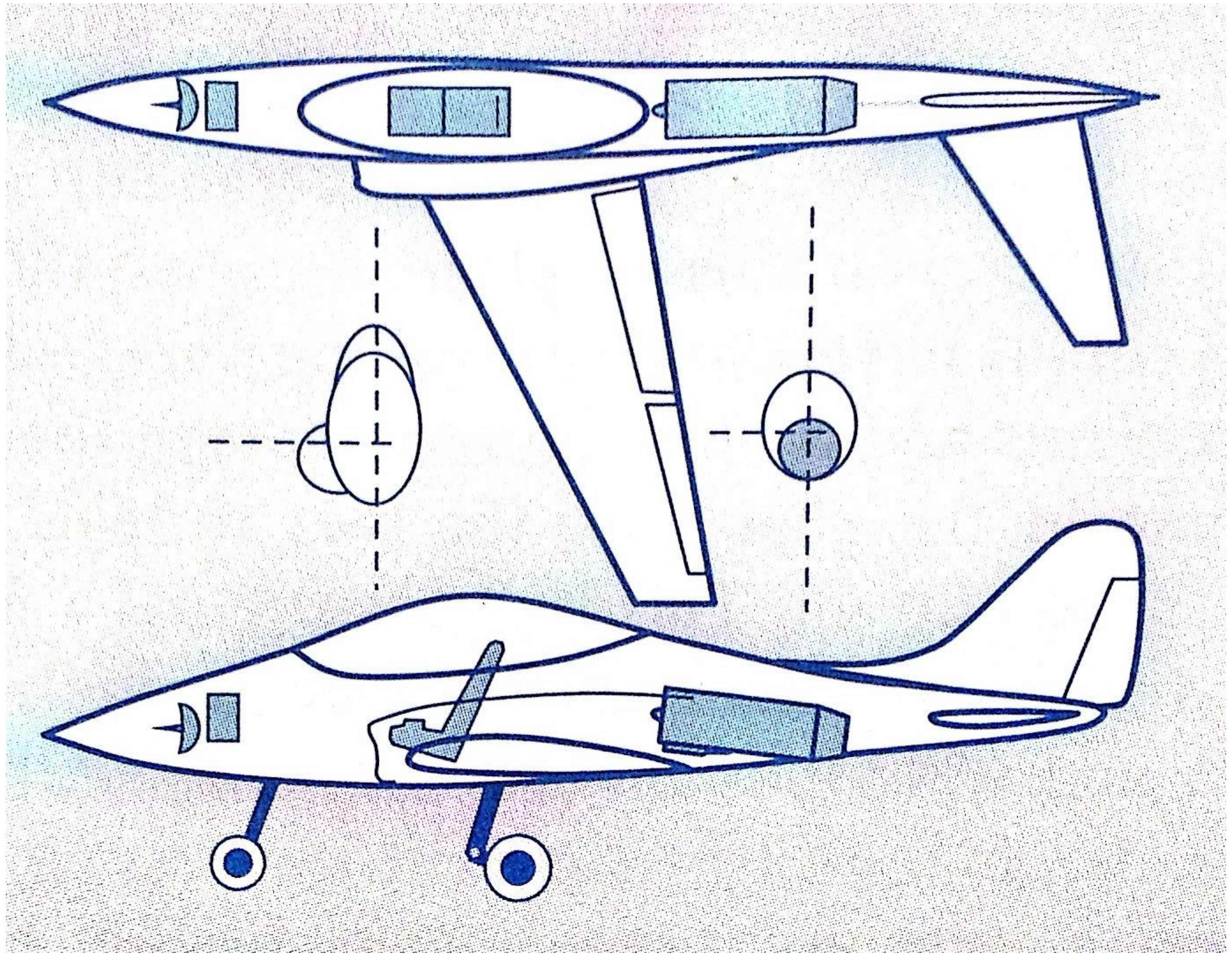
ME4932 Aircraft Performance & Design

Other considerations (Chapters 7,8,9,10,11,15)



Source: Aircraft Design by Daniel P. Raymer

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Other considerations (Chapters 7)

Configuration design and loft:

- In the end, if not properly drawn, the design will never fly.... The analysis is as good as the drawing.
- The layout should start with a sketch showing:
    - Overall aerodynamic arrangement (fuselage, wing, tails)
    - Locations of all major components (landing gear, crew station, payload/passenger compartment, propulsion system, fuel tanks and any other components that affect internal volume or aerodynamics.
- The layout will be analyzed by functional specialists
    - Exact geometries of fuselage, wings, tails and other major external items. Wetted area and volume plots

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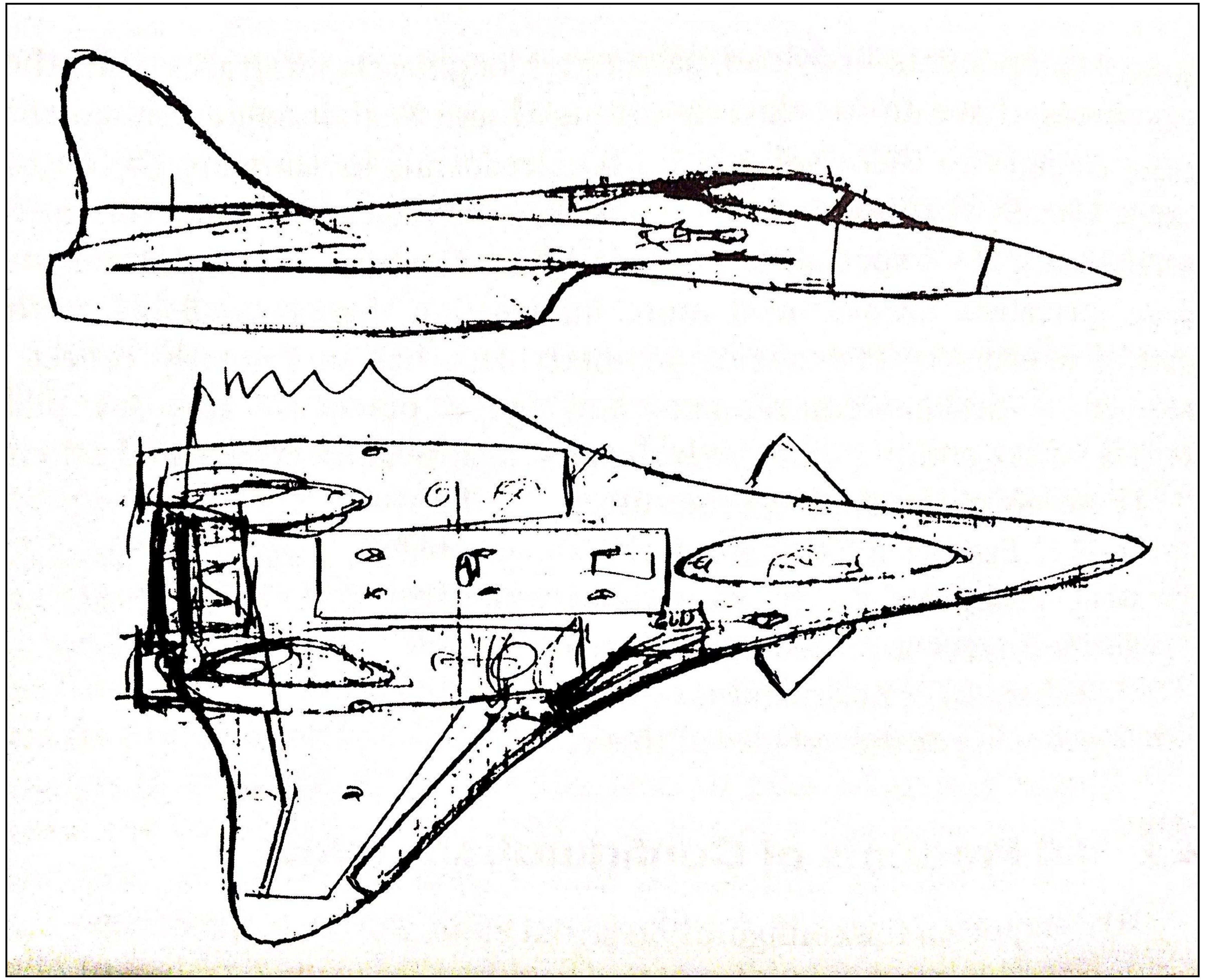
Other considerations (Chapters 7)



Source: Aircraft Design by Daniel P. Raymer

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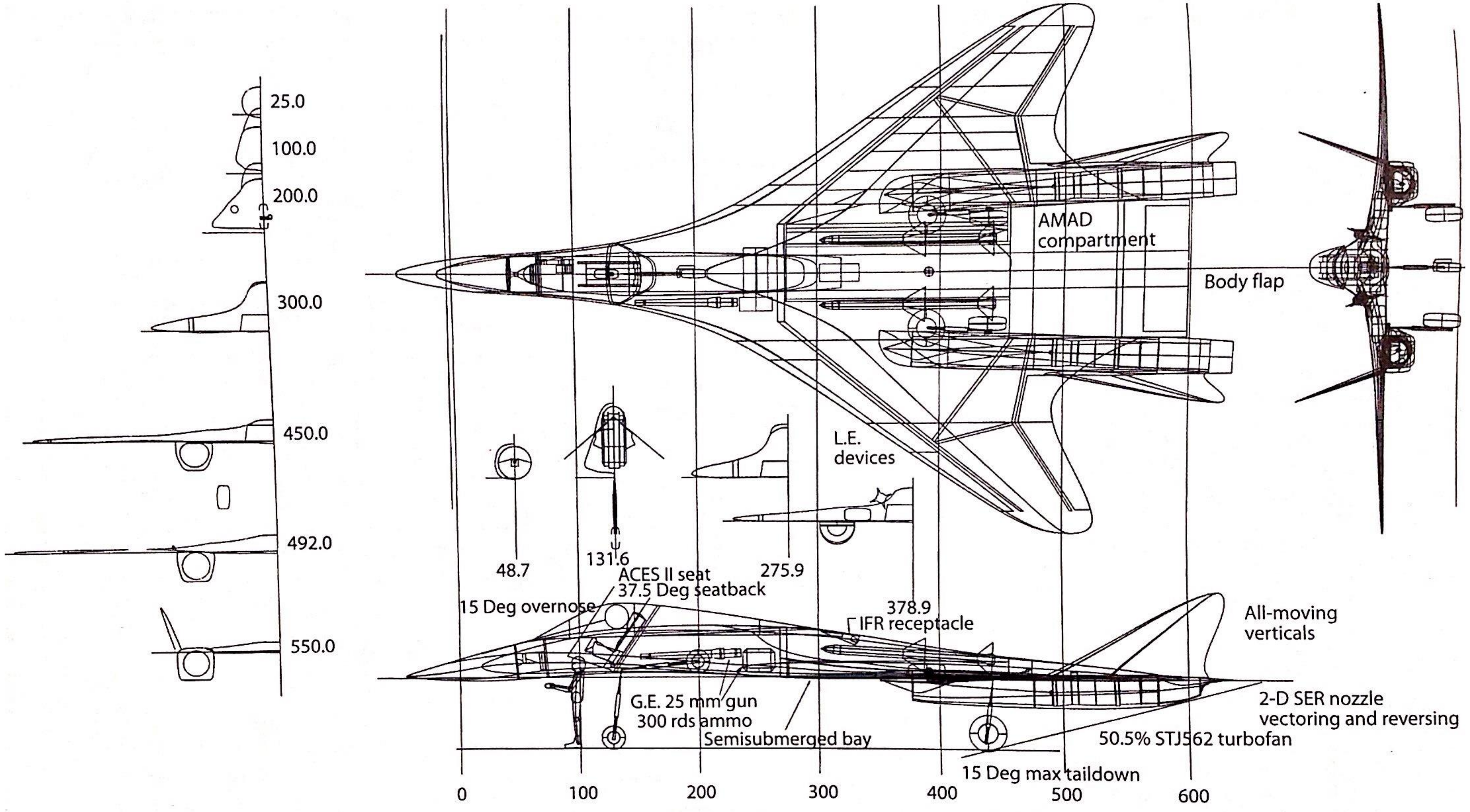
Other considerations (Chapters 7)



Source: Aircraft Design by Daniel P. Raymer

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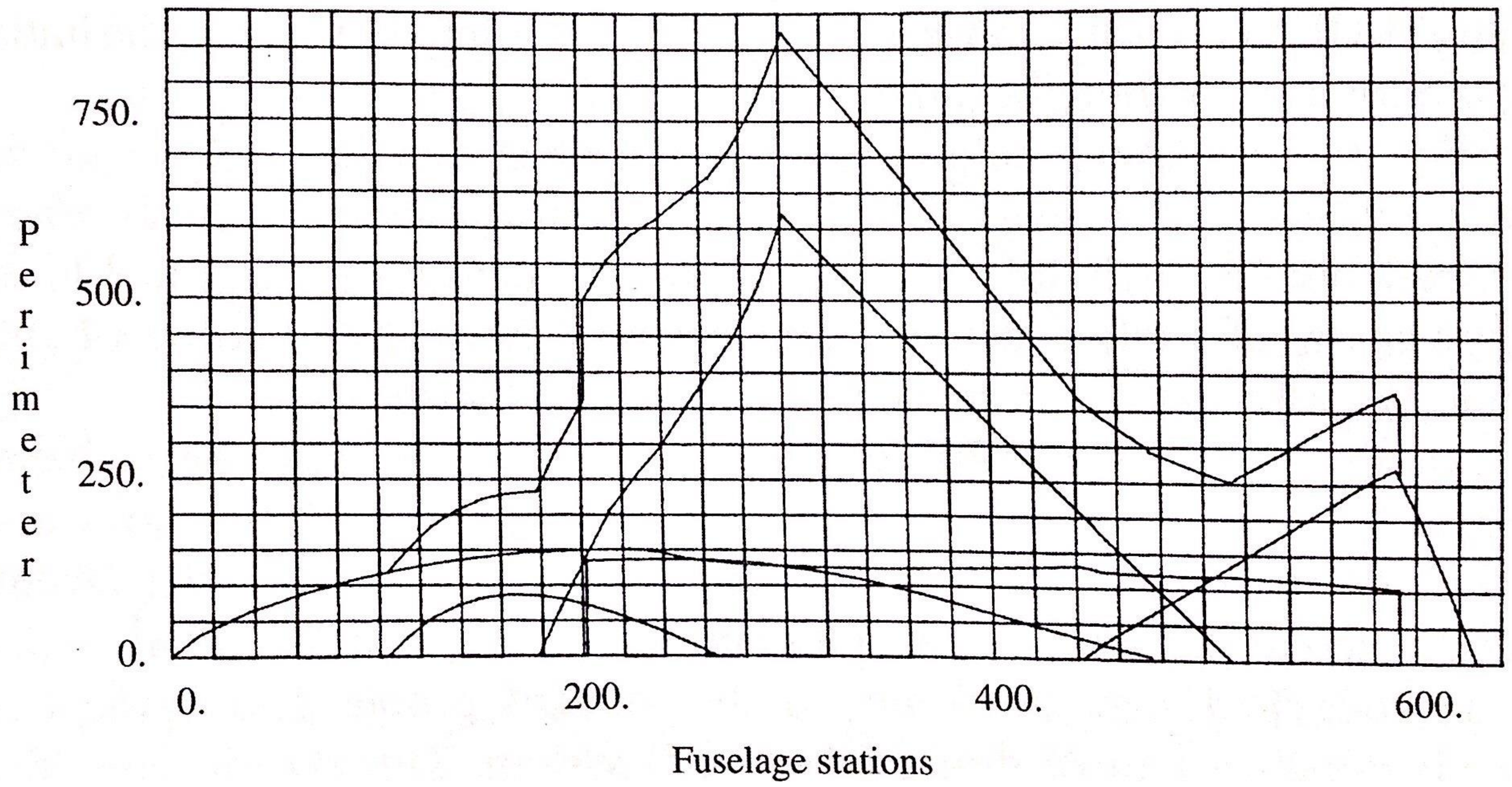
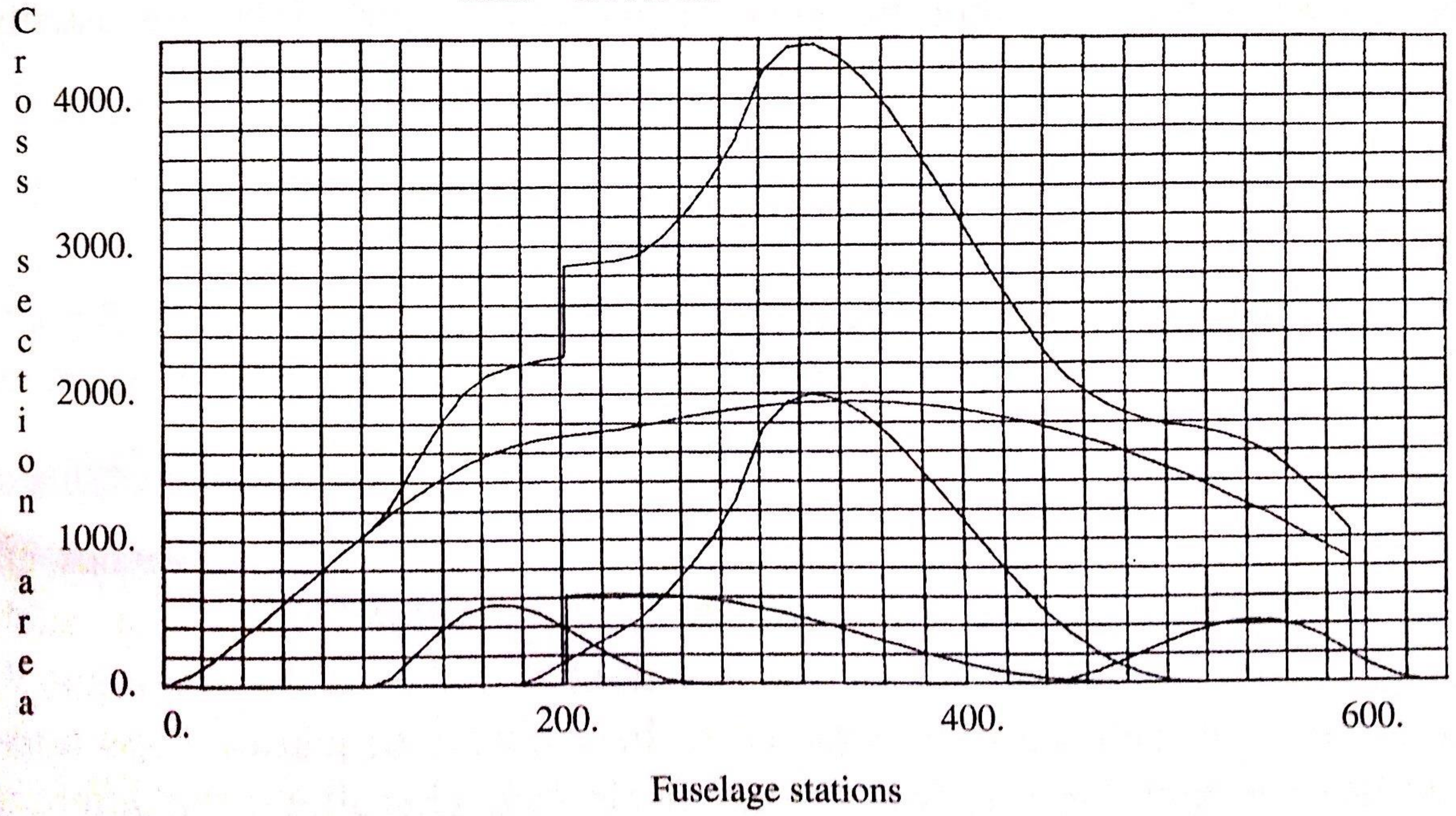
Other considerations (Chapters 7)

Component	Surface
Fuselage	70344.8
Vert tail	26165.3
Wing	102636.7
Circular arc canopy	9071.4
Nacelle	25462.9
Total	233681.0



Component	Volume
Fuselage	847124.4
Vert tail	42903.5
Wing	287005.5
Circular arc canopy	46014.0
Nacelle	95149.8
Total	1318196.8



Source: Aircraft Design by Daniel P. Raymer

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Other considerations (Chapters 8)

- Avoid excess wetted area (friction drag)
- Low volume (tight packaging) vs. maintenance, access, etc.
- For a given volume, lower fineness ratio (L/ Max. Dia.) minimizes wetted area.
- But too low fineness ratio = flow separation! F.R. > 3
- 6 < Subsonic F.R. < 9
- 10< Supersonic F.R. <15
- Avoid discontinuities in slopes. Changes in contour should have radii of at least the length of the fuselage.
- Shape of fuselage cross-section important also. Square = +20% drag!
- Avoid aft facing surfaces (base area).

