Aero 101 for R/C Pilots
Part 2

Brian D. Kelly

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MAR/C

MARYMOOR R/C CLUB

Common Questions from RC Pilots

Part 1 (June 2017)

Before takeoff

- Will this plane be stable?

Takeoff

- How does the prop affect the airplane?
- Do I need right thrust?
- Wind
- Is the “downwind turn” a myth?

Cruise

- How to fine-tune the cg
- Do I need down thrust?

General Handling

- Plane snaps out of a tight turn
- Does dihedral help or hinder me?
- Won’t respond to aileron when slow
- Unstable or too sensitive?

Part 2 (Feb 2018)

Approach

- How can I slow down safely?
- Should I re-trim for approach?
- Use elevator or thrust?
- What will flaps do?
- Handling Crosswinds

Judge what a new plane will be like

- Wing Loading and stall speed
- Power loading
- Aspect Ratio
- Servo size

Part 3

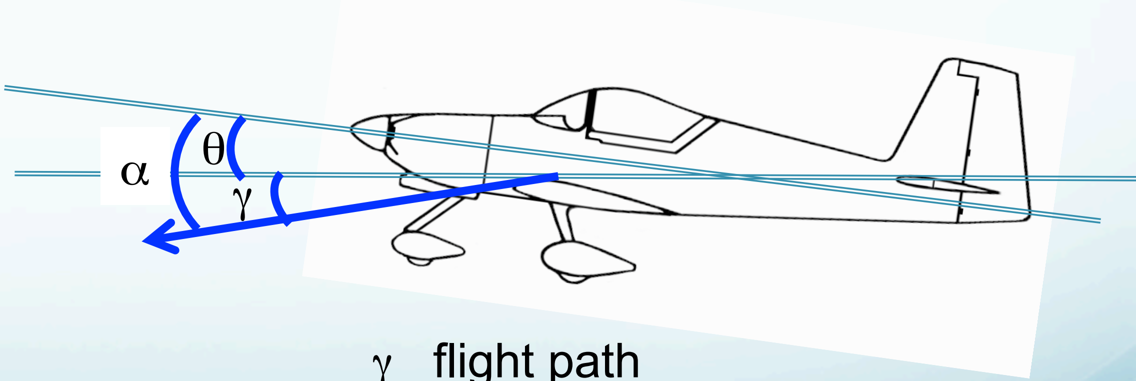
- How can I use my computer transmitter to make the airplane more enjoyable or easier to fly?

How slow can I go on approach?

- Full Scale planes use 1.3 x Stall Speed
  - enough speed to avoid stall while turning onto final approach and deal with some turbulence and pilot lack of precision
- Stall Speed:
  - Wing (Airfoil, Wing Area, Planform, Flaps)
  - Weight
  - Load Factor (G’s) (Bank Angle)

Problem: No Airspeed Indicator

- We eyeball *ground* speed and angle of attack
- We might hold the nose up a little to cause a lower glide speed
- Requires skill, and not every approach is at the same speed



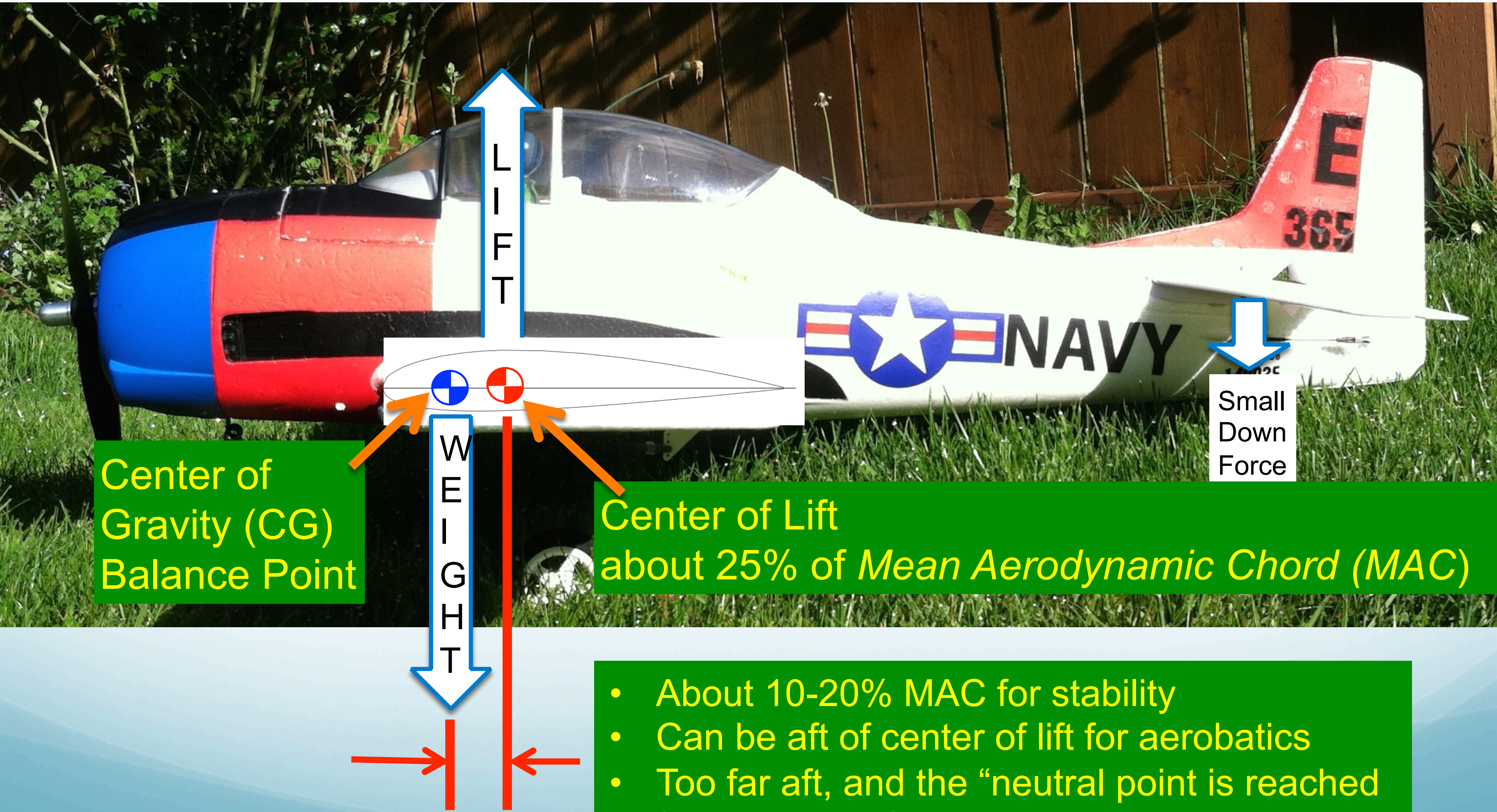
γ flight path
θ pitch
α angle of attack

How do **YOU** control speed on the approach?

