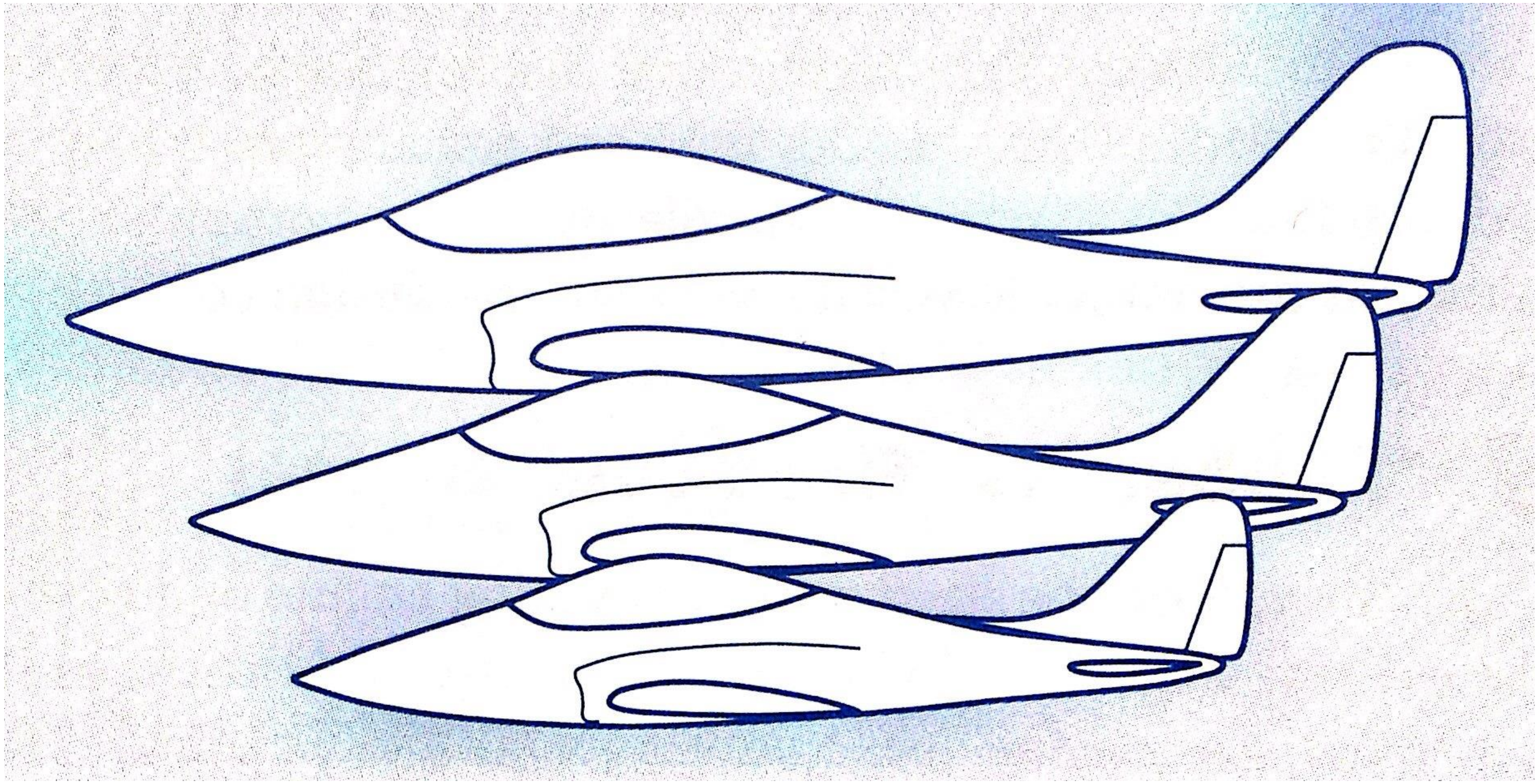
ME4932 Aircraft Performance & Design

Initial Sizing (Chapters 6)



Source: Aircraft Design by Daniel P. Raymer

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Initial Sizing (Chapters 6)

- Method of Chapter 3 was simple and required minimal information
- Single most important calculation, the drawn aircraft must meet requirements!
- More refined method presented here.
- Rubber Engine Sizing
- Fixed-Sized Engine Sizing

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Initial Sizing (Chapters 6)

- Rubber engine sizing
  - T/W can be held to a desired value to satisfy point performance requirements while Wo matches mission (range/loiter) requirement. Basically engine size grows proportionately with Wo.
  - Done during early stages of aircraft project. Project may warrant a new engine development.
  - Even projects where an existing engine must be selected are done this way to learn as much as possible about engine choice consequences!
- Fixed engine sizing
  - Either mission (range/loiter) or point performance requirements are a fallout.