Source: Aircraft Design by Daniel P. Raymer

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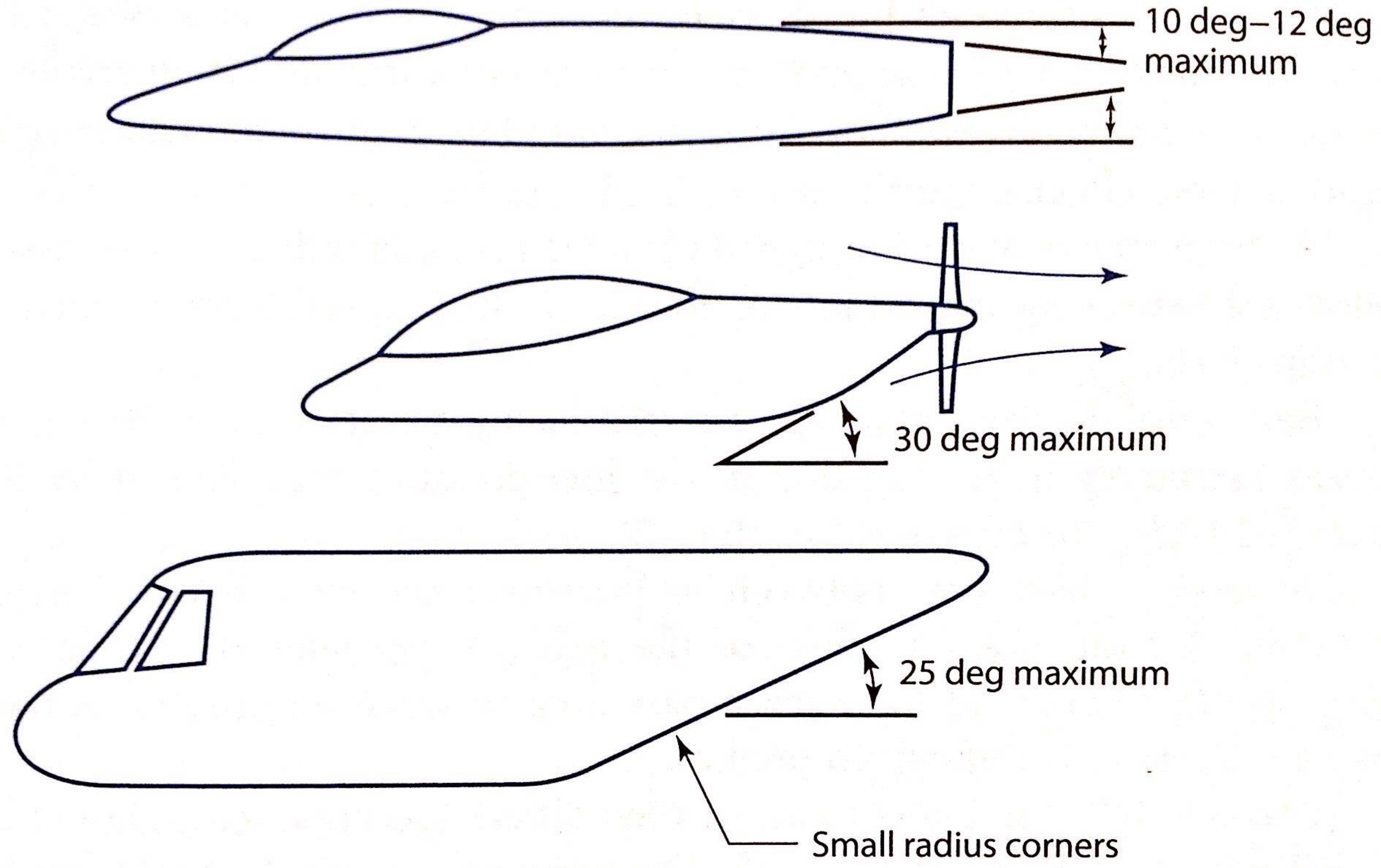
Other considerations (Chapters 8)



Source: Aircraft Design by Daniel P. Raymer

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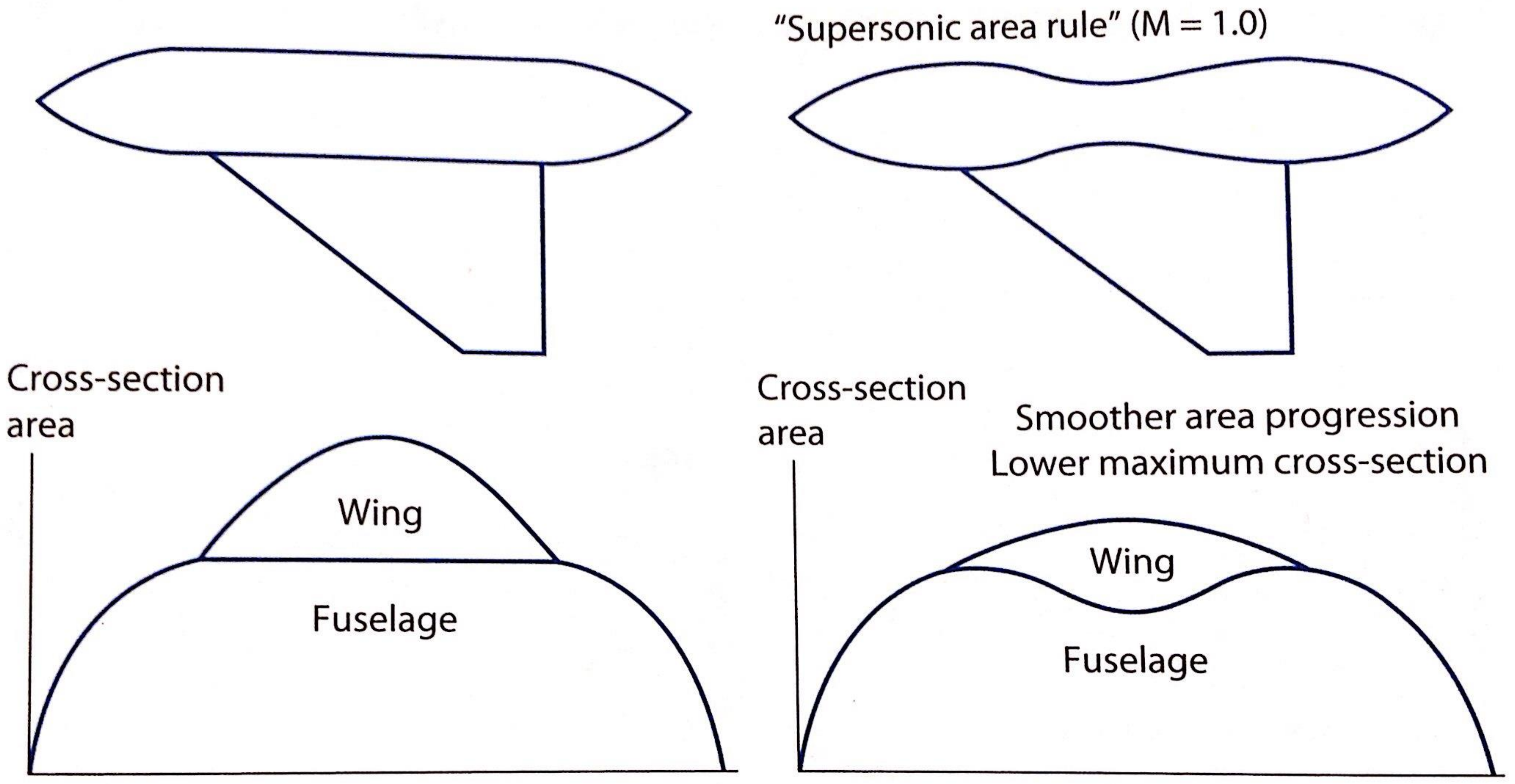
Other considerations (Chapters 8)

- Watch for interference between components

- Supersonic area ruling



Source: Aircraft Design by Daniel P. Raymer

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Other considerations (Chapters 7)

- Wing location with respect to the fuselage:
- A pure trapezoidal flying wing aircraft will be neutrally stable if its c.g. Is longitudinally located at 25% of the mean aerodynamic chord (c-bar). Moments do not change with angle of attack.
- An aft tail adds to the stability, so wing should be located initially so that the aircraft's c.g. is located at 30% m.a.c.
- Unstable, computer-augmented stability a/c use 40%
- Very different locations for canard airplanes. (Control or lifting)

Source: Aircraft Design by Daniel P. Raymer

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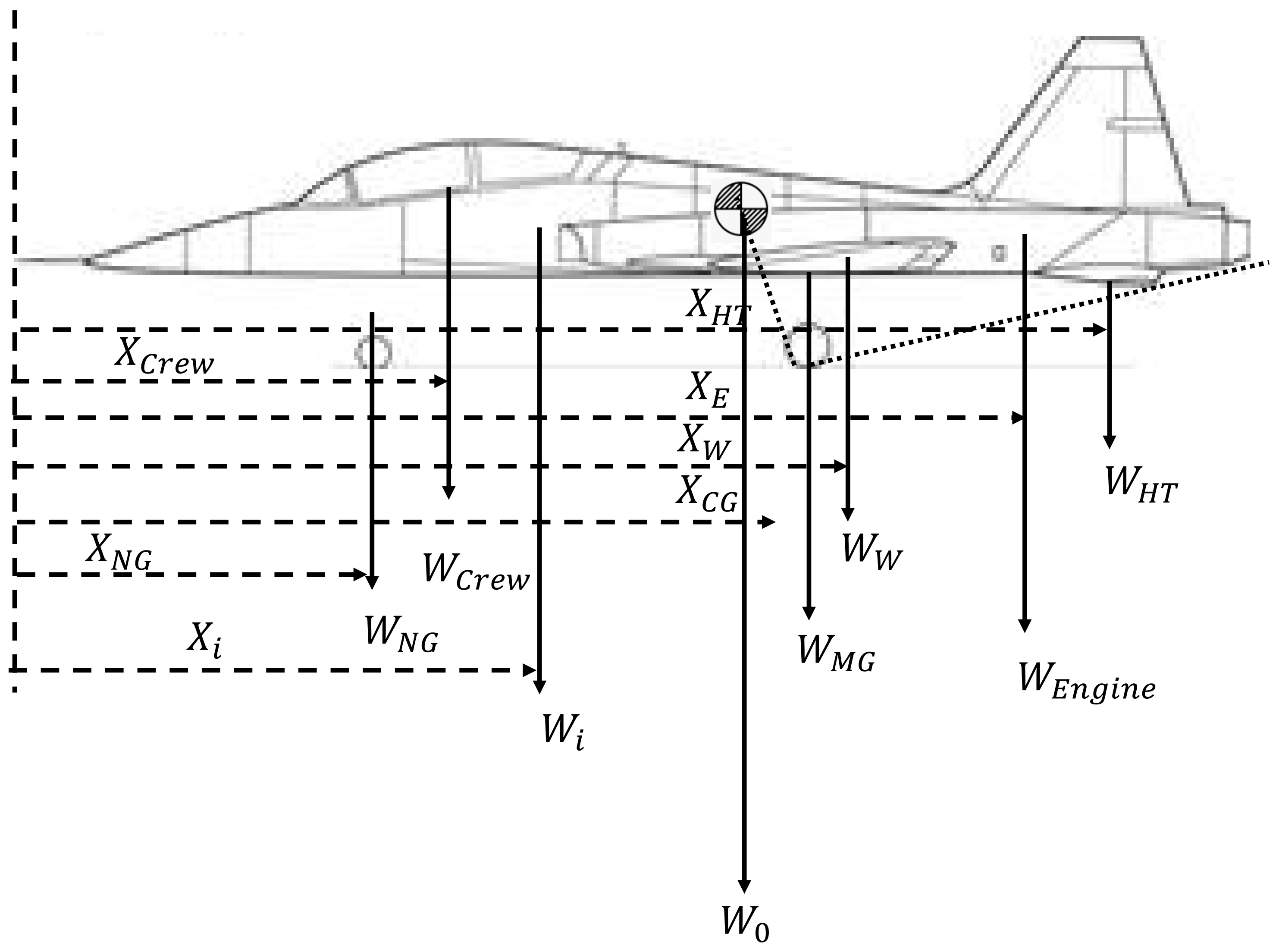
Weights (Chapter 15)

- Determination of C.G. / Wing and Landing Gear Location



$$X_{CG}W_0 = \sum X_i W_i$$

$$\therefore\ X_{CG} = \frac{\sum W_i X_i}{W_0}$$

Source: Aircraft Design by Daniel P. Raymer

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Weights (Chapter 15)

- Approximate Empty Weight Buildup

	Fighters		Transport & Bomber		General aviation		Multiplier	Approximate location
	lb/ft^2	kg/m^2	lb/ft^2	kg/m^2	lb/ft^2	kg/m^2		
Wing	9	44	10	49	2.5	12	$S_{exposed\ planform}$	40% MAC
Horizontal tail	4	20	5.5	27	2	10	$S_{exposed\ planform}$	40% MAC
Vertical tail	5.3	26	5.5	27	2	10	$S_{exposed\ planform}$	40% MAC
Fuselage	4.8	23	5	24	1.4	7	$S_{wetted\ area}$	40–50% length
	Weight ratio		Weight ratio		Weight ratio			
Landing gear*	0.033		0.043		0.057		TOGW	centroid
Landing gear—Navy	0.045		—		—		TOGW	centroid
Installed engine	1.3		1.3		1.4		Engine weight	centroid
"All-else empty"	0.17		0.17		0.1		TOGW	40–50% length

*15% to nose gear, 85% to main gear; reduce gear weight by 0.014 W_0 if fixed gear.

Source: Aircraft Design by Daniel P. Raymer

Weights (Chapter 15)

- After you draw the Dash-One, its weight must be calculated by adding components' weights
- Adjusted Historical Analogy (looking at a similar part on an existing aircraft)
- Statistics (large sample of existing components) + Physics
- Summary Group Weight Statement

Source: Aircraft Design by Daniel P. Raymer

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Weights (Chapter 15)

- Statistical Empty Weight Buildup (Civil Aviation A/C)

$$W_{\text{wing}} = 0.036 S_w^{0.758} W_{\text{fw}}^{0.0035} \left(\frac{A}{\cos^2 \Lambda} \right)^{0.6} q^{0.006} \lambda^{0.04}$$

$$\times \left(\frac{100\, t/c}{\cos \Lambda} \right)^{-0.3} (N_z W_{\text{dg}})^{0.49}$$

(ignore second term if $W_{\text{fw}} = 0$)

$$W_{\text{horizontal tail}} = 0.016 (N_z W_{\text{dg}})^{0.414} q^{0.168} S_{\text{ht}}^{0.896} \left(\frac{100\, t/c}{\cos \Lambda} \right)^{-0.12}$$

$$\times \left(\frac{A}{\cos^2 \Lambda_{\text{ht}}} \right)^{0.043} \lambda_h^{-0.02}$$

Source: Aircraft Design by Daniel P. Raymer

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Weights (Chapter 15)

- Statistical Empty Weight Buildup (Civil Aviation A/C)

$$W_{\text{vertical tail}} = 0.073\left(1 + 0.2\frac{H_t}{H_v}\right)(N_z W_{dg})^{0.376} q^{0.122} S_{vt}^{0.873} \times \left(\frac{100\, t/c}{\cos \Lambda_{vt}}\right)^{-0.49} \left(\frac{A}{\cos^2 \Lambda_{vt}}\right)^{0.357} \lambda_{vt}^{0.039}$$

$$W_{\text{fuselage}} = 0.052\, S_f^{1.086}(N_z W_{dg})^{0.177} L_t^{-0.051} \times (L/D)^{-0.072} q^{0.241} + W_{\text{press}}$$

$$W_{\text{main landing gear}} = 0.095(N_l W_l)^{0.768}(L_m/12)^{0.409}$$

$$W_{\text{nose landing gear}} = 0.125(N_l W_l)^{0.566}(L_n/12)^{0.845}$$

(reduce total landing gear weight by 1.4% of TOGW if nonretractable)

Source: Aircraft Design by Daniel P. Raymer

ME4932 Aircraft Performance & Design

Weights (Chapter 15)

- Statistical Empty Weight Buildup (Civil Aviation A/C)

$$W_{\text{installed engine (total)}} = 2.575 W_{\text{en}}^{0.922} N_{\text{en}}$$

(includes propeller and engine mounts)

$$W_{\text{fuel system}} = 2.49 V_t^{0.726} \left(\frac{1}{1 + V_i/V_t} \right)^{0.363} N_t^{0.242} N_{\text{en}}^{0.157}$$

$$W_{\text{flight controls}} = 0.053 L^{1.536} B_w^{0.371} (N_z W_{\text{dg}} \times 10^{-4})^{0.80}$$

$$W_{\text{hydraulics}} = K_h W^{0.8} M^{0.5}$$

$$W_{\text{electrical}} = 12.57 (W_{\text{fuel system}} + W_{\text{avionics}})^{0.51}$$

$$W_{\text{avionics}} = 2.117 W_{\text{uav}}^{0.933}$$

$$W_{\text{air conditioning and anti-ice}} = 0.265 W_{\text{dg}}^{0.52} N_p^{0.68} W_{\text{avionics}}^{0.17} M^{0.08}$$

$$W_{\text{furnishings}} = 0.0582 W_{\text{dg}} - 65$$

Source: Aircraft Design by Daniel P. Raymer

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Weights (Chapter 15)

	Weight lbs	Loc ft	Moment ft-lbs		Weight lbs	Loc ft	Moment ft-lbs
Structures	**4526**		**106,879**	**Equipment**	**4067**		**80,646**
Wing	1459.4	23.3	34,004	Flight controls	655.7	21.7	14,229
Horizontal tail	280.4	39.2	10,992	APU		0.0	0
Vertical tail		0	0	Instruments	122.8	10.0	1228
Ventral tail		0.0	0	Hydraulics	171.7	21.7	3726
Fuselage	1574	21.7	34,156	Pneumatics		21.7	0
Main landing gear	631.5	23.8	15,030	Electrical	713.2	21.7	15,476
Nose landing gear	171.1	13.0	2224	Avionics	989.8	10.0	9898
Other landing gear		0.0	0	Armament		0.0	0
Engine mounts	39.1	33.0	1290	Furnishings	217.6	6.2	1349
Firewall	58.8	33.0	1940	Air conditioning	190.7	15.0	2860.5
Engine section	21	33.0	693	Anti-icing			0
Air induction	291.1	22.5	6550	Photographic			0
			0	Load & handling	5.3	15.0	79.5
			0	Misc equipment & W_e	1000	31.8	31,800
			0	**Empty weight allowance**	**547**	**23.6**	**12,923**
Propulsion	**2354**		**70,931**	**Total weight empty**	**11,495**	**23.6**	**271,379**
Engine(s)—installed	1517	33.0	50,061				
Accessory drive			0	**Useful load**	**4985**		
Exhaust system			0	Crew	220	15.0	3300
Engine cooling	172	33.0	5676	Fuel—usable	3836	22.3	85,551
Oil cooling	37.8	33.0	1247	Fuel—trapped	39	22.3	864
Engine controls	20	33.0	660	Oil	50	33.0	1650
Starter	39.5	15.7	620	Passengers			0
Fuel system/tanks	568	22.3	12,666	Cargo/payload	840	21.7	18,228
			0	Guns			0
			0	Ammunition	0	21.7	0
			0	Misc useful load			
			0	**Takeoff gross weight**	**16,480**	**22.0**	**362,744**

Group Weight Statement

- Component weight
- Component location
- Moments from x = 0
- Total Weight Empty
- Fuel weight is **adjusted so TOGW = Wo!**
- **Equations used Wo**

Source: Aircraft Design by Daniel P. Raymer

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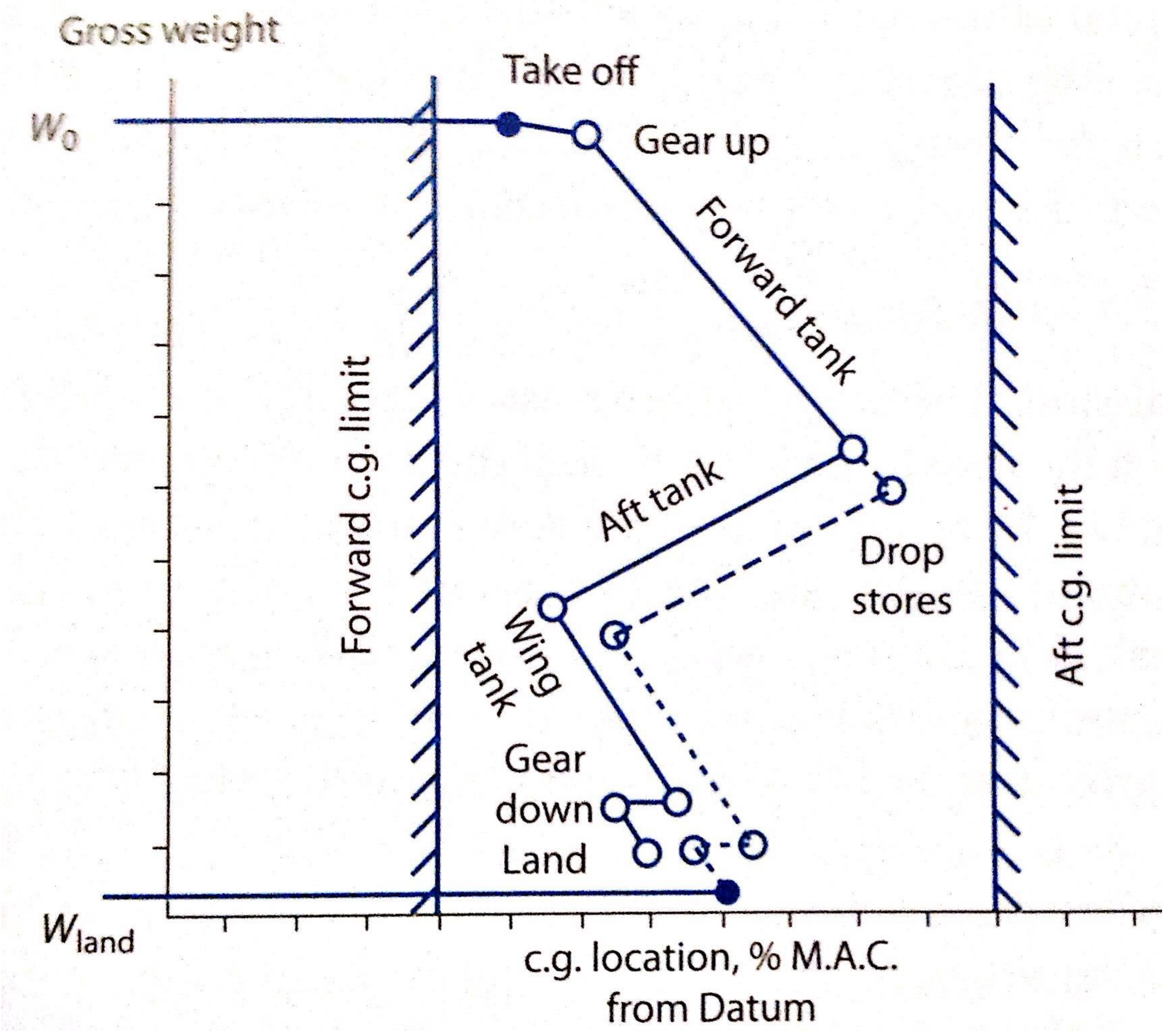
Weights (Chapter 15)

- Center of gravity travel



Source: Aircraft Design by Daniel P. Raymer

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Other considerations (Chapters 8)

- Structural considerations
- Proper layout will avoid weight penalties later
- Load paths must be provided where opposing forces meet
- Wing carry-through structure
- Avoid cutouts to structure
- Span loading = matching weights to lift generated
- Draw bulkheads where large forces are. Wing, landing gear, engines, tails, arresting hook...
- Ribs carry loads from control surfaces, store stations and landing gear to spars and skins.

