16.00 Aerodynamics Lecture

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Lecture outline

- Motivation
- Lift
  - Balloons – buoyancy and Archimedes
  - Airplanes – airfoils and Bernoulli
- Drag
  - Profile drag
  - Induced drag
- Effects of airfoil geometry on lift and drag

What is Aerodynamics?

- "A branch of dynamics that deals with the motion of air and other gaseous fluids, and with the forces acting on bodies in motion relative to such fluids" – *Webster's Dictionary*

Let's discuss…

- What does "aerodynamic" mean to you?

- In what other areas or products besides airplanes does aerodynamics matter?

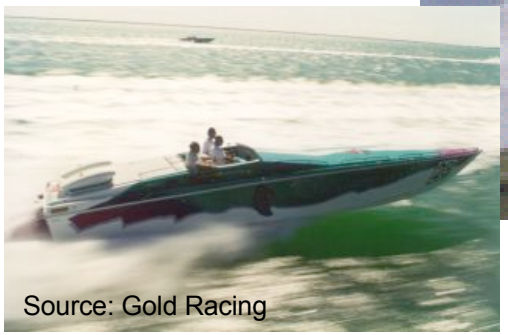
Aerodynamics matters


Source: Boeing


Source: Lexus


Source: lancearmstrong.com


Source: Land and Water Fund of the Rockies


Source: Gold Racing


Source: Japan-Guide.com


Source: Personalizedgolfballs.com

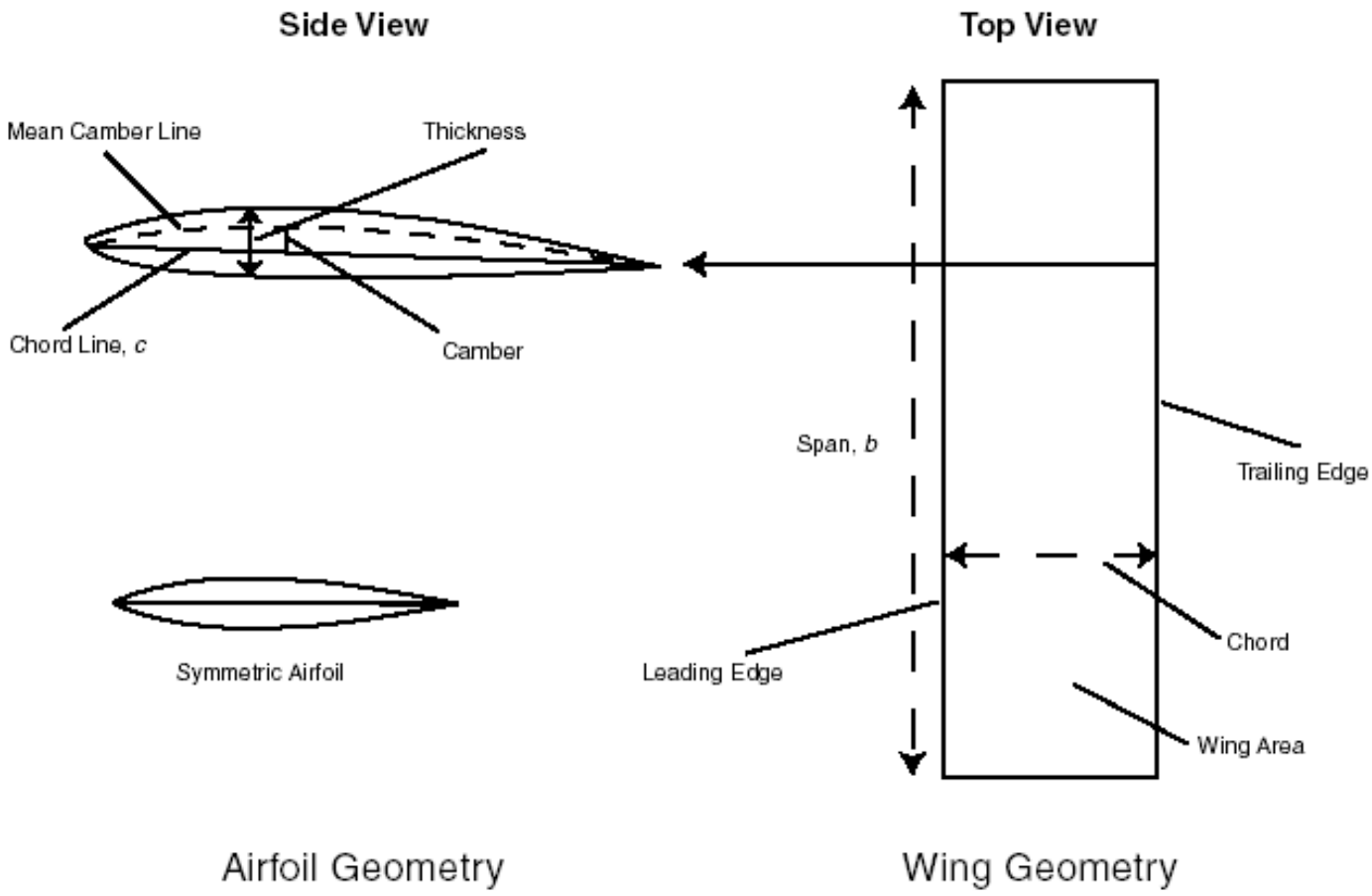
Lift and Balloons

