# Aircraft Design
# Wing Design

Video

# Aircraft Design Process

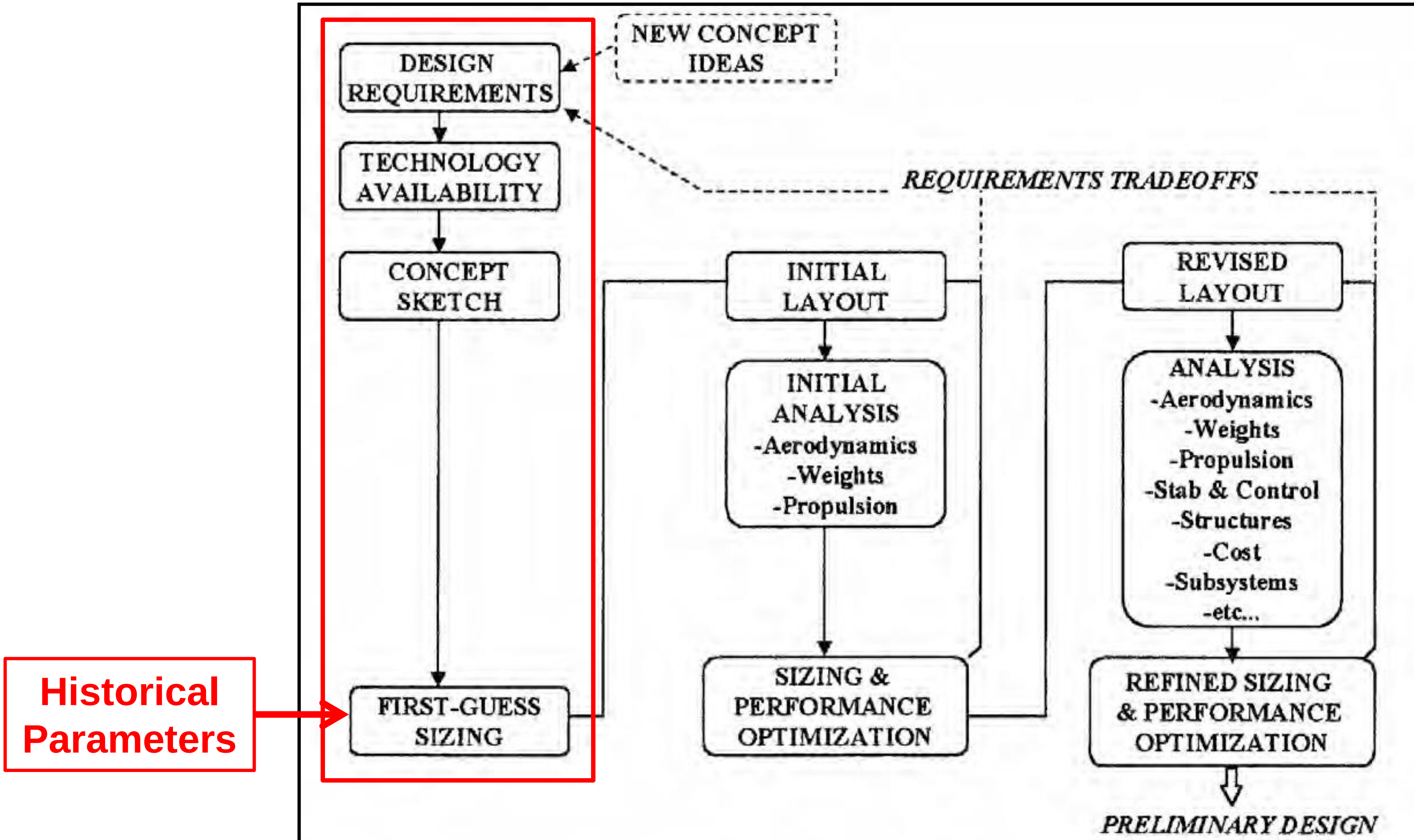



**Fig. 2.4 Aircraft conceptual design process.**

*"Aircraft Design: A Conceptual Approach"* by Daniel P. Raymer, page 9

# Finite Wing

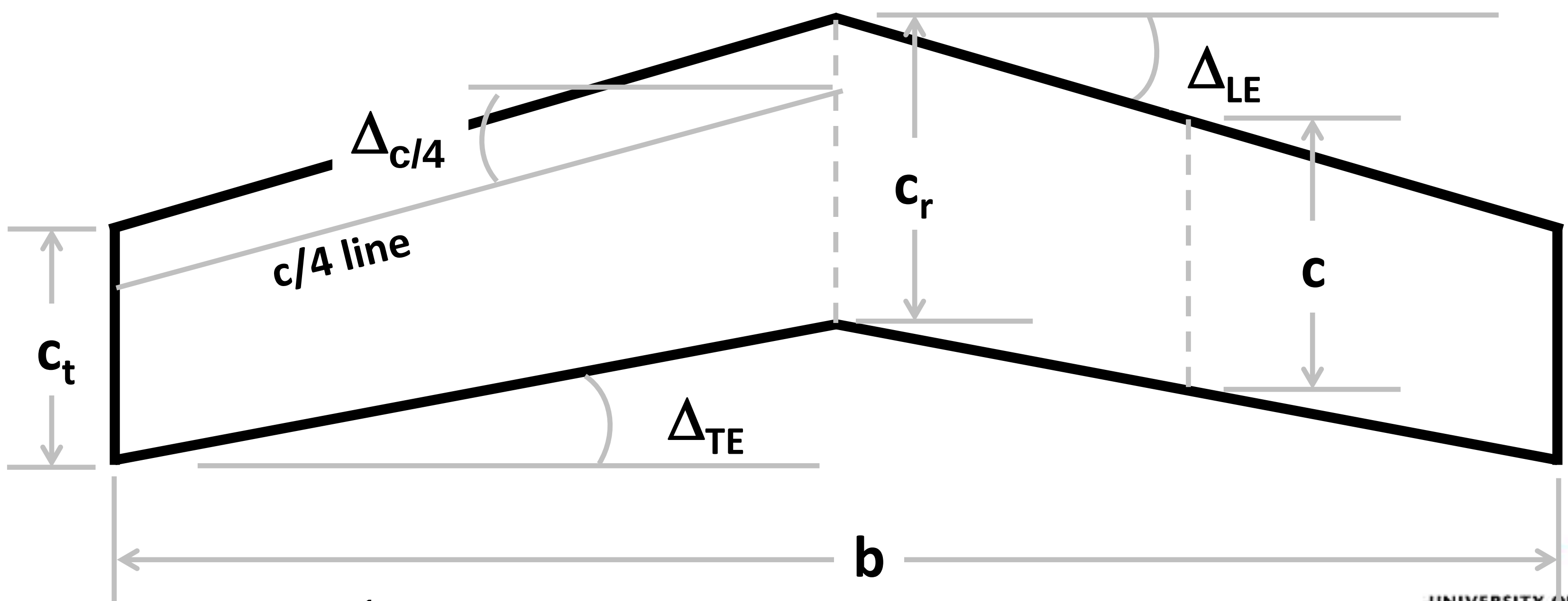
**Wing Planform Characteristics**

| | |
|---|---|
| Wing Area (S) | Leading Edge Sweep ($\Delta_{LE}$) |
| Wing Span (b) | Trailing Edge Sweep ($\Delta_{TE}$) |
| Average Chord (c) | Aspect Ratio (AR) |
| Root Chord ($c_r$) | Taper Ratio ($\lambda$) |
| Tip Chord ($c_t$) | Quarter-Chord Angle ($\Delta_{c/4}$) |