Source: Aircraft Design by Daniel P. Raymer

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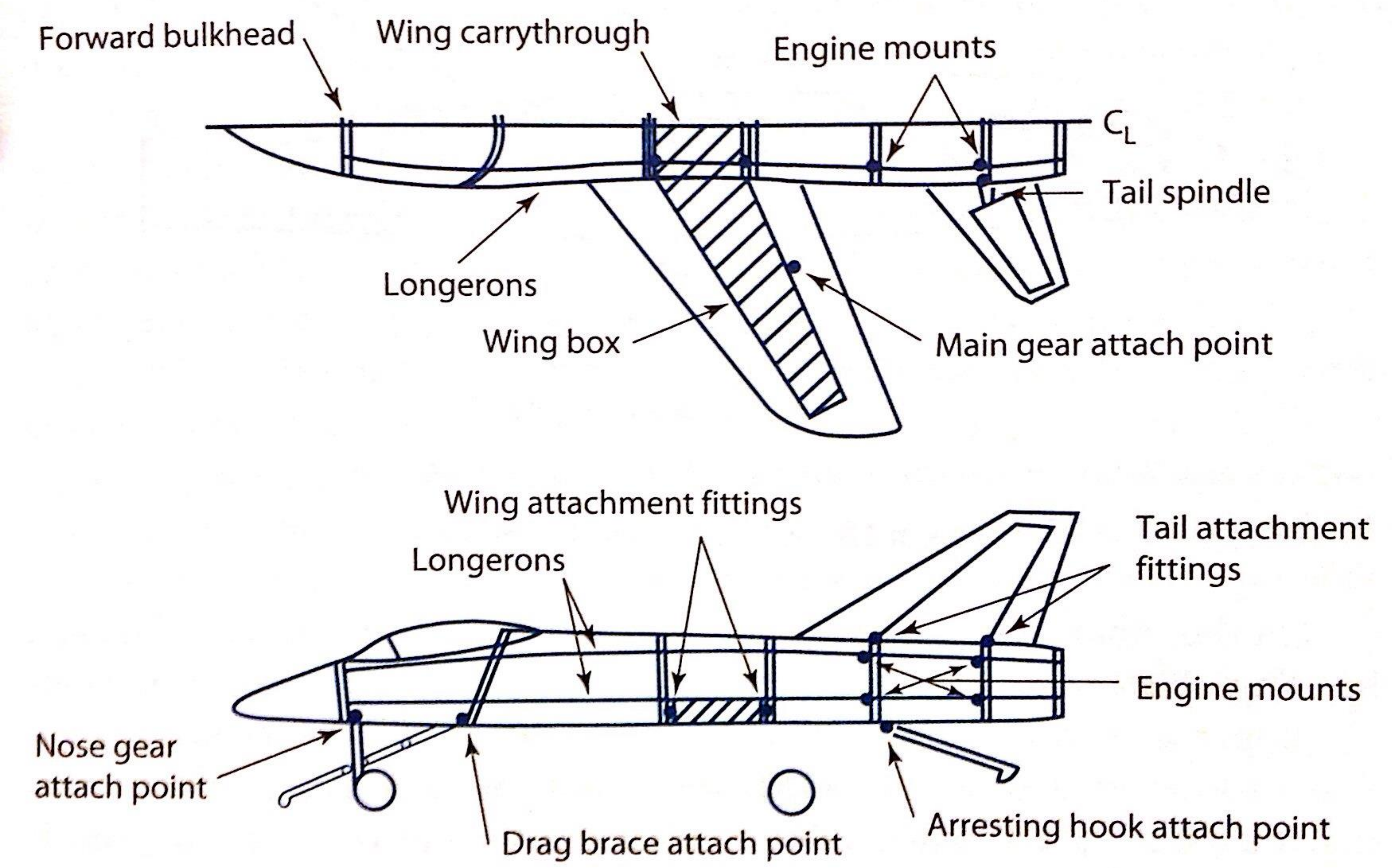
Other considerations (Chapters 8)



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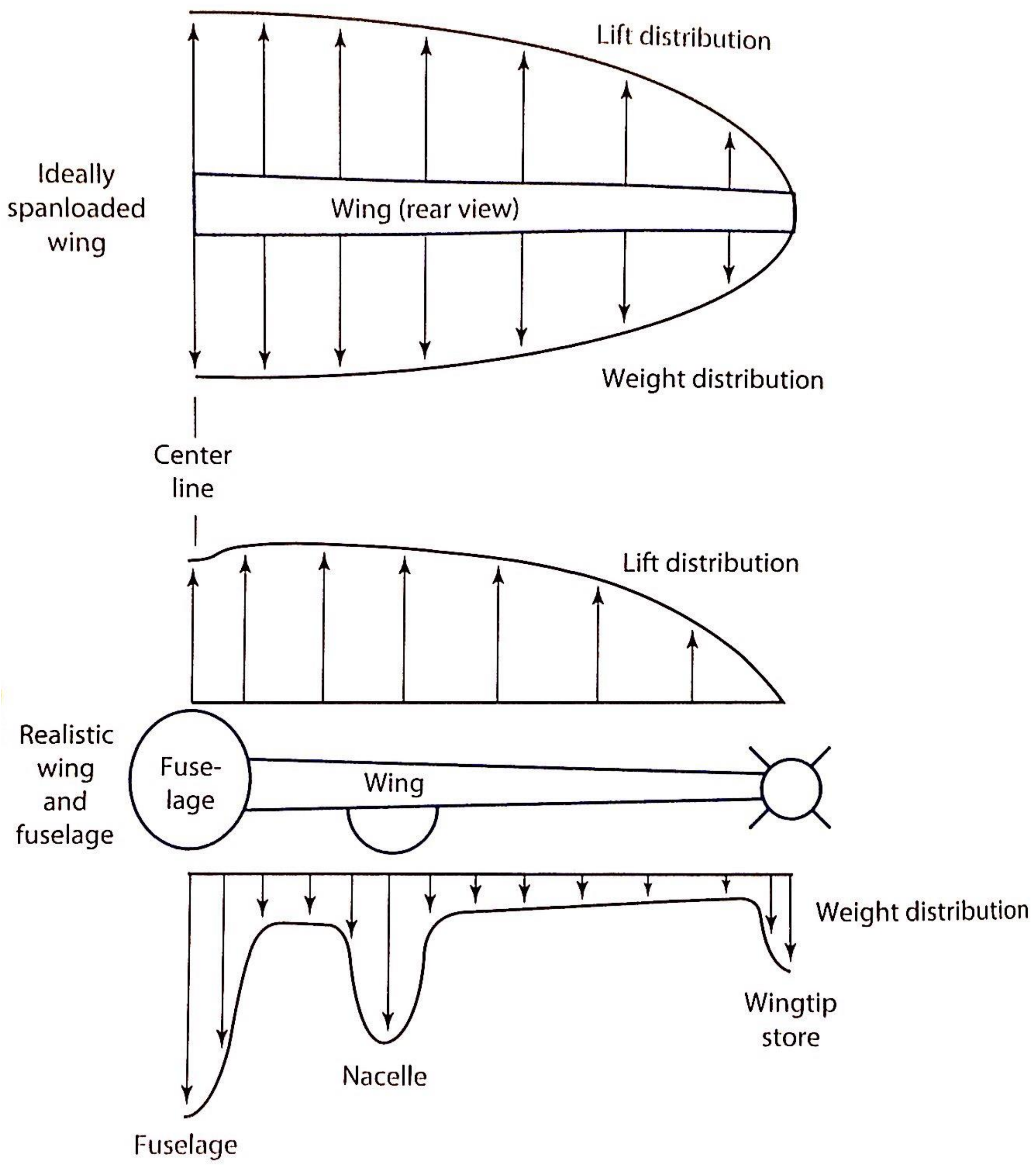
Other considerations (Chapters 8)



Source: Aircraft Design by Daniel P. Raymer

Other considerations (Chapters 8)

Carry-through structure:

- Tremendous bending moment where wing meets the fuselage
- Wing box.- fuselage weight reduced (not subjected to wing bending moments)
- Ring frames.- Heavy bulkheads to carry wing bending moment through fuselage. Used with mid-wing.
- Bending beam and struts.- struts are the lightest approach but draggy.
- Front wing spar 20-30% chord from leading edge
- Aft wing spar 60-75% chord from leading edge

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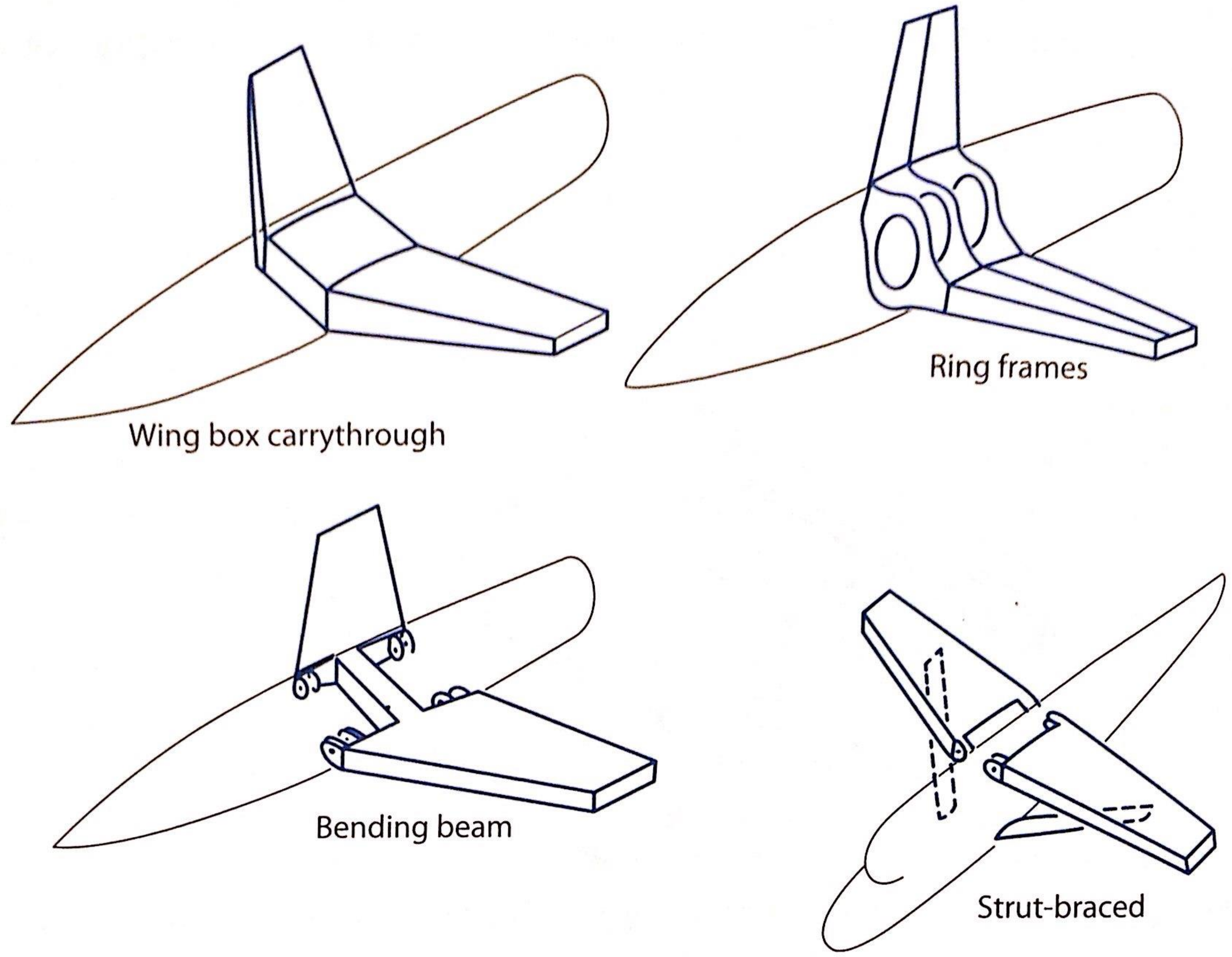
Other considerations (Chapters 8)



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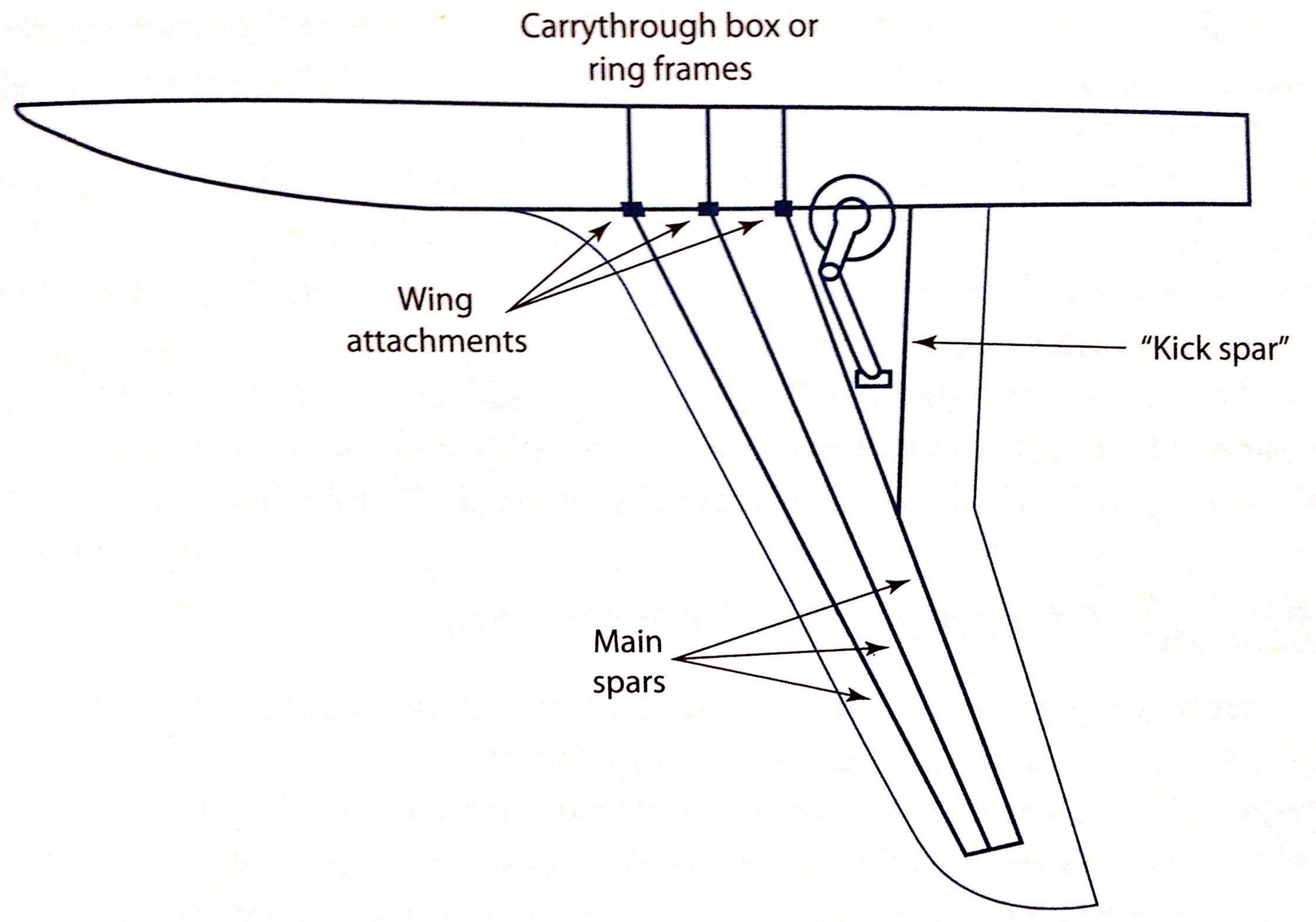
Other considerations (Chapters 8)



Source: Aircraft Design by Daniel P. Raymer

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Other considerations (Chapters 8)

Aural Signature (Exterior Noise)

- Commercial airports anti-noise ordinances
- Mostly caused by airflow shear layers, primarily due to engine exhaust
- Daisy mixer
- Mufflers (very heavy) and aiming exhaust stacks away from the ground
- Extended landing gear noise is significant (streamline)

Source: Aircraft Design by Daniel P. Raymer

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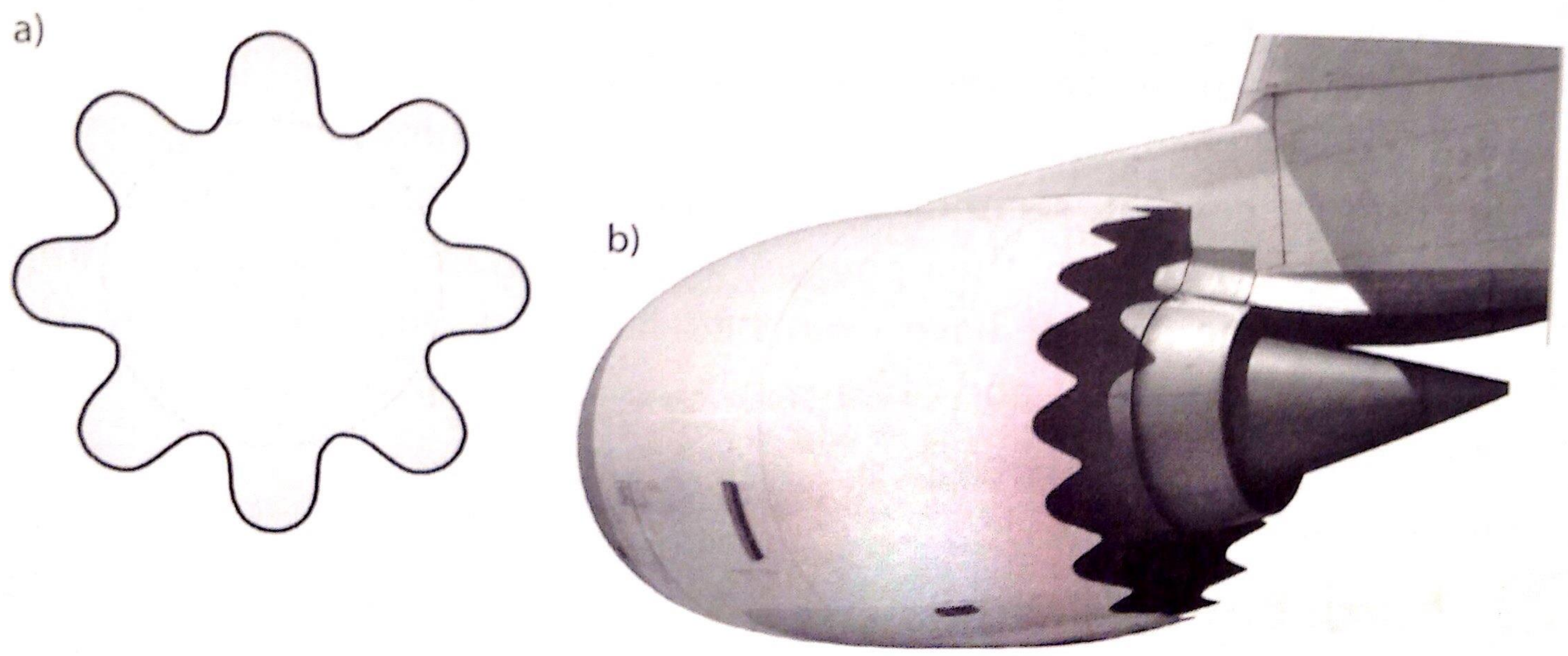
Other considerations (Chapters 8)



Source: Aircraft Design by Daniel P. Raymer

Other considerations (Chapters 8)

Interior Noise

- Primarily due to engines
    - Engine mount design, insulation, mufflers
    - Propeller clearance to fuselage from 1 ft to 50% prop radius better for interior noise but increases vertical size for engine-out yaw
    - Fuselage pod-mounted engines as far from fuselage and aft of pressure vessel
    - Active sound suppression

Source: Aircraft Design by Daniel P. Raymer

Other considerations (Chapters 8)

Crashworthiness

- Reduce probability if injury in a crash
- Propeller arc location
- Fuel away from crew/passenger compartment
- Structure should deflect in a controlled fashion in a crash
- Spread the crash load over a distance over time (shock absorber stroke)

