

## Next: How Big Is the Plane?

- Basic Considerations for Wing Size



## Basic Considerations for Wing Size

- Wing weight is important
- Integrate Aerodynamics and Structures for minimum weight design
- Wing loading is an important design parameter
  - driven by two opposing requirements
- Can define problem reasonably well

## *Wing Size and Wing Loading Issues*

### **Consider Wing Loading to Find Wing Area**

Cruise: Specific Range (*sr*), best range formula, drag rise neglected

$$best\ sr = \frac{1.07}{sfc} \left\{ \frac{(W/S)}{\rho} \right\}^{1/2} \frac{\{AR \cdot E\}^{1/4}}{\{C_{D_0}\}^{3/4}} \frac{1}{W}$$

From Hale, *Intro to A/C Perf*

**Increase:**  $W/S$ , altitude (decreases  $\rho$ ),  $AR$ ,  $E$  ( $L/D$ )

**Decrease:** zero lift drag, weight ( $W$ ),  $sfc$

Here: **HIGH  $W/S$  is desired**

# Wing Loading Considerations (Cont'd)

## *Sustained Maneuvering*

$$n = \frac{q}{(W/S)} \sqrt{\pi ARE \left( \frac{T}{qS} - C_{D0} \right)}$$

## *Takeoff (feet)*

$$l_t = 37.7 \cdot TOP, \quad TOP = \frac{(W/S)}{\sigma \cdot C_{L_{\max}} (T/W)}$$

(from Loftin, NASA RP 1060)

## *Landing*

$$V_{APP} = 17.15 \sqrt{\frac{W/S}{\sigma \cdot C_{L_{APP}}}}, \quad (knots)$$



Here: **LOW W/S is desired**

# Thrust to Weight and Wing Loading

*Engine size (or thrust to weight, T/W)*

- based on sizing the engine to meet constraints typically established by the Specs we've discussed