- Just throttle back and glide
- Hold some UP elevator
- Re-trim the airplane to add some UP elevator
  (like full scale airplanes)
- Some combination
- Not sure – sub-conscious skill !!

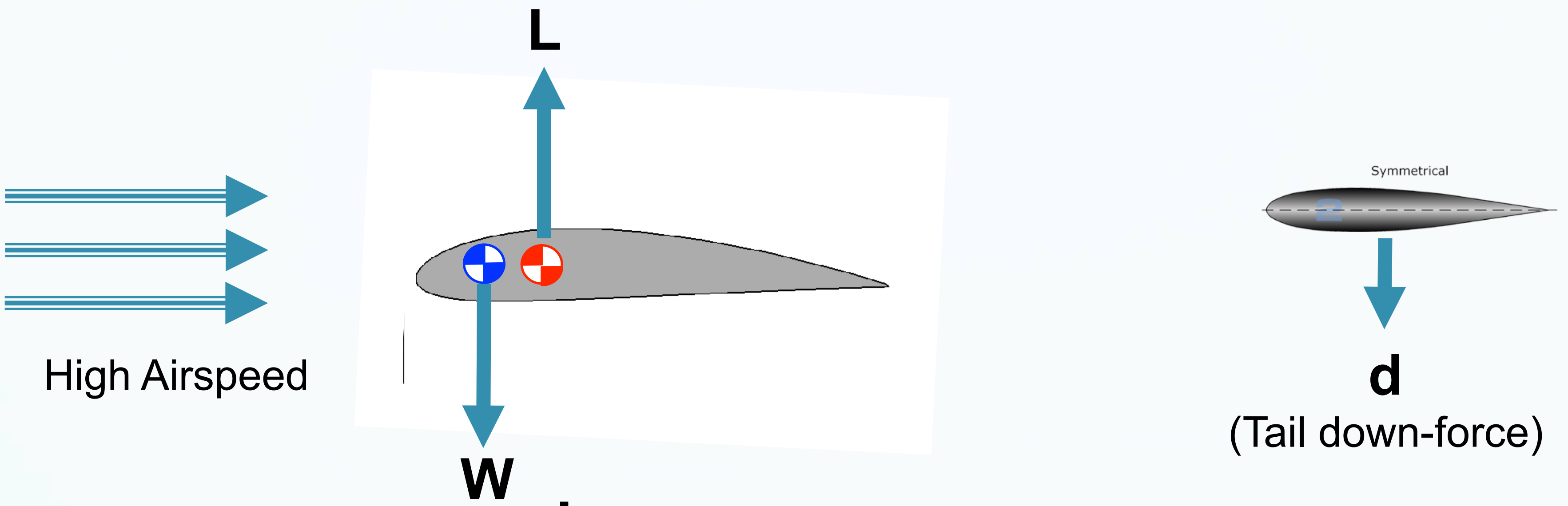
- **The best technique depends on CG, or balance point**
- **Wait, what?**

Centers of Lift and Gravity Determine Pitch and Speed Stability

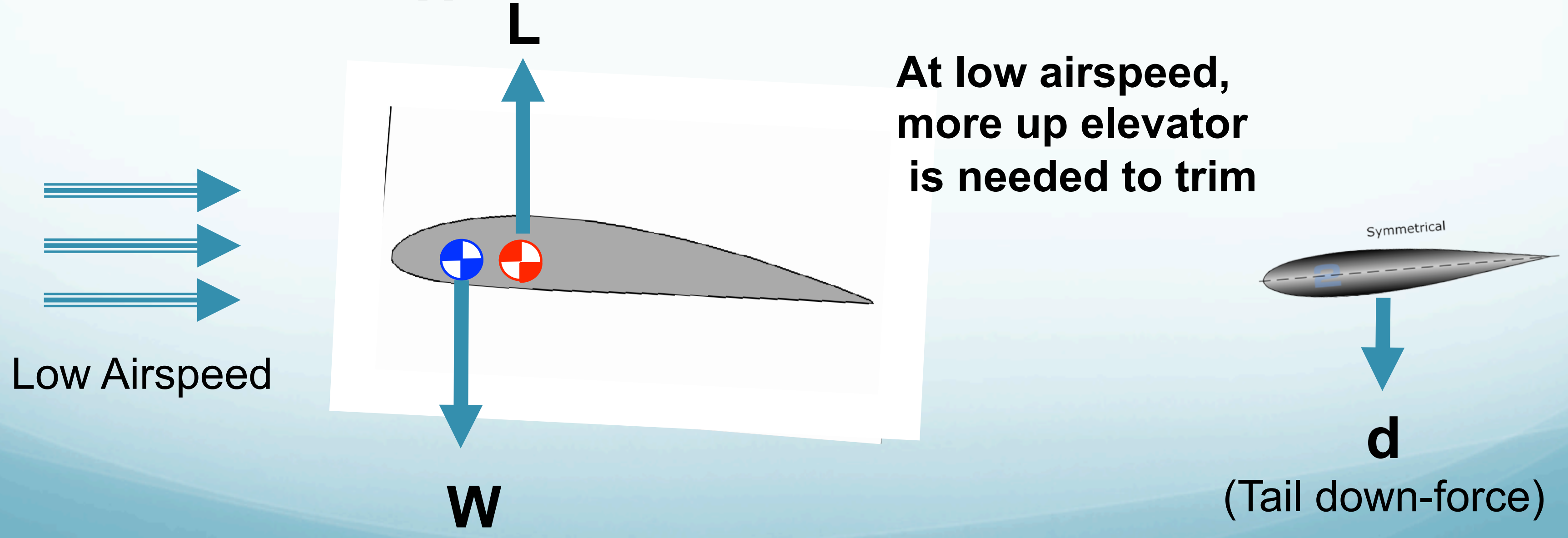


- About 10-20% MAC for stability
- Can be aft of center of lift for aerobatics
- Too far aft, and the “neutral point is reached (truly unstable)