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Initial Sizing (Chapters 6)

- Better We/Wo estimate for jets!

$$W_e/W_0 = [a + b\, W_0^{C1} A^{C2} (T/W_0)^{C3} (W_0/S)^{C4} M_{max}^{C5}] K_{vs}$$

fps units	a	B	C1	C2	C3	C4	C5
Jet trainer	0	4.28	−0.10	0.10	0.20	−0.24	0.11
Jet fighter	−0.02	2.16	−0.10	0.20	0.04	−0.10	0.08
Military cargo/bomber	0.07	1.71	−0.10	0.10	0.06	−0.10	0.05
Jet transport	0.32	0.66	−0.13	0.30	0.06	−0.05	0.05

K_{vs} = variable sweep constant = 1.04 if variable sweep and 1.00 if fixed sweep

Source: Aircraft Design by Daniel P. Raymer

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Initial Sizing (Chapters 6)

- Better We/Wo estimate for propeller-driven aircraft!

$$W_e/W_0 = a + b\, W_0^{C1}\, A^{C2} (hp/W_0)^{C3} (W_0/S)^{C4}\, V_{max}^{C5}$$

fps units	a	b	$C1$	$C2$	$C3$	$C4$	$C5$
Sailplane—unpowered	0	0.76	−0.05	0.14	0	−0.30	0.06
Sailplane—powered	0	1.21	−0.04	0.14	0.19	−0.20	0.05
Homebuilt—metal/wood	0	0.71	−0.10	0.05	0.10	−0.05	0.17
Homebuilt—composite	0	0.69	−0.10	0.05	0.10	−0.05	0.17
General aviation—single engine	−0.25	1.18	−0.20	0.08	0.05	−0.05	0.27
General aviation—twin engine	−0.90	1.36	−0.10	0.08	0.05	−0.05	0.20
Agricultural aircraft	0	1.67	−0.14	0.07	0.10	−0.10	0.11
Twin turboprop	0.37	0.09	−0.06	0.08	0.08	−0.05	0.30
Flying boat	0	0.42	−0.01	0.10	0.05	−0.12	0.18

Source: Aircraft Design by Daniel P. Raymer

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Initial Sizing (Chapters 6)

- Refined sizing equation:

$$W_0 = W_{\text{crew}} + W_{\text{fixed payload}} + W_{\text{dropped payload}} + W_{\text{fuel}} + \left(\frac{W_e}{W_0}\right) W_0$$

- To allow payload drops, Wfuel is calculated at each segment instead of multiplying all weight fractions (before, **all** weight change was due to fuel burn!)

$$W_f = 1.06\left(\sum_{1}^{x} W_{f_i}\right)$$

- As before, guess Wo and **iterate.**

Source: Aircraft Design by Daniel P. Raymer

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Initial Sizing (Chapters 6)

- Geometry sizing of the fuselage (starting point):

Length = aW_0^C (ft or {m})	a	C
Sailplane—unpowered	0.86 {0.383}	0.48
Sailplane—powered	0.71 {0.316}	0.48
Homebuilt—metal/wood	3.68 {1.35}	0.23
Homebuilt—composite	3.50 {1.28}	0.23
General aviation—single engine	4.37 {1.6}	0.23
General aviation—twin engine	0.86 {0.366}	0.42
Agricultural aircraft	4.04 {1.48}	0.23
Twin turboprop	0.37 {0.169}	0.51
Flying boat	1.05 {0.439}	0.40
Jet trainer	0.79 {0.333}	0.41
Jet fighter	0.93 {0.389}	0.39
Military cargo/bomber	0.23 {0.104}	0.50
Jet transport	0.67 {0.287}	0.43

- Reality of packaging internal components will ultimately establish fuselage length

Source: Aircraft Design by Daniel P. Raymer

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Initial Sizing (Chapters 6)

- Sref = Wo / W/S

- Can now lay out the trapezoidal wing using aspect ratio, taper ratio, sweep, etc.