$$S = b\,c$$

$$AR = \frac{b^2}{S} = \frac{b}{c}$$

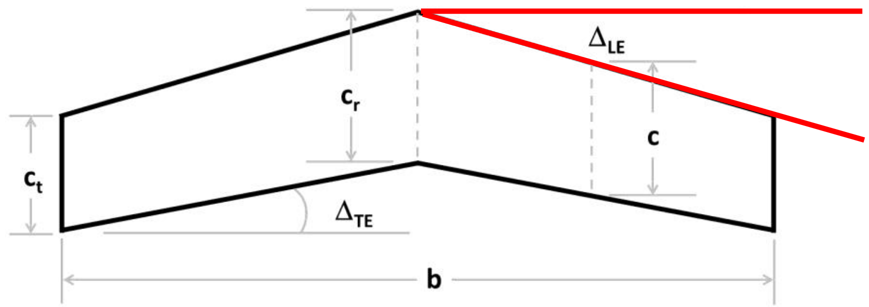
$$\lambda = \frac{c_t}{c_r}$$




$$\Delta_{c/4} = \tan^{-1}[\tan\Delta_{LE} - 0.25 * c_r * (1-\lambda)/(b/2)]$$

University of Cincinnati

# Aircraft Aerodynamics




**Wing Sweep (Δ)**

**Indicator of an aircraft's subsonic cruise speed**

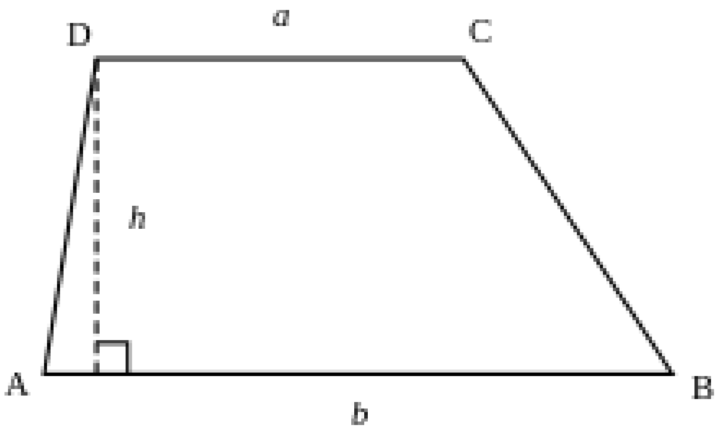
**Affects Divergence Mach Number**

**Low wing sweep (0 to 20 degrees) – sailplanes, gliders**
**High aspect ratio (AR = 20 - 25)**
**Slower cruise speed (0.2 - 0.6 Mach)**