Trimmed Flight for Stable Airplane

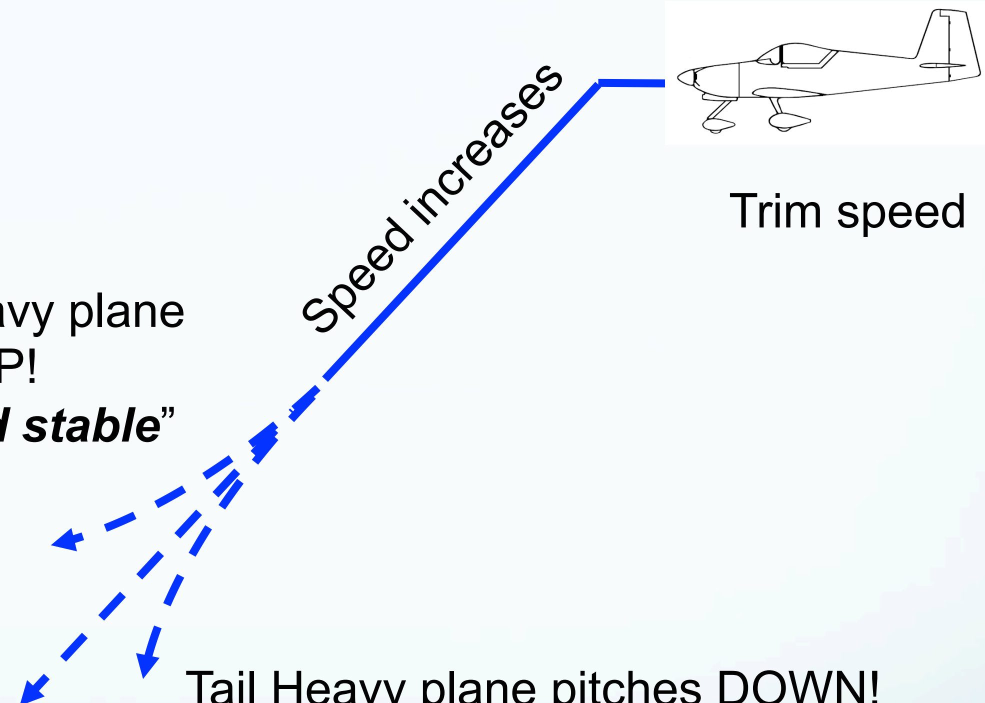


At low airspeed, more up elevator is needed to trim



Response to Speed Changes

- Trim for mid to low power
- Fly high and level
- Nose down about 45^{o}
- Hands off controls
- Let airplane accelerate
- Observe pitch



Another way:
http://www.flyrc.com/aerobatic-trimming/

Should I Re-Trim for the Approach?

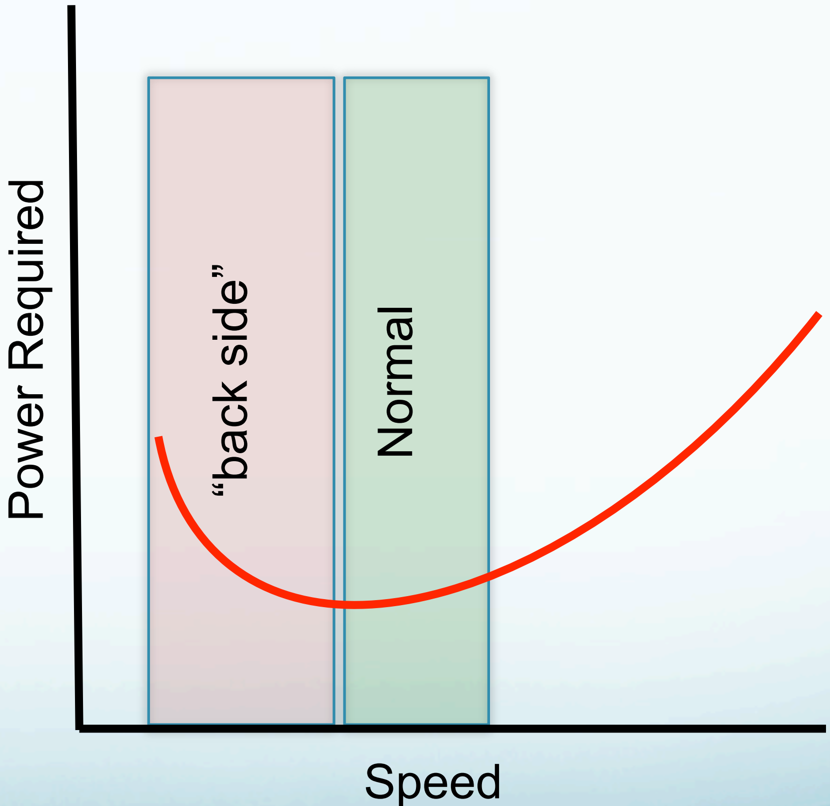
- If your plane is ***speed-stable*** (a little nose heavy), and trimmed for "cruise"
  - Hold UP elevator to glide slower on approach
    (Down-thrust reduces the need for this)
  - OR re-trim for approach speed (put in some up-trim)
  - OR program transmitter to put in some UP elevator on a switch
  - OR program elevator with flaps to achieve low trimmed speed
- If your plane is neutrally stable (dive test)
  - no re-trimming needed any time
  - somewhat more difficult to fly approaches consistently, but "expert" pilots have no trouble

How to find the trim setting for Approach Speed

- **Get comfortable practicing stalls at high altitude**
- Cruise slowly at about 1/3 power
- Trim the plane for hands-off level flight (elevator trim)
- Glide at zero power, no elevator input – trim again if needed for nice glide at approach speed
- Do 45^{o} bank turns to ensure stall margin
- Pull into a stall during the turn to “feel” stall margin
- Do approaches without holding elevator to see what speed the glide is
- Airplane should seek and hold a reasonable speed during the approach without having to hold elevator
- Be ready for large pitch-up during a go-around

Should I Control Altitude with Elevator or Thrust on Approach?

- If speed is high, elevator works for altitude control
- If too slow, power required increases when pitch up - “back side of power curve”
- Normal approach is slow, but not “back side” (unless very low aspect ratio)

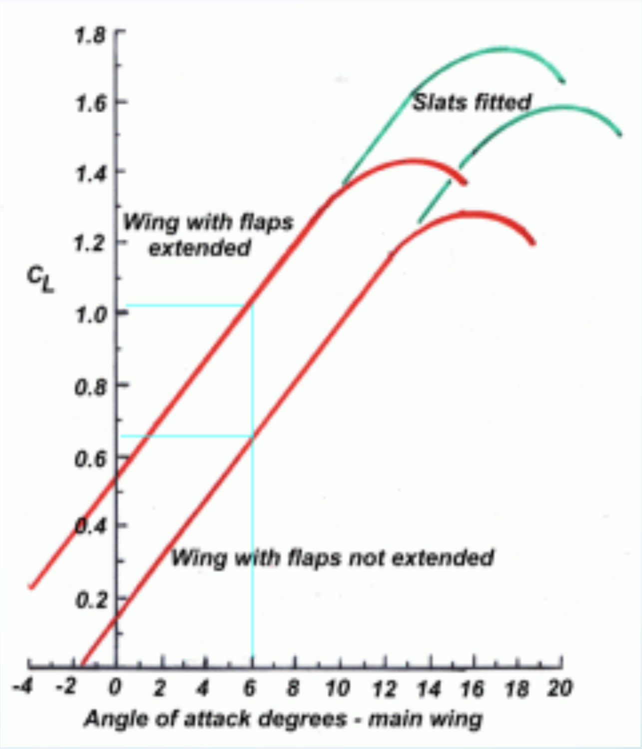


Answer?