- Buoyancy is easiest way of generating lift
- Archimedes principle
  - Difference in pressure on surface of a body = volume displaced
  - Weight of fluid displaced = buoyant force
- Net force
  - $F_{net} = \rho g V$
- Static equilibrium
  - $m_{payload} = (\rho - \rho_{int})V$

Ballooning on Mars?

- We want to design a balloon to carry a 2-kg payload on Mars. What gas should we use in the balloon, and how big does the balloon have to be?
- Helpful links:
  - http://www.members.axion.net/~enrique/density.html
  - http://www.flyers.org/simulators/atmospheric.htm

Airfoil terminology



Source: Newman, Dava J., *Interactive Aerospace Engineering and Design*

Aspect ratio

- Aspect ratio = b^2 / S, where b is span; S is wing area
  - For rectangular wing, AR = b/c

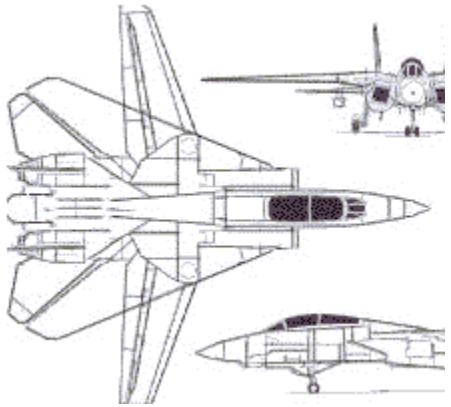
- For a table of aspects ratios for different vehicles, check out http://www.aerodyn.org/Wings/ar-tables.html