**Medium wing sweep (20 to 40 degrees) – airliners, cargo, bombers**
**Medium aspect Ratio (AR = 8 - 10)**
**Moderate cruise speed (0.6 - 0.85 Mach)**

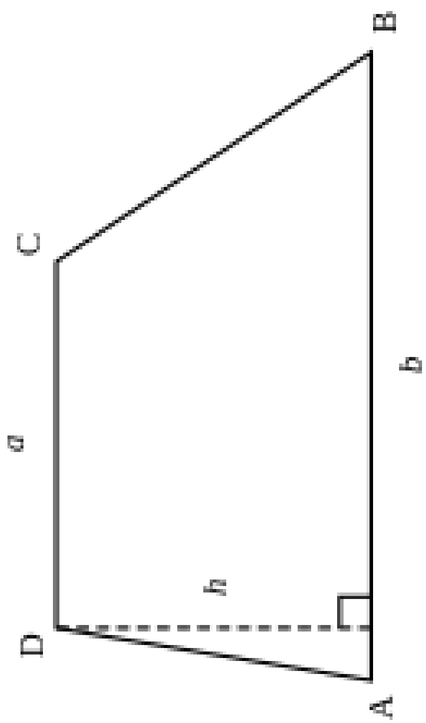
**High wing sweep (40 to 70 degrees) – fighters, supersonic aircraft**
**Low aspect ratio (AR = 2 - 4)**
**Faster cruise speeds (0.8 - 0.9 Mach)**

