

# AE 451 Aeronautical Engineering Design I

## Special Considerations

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# Aerodynamic considerations

- Design arrangement:

Overall arrangement and smoothness of the fuselage has a major effect on aerodynamic efficiency.

Minimization of wetted area is a powerful approach since it is related to friction drag.

- ⇒ tight internal packaging and low fineness ratio.

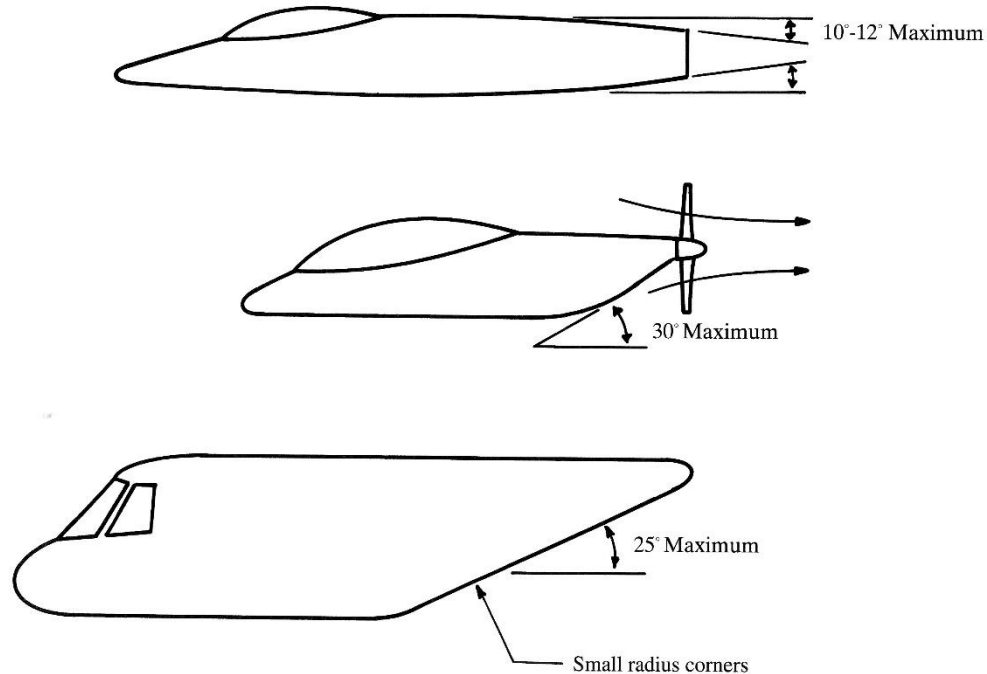
- ⇒ disadvantages: poor maintainability and high wave drag.

To prevent separation, aft fuselage deviation from freestream  $< 10^\circ$ - $12^\circ$ .

For pusher propeller configurations  $\approx 30^\circ$  can be maintained without flow separation.

# Aerodynamic considerations

Lower surface upsweep  $\approx 25^\circ$  for rear-loaded transport airplanes provided that fuselage lower corners are sharp.



**Fig. 8.1 Longitudinal contour guidelines.**

# Aerodynamic considerations

- Base Area: any unfaired, rearward facing blunt surface.
  - Causes extremely high drag due to low pressure.
  - A base area near jet exhausts may be filled in by the pressure field of the jet exhausts.
- If there are sharp corners in an airplane forebody, vortices will be produced at high  $\alpha$ . These can be ingested by the engine and/or wing or tail surfaces will be effected.

# Aerodynamic considerations

- Supersonic area rule:

Supersonic wave drag is related to the longitudinal change in aircraft's total cross sectional area.

Wave drag can be calculated using the second derivative of the volume distribution plot.

⇒ Sears-Haack body has the lowest wave drag.

It is impossible to match this shape in a real airplane.

⇒ A compromise is area-ruling that can reduce the wave drag by 50 %.

Even subsonic airplanes can benefit from area-ruling.

# Aerodynamic considerations

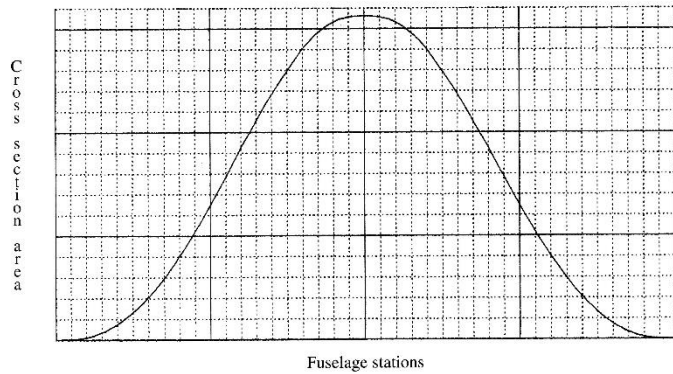


Fig. 8.3 Sears-Haack volume distribution.

