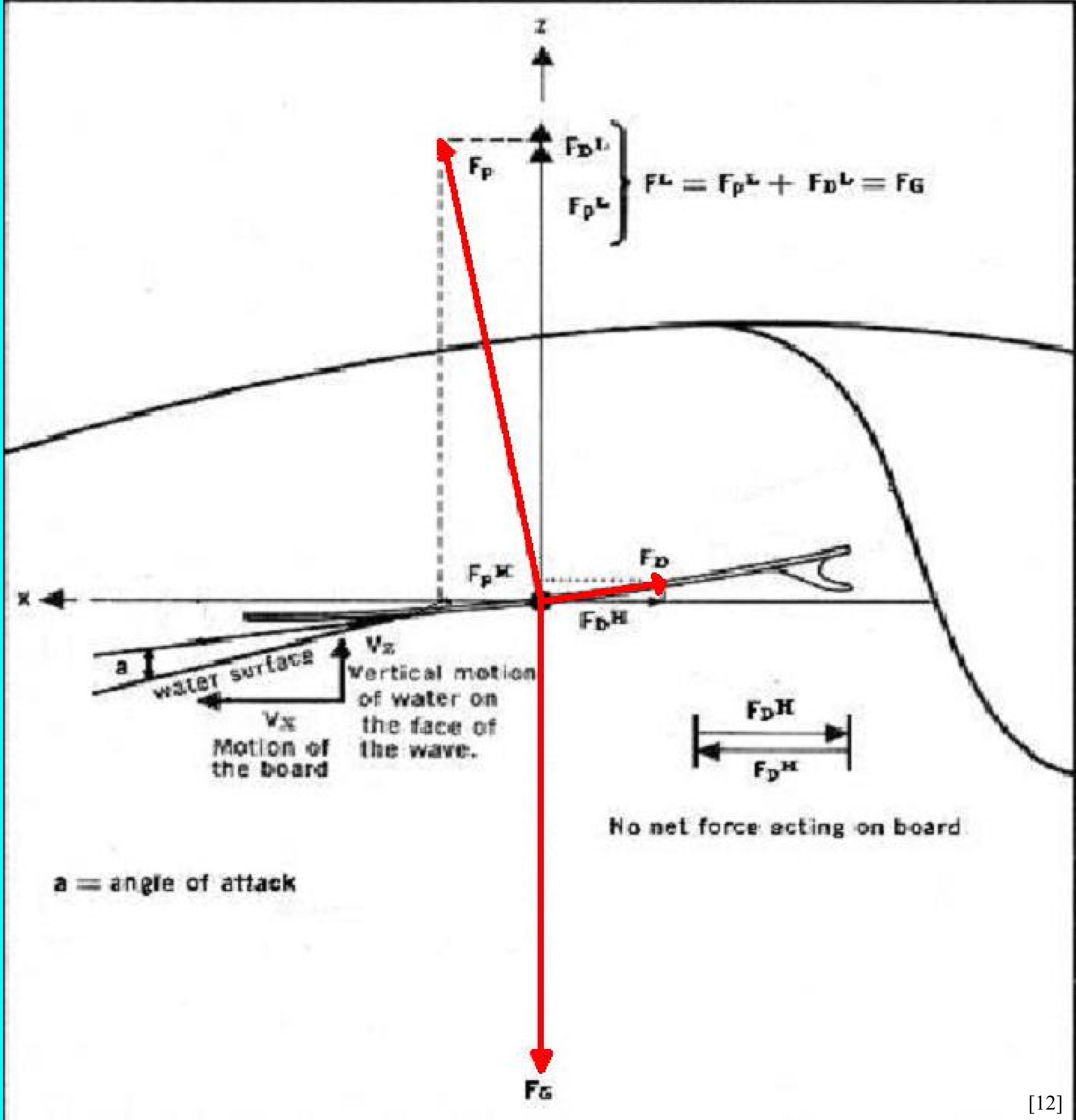
Dynamic Equilibrium

3 Basic Forces
Gravity
Lift
Drag

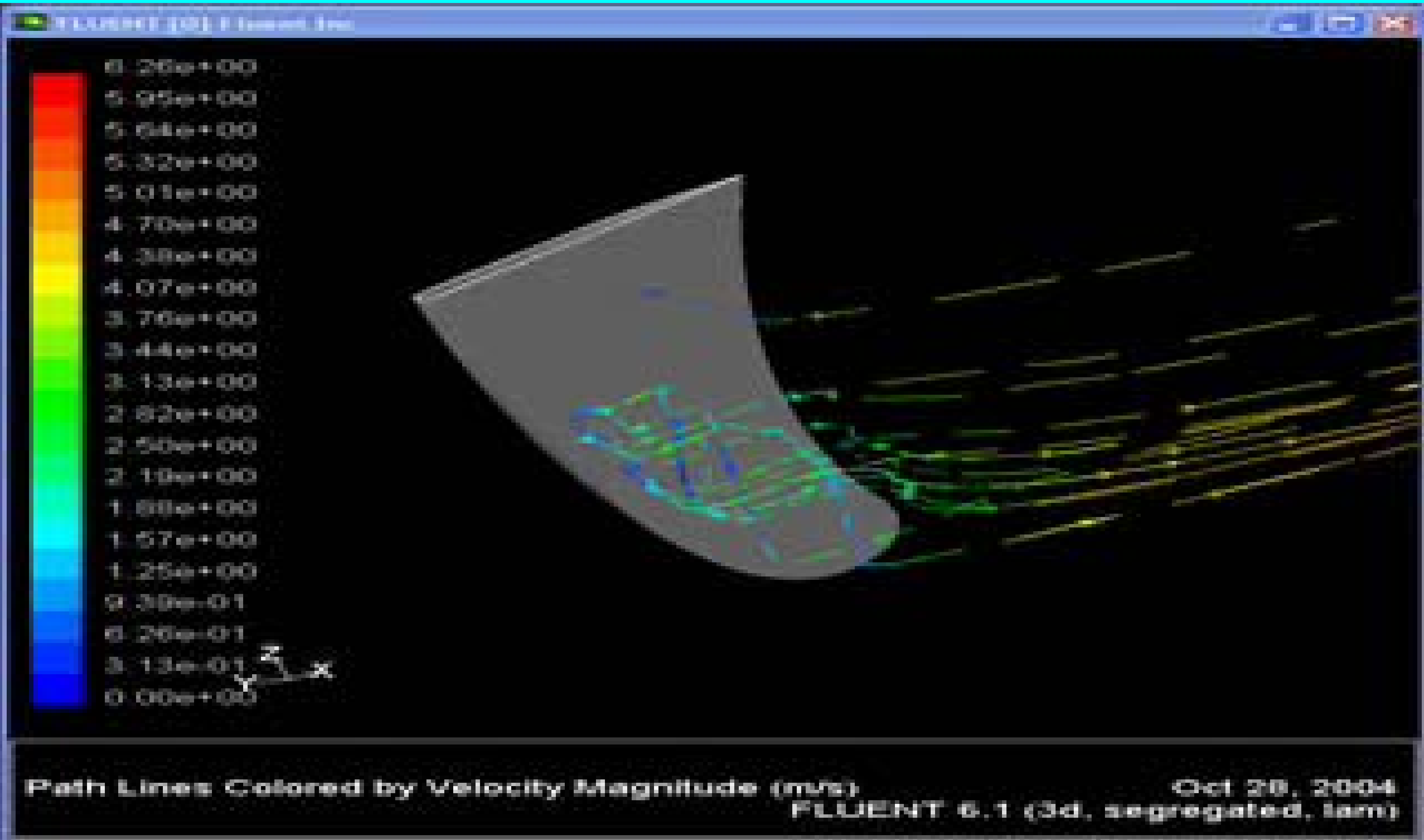
Vertical lift and drag components cancelled by gravity

Horizontal lift and drag components cancel each other



[12]

Computational Fluid Dynamics
At SURFS



Fluid Flow Around Fins

Debate: Is it better to have glassed-on fins rather than removable fins?