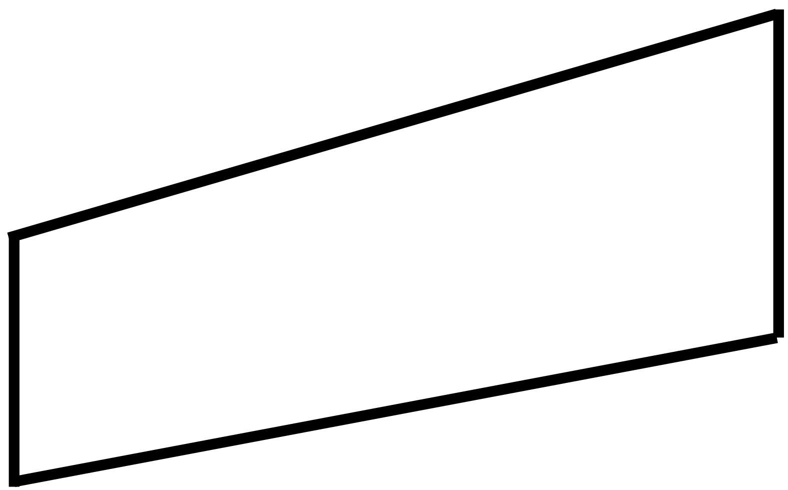
# Aircraft Wing Dimensions

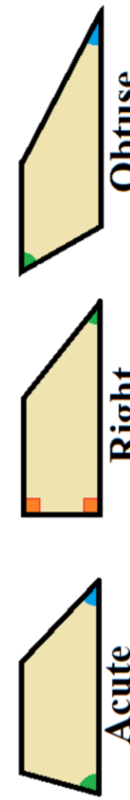



**Wing Planform Assumption**

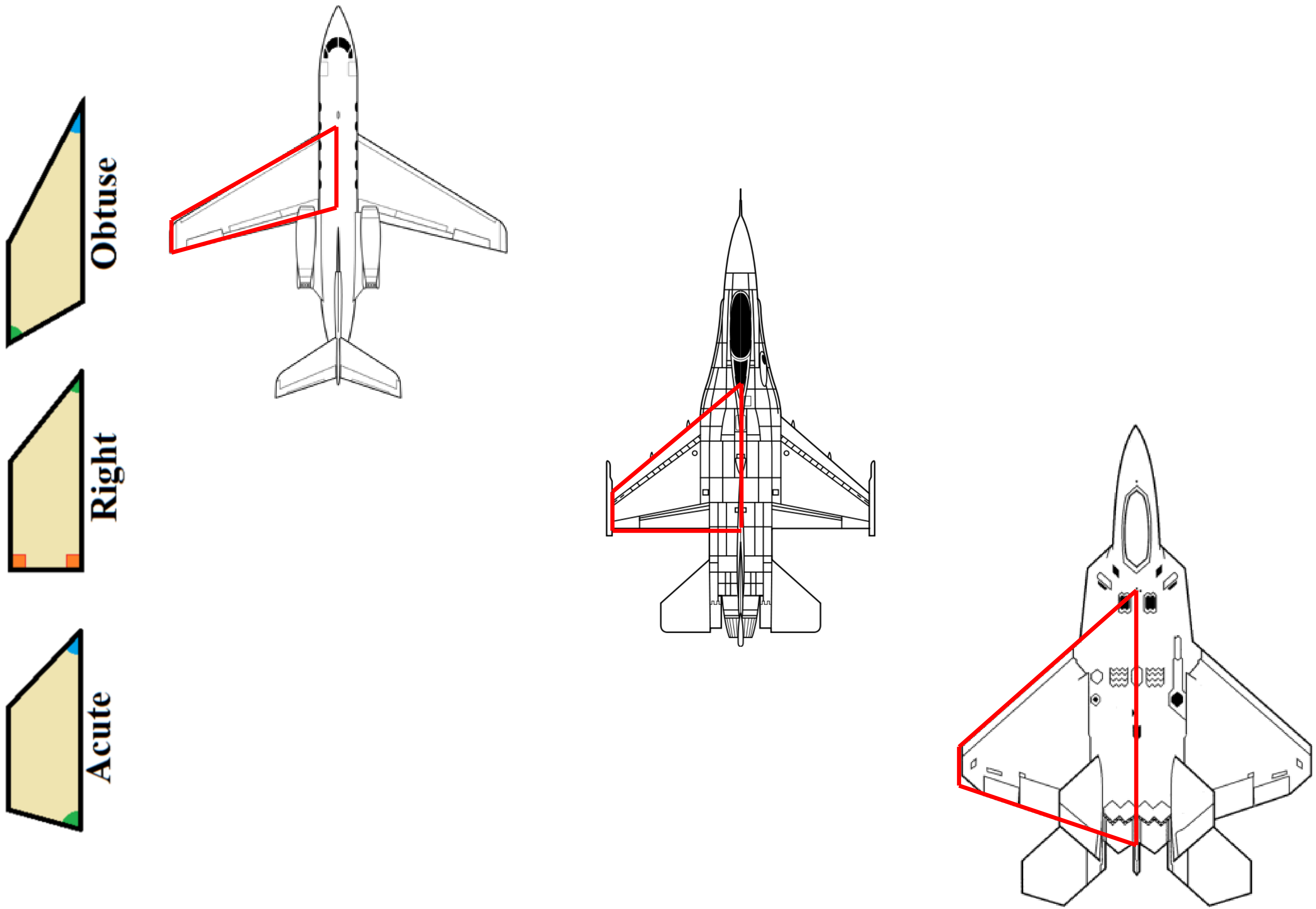
- Convex quadrilateral = trapezoid
- Acute, Right, or Obtuse Trapezoid