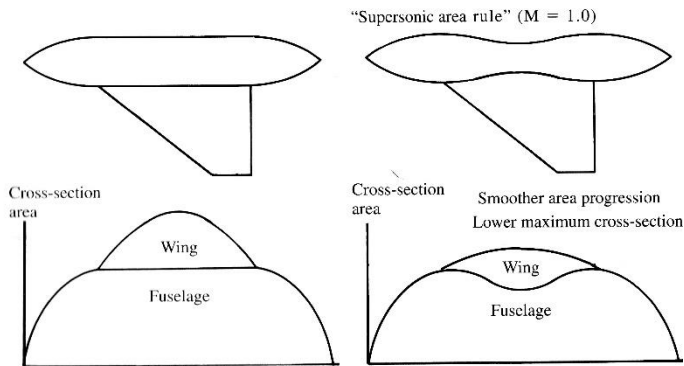
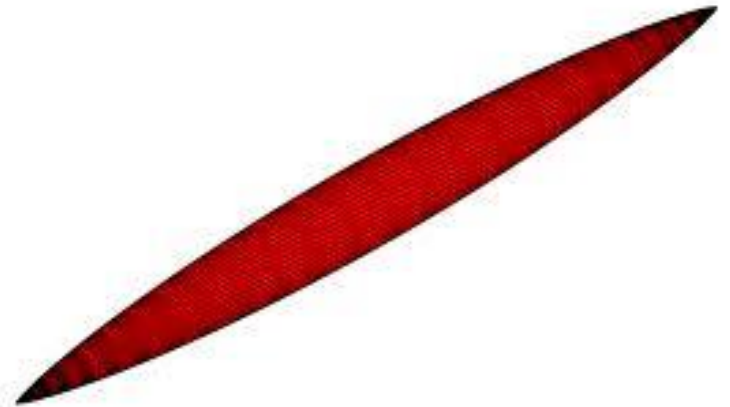


Fig. 8.4 Design for low wave drag.



# Crew station, passengers and payload

- The crew station effects the conceptual design in the visibility requirements.

The pilot must be able to see the runway during landing, so the nose of the airplane must slope away from the pilot's eye at some specified angle. Increases drag but safety > drag!

Military airplanes consider 95 % percentile pilot, height between 1.66-1.86m.

# Crew station, passengers and payload

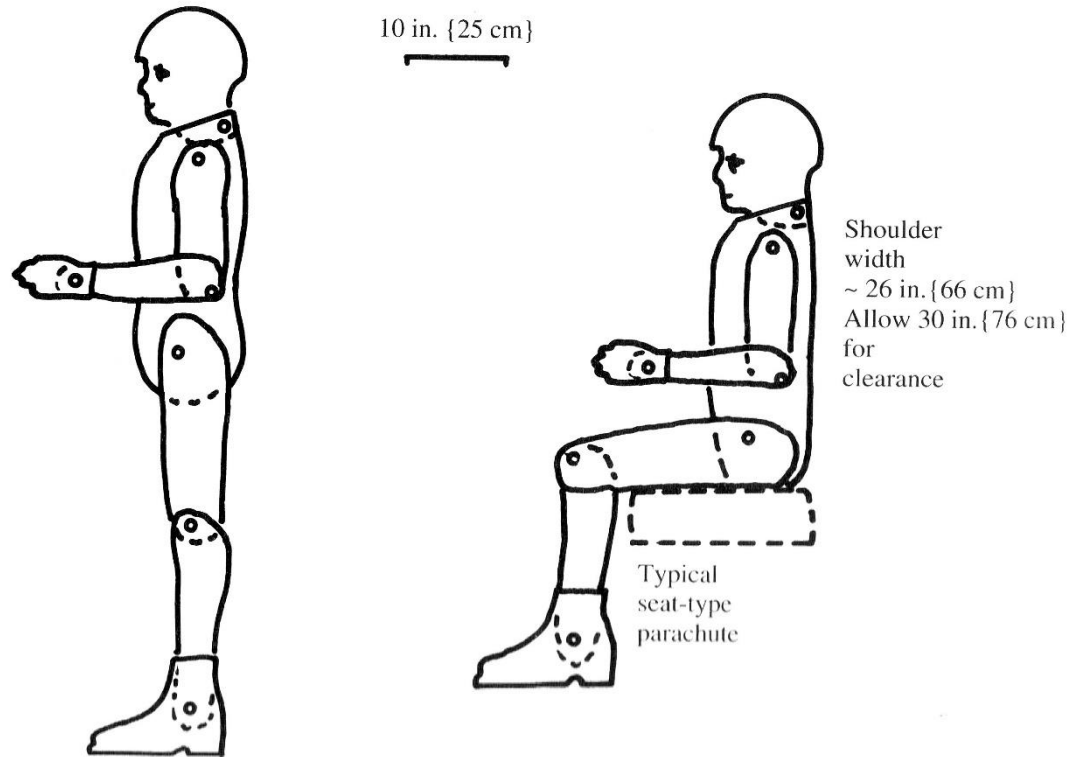


Fig. 9.1 Average 95th percentile pilot.