Source: Aircraft Design by Daniel P. Raymer

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Initial Sizing (Chapters 6)

- Tail volume coefficient:
  - Tail effectiveness is proportional to to the force generated by it and its moment arm
  - Since the tail has to counter the moments of the wing, its size is proportional to the wing's
  - The vertical tail's moments are non-dimensionalized with wing span, and the horizontal tail's with m.a.c. (c-bar):

$$c_{VT} = \frac{L_{VT} S_{VT}}{b_W S_W}$$

$$c_{HT} = \frac{L_{HT} S_{HT}}{C_W S_W}$$

- Lengths measured with respect to 25% chord of m.a.c. of all surfaces.

Source: Aircraft Design by Daniel P. Raymer

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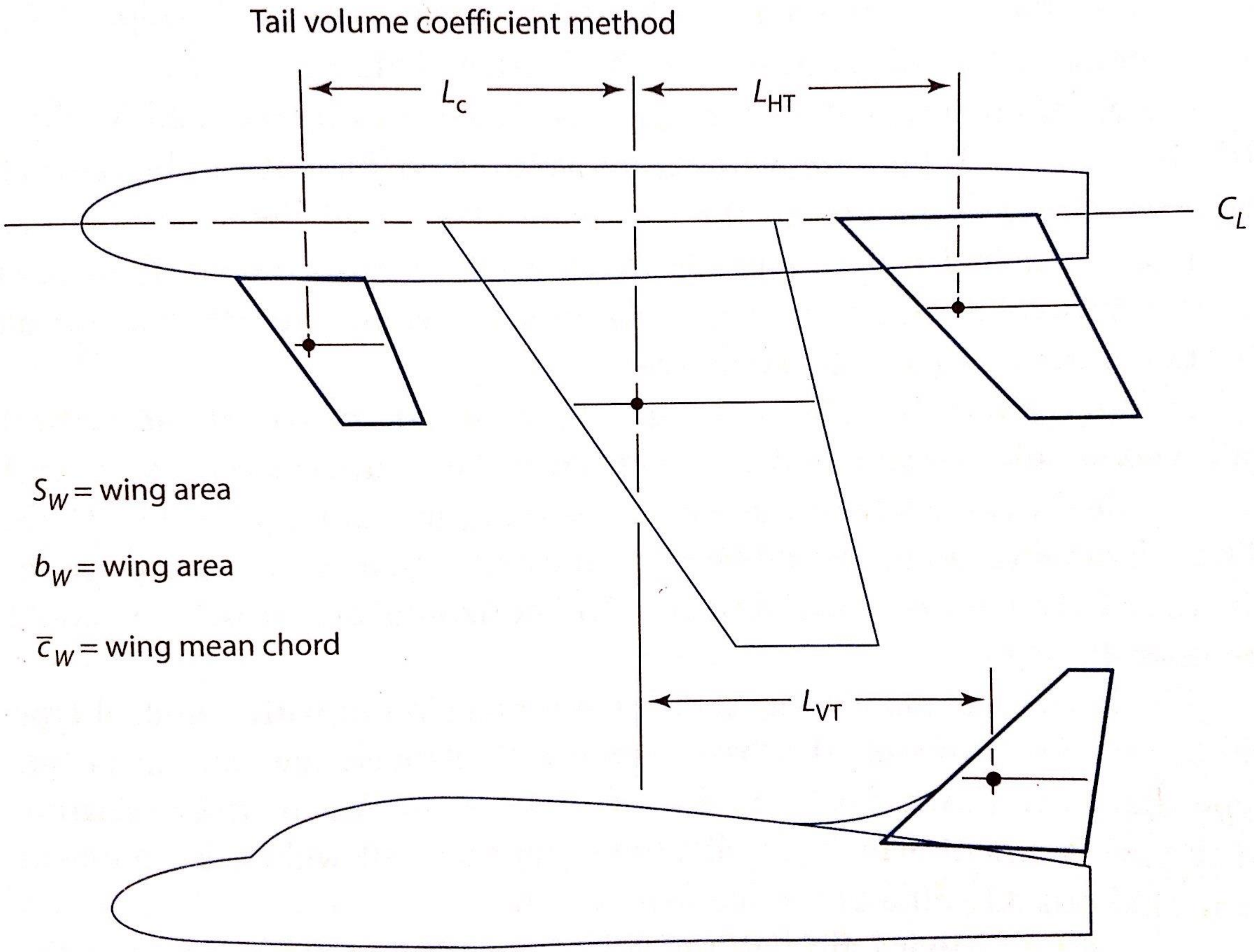
Initial Sizing (Chapters 6)



$$S_{VT} = \frac{c_{VT} b_W S_W}{L_{VT}}$$

$$S_{HT} = \frac{c_{HT} \bar{C}_W S_W}{L_{HT}}$$

Source: Aircraft Design by Daniel P. Raymer

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Initial Sizing (Chapters 6)