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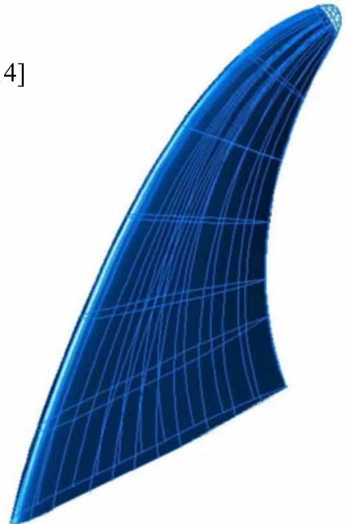
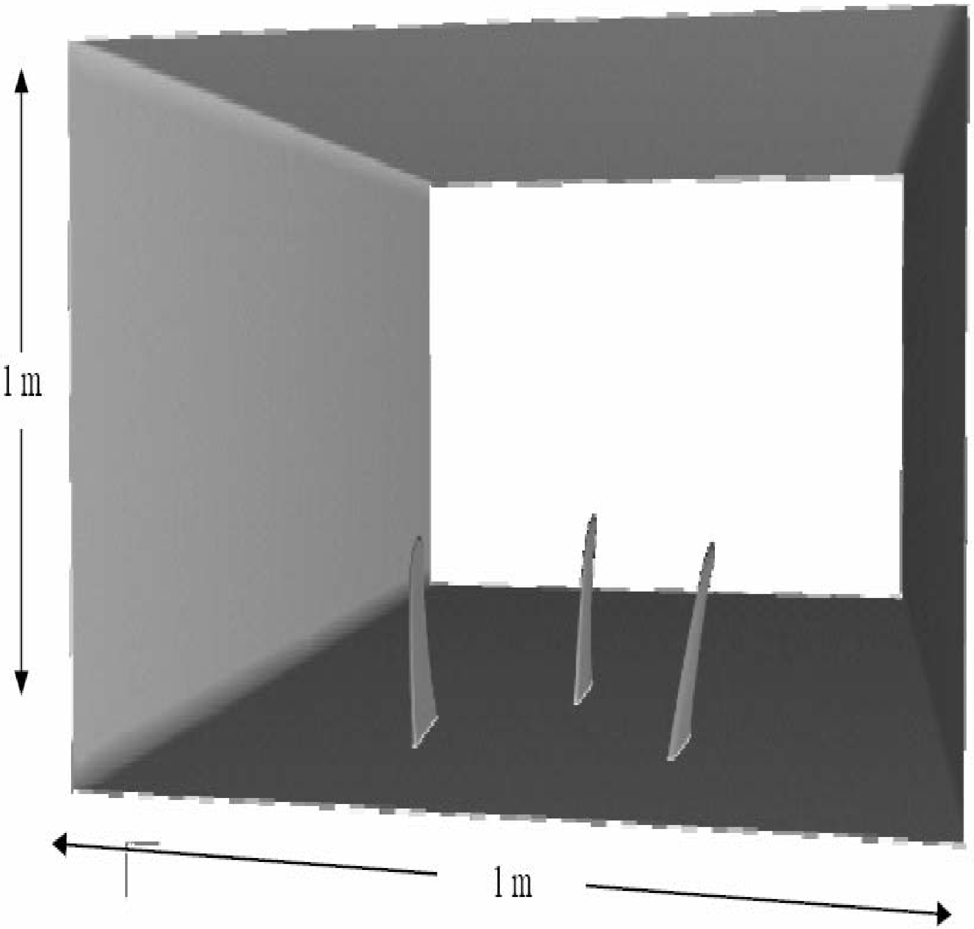
← Glass-on

[14]