Source: Aircraft Design by Daniel P. Raymer

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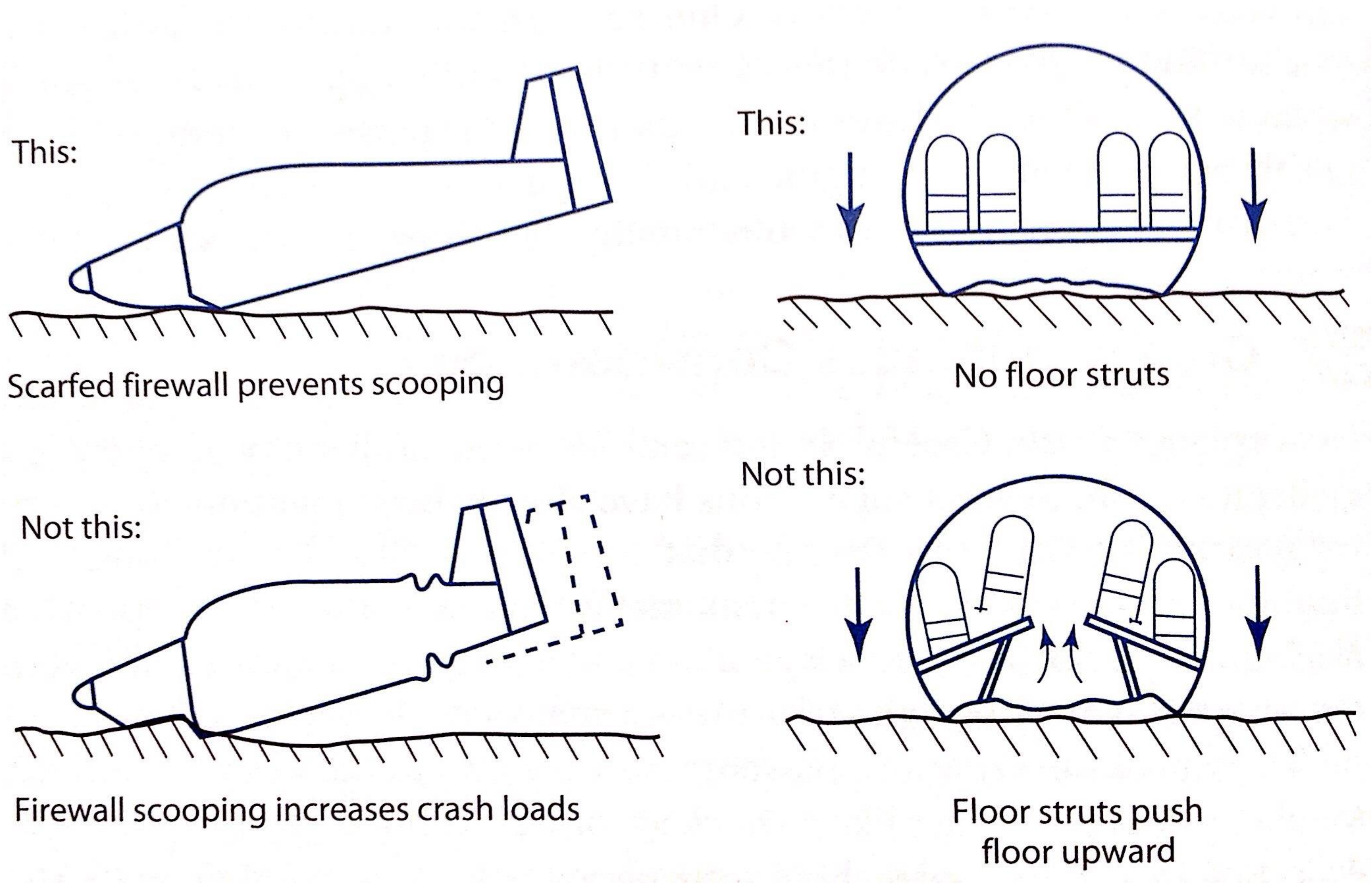
Other considerations (Chapters 8)



Source: Aircraft Design by Daniel P. Raymer

Other considerations (Chapters 8)

Producibility

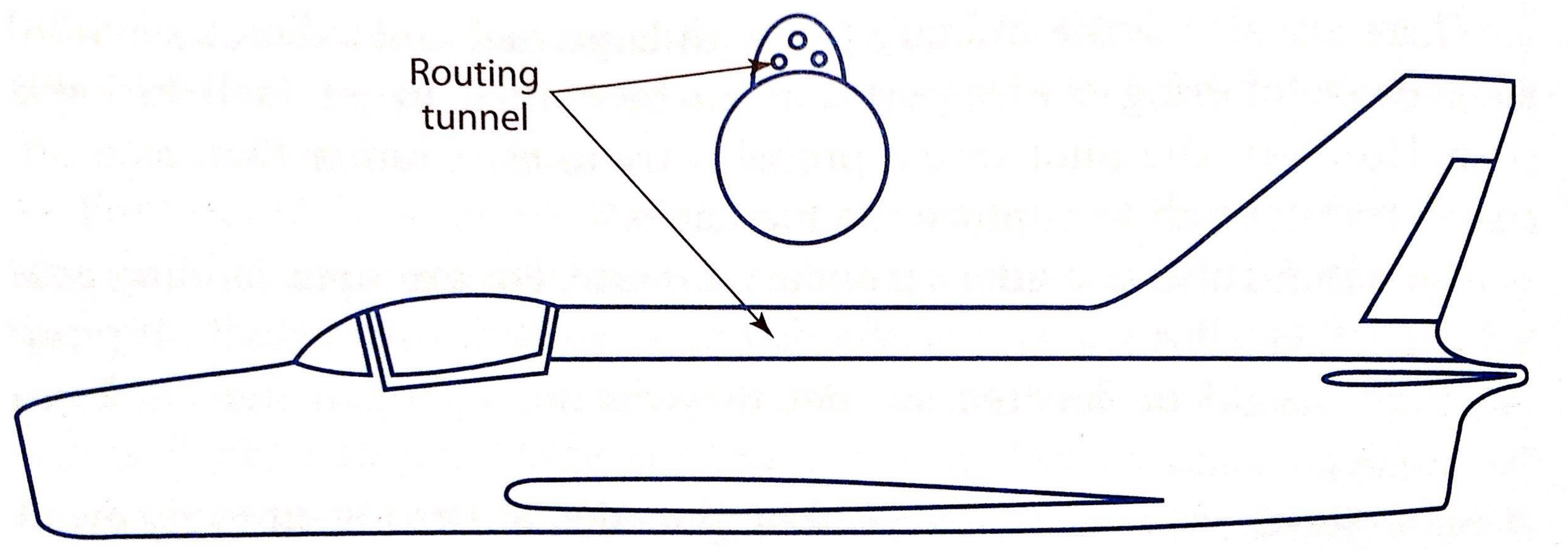
- Design for production
    - Materials selected = $
    - Fabrication processes / tooling / man-hours = $
    - Flat wrap
    - Part commonality
    - Left-right interchangeability (landing gear, uncambered tail)
    - Forgings (wing sweep pivots, all moving tail pivots) = $

Source: Aircraft Design by Daniel P. Raymer

Other considerations (Chapters 8)

Producibility (continued)

- Routing channels and location of components save man-hours
    - Hydraulic lines, electrical cable, versus location internal components.
- Connected versus separate systems



Source: Aircraft Design by Daniel P. Raymer

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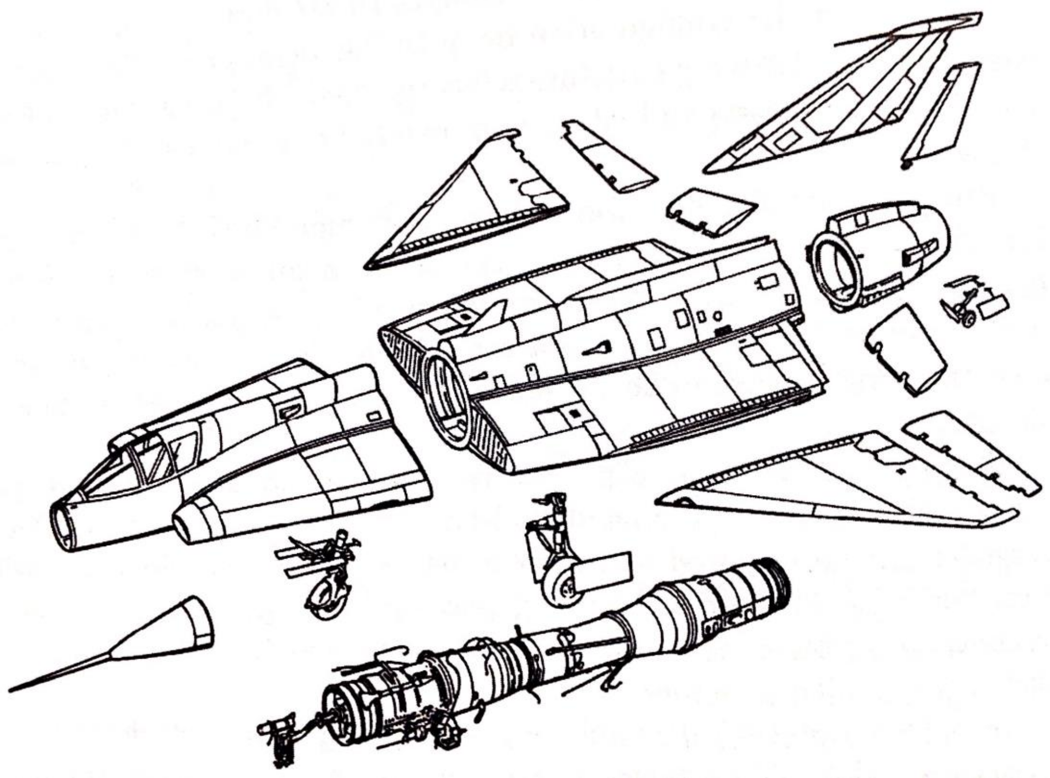
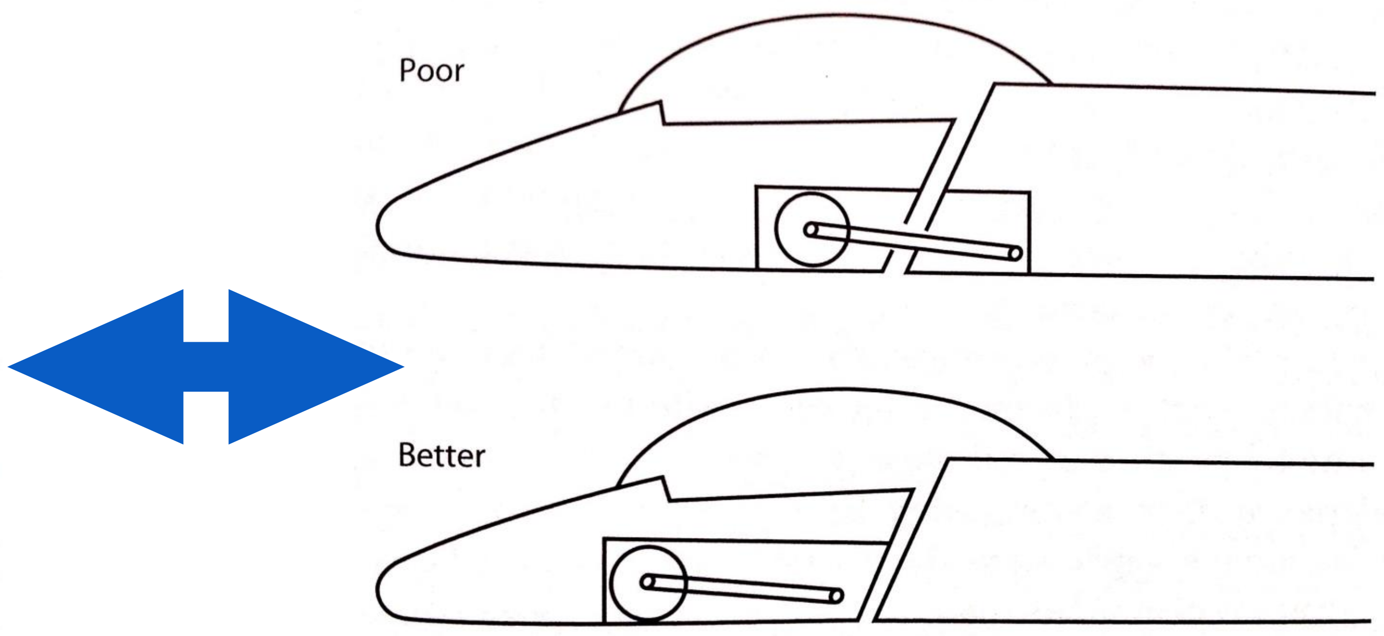
Other considerations (Chapters 8)

Producibility (continued)

- Poorly located components across manufacturing breaks





Source: Aircraft Design by Daniel P. Raymer

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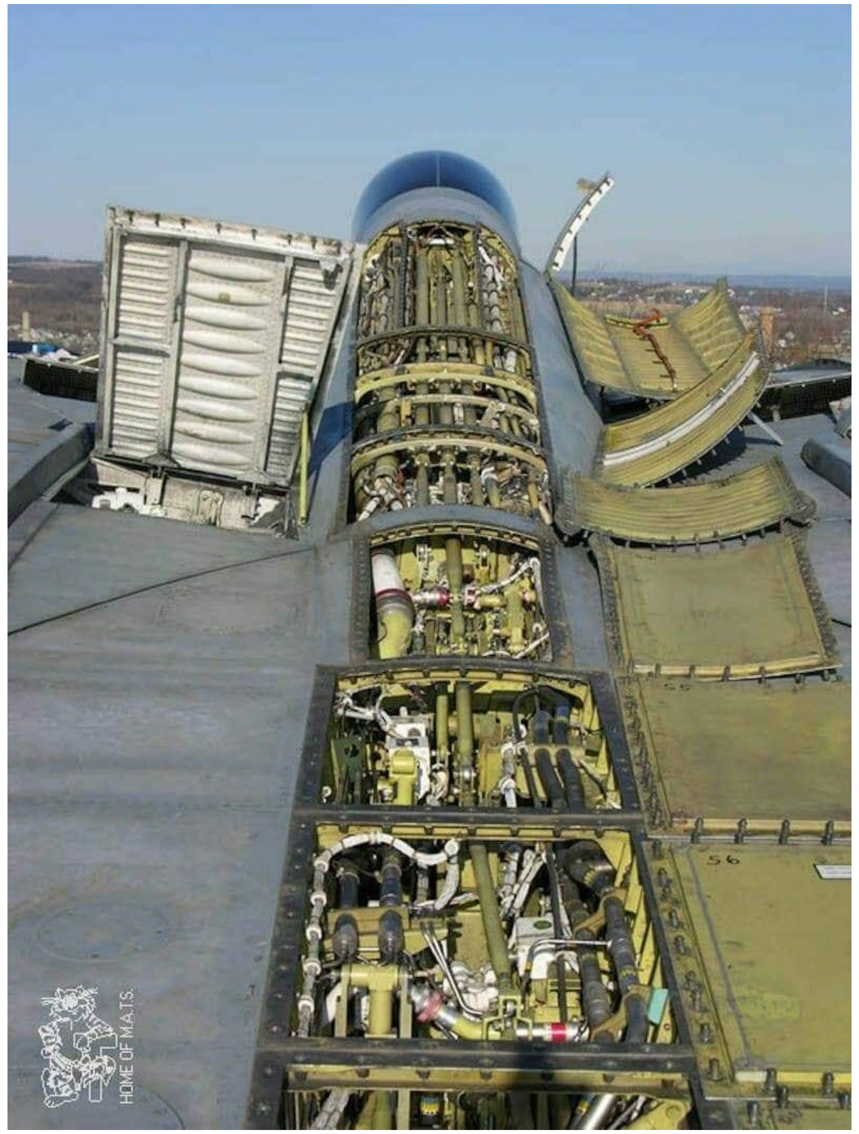
Other considerations (Chapters 8)

Maintainability



- The ease with which the aircraft can be fixed
- Location of systems
    - More prone to failure/maintenance = easiest access
    - F-4 radio under the ejection seat!
- Number of doors and structural doors
    - Access door area = 50% of wetted area on fighters!
    - Structural doors may require jacking of the aircraft!
- Avoid removal of major structural components
    - Harrier wing has to removed to remove engine!

Source: Aircraft Design by Daniel P. Raymer

ME4932 Aircraft Performance & Design

Other considerations (Chapters 9)

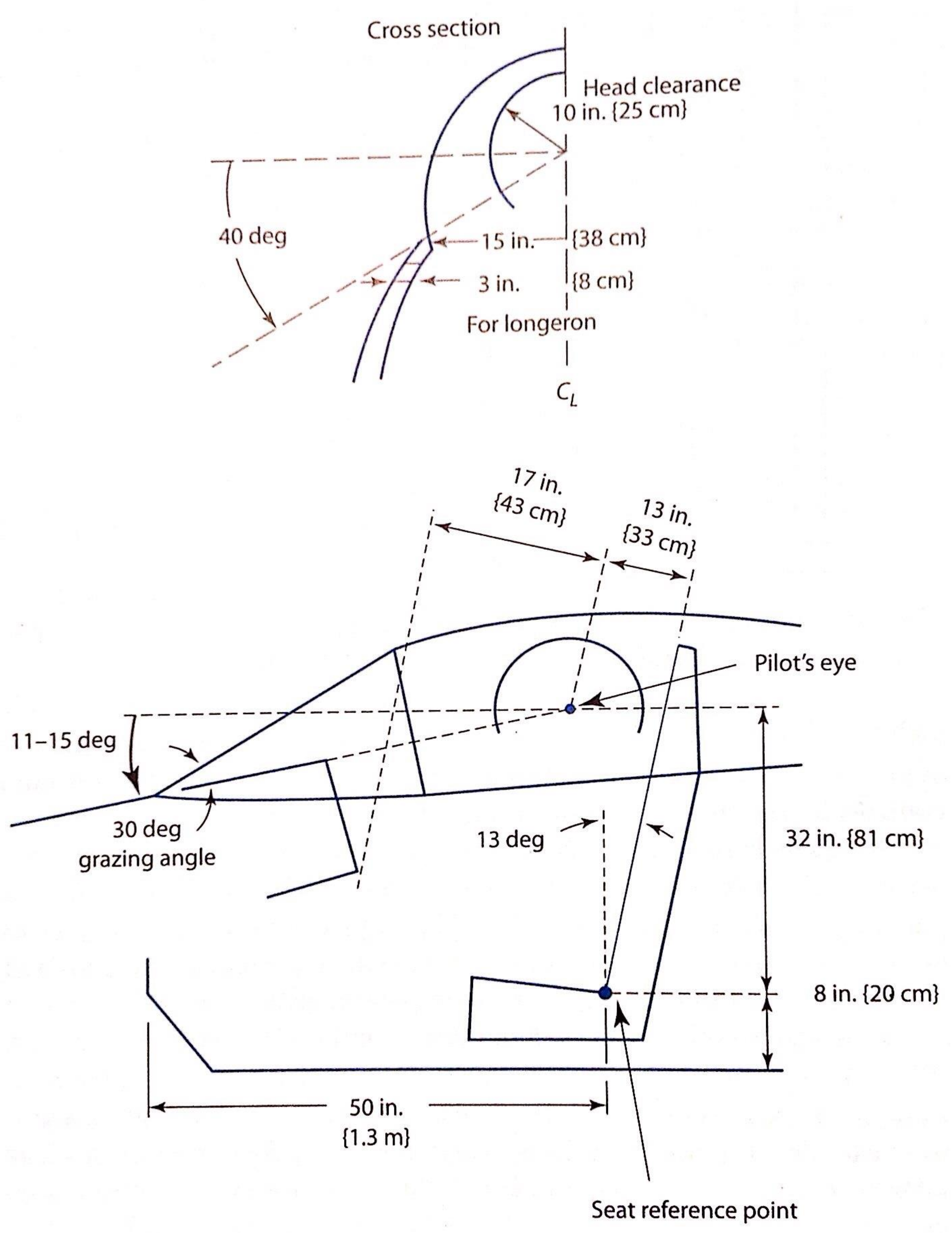
Crew Station

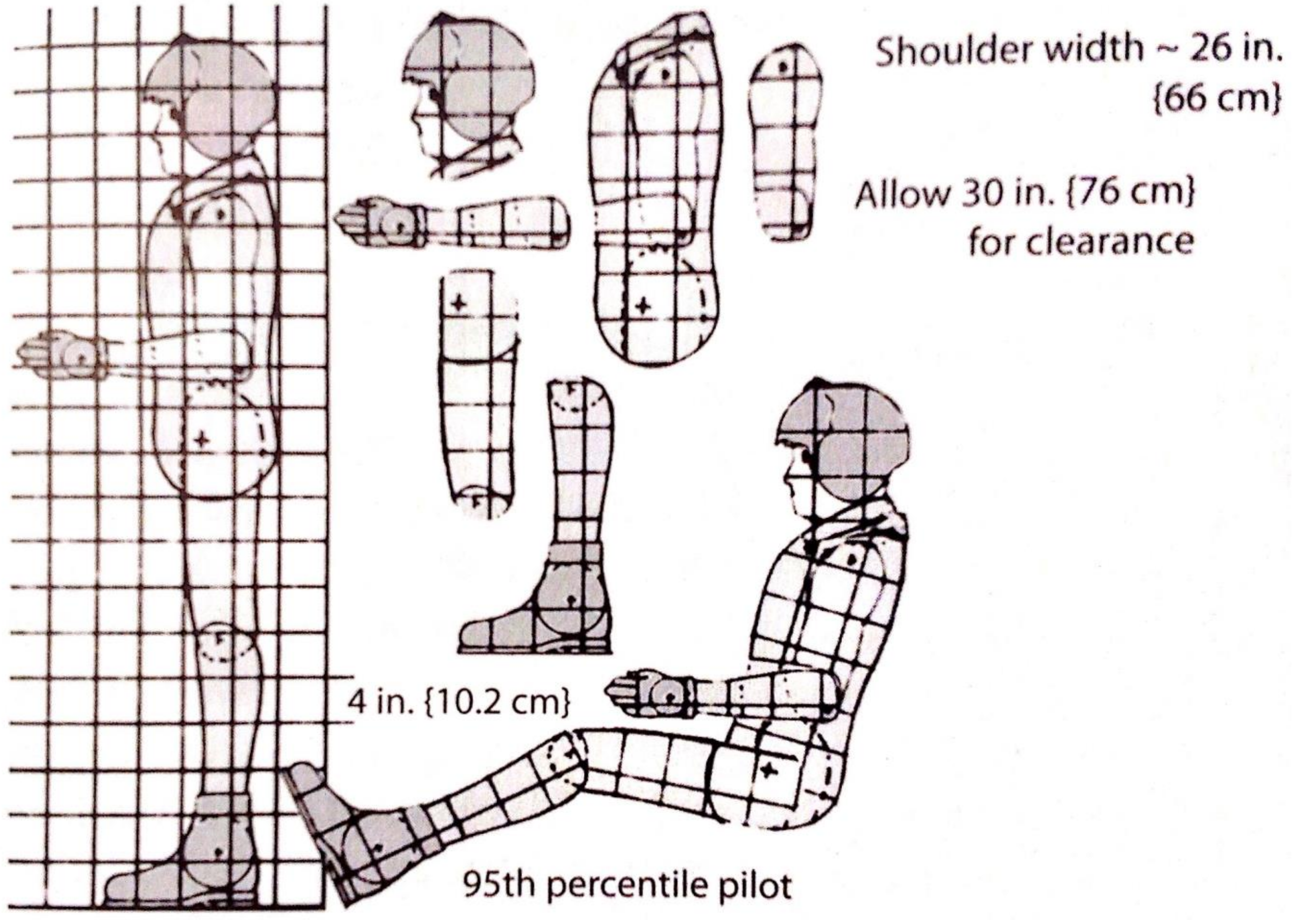
- Average pilot size
- Satisfy vision requirements; different for each type of aircraft
  - Shapes the front end of the aircraft
  - Over-the-nose vision angle
  - Over-the-side vision angle
  - Ejection seat, crew capsule