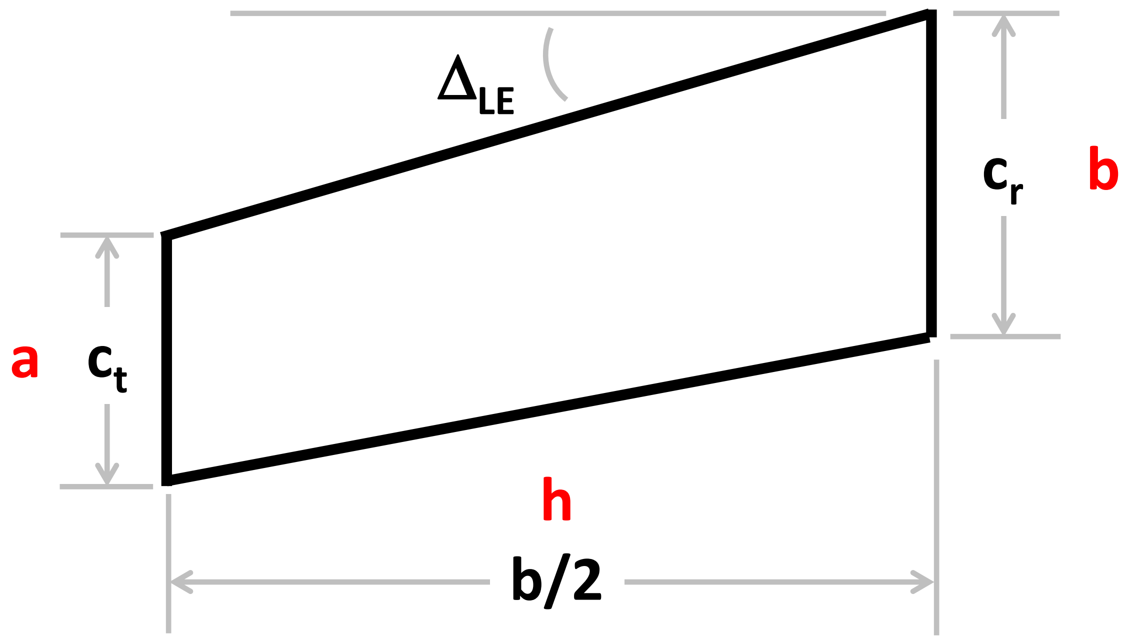





# Aircraft Wing Dimensions



# Aircraft Wing Dimensions



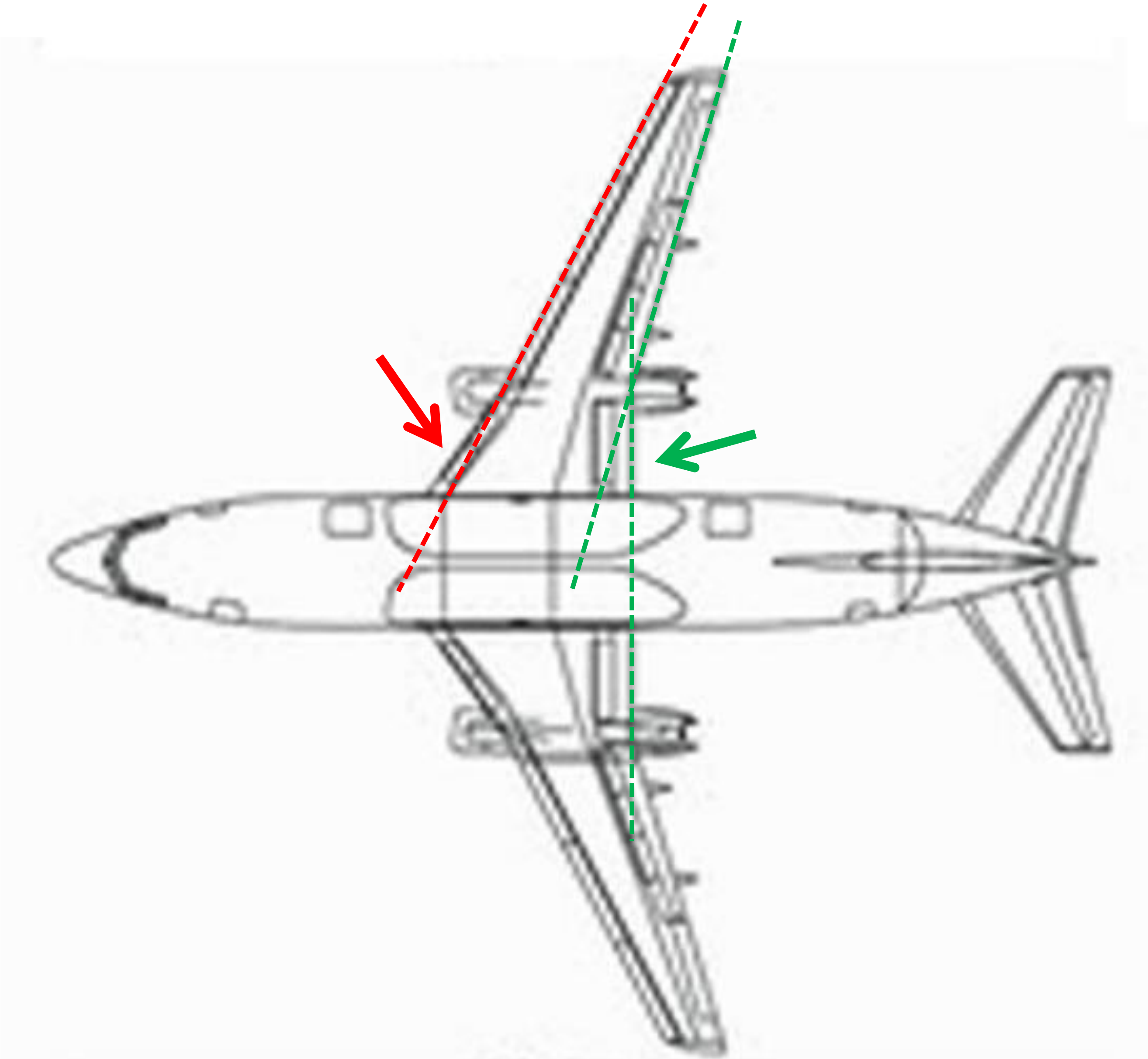

$$\text{Area of Trapezoid} = h * \frac{a+b}{2}$$

$$\text{Wing Area } (S_{trap}) = \frac{b}{2} * \frac{c_t + c_r}{2} \text{ x } 2 = b * \frac{c_t + c_r}{2}$$