← Removable



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Drag Results

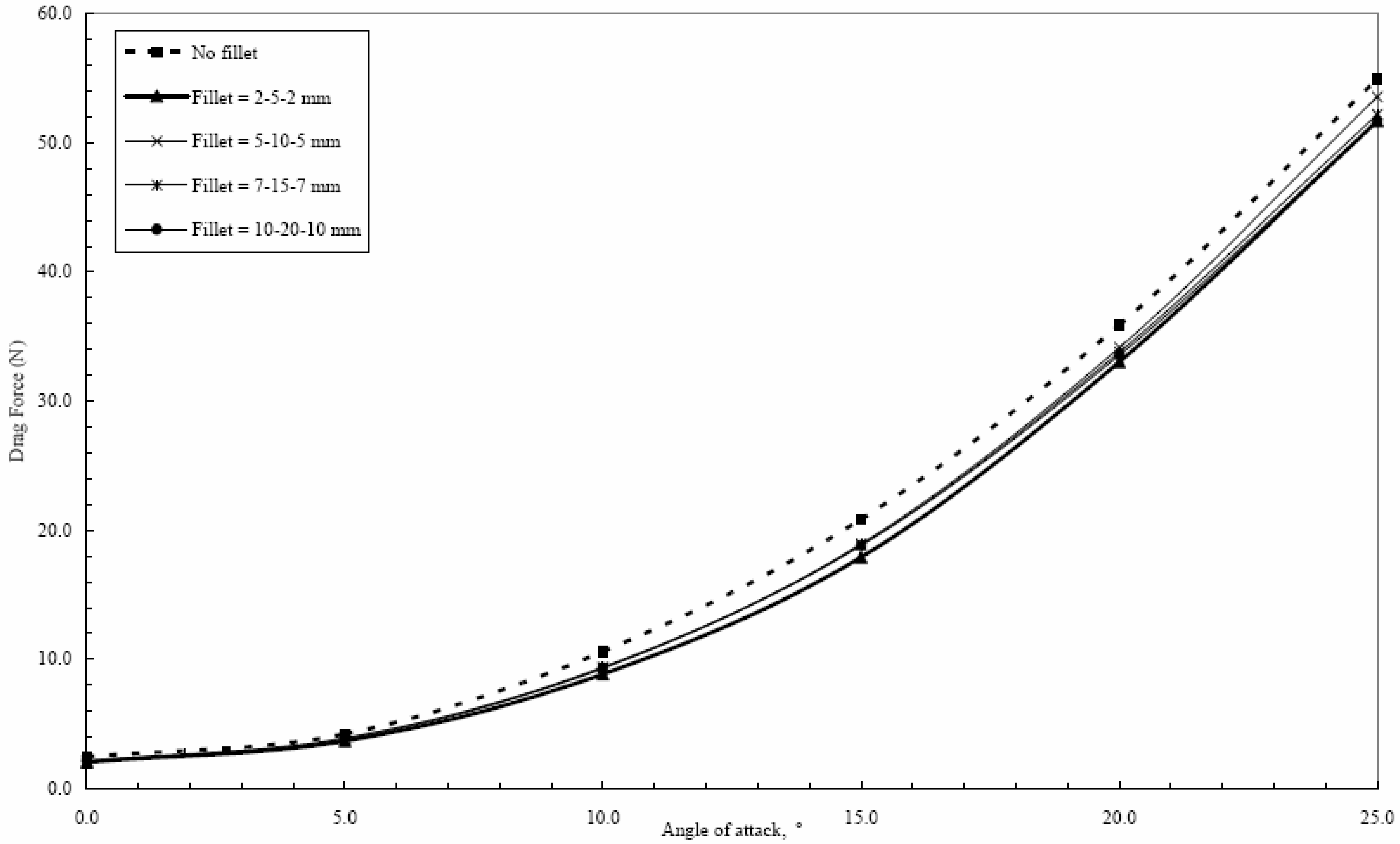

Figure 9 – Drag force for fillets of various sizes

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Negligible difference in Drag!