Source: Aircraft Design by Daniel P. Raymer

ME4932 Aircraft Performance & Design

Other considerations (Chapters 9)





Source: Aircraft Design by Daniel P. Raymer

Other considerations (Chapters 9)

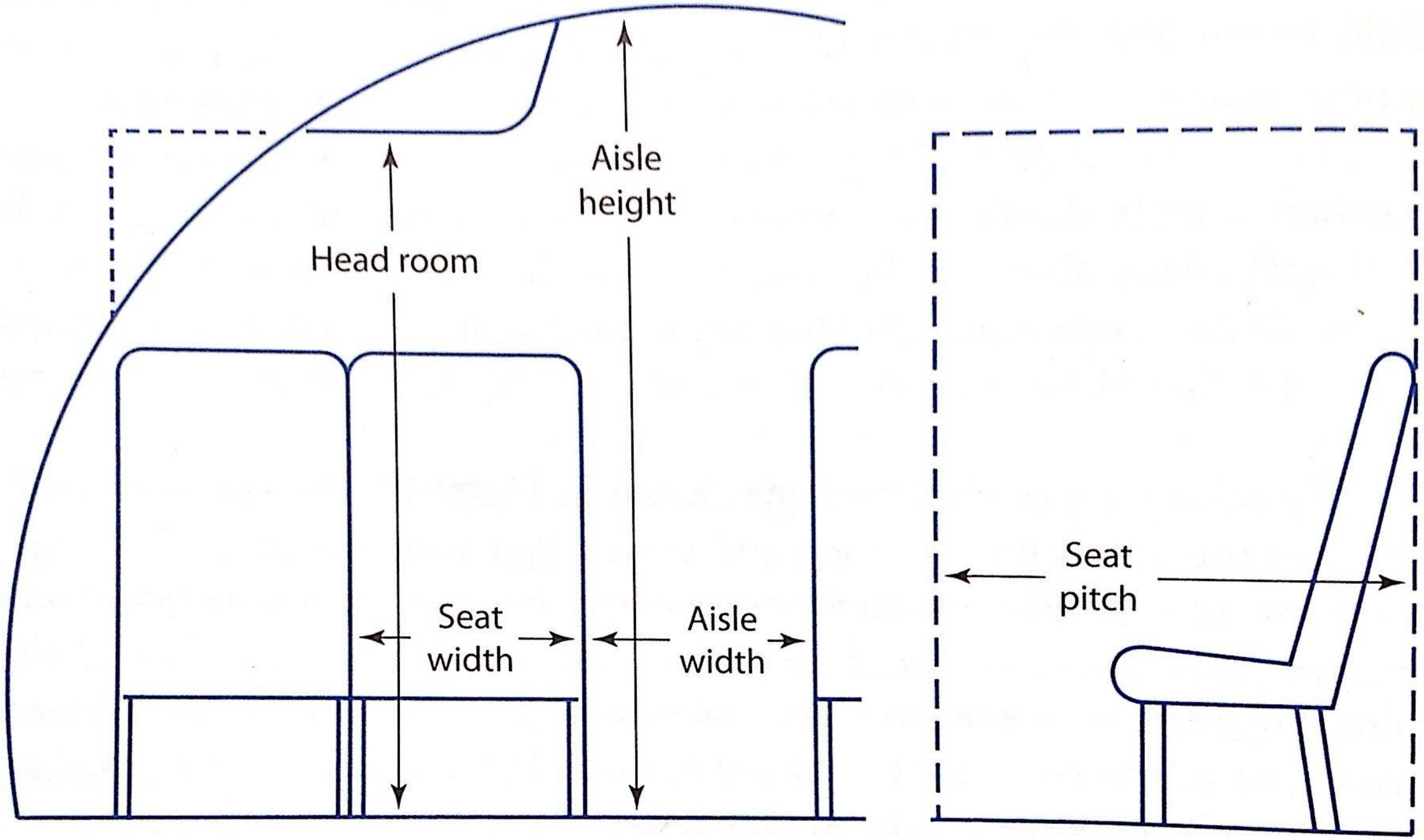
Passenger compartment

- Actual airliner cabin seat arrangement has more to do with marketing
    - Airline in the end changes pitch and width as economically necessary
    - Three seats per aisle
    - Passenger with carry-on bags = 180 lbs.
    - Checked luggage weight = 40-60 lbs.

Source: Aircraft Design by Daniel P. Raymer

ME4932 Aircraft Performance & Design

Other considerations (Chapters 9)



Source: Aircraft Design by Daniel P. Raymer

ME4932 Aircraft Performance & Design

Other considerations (Chapters 9)

	First class	Economy	High-density/ small aircraft
Seat pitch, in. {cm}	38–40 {97–102}	34–36 {86–91}	30–32 {76–81}
Seat width, in. {cm}	20–28 {51–71}	17–22 {43–56}	16–18 {41–46}
Head room, in. {cm}	>65 {165}	>65 {165}	—
Aisle width, in. {cm}	20–28 {51–71}	18–20 {46–51}	≥12 {30}
Aisle height, in. {cm}	>76 {193}	>76 {193}	>60 {152}
Passengers per cabin staff (international-domestic)	16–20	31–36	≤50
Passengers per lavatory (40 × 40 in.) {1 × 1 m}	10–20	40–60	40–60
Galley volume per passenger, ft^3 {m^3}	5–8 {0.14–0.23}	1–2 {0.03–0.06}	0–1 {0–0.03}

- Airlines actually use 31 in. for pitch and 17 in. width!

Source: Aircraft Design by Daniel P. Raymer

Other considerations (Chapters 9)

Cargo

- For commercial airliners, use existing cargo containers
- 8.6-15.6 cubic feet of cargo volume (luggage+ paid cargo) on airliners
- 6-8 cubic feet for small transports
- Military cargo pallets measure 88 x 108 in.
- Military cargo floor at 4-5 ft height to allow for truck bed loading

Source: Aircraft Design by Daniel P. Raymer

Other considerations (Chapter 9)

Weapons

- Close to c.g. to avoid pitching moment
- External
  - Simpler, lighter, but more drag!
  - Except for small A-A missiles, no supersonic flight!
  - Conformal of semi-submerged - not as flexible
- Internal
  - Lower drag
  - Good for reducing radar signature
- Clearance
  - Weapon to weapon , ground and rest of aircraft!
- Gun
  - Muzzle away from cockpit
  - Centerline

Source: Aircraft Design by Daniel P. Raymer

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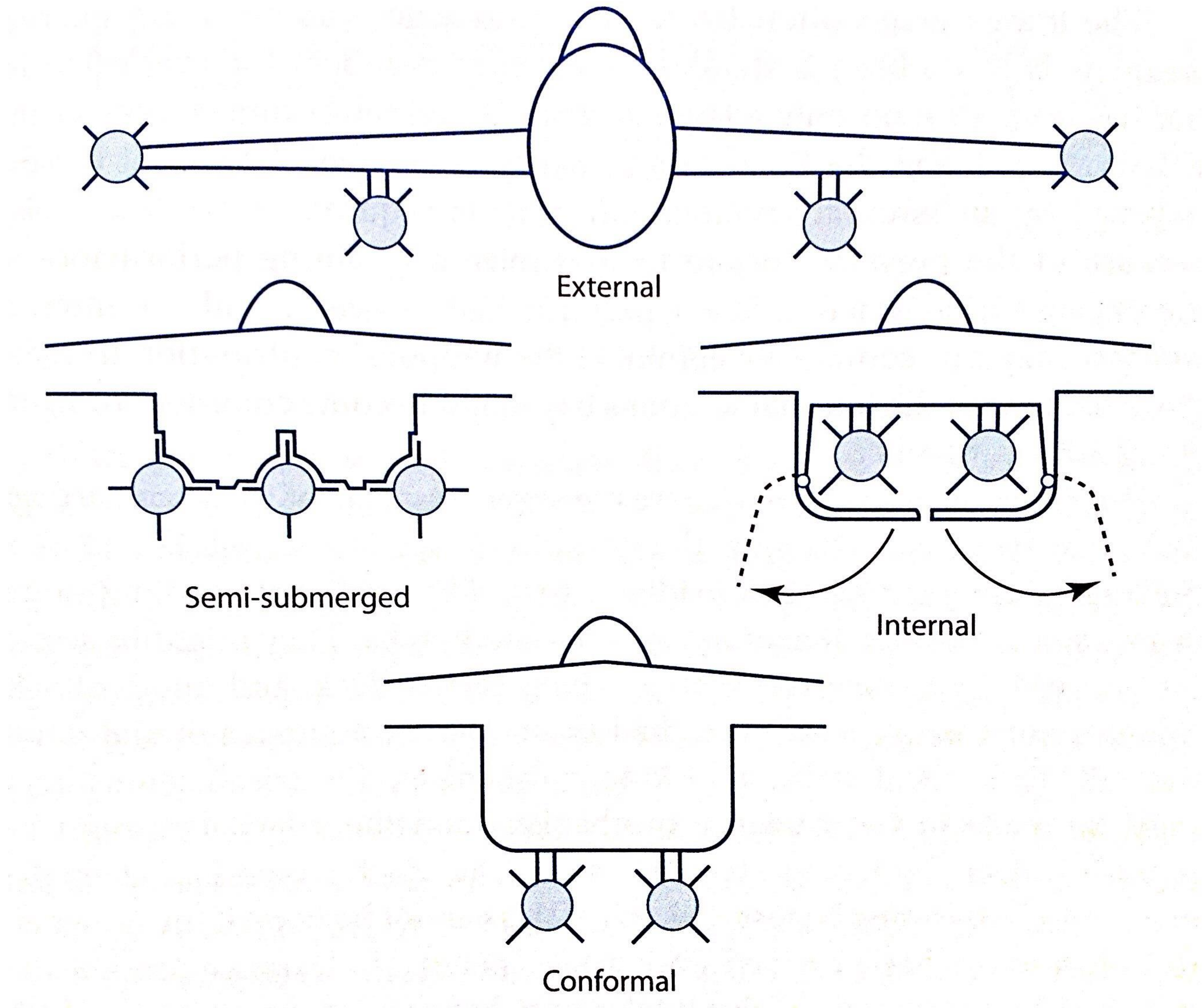
Other considerations (Chapters 9)



Source: Aircraft Design by Daniel P. Raymer

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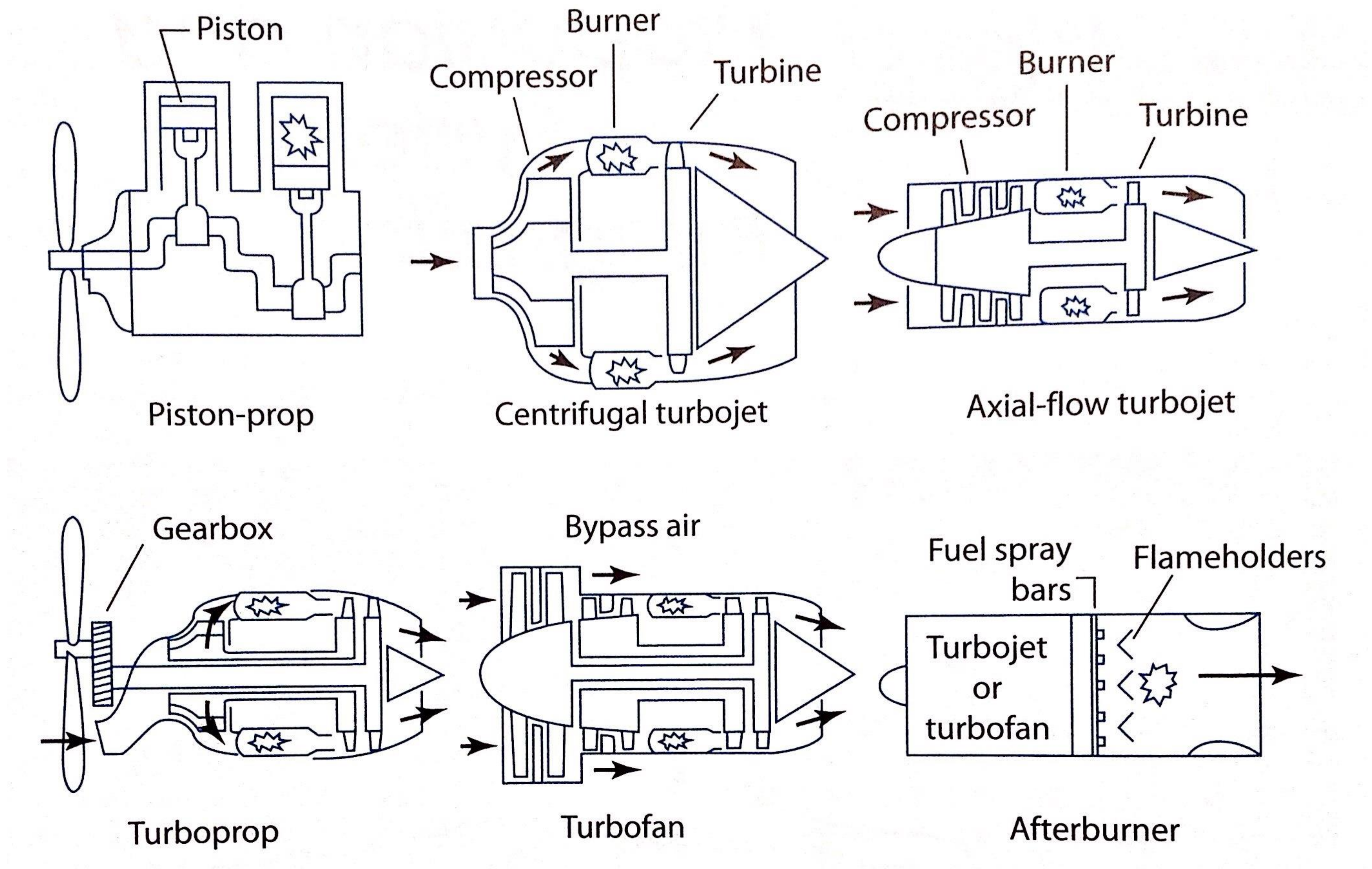
Other considerations (Chapter 10)

Propulsion and Fuel System Integration



Source: Aircraft Design by Daniel P. Raymer

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Other considerations (Chapter 10)

Propulsion and Fuel System Integration

- Engine is one of the largest weight/volume items!
- Piston-Prop
  - Cheap and lowest fuel consumption at low speeds
  - Noise and vibration
  - Rapidly loses thrust with increasing velocity

Source: Aircraft Design by Daniel P. Raymer

ME4932 Aircraft Performance & Design

Other considerations (Chapter 10)

Propulsion and Fuel System Integration

- Jets
    - Turboprops
        - Fell out of favor due to the need for speed
        - Prop-fans (turboprop) use advanced aerodynamics propellers. Near-sonic speeds. Noisy.
    - Turbo fans have the best subsonic efficiency and lowest noise.
        - Open rotors (BPR>30 turbofan) use no duct. Noisy.
    - Turbojets for efficient M>2.0 operation

Source: Aircraft Design by Daniel P. Raymer

Other considerations (Chapter 10)

Propulsion and Fuel System Integration

- After-burning or reheat
  - Fuel burned in core at 60:1 air to fuel ratio (stoichiometric = 15:1) to keep TIT safe.
  - Excess uncombusted hot air will burn and increase thrust 100%.
  - After-burner uses twice more fuel than core per pound of thrust.
  - Increases length 100% and engine weight 20-30%

Source: Aircraft Design by Daniel P. Raymer

ME4932 Aircraft Performance & Design

Other considerations (Chapter 10)

Propulsion and Fuel System Integration

- Ramjet and Scramjets
  - Specially above Mach 3, an inlet will compress air enough that it will burn when fuel is added (ramjet)
  - Scramjets burn supersonic flow
  - They need other forms of propulsion for takeoff and acceleration to high supersonic speeds.

Source: Aircraft Design by Daniel P. Raymer

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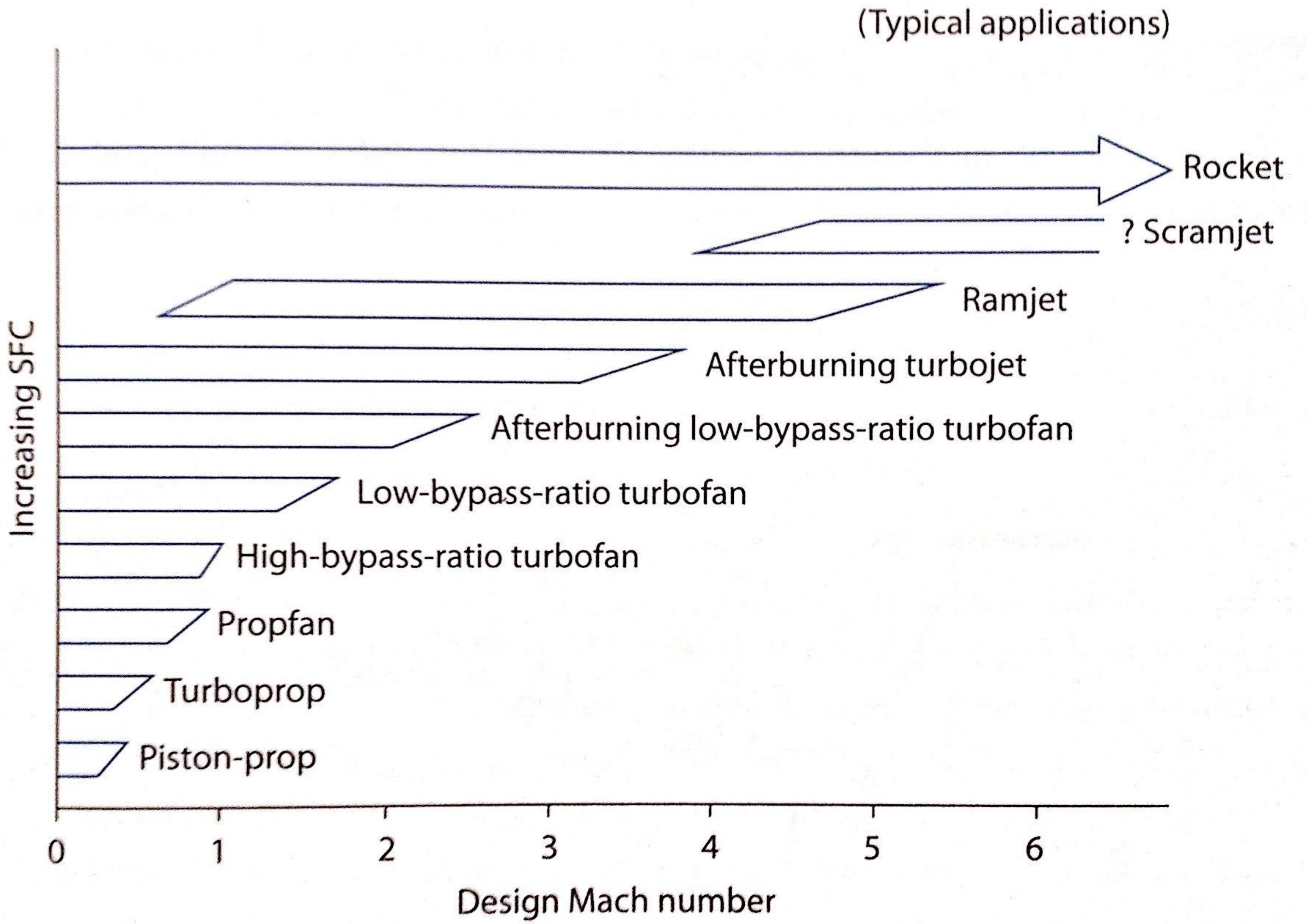
Other considerations (Chapter 10)