Comparing aspect ratios


Source: NASA

Source: Boeing


Source: HowStuffWorks.com


Source: http://www.geocities.com/CapeCanaveral/8629/f14.htm


Source: Concordesst.com

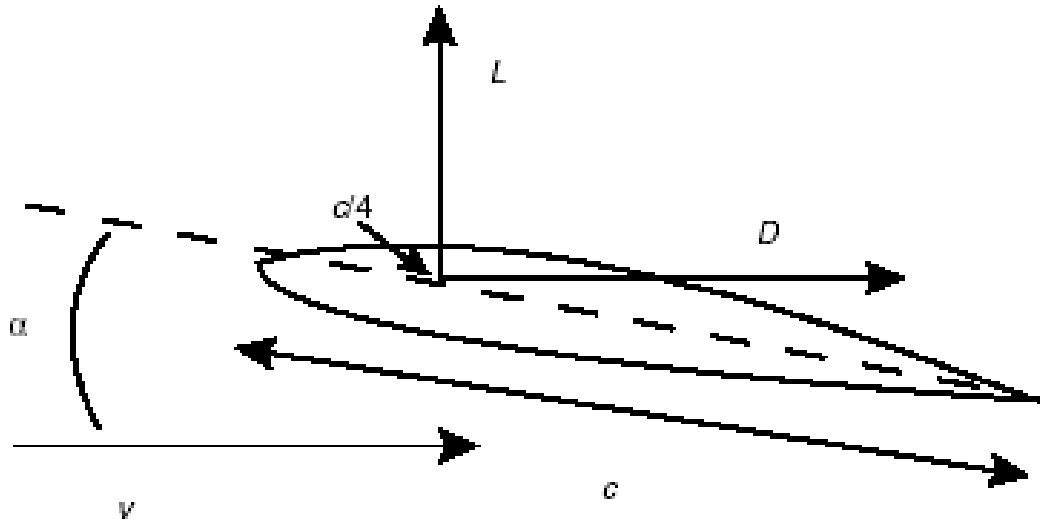
FoilSim

- NASA software you will use in your homework assignment

- http://www.lerc.nasa.gov/WWW/K-12/airplane/foil2.html

Lift and drag on airplanes

- Lift and drag are mechanical forces generated on the surface of an object as it interacts with a fluid



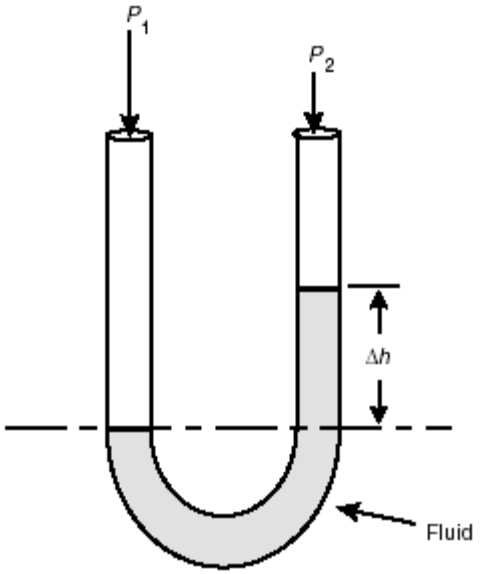
Source: Newman, Dava J., *Interactive Aerospace Engineering and Design*

What is lift?

- Lift is the force that holds an aircraft in the air
  - $L = (P_l - P_u)S$
- Coefficient of lift: empirical nondimensional parameter for easier evaluation of lift
  - $C_L = L / (1/2 \rho V^2 S)$
  - q = dynamic pressure = $1/2 \rho V^2$
  - Substituting in q, $L = qSC_L$

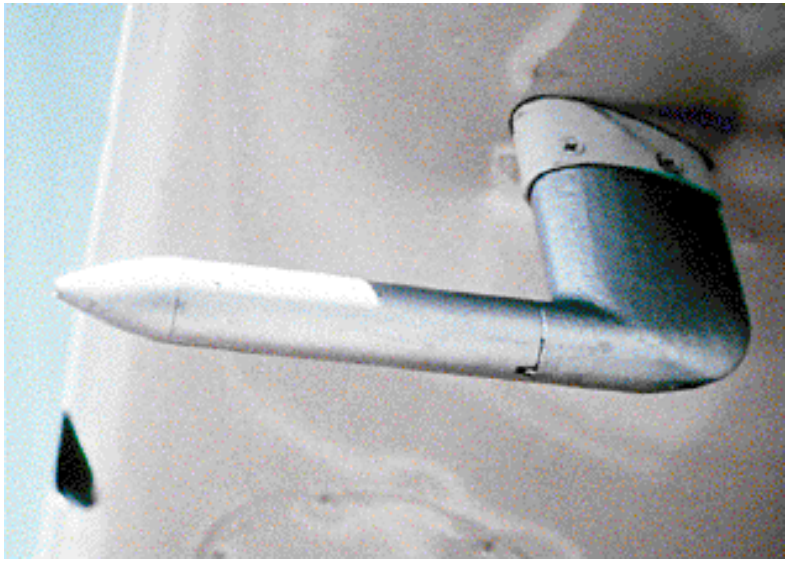
Bernoulli and pitot tubes

- Simple form of Bernoulli's equation
  - $P + 1/2\ \rho v^2 = P_0$
- Basis of pitot tube, which measures airplane velocity
  - $v = \sqrt{2((P_0 - P)/\rho)}$



Source: Newman, Dava J., *Interactive Aerospace Engineering and Design*

What do pitot tubes look like?