Lift Results

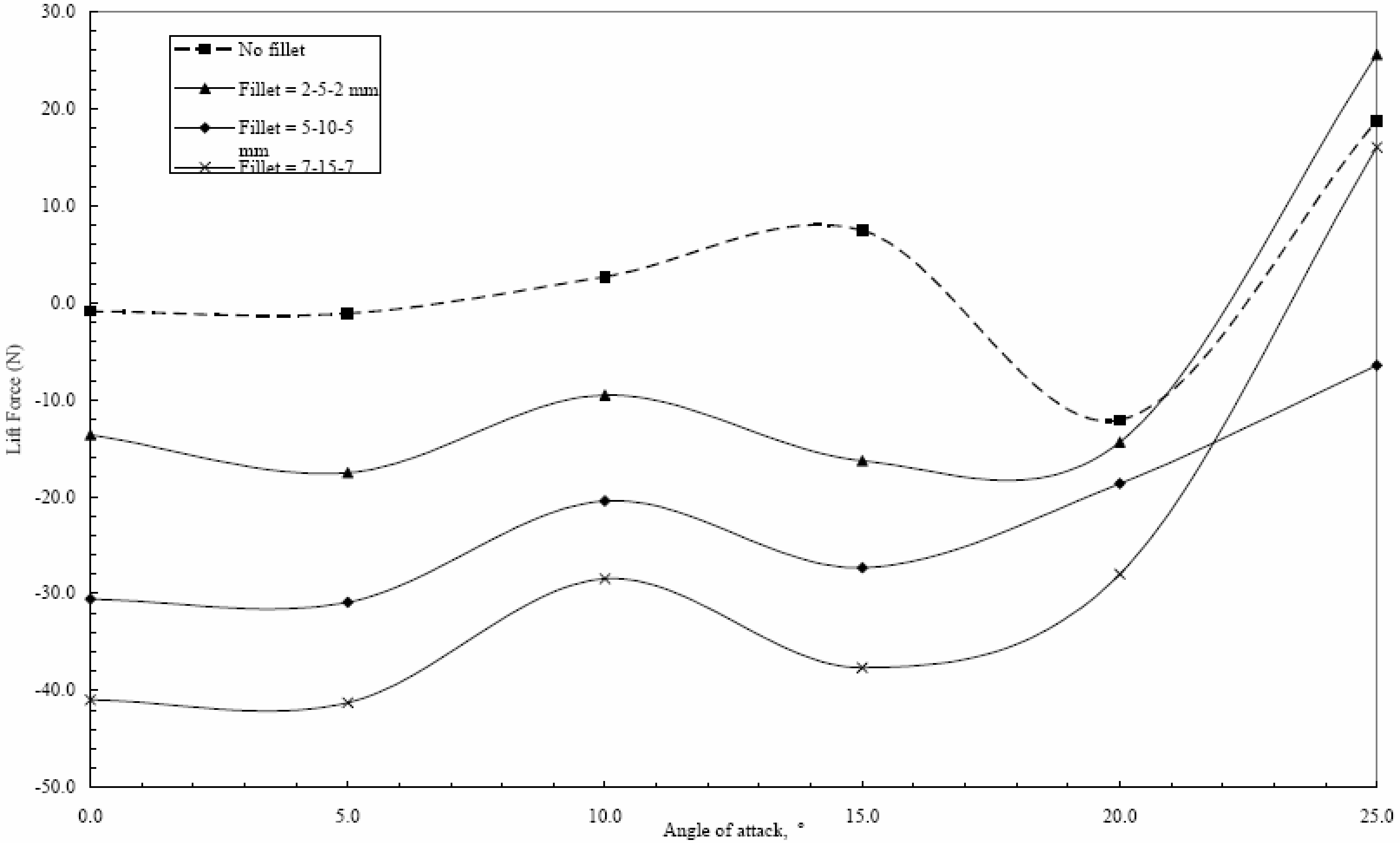


Figure 10 – Lift force for fillets of various sizes

[17]

Noticeable Difference in Lift!

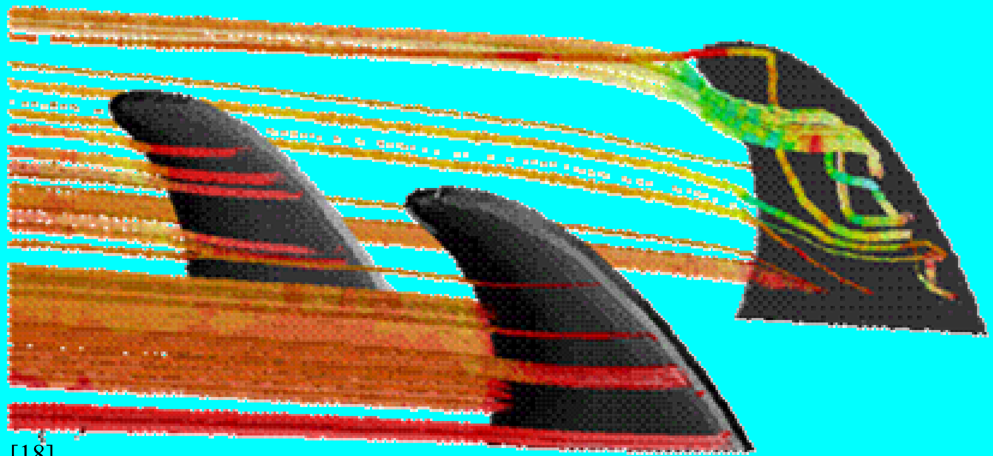
Future Research

-Use a more realistic model that takes turbulent flow into account

-Analyze other design features of a surfboard

-Stress analysis of surfboards

-Analyze more complex drag components



[18]

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[2] T. Hendricks, “Surfboard Hydrodynamics, Part II: Pressure”, *Surfer*, Vol. **10**, No. 1, March 1969

[3] T. Hendricks, “Surfboard Hydrodynamics, Part III: Separated Flow”, *Surfer*, Vol. **10**, No. 2, May 1969

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Pictures

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[2] Proline Longboard www.hotwaxsurfshop.com

[3] Proline Shortboard www.hotwaxsurfshop.com

[4] http://www.eng.fsu.edu/~dommelen/research/airfoil/airfoil.html

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[7] http://www.rodndtube.com/surf/info/info_images/SfrMagV10N1-69-03-TH2.jpg

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Video

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