- Propulsion system selection



Source: Aircraft Design by Daniel P. Raymer

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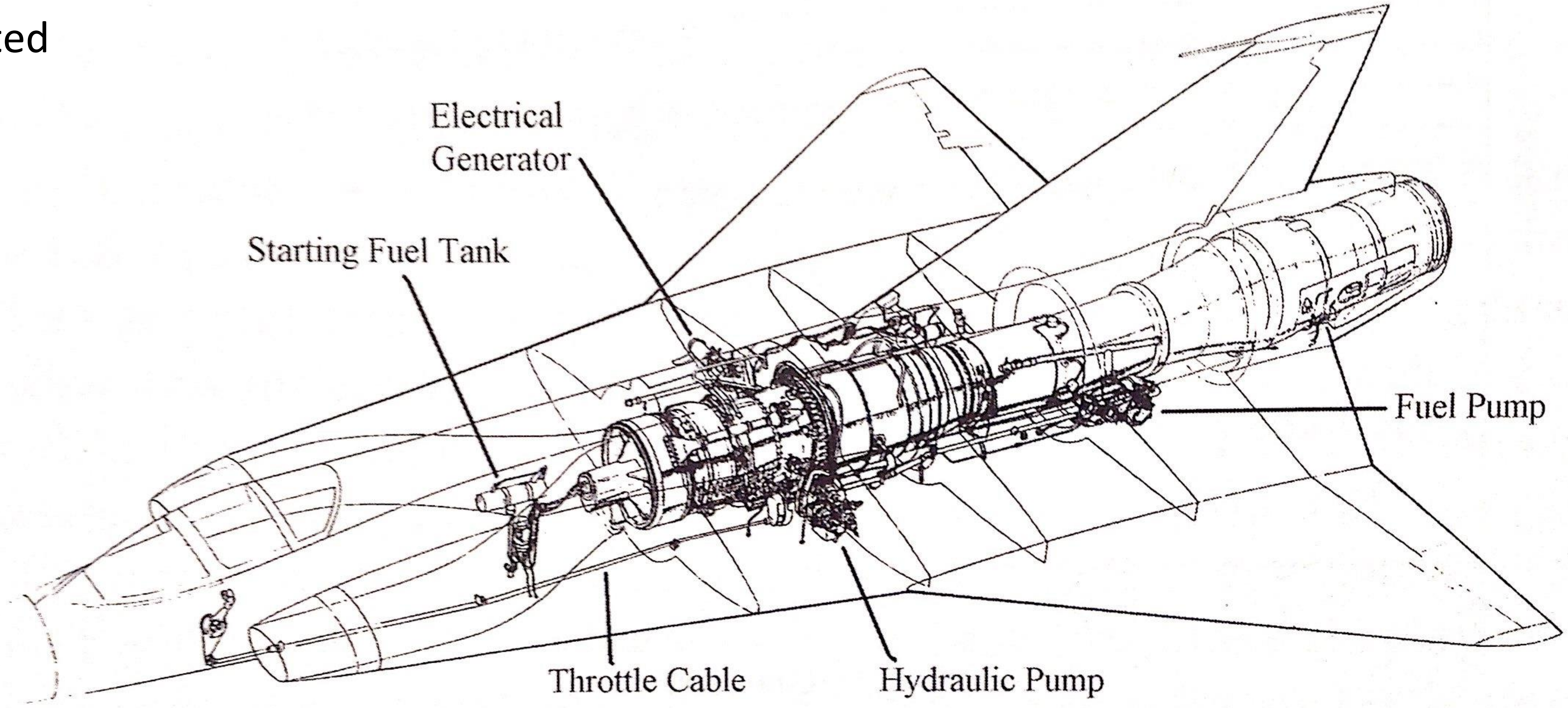
Other considerations (Chapter 10)

- Jet engine integration
- Complicated



Source: Aircraft Design by Daniel P. Raymer

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Other considerations (Chapter 10)

Jet engine integration

- Allowances for cooling air around engine and nozzles and for access and removal
- Strong structure at engine mounts
- Radius 20-40% more under engine for accessories (fuel and oil pumps, power takeoff gearboxes, engine control boxes)
- Engine dimensions from manufacturer (fixed engine) or statistical (complete rubber engine)

Source: Aircraft Design by Daniel P. Raymer

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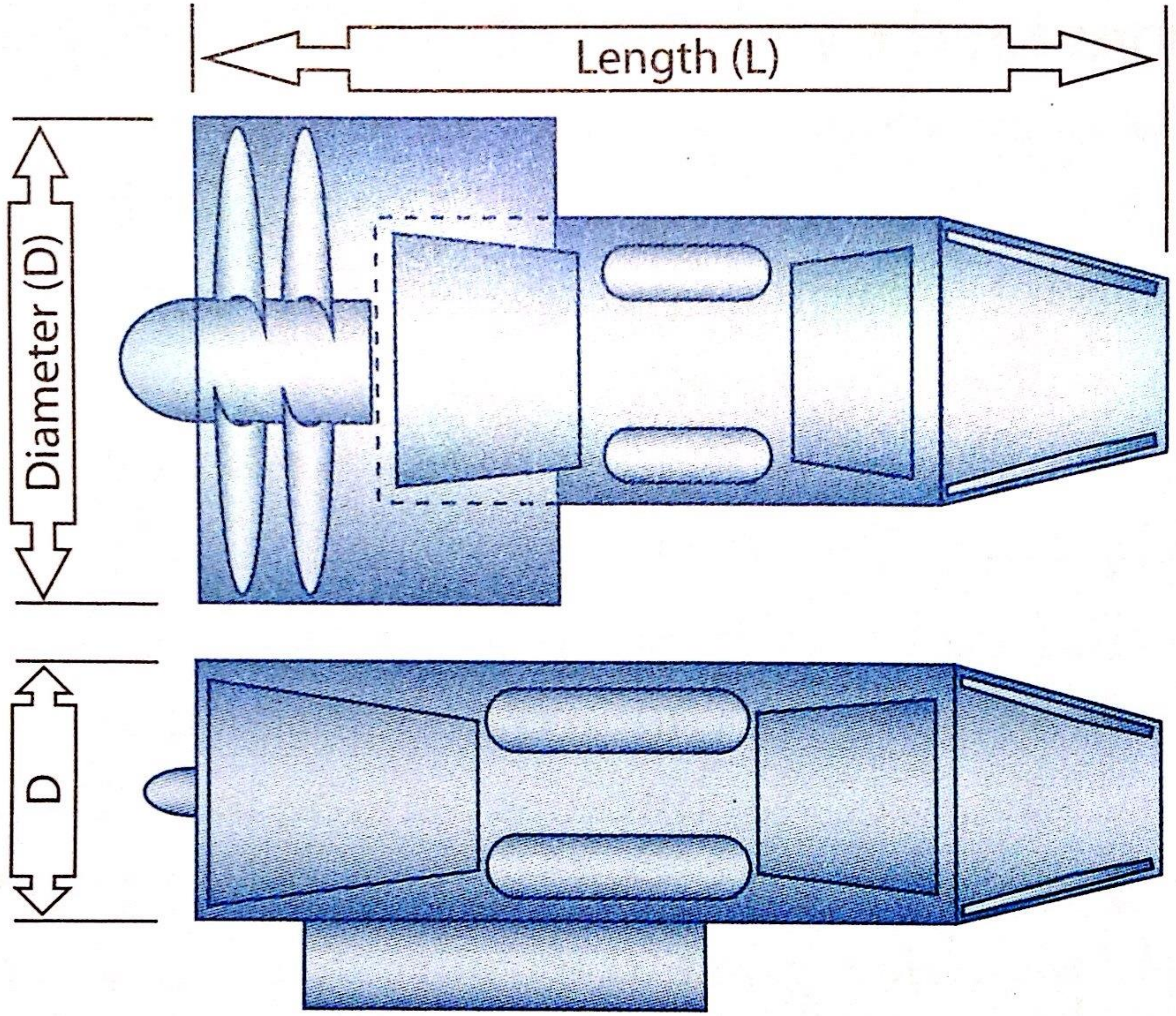
Other considerations (Chapter 10)

$$L = L_{\text{actual}}(\text{SF})^{0.4}$$

$$D = D_{\text{actual}}(\text{SF})^{0.5}$$

$$W = W_{\text{actual}}(\text{SF})^{1.1}$$



Scale factor: $\text{SF} = T_{\text{required}}/T_{\text{actual}}$

Source: Aircraft Design by Daniel P. Raymer

Other considerations (Chapter 10)

Jet engine integration (continued)

- Inlet must slow air down (0.4-0.5M)to avoid compressor blades from going sonic, with minimum total pressure loss. 10%P_o loss =13% thrust loss!
- Inlet design is a function of design Mach.
- Diffuser internal angles < 10^0.
- Inlet location should ensure good quality air. Podded engines initially located with respect to wing or fuselage according to guidelines.
- Capture area set so freestream slows down 50% as it reaches inlet plane.
- B.L diverters

Source: Aircraft Design by Daniel P. Raymer

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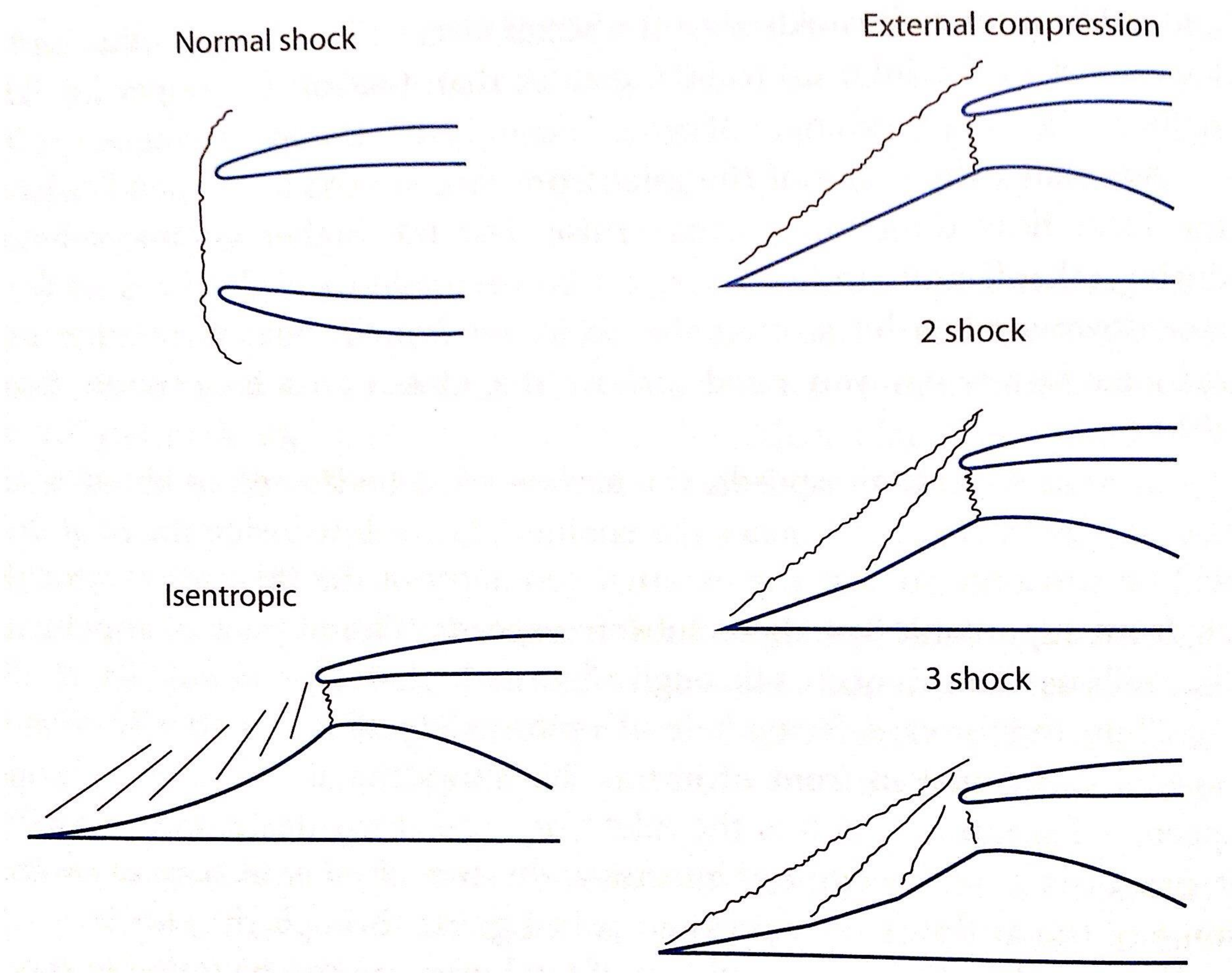
Other considerations (Chapter 10)



Source: Aircraft Design by Daniel P. Raymer

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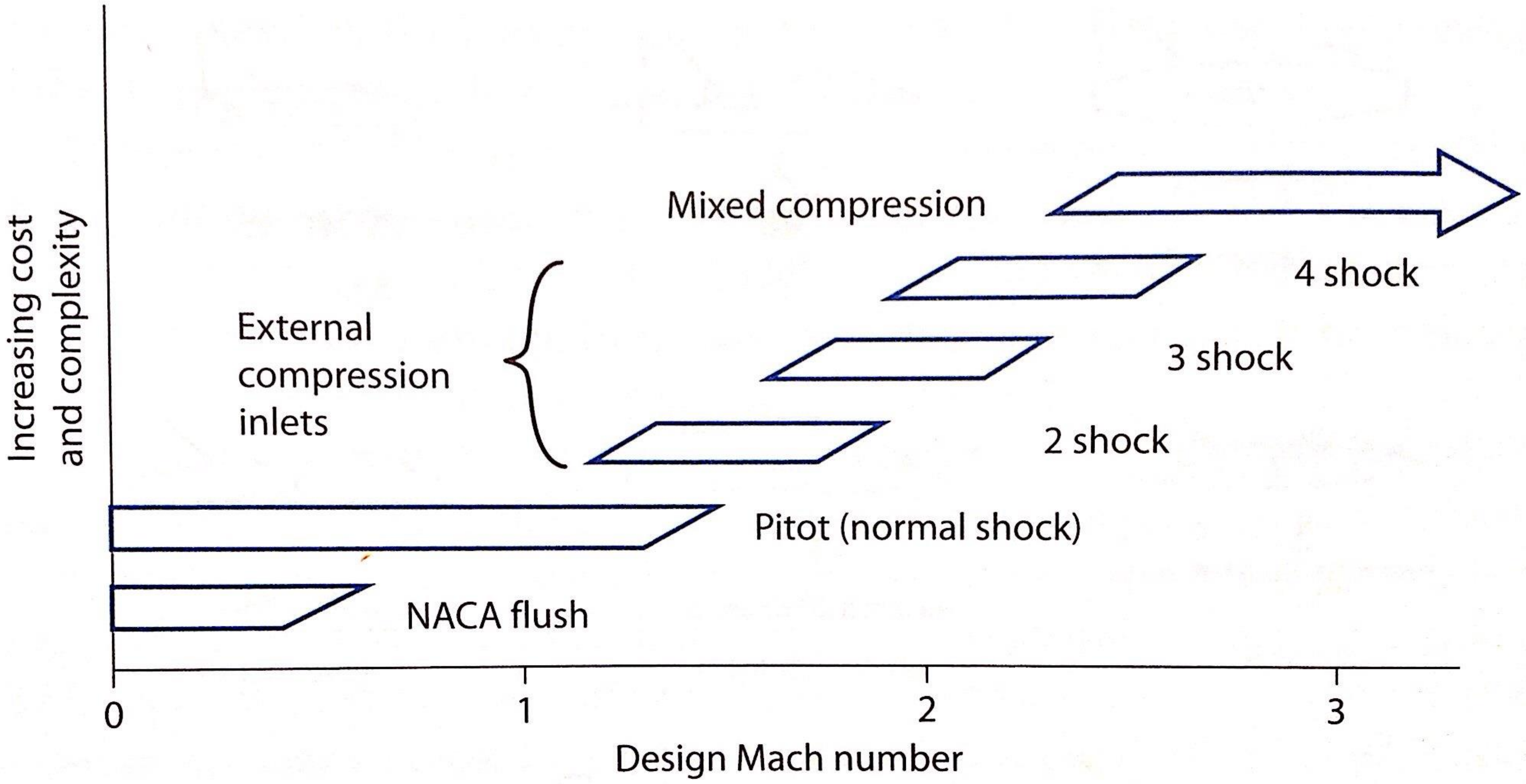
Other considerations (Chapter 10)



Source: Aircraft Design by Daniel P. Raymer

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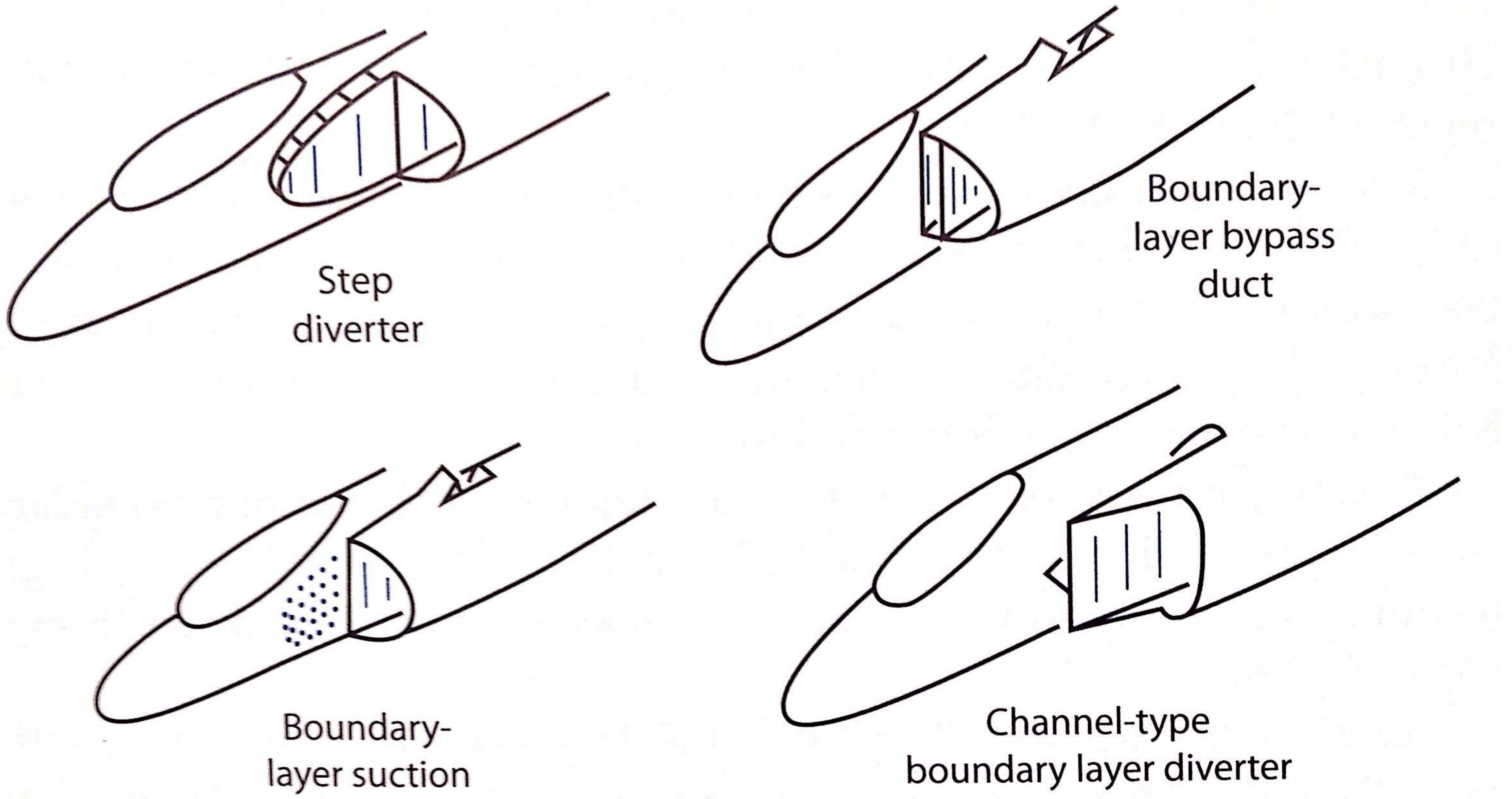
Other considerations (Chapter 10)



Source: Aircraft Design by Daniel P. Raymer

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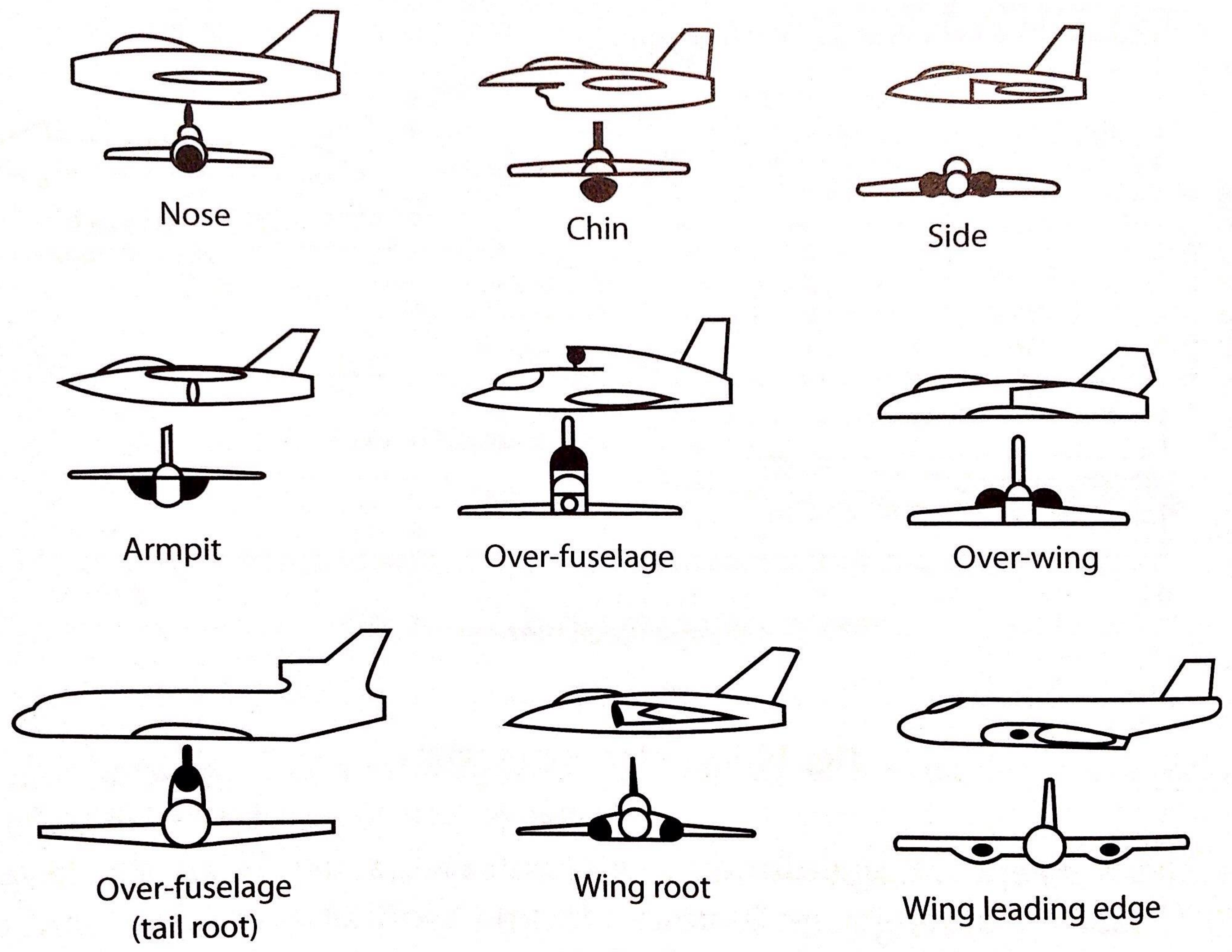
Other considerations (Chapter 10)