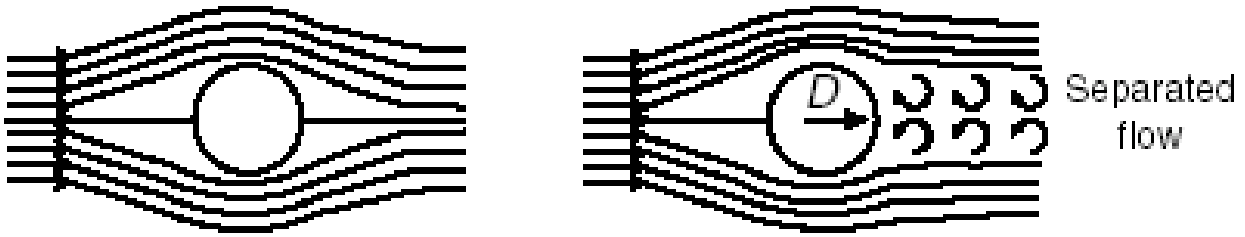


What is drag?

- Aerodynamic force that opposes an aircraft's motion through the air, caused by interaction and contact of a solid body with a fluid
- Aerodynamic friction
- Aerodynamic resistance to motion
- Depends on wing shape, angle of attack, effects of air viscosity and compressibility

Profile drag

- Related to viscous effects of flow over lifting surface
- Also called “form drag” due to separation of boundary layer around the object’s form

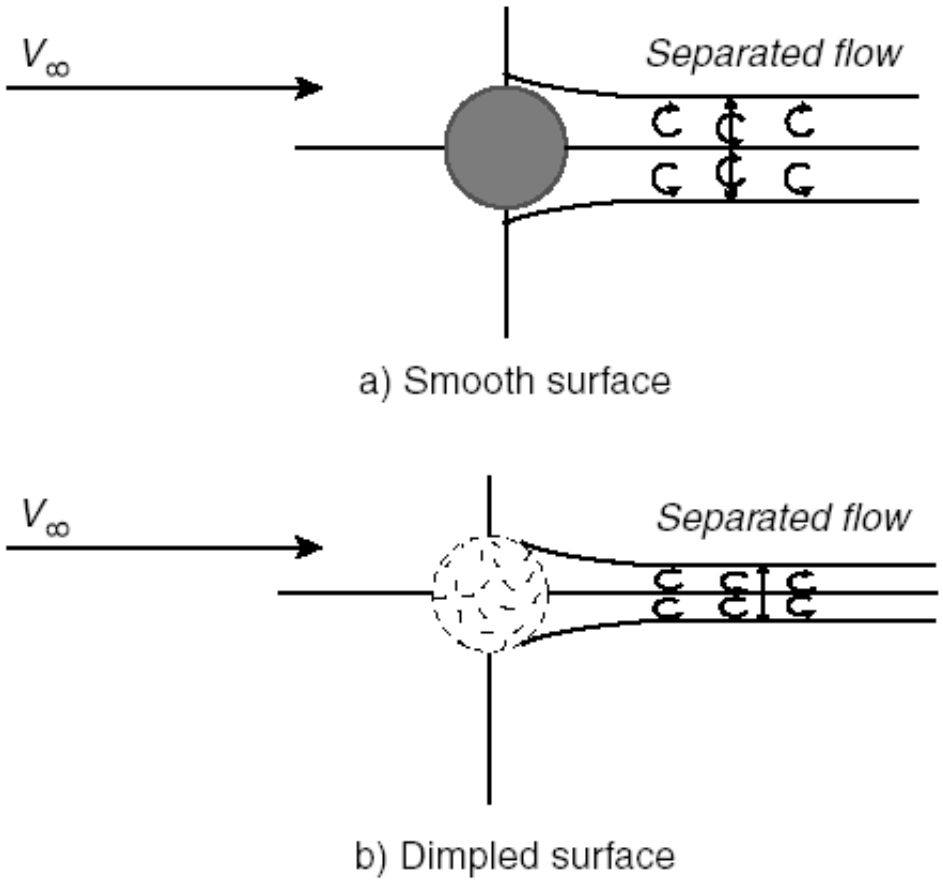


Frictionless flow: no drag Real flow: finite drag

Source: Newman, Dava J., *Interactive Aerospace Engineering and Design*

Profile drag (cont.)