- On approach, make small altitude corrections
  -- with elevator if you are fast (but you shouldn't be)
  -- with power if you are slow
- Always strive for a "stabilized approach" – nice and straight with small corrections
- Ideally, trim for a hands-off approach, and make small altitude corrections with power

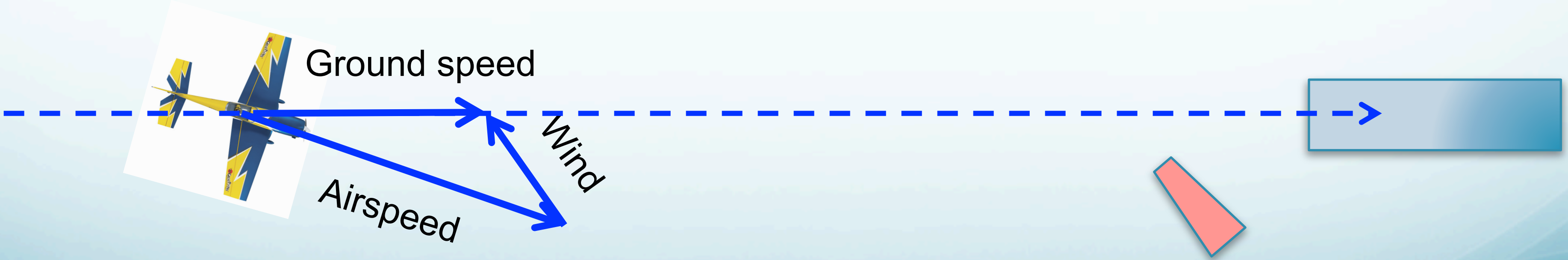
What will happen with Flaps?

- Max lift coefficient, C_{lmax} increases
- Stall speed decreases
- Drag increases
  - A little power might be needed
- Airplane may pitch (usually up)
- Approach will be more nose down
- Use same technique to trim for approach speed
  - Use flap>elevator correction to trim for approach speed when flaps are down



Wind on the Approach

- Check the sock or feel the wind on your neck
- Hold wings level on approach, and watch for drift
- If drift, make a small turn, level wings, and assess again
- Holding a crab angle is simply holding a heading with wings level – no need to hold rudder or aileron
- Holding rudder will introduce unwanted roll in trainers



Wind at touchdown

- Full scale technique is to lower the upwind wing to counter crosswind, and align fuselage to the runway with the rudder a bit before touchdown.
- RC pilots of large airplanes on paved runways might use this technique – not easy!
- Luckily, less wind close to the ground
- With a grass field, landing in a crab is no problem

Judging what a new plane will be like

- Wing Loading, airfoil, stall speed
- Wing "Cubic Loading"
- Power Loading
- Aspect Ratio
- Servo torque requirements

Wing Loading

- Ounces of airplane weight per square foot of wing area
- Wing loading = Weight (oz.) / Wing area (square feet)
- Higher wing loading = higher stall speed
- Low: 5-15
  - Trainers, light foamies
- Medium: 15-30
  - Sport planes, some 3D planes
- High: 40 - 50 oz./ft^2
  - Large Warbirds
  - Mr. Mulligan

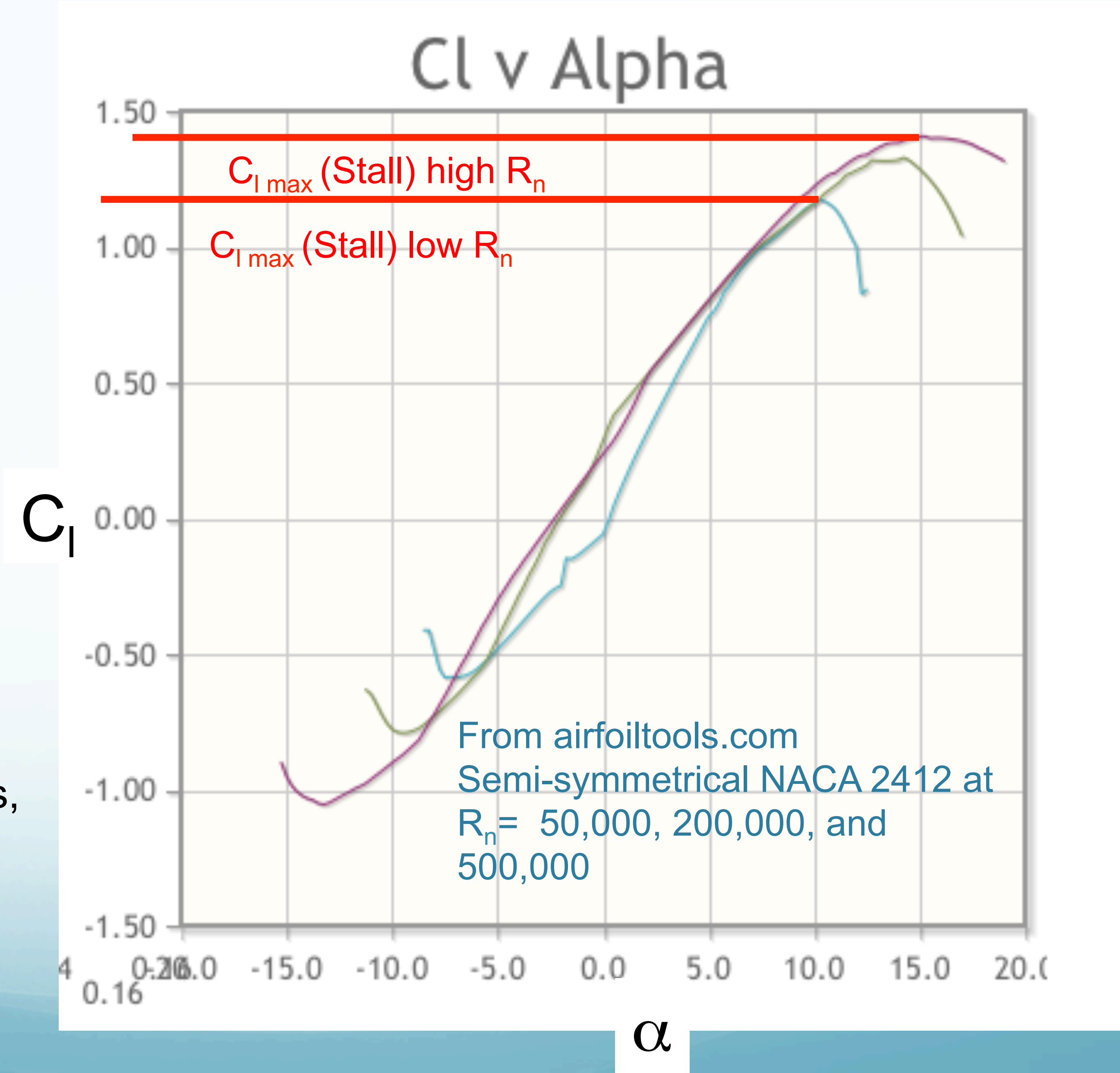
Stall occurs at Maximum Lift Coefficient