*Wing size (or wing loading, W/S)*

- also based on meeting key requirements

*T/W - W/S charts are typically used*

- putting all the constraints on the plot lets you select the best combination

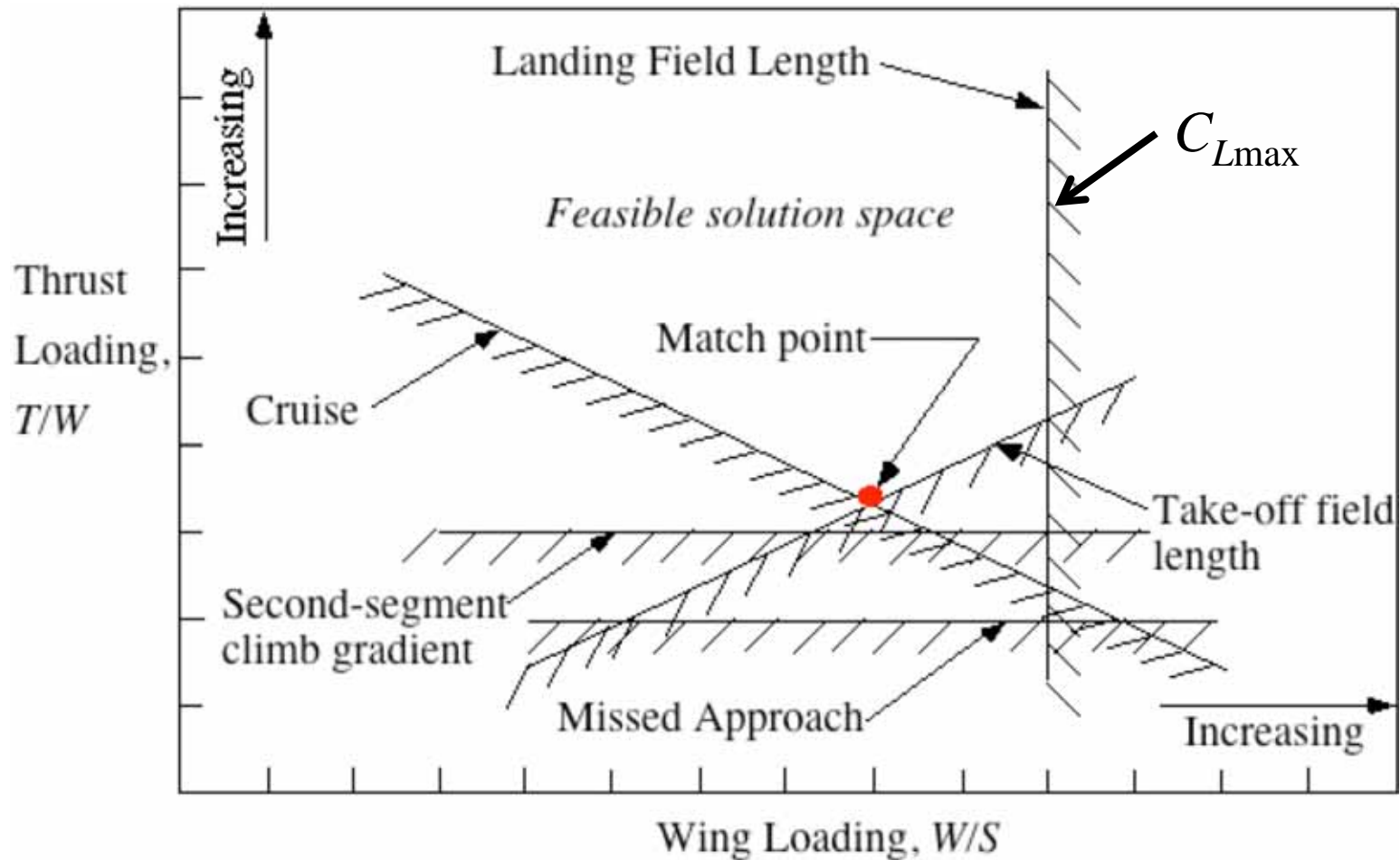
*Often the wing is allowed to be bigger,  
- to allow for future growth*