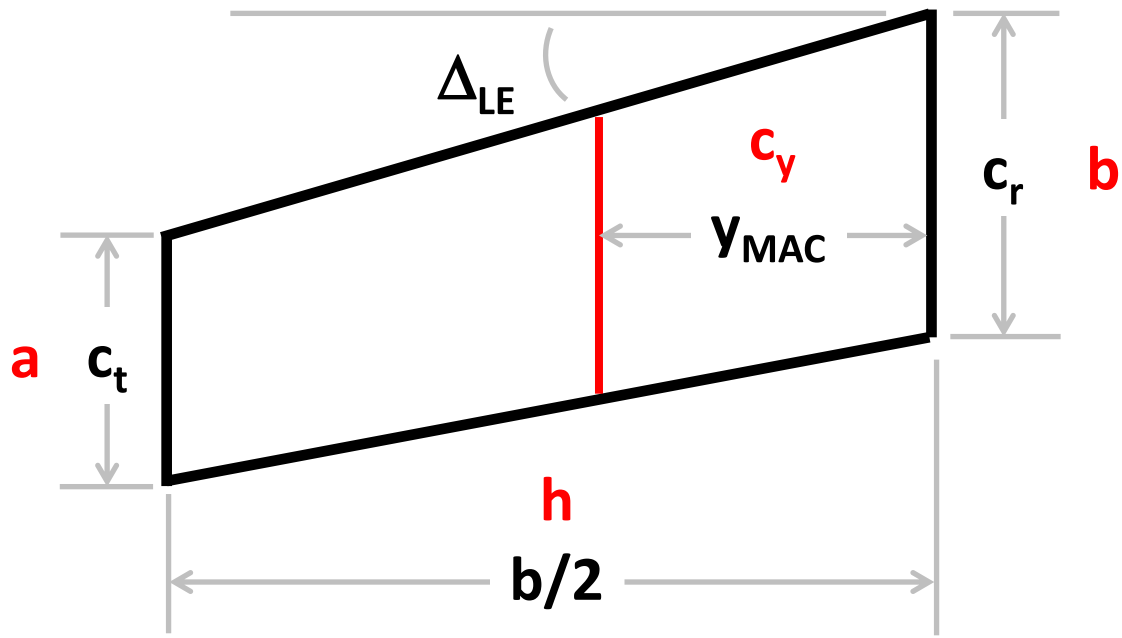
$$AR_{trap} = \frac{b^2}{S_{trap}} = \frac{b}{c}$$

UNIVERSITY OF Cincinnati

# Aircraft Wing Dimensions



# Aircraft Wing Dimensions




$$\text{Centroid of Trapezoid: } c_y = h * \frac{2a + b}{3(a+b)}$$

$$\text{Centroid of Wing: } y_{MAC} = \frac{b}{2} * \frac{2c_t + c_r}{3(c_t + c_r)}$$

University of Cincinnati

# Aircraft Wing Dimensions

$$y_{MAC} = \frac{b}{2} * \frac{2\,c_t + c_r}{3\,(c_t + c_r)}$$

$$y_{MAC} = \frac{b}{6} * \frac{2\,c_t + c_r}{c_t + c_r}$$

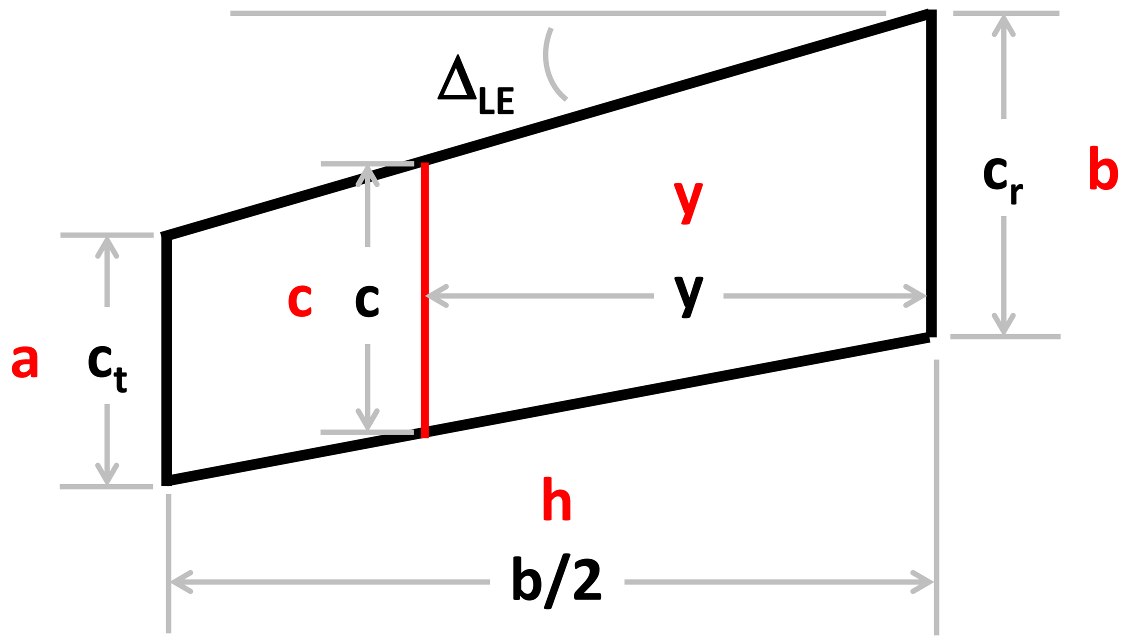
$$y_{MAC} = \frac{b}{6} * \frac{c_r\,(\,2\,\frac{c_t}{c_r} + 1\,)}{c_r\,(\,\frac{c_t}{c_r}\; +1\,)}$$