We fly at low Reynolds numbers

C_{lmax} around 1.2 for typical airfoils

A little more for high camber and flat bottom airfoils, about 1.4

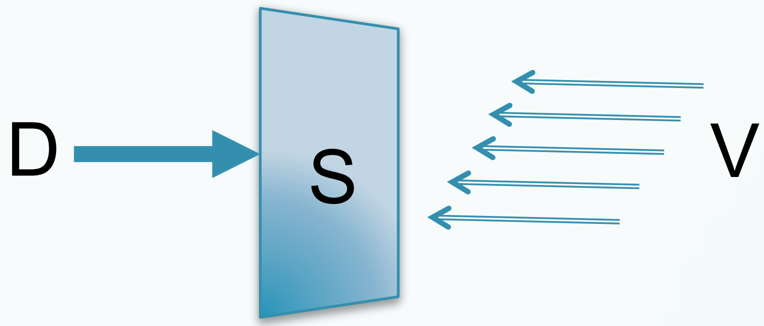
C_{Lmax} for the whole wing is lower due to tip effects, maybe 20-30%



Lift Coefficient and Dynamic Pressure

- Dynamic Pressure (aka “flat plate drag)
  - q is dynamic pressure in pounds per square foot
  - ρ (Greek letter rho) is density of air. 0.002378 slugs/ft^3 at sea level
  - V is velocity, or speed, in feet per second

$$q = \frac{1}{2} \rho V^2$$



Flat Plate

Lift = C_L q S

C_L is *Coefficient of Lift*
S is the *reference area*,
(usually wing area)

Drag = C_d q S

C_d is *Coefficient of Drag*
S is the *reference area*
(usually frontal area)

How to Calculate Stall Speed

$L = C_L \, q \, S$

$L = C_L \, \tfrac{1}{2} \rho \, \mathbf{V}^2 \, S$ Lift = Weight

$V = \sqrt{2W / (C_L \, \rho \, S)}$

$V_{\text{stall feet per sec}} = \sqrt{2W / (C_{Lmax} \, \rho \, S)}$

$\rho = 0.002378$ slugs/ft^3
W = weight in pounds
S = Wing area in square feet
V = speed in ft/sec

$Ft^2 = in^2 / 144$

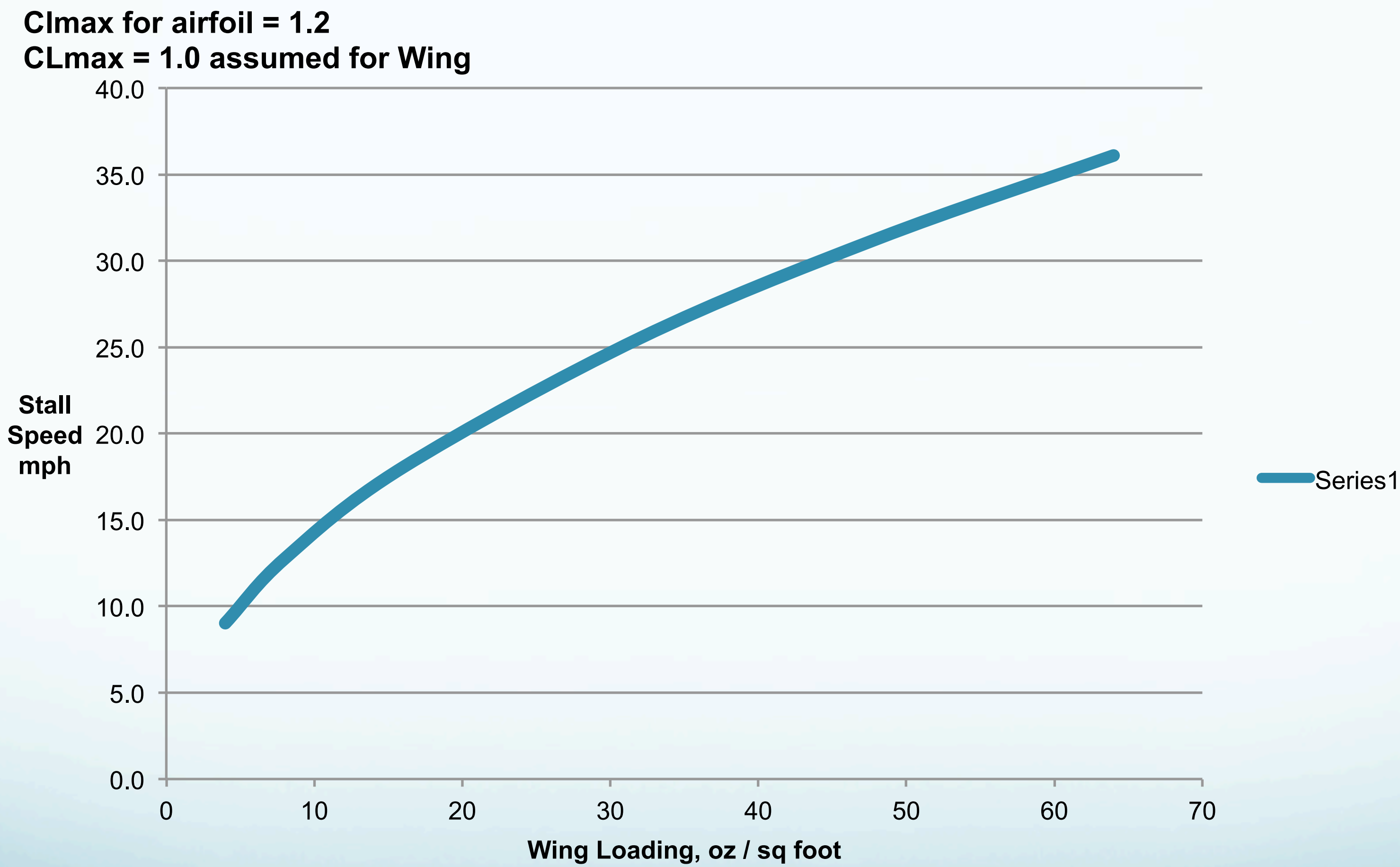
$V_{mph} = V_{ft/sec} \times 0.68$

Get C_{lmax} for ***airfoil*** from airfoiltools.com – use data for low Reynolds number