*Prop Airplanes use Power Loading, W/P in place of T/W*

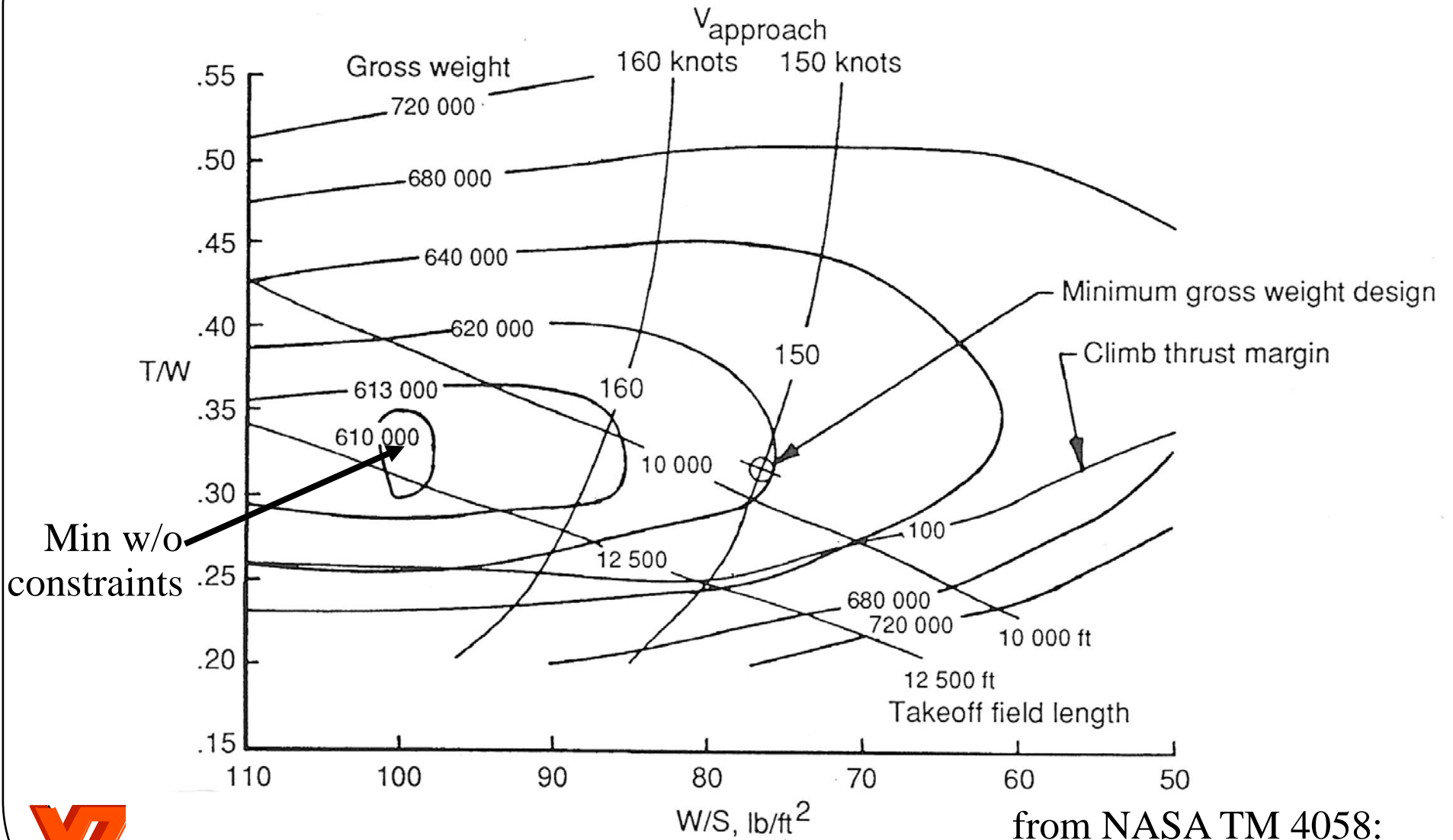
see L.K. Loftin, Jr., pages 358-360, "Subsonic Aircraft: Evolution and the Matching of Size to Performance," NASA RP 1060, Aug. 1980, for examples for prop airplanes.



# Thrust Loading and Wing Loading Matching



# Thumbprint Plot for an HSCT



## Example of Constraint Lines

*(approximate examples, be able to derive your own)*

$$\text{Takeoff: } T/W) \cong \frac{37.7 \cdot W/S)_{\text{Takeoff}}}{\sigma \cdot C_{L_{\max \text{ TO}}} \cdot s_{\text{TOFL}}}$$

$$\text{Landing: } W/S) \cong 2.8 \rho \cdot C_{L_{\max \text{ Ldg}}} \cdot s_{\text{ldgfl}}$$

Cruise ( $T = D$ ):

$$T/W) = q \frac{C_{D0}}{(W/S)_{\text{cruise}}} + \frac{(W/S)_{\text{cruise}}}{q\pi A R E}$$

Climb gradient requirements:

$$T/W) = \left( \frac{N}{N-1} \right) \left( \text{CGR} + \frac{1}{L/D} \right)$$

where,  $\sigma = \frac{\rho}{\rho_{\text{sea level}}}$

Note: convert  $T/W$  to  $M=0, h=0$  values,  $W/S$  to takeoff values  
 $N$  is number of engines,  $\text{CGR}$  is the climb gradient,  $q$  implies best altitude, Mach, and  $L/D$  should be for correct flight condition.



## BTW, Transport Propulsion Sizing

There is another important constraint for transports:

The airplane must meet the initial cruise altitude requirement

- at the initial cruise altitude (about 98% of TOGW), the so-called “top of climb”, airplane must still have a specified rate of climb (500 or 300 ft/min)

According to the book by Jenkinson, Simpkin and Rhodes, *Civil Jet Aircraft Design*,

- Twin-engine aircraft are likely to be second-segment climb critical
- Four-engine aircraft are likely to be climb critical (top of climb performance)