- Vortex ingestion
- Foreign objects
- Duct length
- High AOA

Source: Aircraft Design by Daniel P. Raymer

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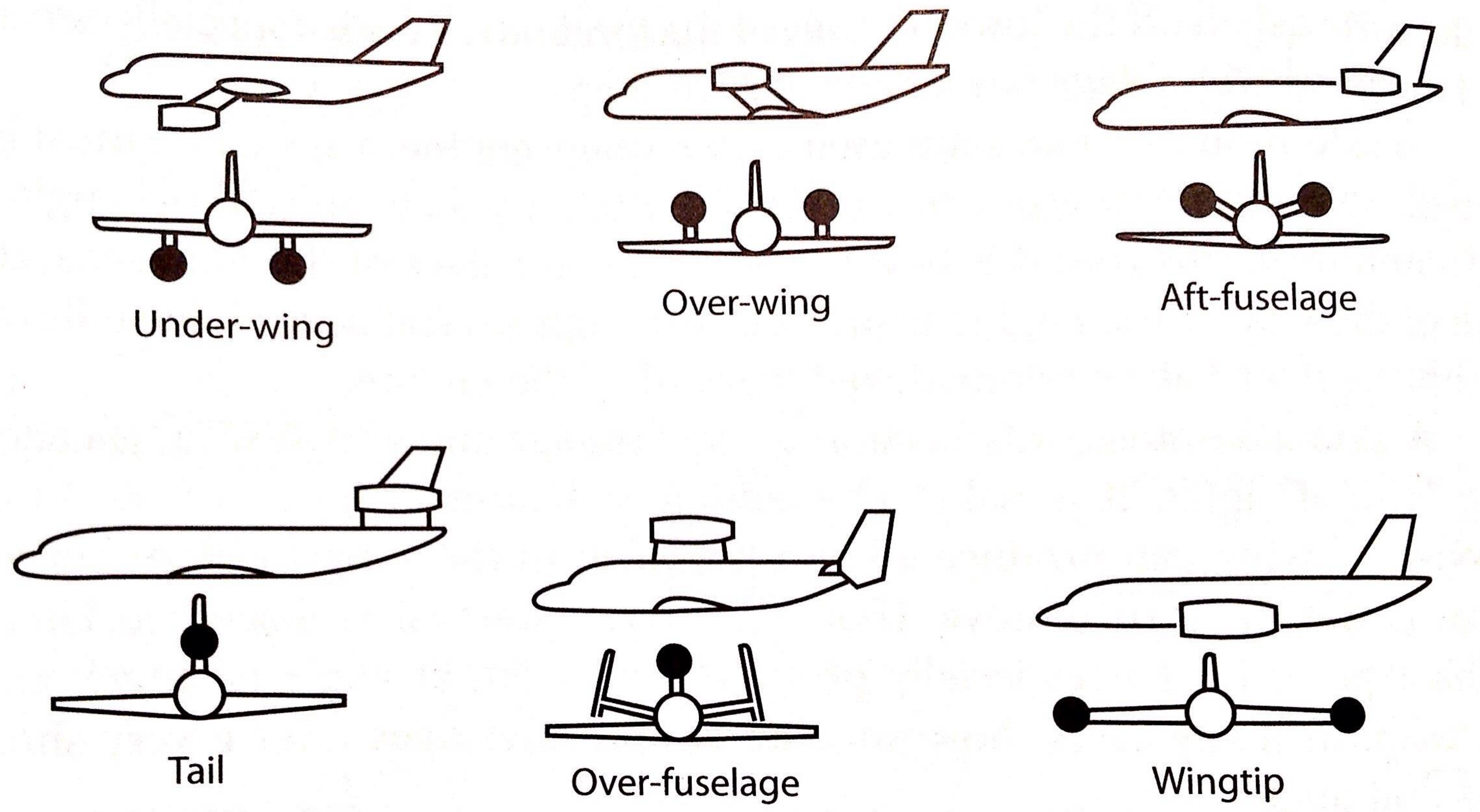
Other considerations (Chapter 10)



- Wetted area
- Short duct
- Nice air
- Low noise
- Easy Maintenance

Source: Aircraft Design by Daniel P. Raymer

Other considerations (Chapter 10)

- The limit for propeller diameter is tip speed

$$(V_{\text{tip}})_{\text{static}} = \pi n D \qquad (V_{\text{tip}})_{\text{helical}} = \sqrt{V_{\text{tip}}^2 + V^2}$$

- Helical tip speed < 950 ft/s (metal)
- Helical tip speed < 850 ft/s (wood)
- Helical tip speed < 700 ft/s (noise)

Source: Aircraft Design by Daniel P. Raymer

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Other considerations (Chapter 10)

- Propeller sizing using historical values limited by real life considerations:

$$D = K_p \sqrt[4]{\text{Power}}$$

	British units	Metric units
No. blades	K_p	K_p
2	1.7	0.56
3	1.6	0.52
4+	1.5	0.49
Power units	hp	kW
Diameter units	ft	m

Source: Aircraft Design by Daniel P. Raymer

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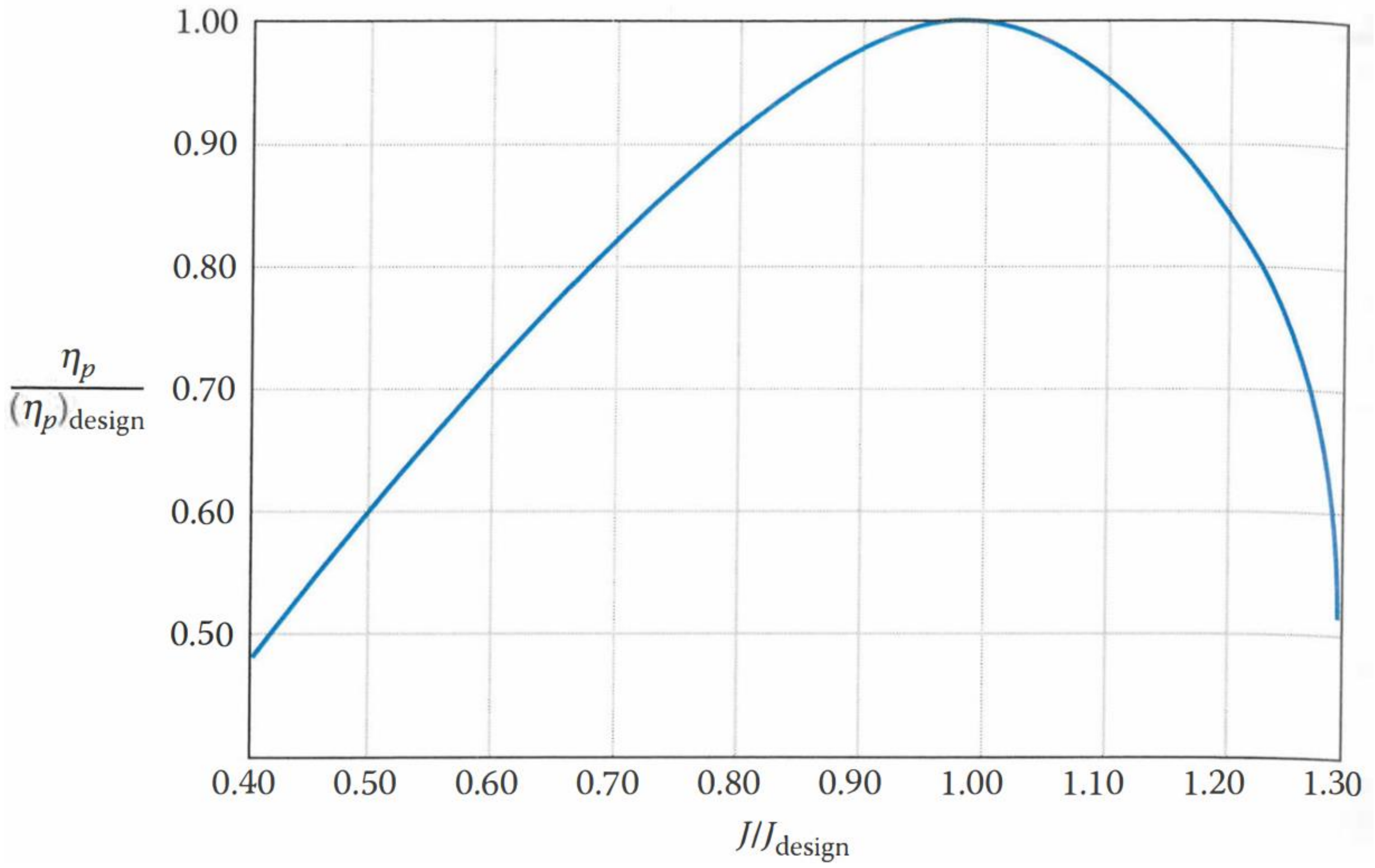
Other considerations (Chapter 10)

- Off-design propeller efficiency of the optimum propeller



Source: Aircraft Design by Daniel P. Raymer

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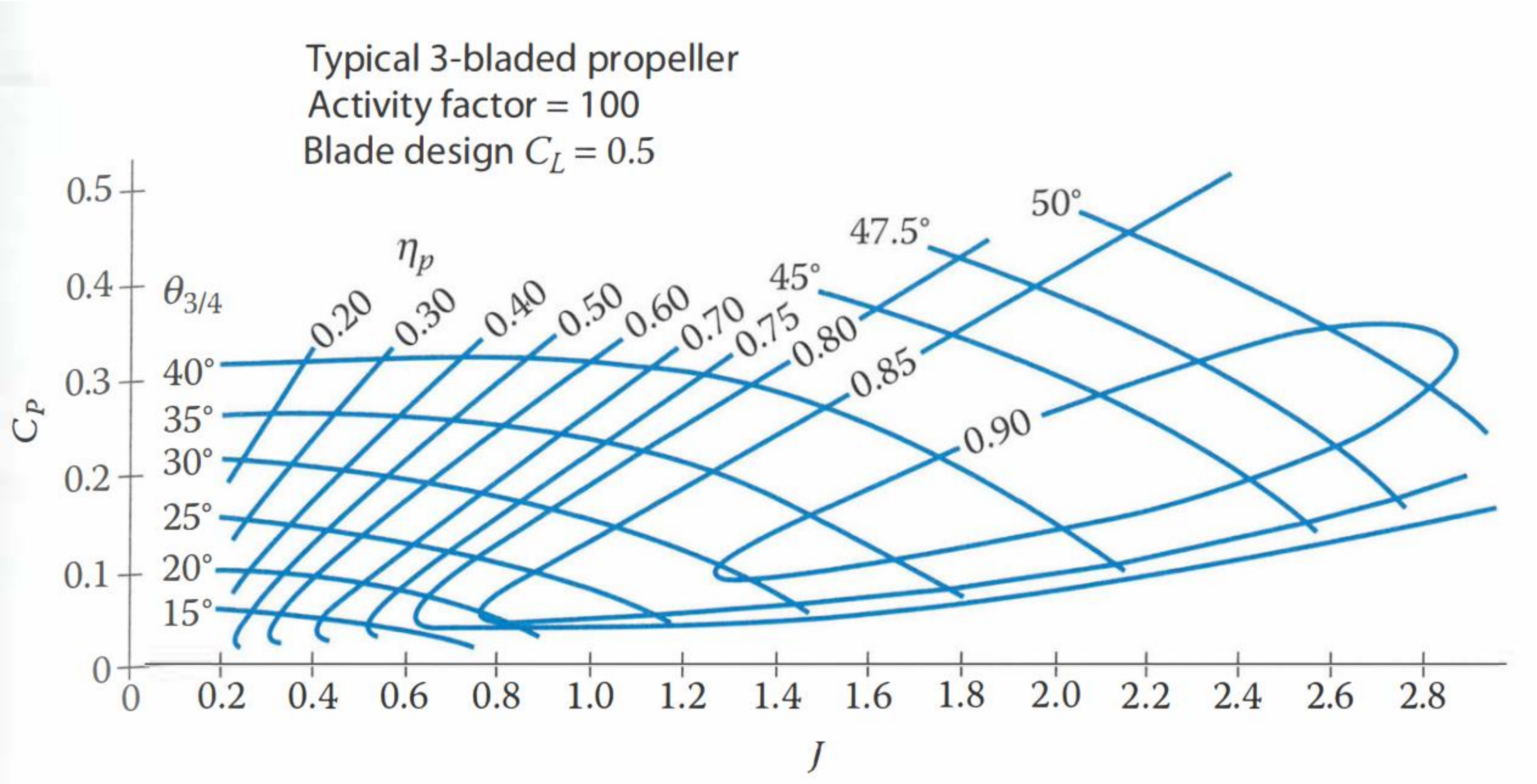
Other considerations (Chapter 10)

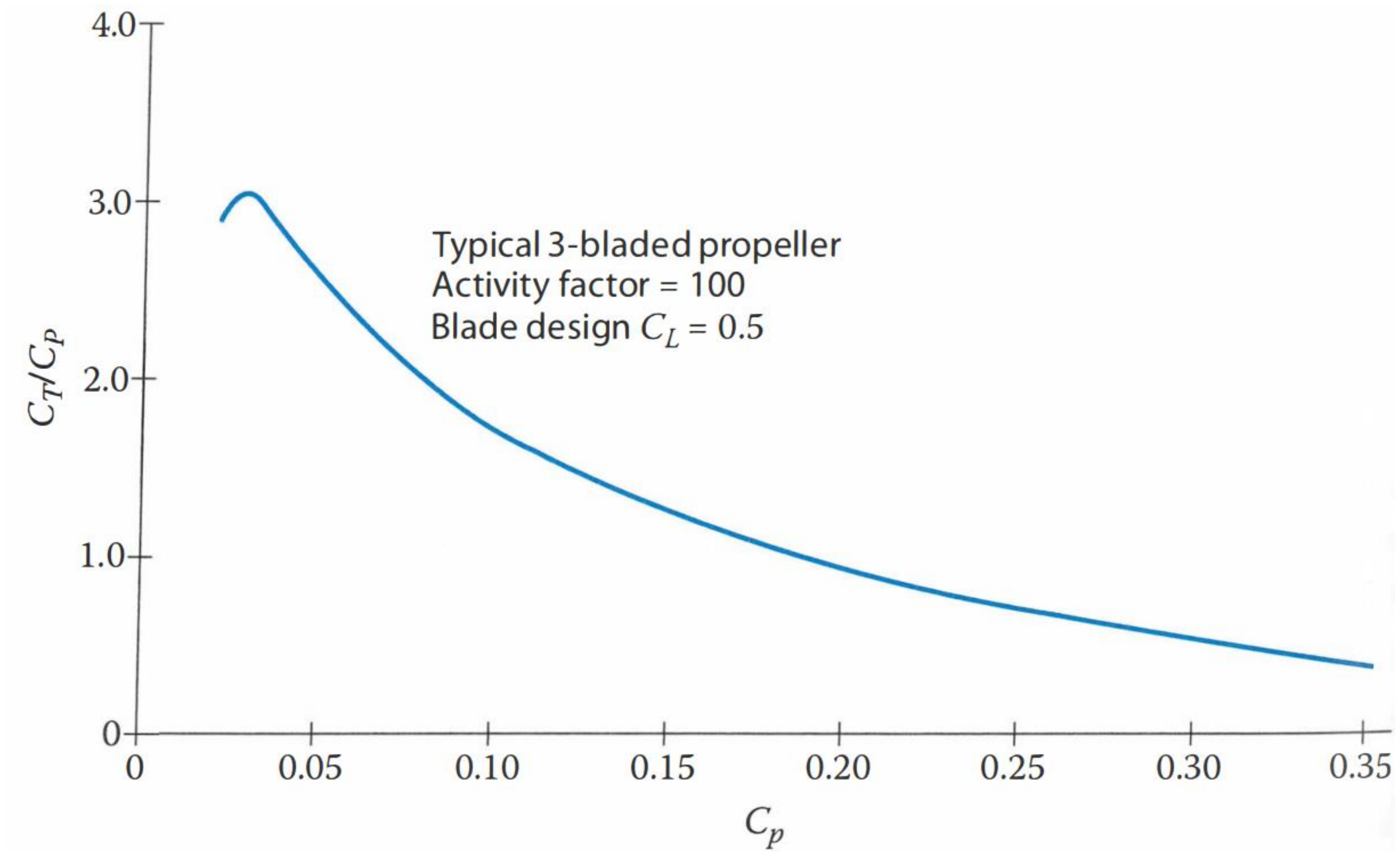
- Knowing horsepower, appropriate pitch and on-design efficiency.



Source: Aircraft Design by Daniel P. Raymer

Other considerations (Chapter 10)

- Knowing horsepower, find static thrust.



Source: Aircraft Design by Daniel P. Raymer

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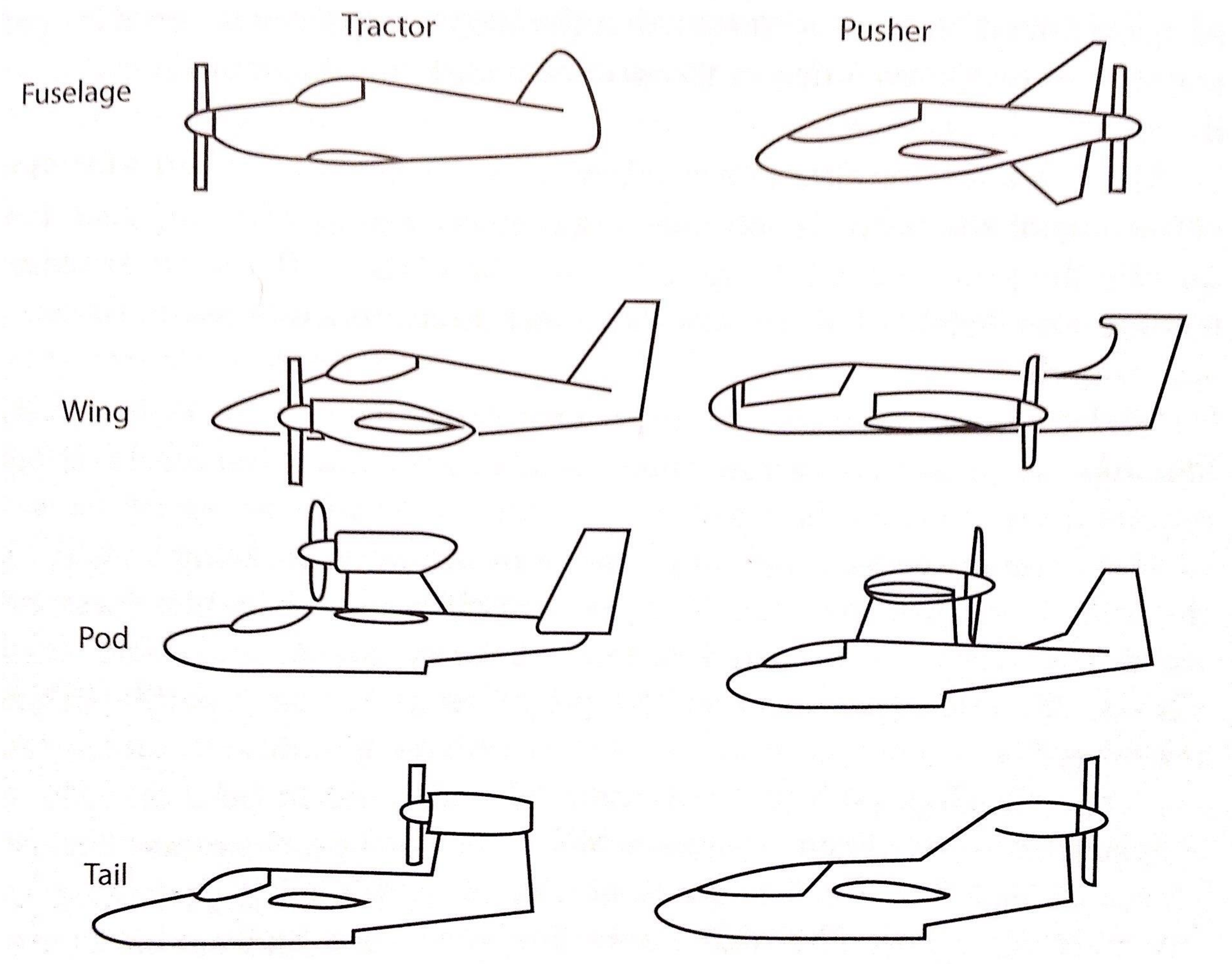
Other considerations (Chapter 10)



Source: Aircraft Design by Daniel P. Raymer

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Other considerations (Chapter 10)

- Piston and turboprop rubber engine (scaling existing engine)

X	Piston engines			
	Opposed	In-line	Radial	Turboprop
Weight	0.78	0.78	0.809	0.803
Length	0.424	4.24	0.310	3.730
Diameter	——*	——*	0.130	0.120

*Width and height vary insignificantly within +50% power.

$X_{scaled} = X_{actual} SF^{\dagger}$.

†From table values $SF = \text{power}_{scaled}/\text{power}_{actual}$.