# Crew station, passengers and payload

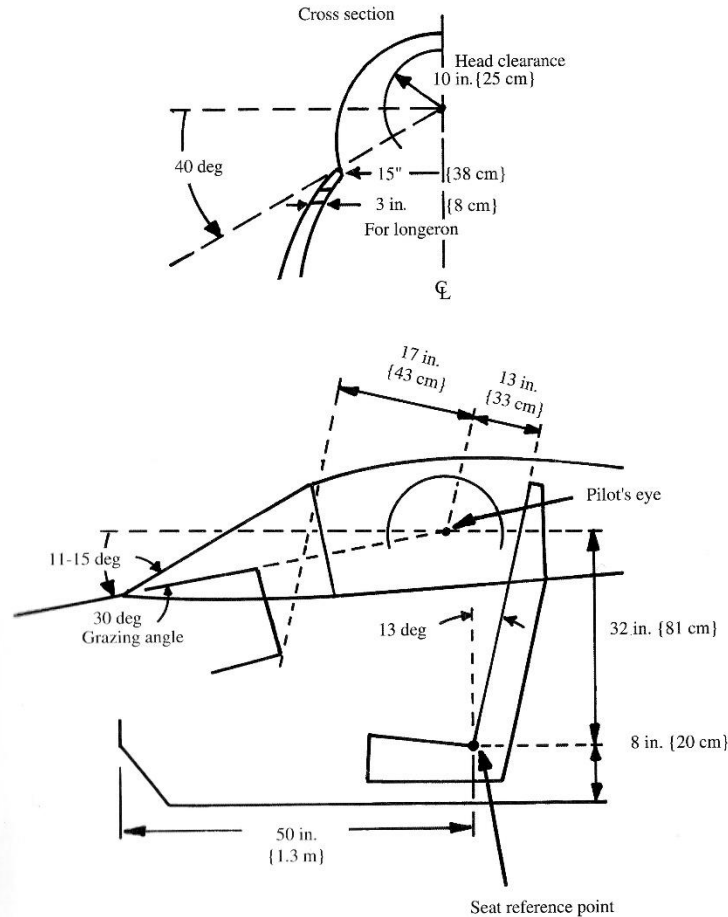


Fig. 9.2 Typical fighter cockpit.

# Crew station, passengers and payload

Most cockpits have 13° seatback angle, 30° in the F-16, 70° has been proposed.

$$\alpha_{overnose} \approx \alpha_{approach} + 0.07V_{approach} \quad (V \text{ in knots})$$

Overall length of cockpit:

- 150" for a four crewmember cockpit,
- 130" for 3 crewmembers,
- 100" for 2 crewmembers.

# Crew station, passengers and payload

- Passenger compartment:

There should be no more than 3 seats accessed from one aisle.

Assume passengers weight as 180 lb in average and bring in 40-60 lb of checked-in baggage.

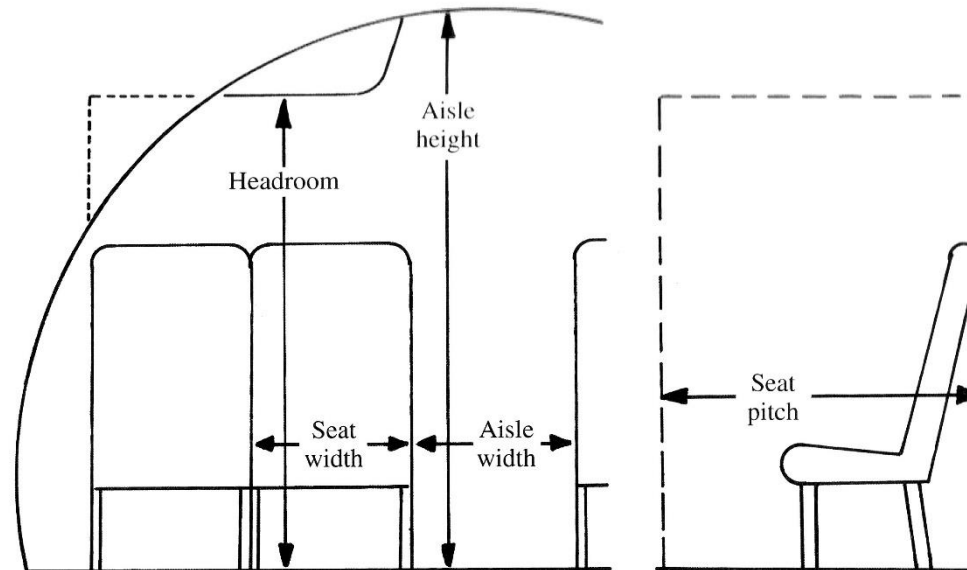
The fuselage external dimensions are determined by estimating the required structural thickness:

≈ 1" for small airplanes,

≈ 2" for large airplanes.