Crudely estimate C_{Lmax} for the *wing* by reducing C_{lmax} for *airfoil* by 20-30%

- **More reduction for low Aspect Ratio, e.g. many jets**
- **Less reduction for higher Aspect Ratio**

Estimate Stall Speed from Wing Loading

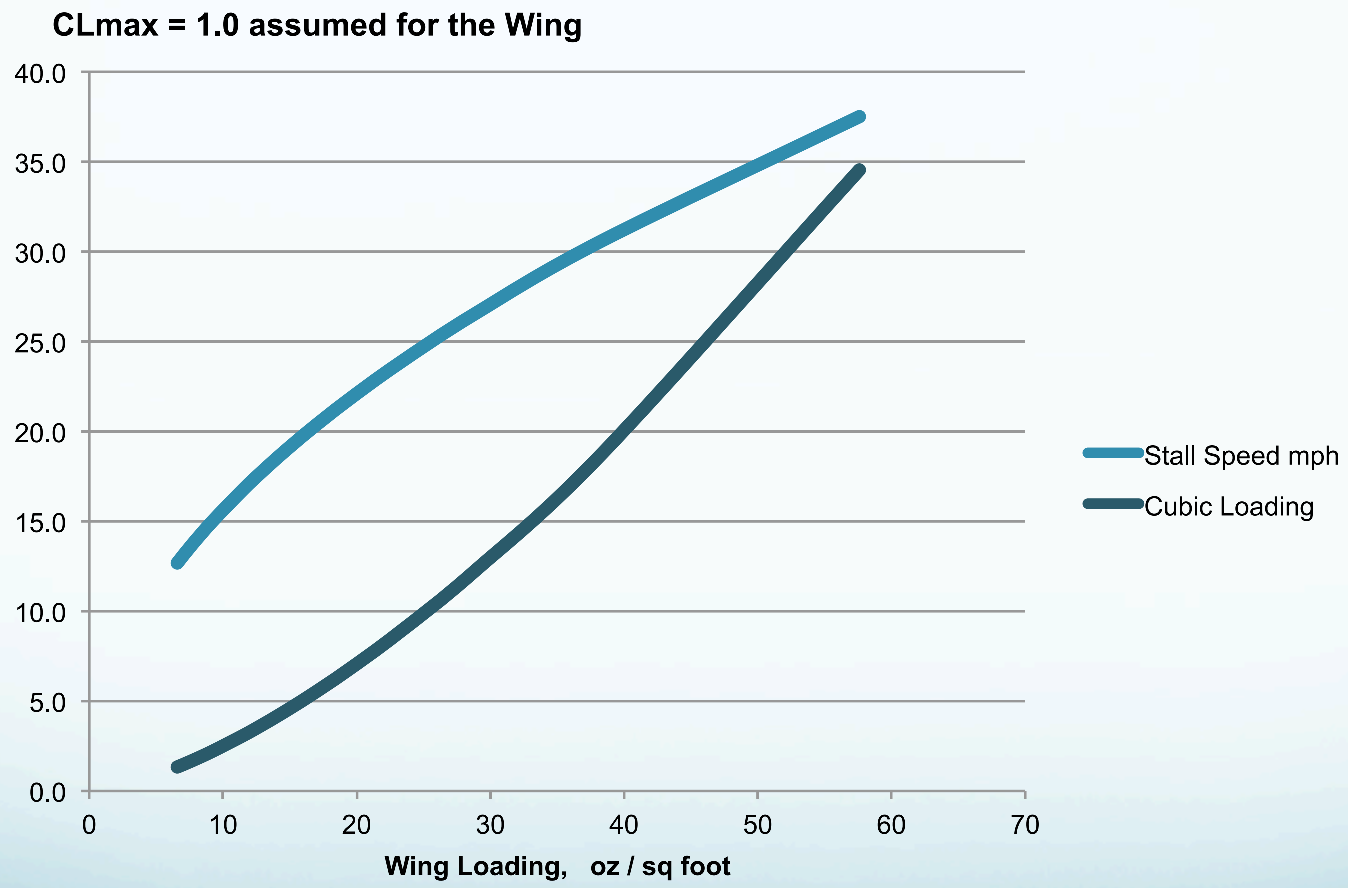


This estimate works for conventional configuration airplanes – not for delta planforms and scale jets

Wing Cube Loading

- Two airplanes of different size will seem more similar in flight if they have the same WCL.
- Accounts for larger airplanes seeming slower and having proportionally lower stall speeds
- Works for similar configurations and similar power loading
- See a thorough explanation by Francis Reynolds at:
  http://www.theampeer.org/CWL/reynolds.htm
- WCL = oz. / (wing sq. feet)$^{1.5}$

Wing Loading, Cubic Loading, and Stall Speed

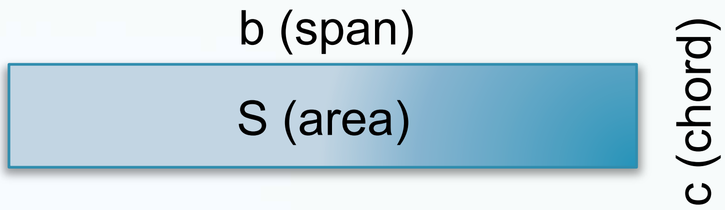


Power Loading

Airplane Type	Watts per pound	Horsepower per pound	Cu. Inches per pound	Cubic centimeters per pound
Slow Flyer	50	.07	.04	.67
Powered glider	50-80	.07 - .11	.05	.87
Sport Flying, aerobatics, warbirds	80-120	.11 - .16	.08	1.34
Pattern	120-180	.16 - .24	.12	2.01
Faster jets, 3D	180-200+	.24 - .27 +	.16	2.55

- Based on 10cc/hp for OS GT60 2-stroke gas engine
- Results differ for 4-stroke, and multiple cylinders