$$\lambda = \frac{c_t}{c_r}$$

$$\boxed{y_{MAC} = \frac{b}{6}\,\frac{1+2\lambda}{1+\lambda}}$$

UNIVERSITY OF Cincinnati

# Aircraft Wing Dimensions




The local chord length at any point y away from the longer side

$$c = b\left[1 - \left(1 - \frac{a}{b}\right)\frac{y}{h}\right]$$

$$c = c_r\left[1 - (1 - \lambda)\frac{y}{(b/2)}\right]$$

# Aircraft Wing Dimensions

**The local chord at any point y away the Root Chord**

$$\mathbf{c = c_r \left[1 - (1-\lambda)\frac{y}{(b/2)}\right]}$$

**We can substitute y with the equation for $y_{MAC}$**

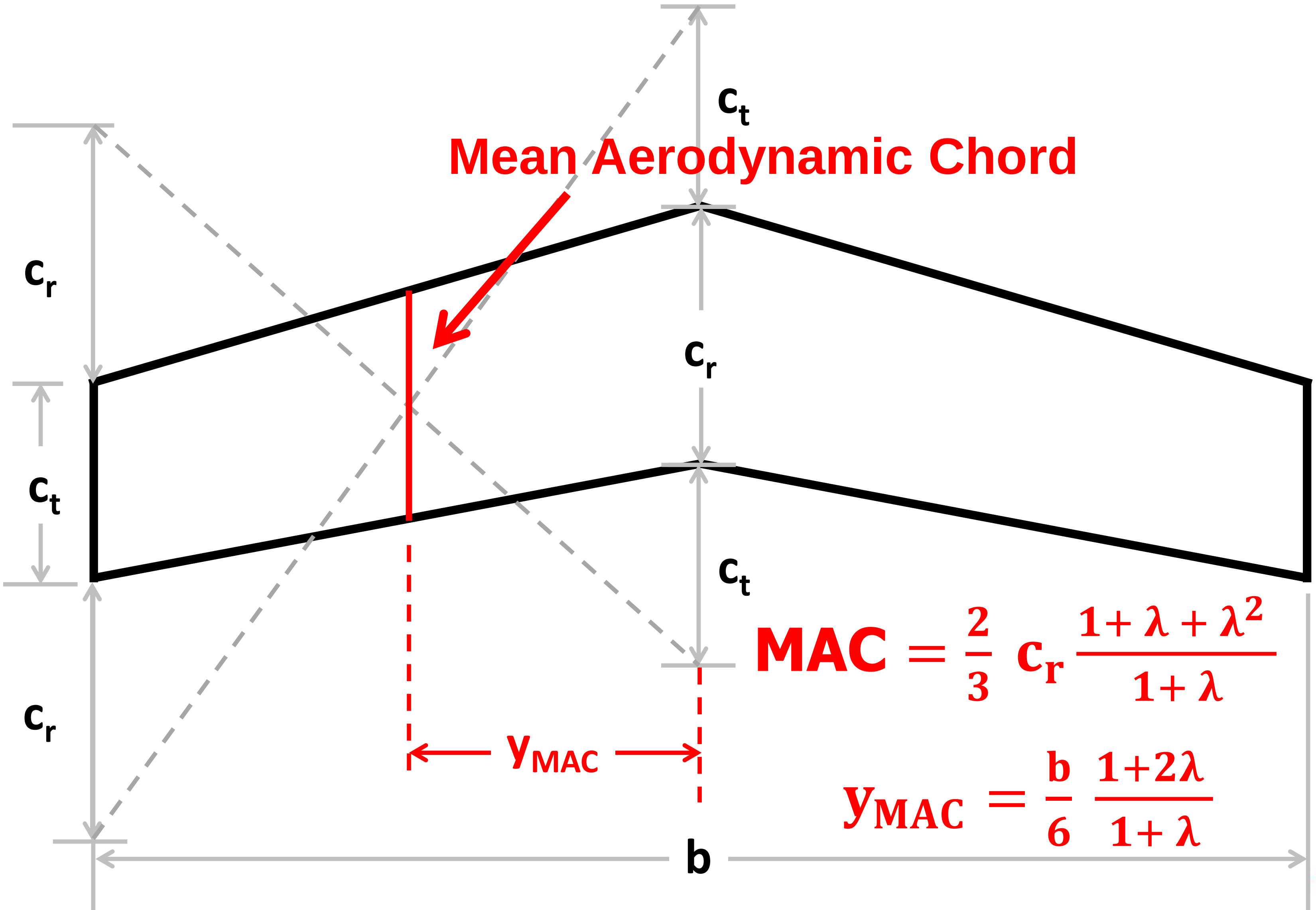
$$\mathbf{y = y_{MAC} = \frac{b}{6}\,\frac{1+2\lambda}{1+\lambda}}$$

**… lots of algebra will eventually yield …**

$$\boxed{\mathbf{MAC = \frac{2}{3}\,c_r\,\frac{1+\lambda+\lambda^2}{1+\lambda}}}$$