- Dimples = greater skin friction drag = greater distance to separation of flow = lower profile drag



Source: Newman, Dava J., *Interactive Aerospace Engineering and Design*

Induced drag

- Arises from 3-dimensional effects of a wing caused by downwash velocity near wing tip
- Vortices create a downward velocity component at the wing
- Non-dimensional coefficient of induced drag:
  - $C_{D_I} = C_L^2 / \pi e \mathrm{AR}$

Induced drag

Source: Newman, Dava J., *Interactive Aerospace Engineering and Design*

Total drag

- Total drag = profile drag + induced drag

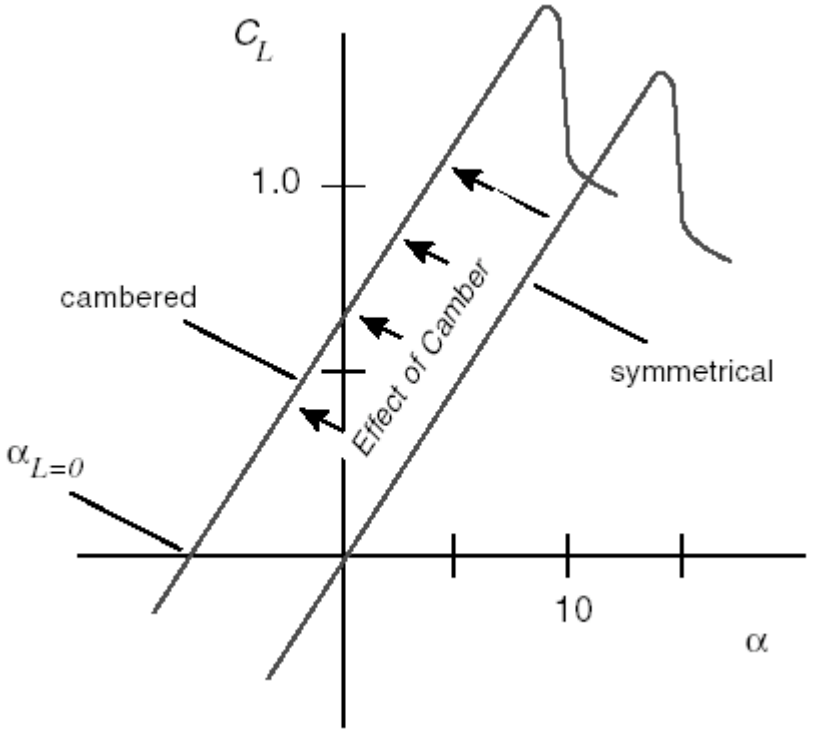
- Coefficient of total drag
  - $C_{D_{TOTAL}} = C_{D_0} + C_L^2 / \pi e \mathrm{AR}$

Class exercise

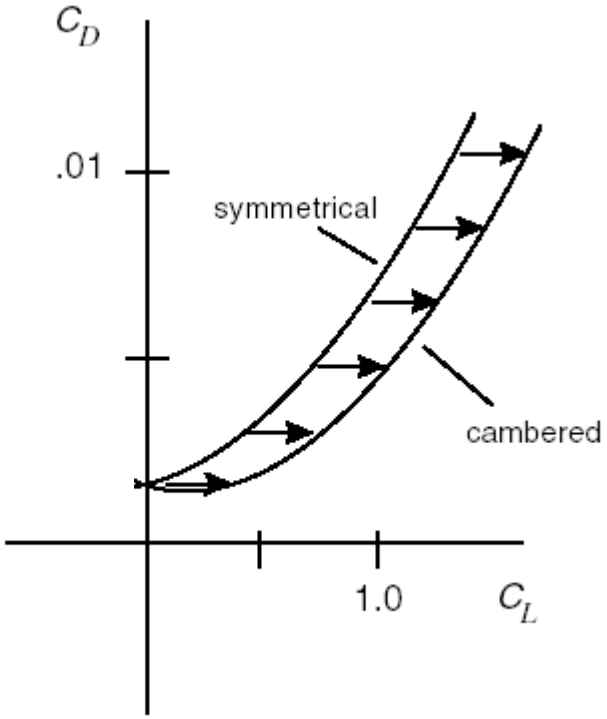
- You and your partner are Senior Aerodynamics Consultants at BlueSky Enterprises. Your clients have challenged you to apply your extensive aerodynamics expertise to design an innovation for an existing product or service of your choosing.
- They want your answer in 10 minutes.
- Prepare a 1-minute pitch on your product innovation to present to the clients.
- Caveat: You can't pick any of the aerodynamics application areas we discussed earlier! Be creative.