Aspect Ratio

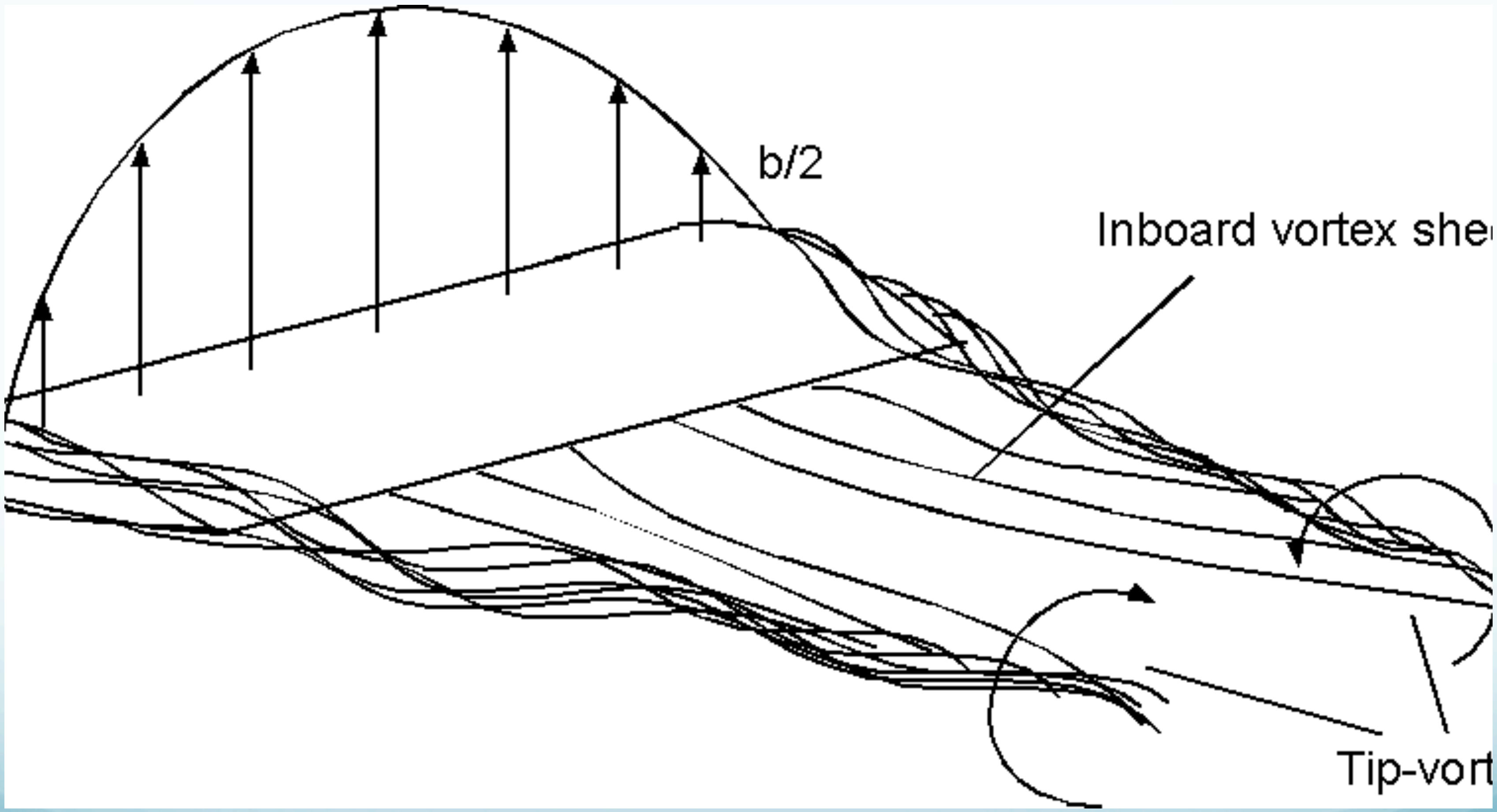


AR = b/c for a rectangular wing

Or..

AR = b^2/S for any planform

Aspect Ratio



Low AR planes fly approach on "back-side" of power curve

- Much drag at approach speeds
- Thrust MUST be used to control altitude
- UP elevator will increase drag so much that speed will drop and airplane will descend!

Lift and Drag for a Total Airplane

- Total Drag = Parasite Drag + Induced Drag
  - $C_D = C_{dp} + C_{di}$

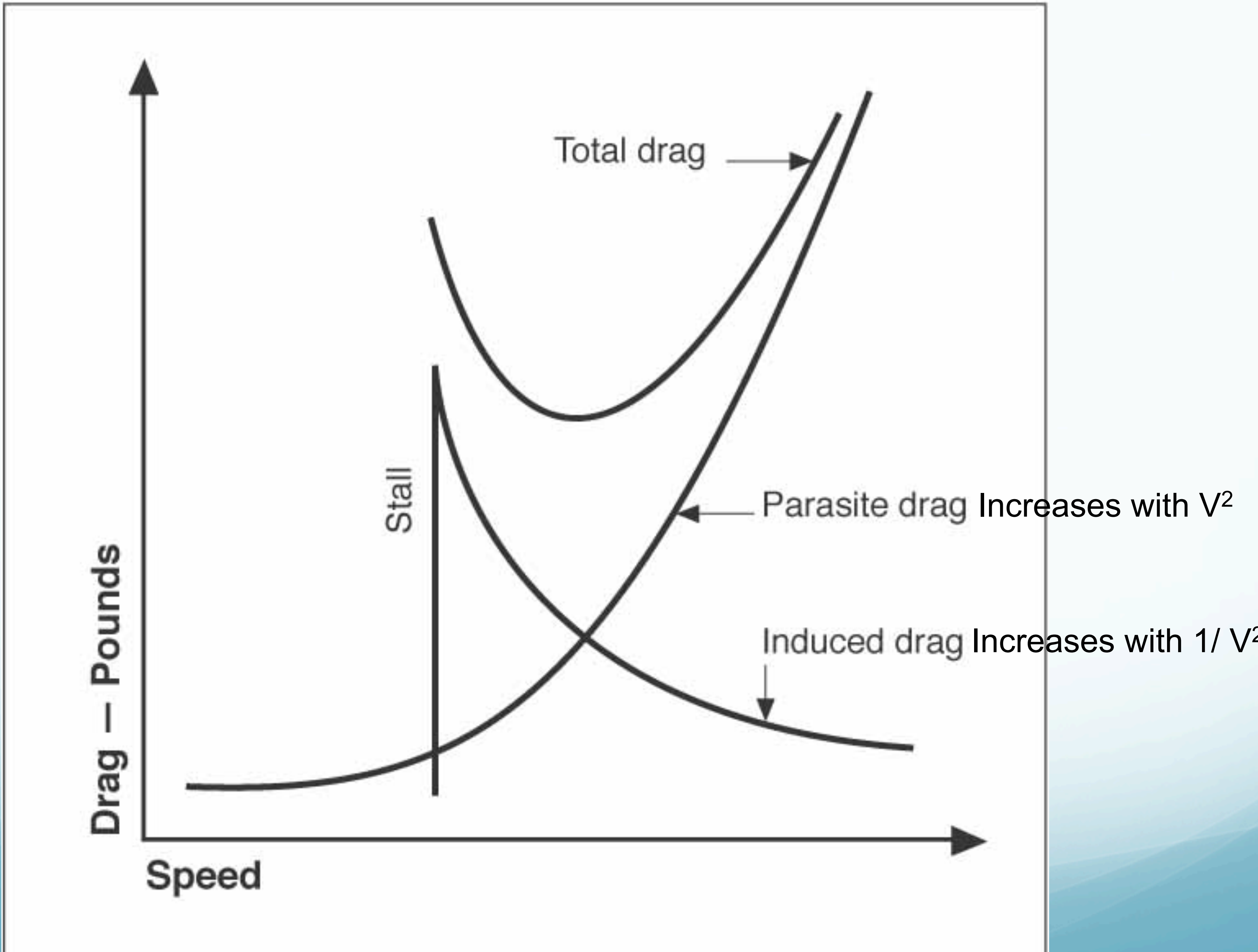
- *Parasite Drag*, C_{dp} is *skin friction + pressure drag (aka form drag)*
  - *Measured when Lift = 0*