UNIVERSITY OF Cincinnati

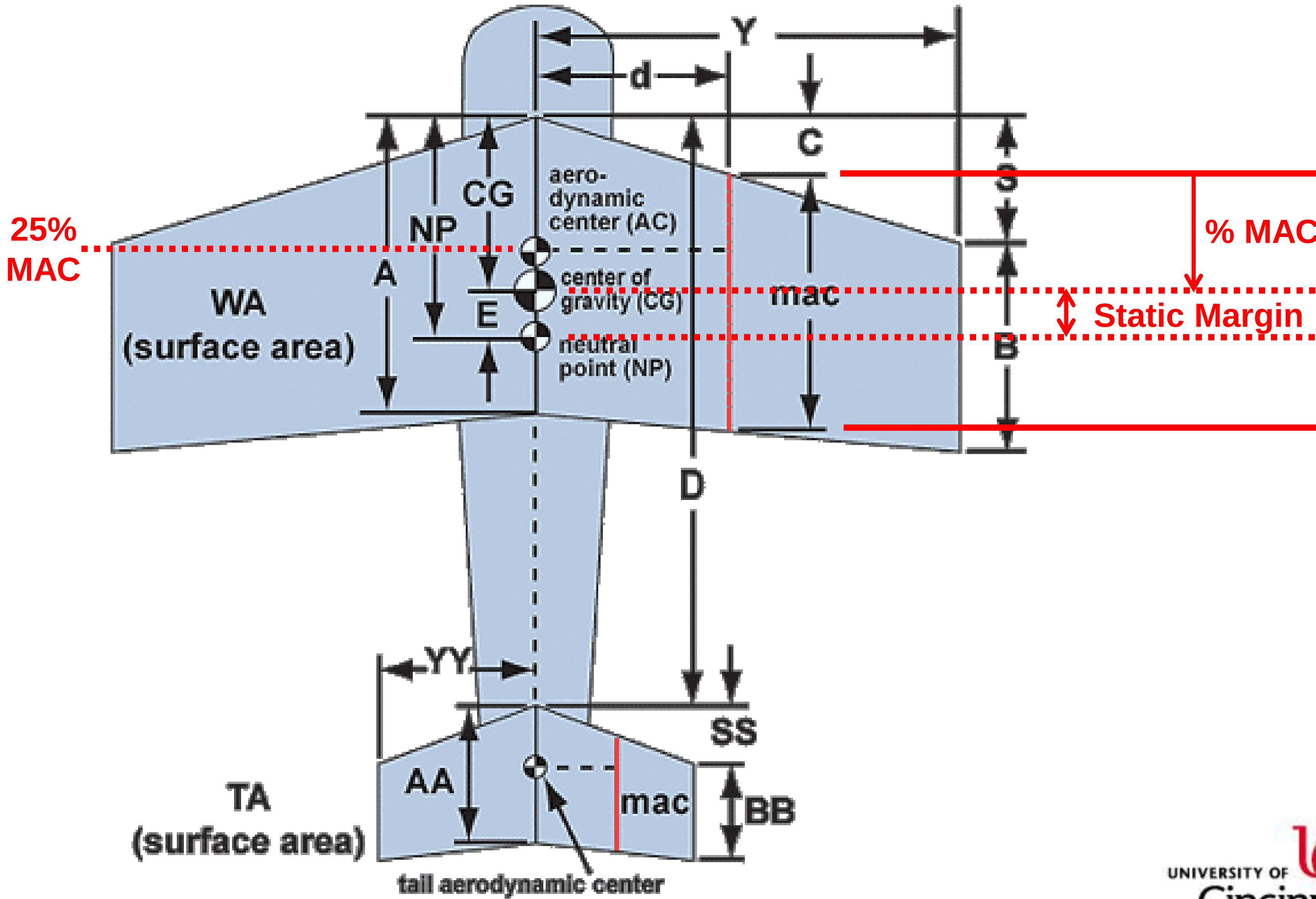
# MAC Graphical Determination




$$\mathbf{MAC} = \frac{2}{3}\, c_r \,\frac{1+\lambda+\lambda^2}{1+\lambda}$$

$$y_{MAC} = \frac{b}{6}\,\frac{1+2\lambda}{1+\lambda}$$

# MAC Significance



# HW #2 – Wing Calculations

| **Design Parameters** | | |
|---|---|---|
| $S_{ref}$ | 608 | $ft^2$ |
| b | 42.7 | ft |
| $\Lambda_{LE}$ | 46.0 | deg |
| $c_t$ | 5.1 | ft |
| $c_r$ | 23.3 | ft |

| **Calculations** | | |
|---|---|---|
| $S_{trap}$ | 606.3 | $ft^2$ |
| $AR_{ref}$ | 2.9988 | |
| $AR_{trap}$ | 3.0070 | |
| $\lambda$ | 0.2189 | |
| MAC | 16.1 | ft |
| $y_{mac}$ | 8.4 | ft |

**Plotting:**

**Spanwise View**

| x (ft) | + y (ft) | - y (ft) |
|---|---|---|
| 0.00 | 0.00 | 0.00 |
| 23.30 | 0.00 | 0.00 |
| 27.21 | 21.35 | -21.35 |
| 22.11 | 21.35 | -21.35 |
| 0.00 | 0.00 | 0.00 |

**Sweep Angles**

| | x/c | $\Lambda_{x/c}$ (deg) |
|---|---|---|
| LE | 0.00 | 46.0 |
| 1/4C | 0.25 | 39.4 |
| TE | 1.00 | 10.4 |

**Input data from fact sheet and three-view drawing measurements**

**Measurement check**

UNIVERSITY OF Cincinnati

# Questions?