Effects of camber

Lift Curve



Drag Polar Curve



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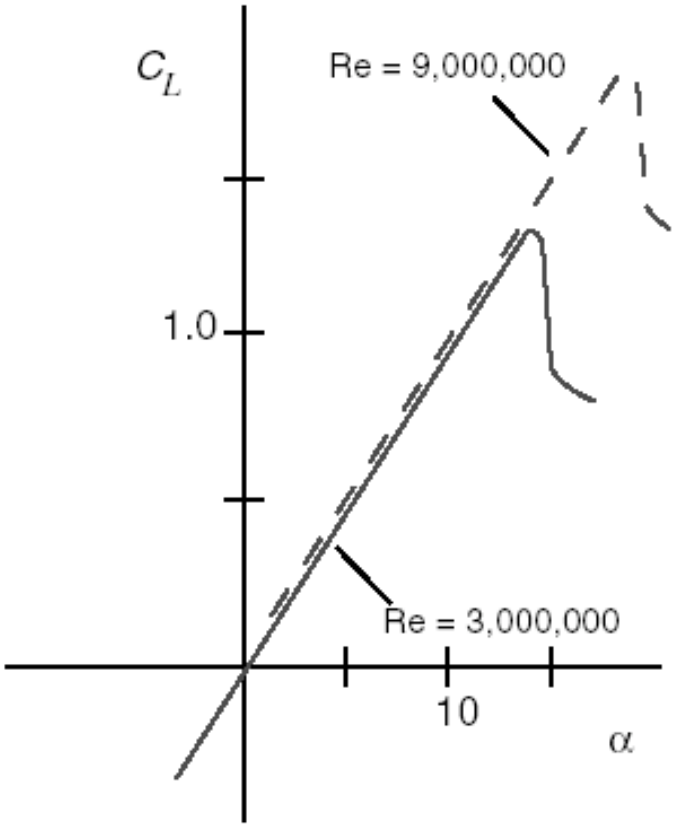
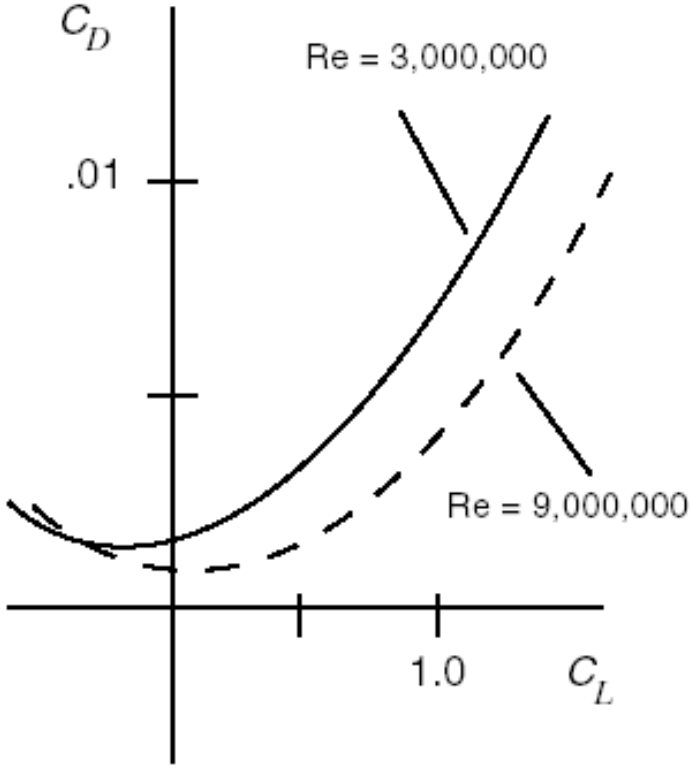
Effect of skin friction drag

Lift Curve



Drag Curve



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