Source: Aircraft Design by Daniel P. Raymer

ME4932 Aircraft Performance & Design

Other considerations (Chapter 10)

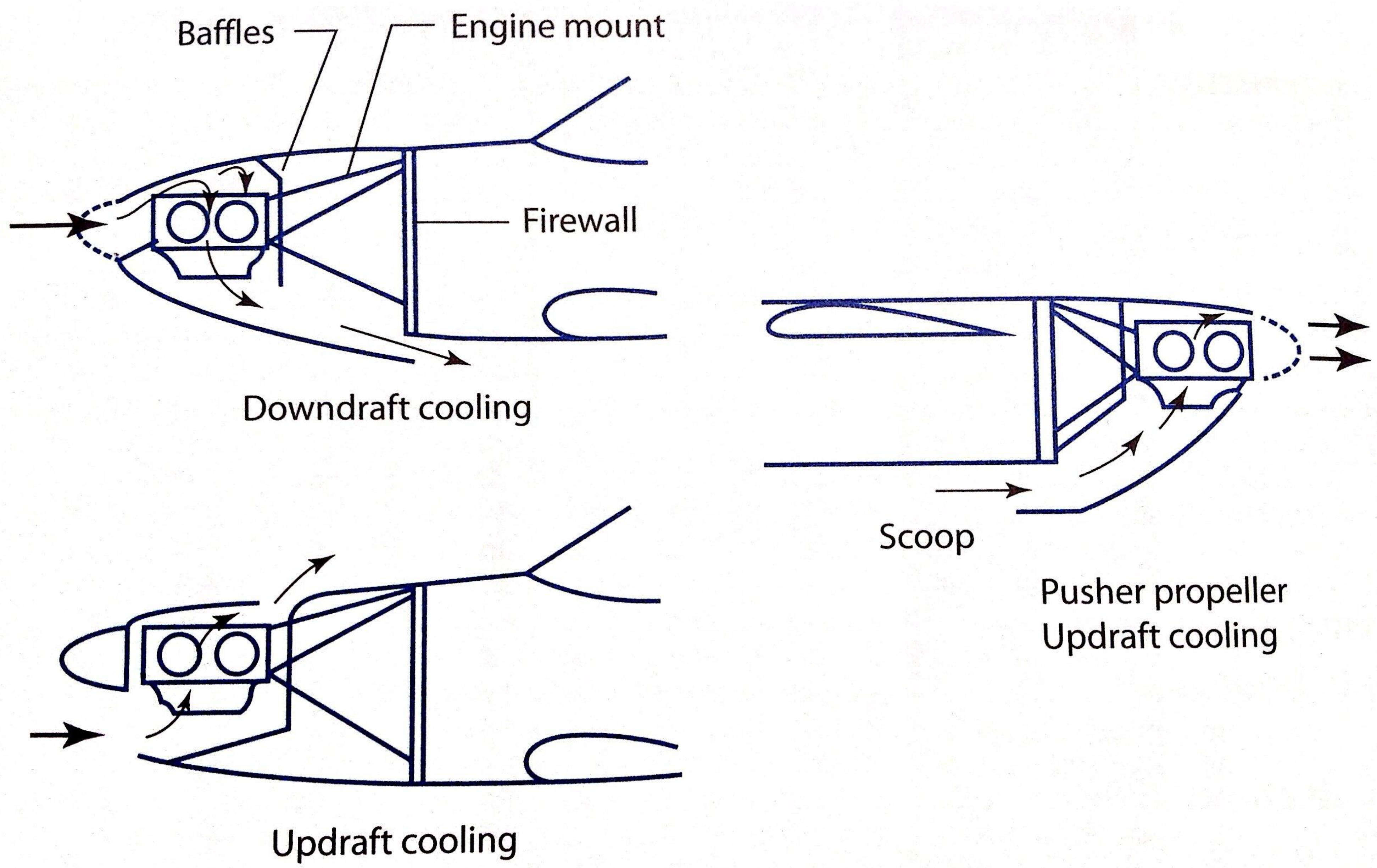
- Piston and turboprop rubber engine (nominal engine)

Engine Parameter "X"	Piston engines						Turboprop	
	Opposed		In-line		Radial			
	a	b	a	b	a	b	a	b
British: $X = a(\text{bhp})^b$ [lb or ft]								
Weight	5.47	0.780	5.22	0.780	4.90	0.809	1.67	0.803
Length	0.32	0.424	0.49	0.424	0.52	0.310	0.35	0.373
Diameter	Width 2.6–2.8 ft		Width 1.4–1.6 ft		1.7	0.130	0.8	0.120
	Height 1.8–2.1 ft		Height 2–2.2 ft					
Typical propeller, rpm	2770		2770		2300			
Applicable bhp range	60–500		100–300		200–2000		400–5000	
Metric: $X = a(\text{power})^b$ [kg or m]								
Weight	3.12	0.780	2.98	0.780	2.82	0.809	0.96	0.803
Length	0.11	0.424	0.17	0.424	0.174	0.310	0.12	0.373
Diameter	Width 0.8–0.9		Width 0.4–0.5		0.54	0.130	0.25	0.120
	Height 0.6–0.7		Height 0.6–0.7					
Typical propeller, rpm	2770		2770		2300			
Applicable power range, kW	45–370		75–225		150–1500		300–3728	

Source: Aircraft Design by Daniel P. Raymer

ME4932 Aircraft Performance & Design

Other considerations (Chapter 10)



$$A_{\text{cooling}} = \frac{\text{bhp}}{2.2 V_{\text{climb}}}$$

Source: Aircraft Design by Daniel P. Raymer

ME4932 Aircraft Performance & Design

Other considerations (Chapter 10)

Tractor (front)

+ heavy engine up front = smaller tails

- disturbed air on aircraft

+ cooling air

+ undisturbed air on prop (better prop efficiency)

Source: Aircraft Design by Daniel P. Raymer

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Other considerations (Chapter 10)

Pusher (aft)

+ Lower friction drag (aircraft flies in undisturbed air)

+ Can have shorter fuselage as prop helps turn flow around fuselage

+ Reduces cabin noise

+ Prop less efficient (disturbed air by a/c)

- Larger horizontal tail

- Longer landing gear for takeoff and landing

- Prop vulnerable from objects thrown by wheels

Source: Aircraft Design by Daniel P. Raymer

Other considerations (Chapter 10)

Wing-mounted

+ Reduces wing weight through span loading

- Engine-out controllability

- Low wing = longer landing gear

- Pusher prop less efficient (disturbed air by wing's lower/upper wing flow)

Source: Aircraft Design by Daniel P. Raymer

Other considerations (Chapter 10)

Ducted fans

- More efficient than a prop of same diameter but normally you wouldn't want a prop of that small diameter! A larger prop is always better!

- Gap between blade tips and duct must be minuscule (not easy)

+Safer

+Quieter

Source: Aircraft Design by Daniel P. Raymer

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Other considerations (Chapter 10)

Fuel tanks

- Discrete = Containers fabricated separately
- Bladder = Pre-shapes bag stuffed in cavity
    - Self-sealing
    - Lose 10% of volume
- Integral = Cavities within structure
- Total fuel c.g. Should be close to aircraft c.g.
- Fuel can be pumped to manage c.g.

Source: Aircraft Design by Daniel P. Raymer

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Other considerations (Chapter 10)

- Fuel densities:

	0°F {−18°C}	Mil-spec density 59°F {15°C}	100°F {38°C}
Aviation gasoline	6.1 {0.73}	6.0 {0.72}	5.7 {0.68}
JP-4/JET-B	6.7 {0.80}	6.5 {0.78}	6.4 {0.77}
JP-5	7.2 {0.86}	6.8 {0.82}	6.8 {0.82}
JP-8/JET-A1	—	6.7 {0.80}	—

Source: Aircraft Design by Daniel P. Raymer

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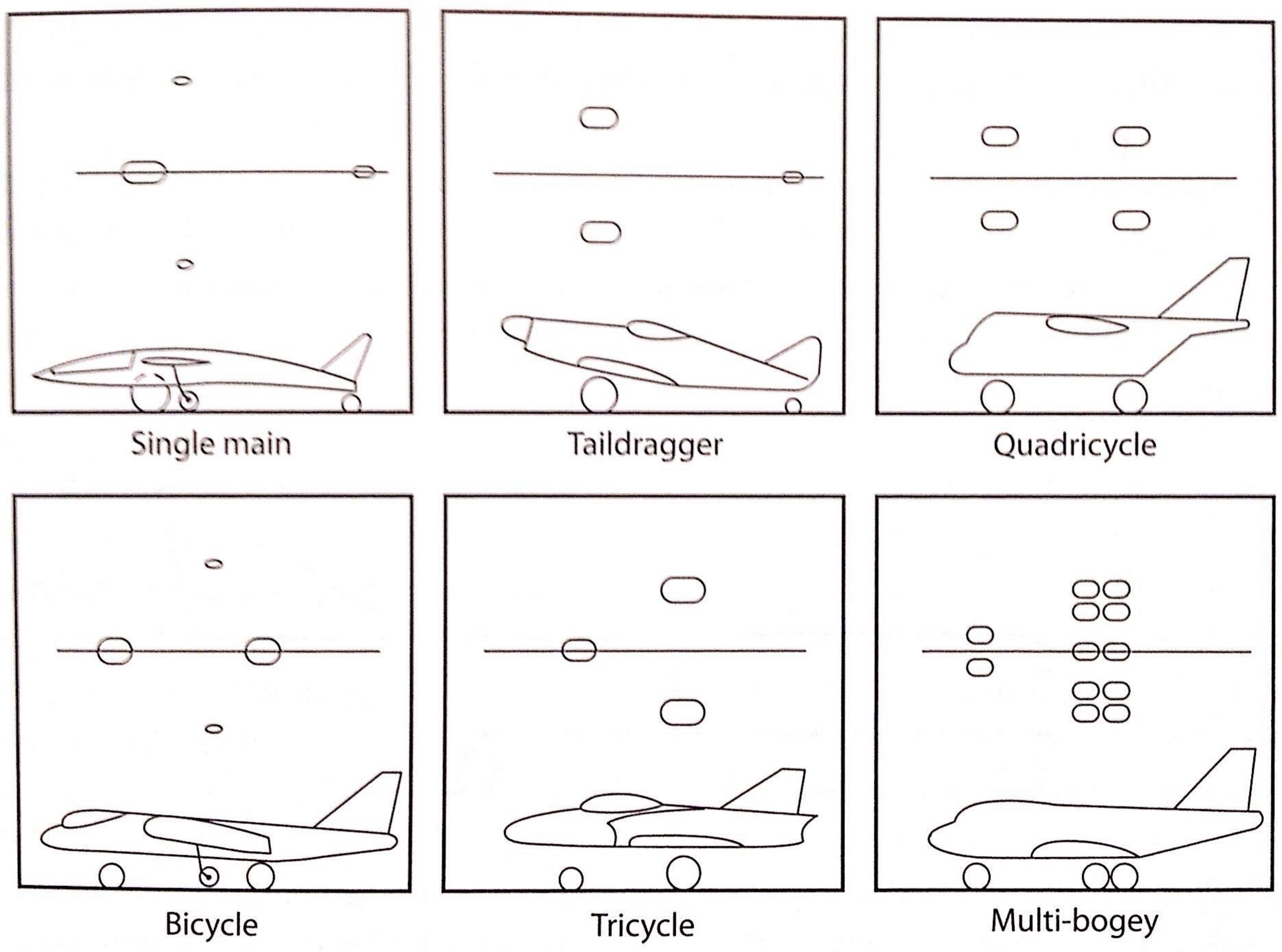
Other considerations (Chapter 11)

- Landing gear



Source: Aircraft Design by Daniel P. Raymer

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Other considerations (Chapter 11)

Landing Gear

- Single main (simplicity - sailplanes)
- Bicycle
  - Must takeoff and land flat (high aspect ratio/camber/flaps)
  - Aircraft with narrow fuselage and long span
- Taildragger
  - Better propeller clearance
  - Less drag and weight
  - More lift for rough-field operations
  - Inherently unstable (ground loop, gear collapse, bad on side winds)

Source: Aircraft Design by Daniel P. Raymer

ME4932 Aircraft Performance & Design

Other considerations (Chapter 11)

Landing Gear (continued)

- Tricycle
    - Good for side winds (crab)
    - Forward visibility in ground
    - Horizontal cabin floor
- Quadricycle
    - To put cargo floor very low on ground
- Multiple Tires
    - To distribute load with reasonably sized tires on bogeys
    - 50-150 K lbs. (2 wheels/strut)
    - 200-400 K lbs. (4wheels/strut)
    - 400 K lbs. (6 wheels/strut)

Source: Aircraft Design by Daniel P. Raymer

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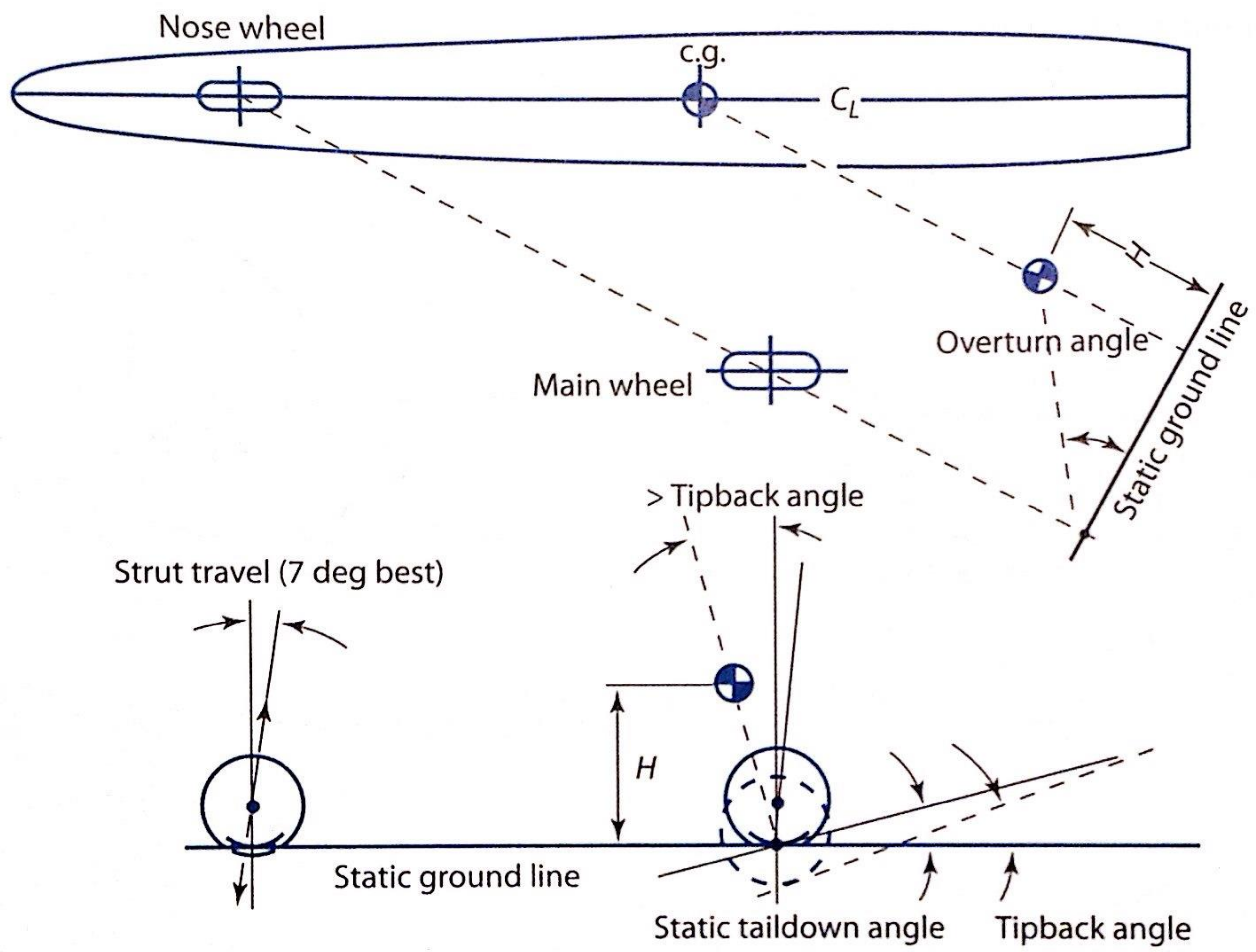
Other considerations (Chapter 11)



Source: Aircraft Design by Daniel P. Raymer

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Other considerations (Chapter 11)

Tricycle gear

- Length of landing gear so tail does not hit ground at 90% CLmax
- 7 inch propeller-ground clearance
- Angle off vertical from main wheel position to C.G. should be greater than tipback angle or 15 degrees (whichever larger)
- Nose wheel should not carry more than 20% or less than 5% of aircraft weight
- Overturn angle < 63 degrees

Source: Aircraft Design by Daniel P. Raymer

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Other considerations (Chapter 11)

Tire sizing:

Aircraft type	Diameter A	Diameter B	Width A	Width B
British units: Main wheels diameter or width (in.) = AW_W^B				
General aviation	1.51	0.349	0.7150	0.312
Business twin	2.69	0.251	1.170	0.216
Transport/bomber	1.63	0.315	0.1043	0.480
Jet fighter/trainer	1.59	0.302	0.0980	0.467
Metric units: Main wheels diameter or width (cm) = AW_W^B				
General aviation	5.1	0.349	2.3	0.312
Business twin	8.3	0.251	3.5	0.216
Transport/bomber	5.3	0.315	0.39	0.480
Jet fighter/trainer	5.1	0.302	0.36	0.467

W_W = Weight on wheel.

- After you size the tires, pick the closest ones from a catalog!
- When drawing wheel wells allow for 3-5% tire growth +1"
- Check wheel diameter required for disk brake sizing!

Source: Aircraft Design by Daniel P. Raymer

ME4932 Aircraft Performance & Design

Other considerations (Chapter 11)

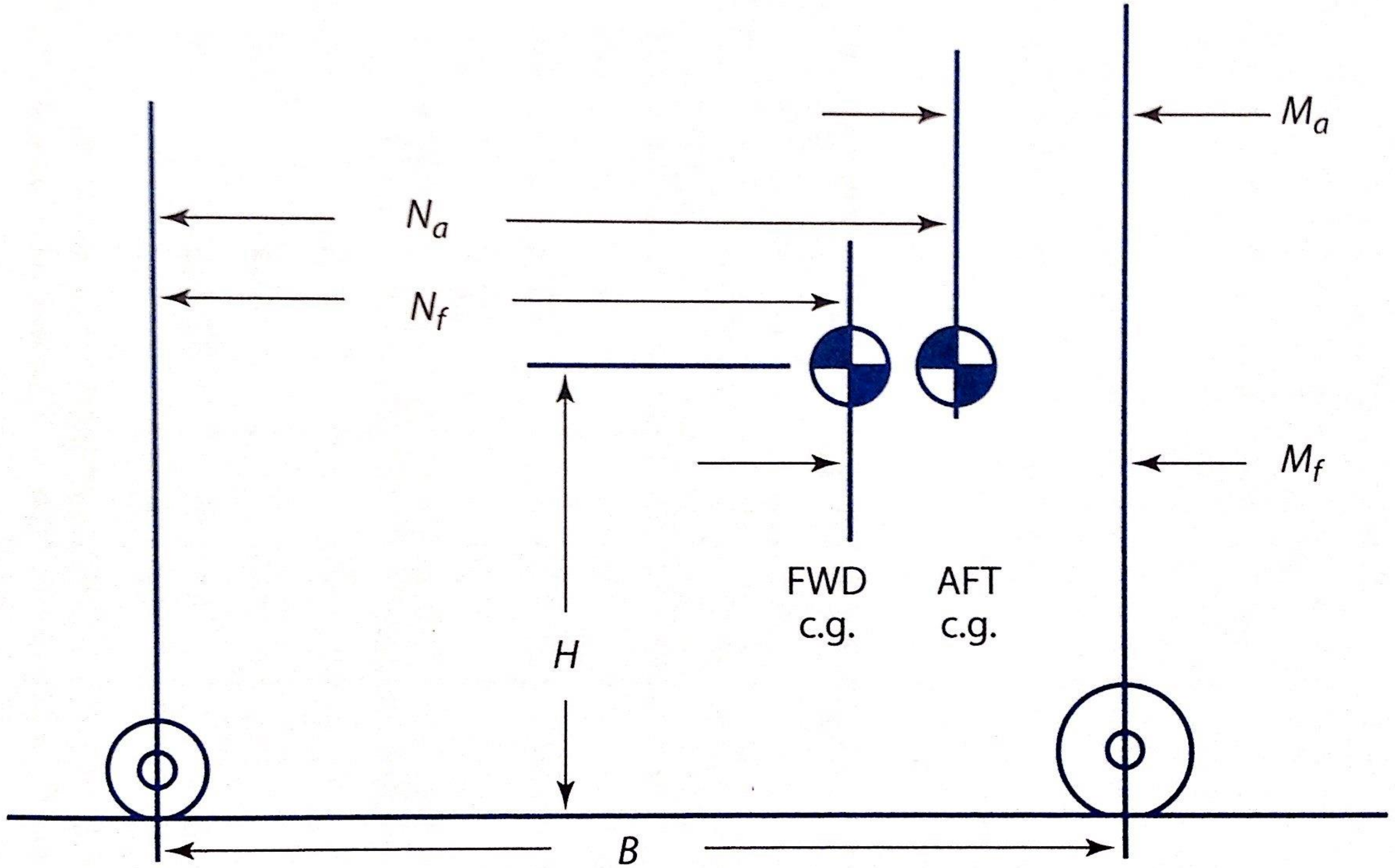
Determination of Loads on Tires:

$$(\text{Max Static Load}) = W\frac{N_a}{B}$$

$$(\text{Max Static Load})_{\text{nose}} = W\frac{M_f}{B}$$

$$(\text{Min Static Load})_{\text{nose}} = W\frac{M_a}{B}$$

$$(\text{Dynamic Braking Load})_{\text{nose}} = \frac{10\,HW}{gB}$$



Source: Aircraft Design by Daniel P. Raymer