- *Induced Drag, C_{di}, aka* "Drag due to lift"

  $C_{di} = C_L^2 / (\pi e AR)$

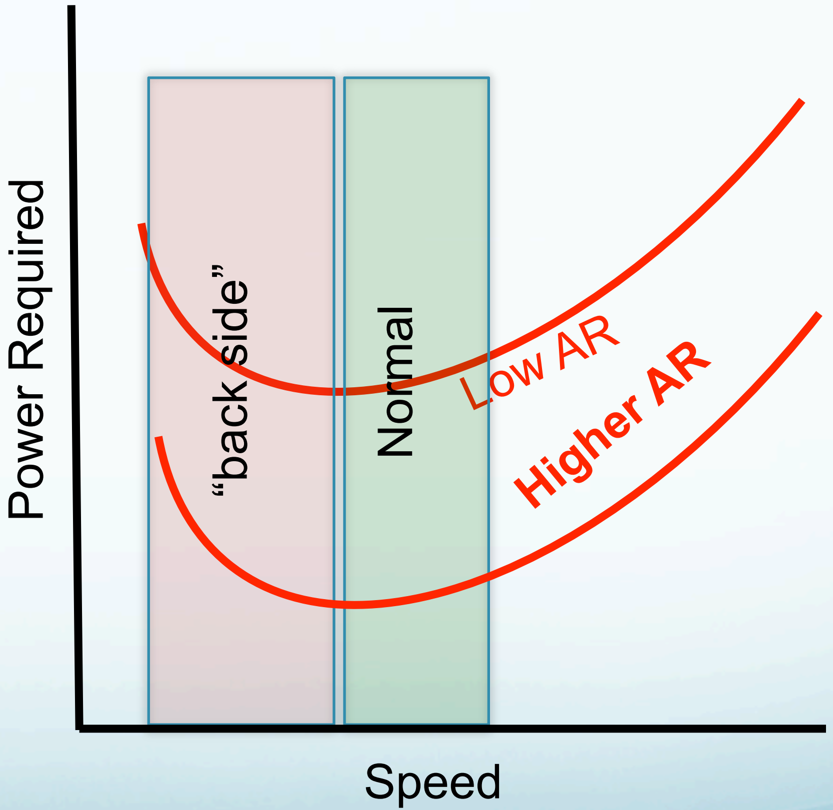
  - e is an efficiency factor for the wing, how close it is to the "ideal" elliptical lift distribution
  - AR is Aspect Ratio = $Span^2$ / Area

- At the speed for best L/D, Induced Drag is equal to parasite drag!

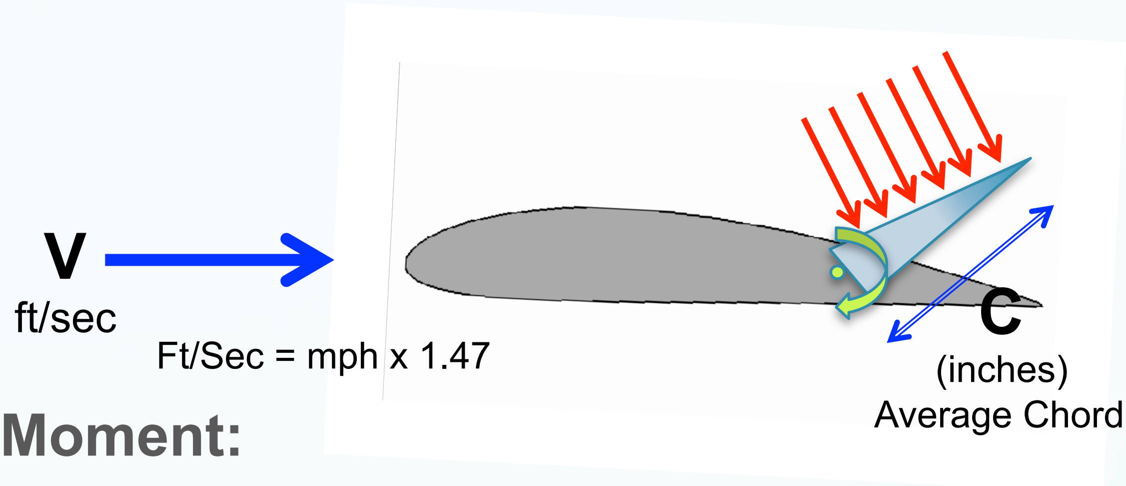

Total drag
Parasite drag Increases with V2
Induced drag Increases with 1/ V2
Stall
Drag – Pounds
Speed

Effect of Low Aspect Ratio

- *Induced Drag* (drag due to lift) becomes dominant quickly at low speeds
- Any effort to increase altitude with elevator reduces speed and increases drag immediately – and then altitude drops!
- Altitude must be controlled with thrust



How Big Should the Servo Be?



Crude Estimate of Hinge Moment:

- Assumptions:
  - Uniform pressure distribution
  - Pressure is dynamic pressure **$q = \frac{1}{2} \rho V^2$** (pounds per sq. foot)
- **Hinge moment = Force x lever arm**

= q x (sq in of surface) x C/2 x 16/144

= 0.5 x 0.002378 x (speed in ft/sec)^2 x C/2 x 16/144

= torque, oz - inches