- Typical tail volume coefficients:

	Typical values	
	Horizontal c_{HT}	Vertical c_{VT}
Sailplane	0.50	0.02
Homebuilt	0.50	0.04
General aviation—single engine	0.70	0.04
General aviation—twin engine	0.80	0.07
Agricultural	0.50	0.04
Twin turboprop	0.90	0.08
Flying boat	0.70	0.06
Jet trainer	0.70	0.06
Jet fighter	0.40	0.07–0.12*
Military cargo/bomber	1.00	0.08
Jet transport	1.00	0.09

Source: Aircraft Design by Daniel P. Raymer

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Initial Sizing (Chapters 6)

- Front-mounted propeller , L_{HT} is about 60% of fuselage length
- For engines on the wings, 50-55%
- Aft-mounted engines,45-50%
- Sailplane, 65%
- For all-moving tails, can reduce volume coefficient 10-15%
- For t-tail, can reduce volume coefficient 5%
- For a v-tail, find conventional areas and split them between two. Dihedral should be arctangent of square root of required vertical and horizontal areas)
- For a control canard, C_{HT} is approx. 0.1. Consider only the exposed area.
- For a lifting canard, designer must decide canard/wing area split.

Source: Aircraft Design by Daniel P. Raymer

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Initial Sizing (Chapters 6)

Control surface sizing:

- Roll = Ailerons
- Pitch = Elevator
- Yaw = Rudder
- Finally sized by dynamics, structures, control system cons

Source: Aircraft Design by Daniel P. Raymer

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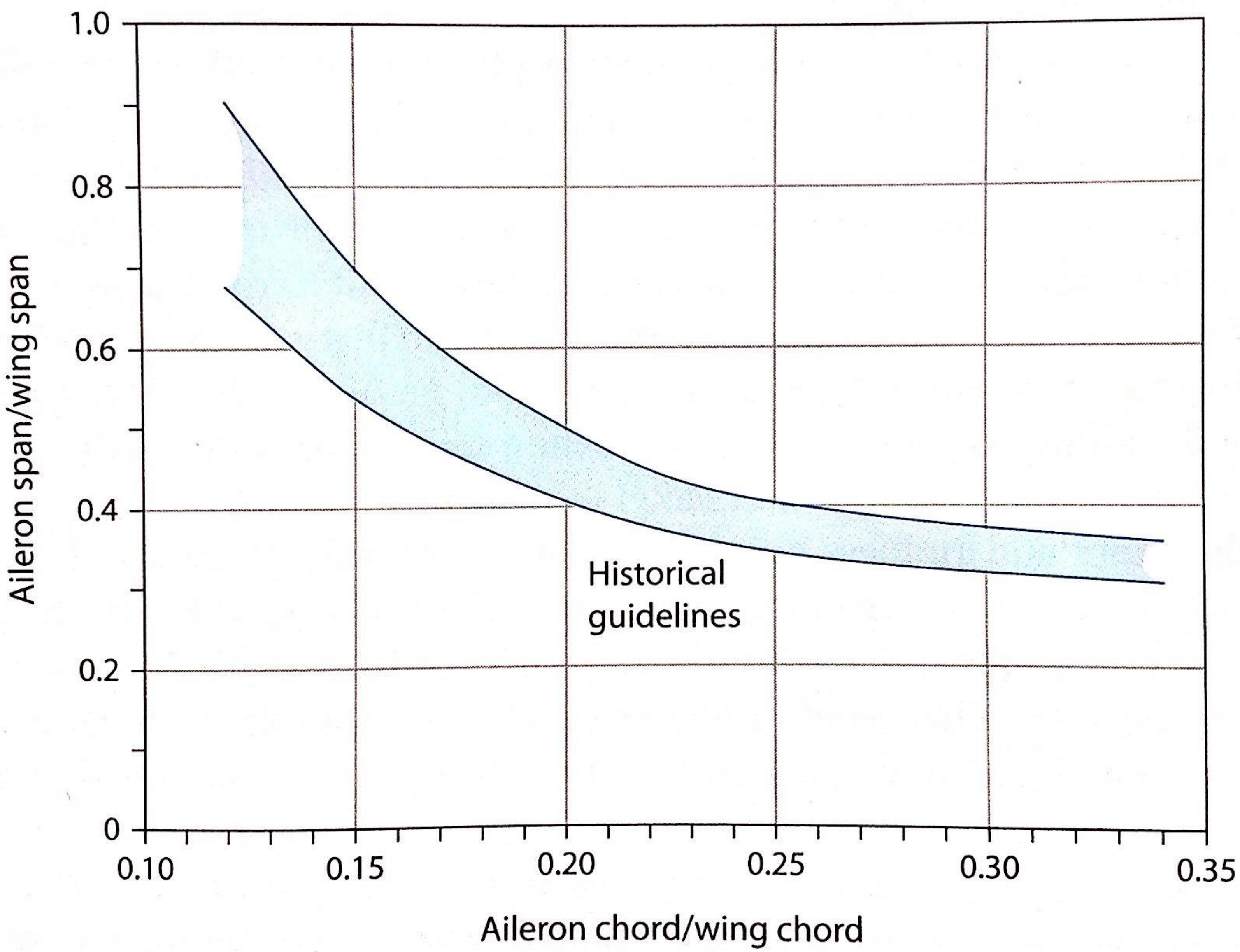
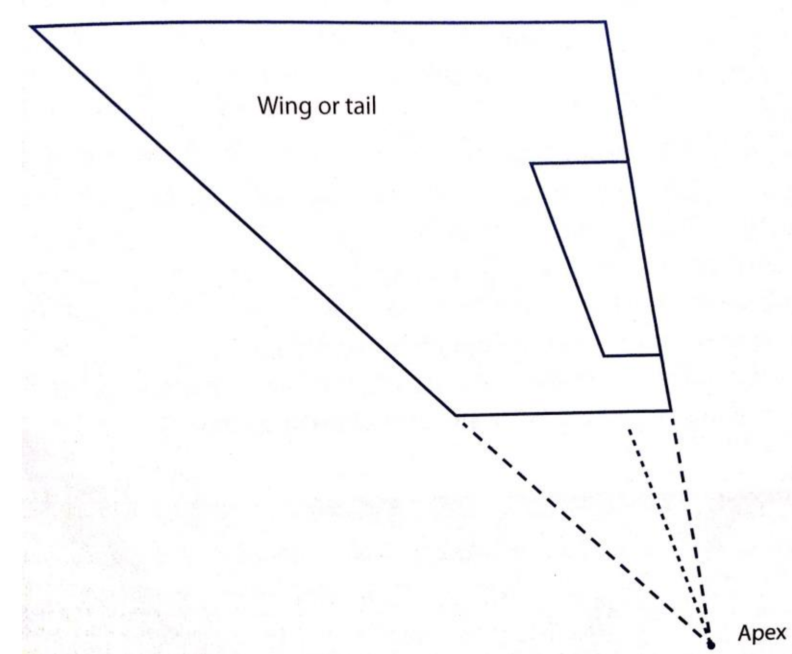
Initial Sizing (Chapters 6)





- Wing flaps occupy part of wing inboard of ailerons. If more needed, use of spoilers for roll control could be used.

Source: Aircraft Design by Daniel P. Raymer

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Initial Sizing (Chapters 6)

Aircraft	Elevator C_e/C	Rudder C_r/C
Fighter/attack	0.30*	0.30
Jet transport	0.25†	0.32
Jet trainer	0.35	0.35
Biz jet	0.32†	0.30
GA single	0.45	0.40
GA twin	0.36	0.46
Sailplane	0.43	0.40

*Supersonic usually all-moving tail without separate elevator.
†Often all-moving plus elevator.

Source: Aircraft Design by Daniel P. Raymer

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Initial Sizing (Chapters 6)

Other things to consider in control surface sizing :

- Aileron reversal in high speed aircraft
    - Spoilers, rolling tail
- Flutter
    - Mass or aerodynamic balancing
    - Connection of left-right elevators
- All moving surfaces

Source: Aircraft Design by Daniel P. Raymer

- Homework
- 6.2, 6.3, 6.4