# Crew station, passengers and payload

- Passenger compartment:



**Fig. 9.3 Commercial passenger allowances.**

# Crew station, passengers and payload

- Passenger compartment:

**Table 9.1 Typical passenger compartment data**

	First class	Economy	High density/ small aircraft
Seat pitch (in. or cm)	38–40 {97–102}	34–36 {86–91}	30–32 {76–81}
Seat width (in. or cm)	20–28 {51–71}	17–22 {43–56}	16–18 {41–46}
Headroom (in. or cm)	>65 {165}	>65 {165}	—
Aisle width (in. or cm)	20–28 {51–71}	18–20 {46–51}	≥12 {30}
Aisle height (in. or cm)	>76 {193}	>76 {193}	>60 {152}
Passengers per cabin staff (international-domestic)	16–20	31–36	≤50
Passengers per lavatory (40" × 40") {1 m × 1 m}	10–20	40–60	40–60
Galley volume per passenger (ft <sup>3</sup> or m <sup>3</sup> per passenger)	5–8 {.14–.23}	1–2 {.03–.06}	0–1 {0–.03}

# Crew station, passengers and payload

- Cargo compartment:

Usually, standard containers are used, like the LD-3 container for civilian transports.

Cargo containers need doors of at least 70" in width.

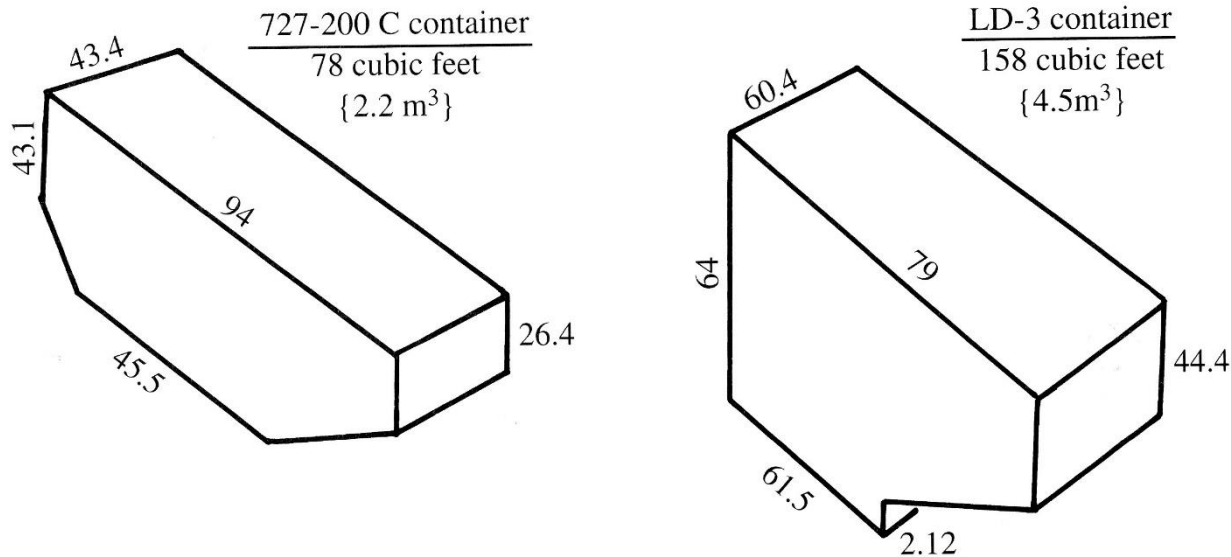
Cargo volume/passenger: 8.6-15.6 ft<sup>3</sup>.

Military transports use pallets for Cargo measuring 88"x108".

Military transports must have their Cargo compartment floors approximately 4-5 ft above the ground to allow direct loading and unloading of cargo from a truck.

# Crew station, passengers and payload

- Cargo compartement:



**Fig. 9.4 Cargo containers.**

# Crew station, passengers and payload



# Crew station, passengers and payload



# Crew station, passengers and payload



# Weapons carriage

- There are four main weapon carriage options.

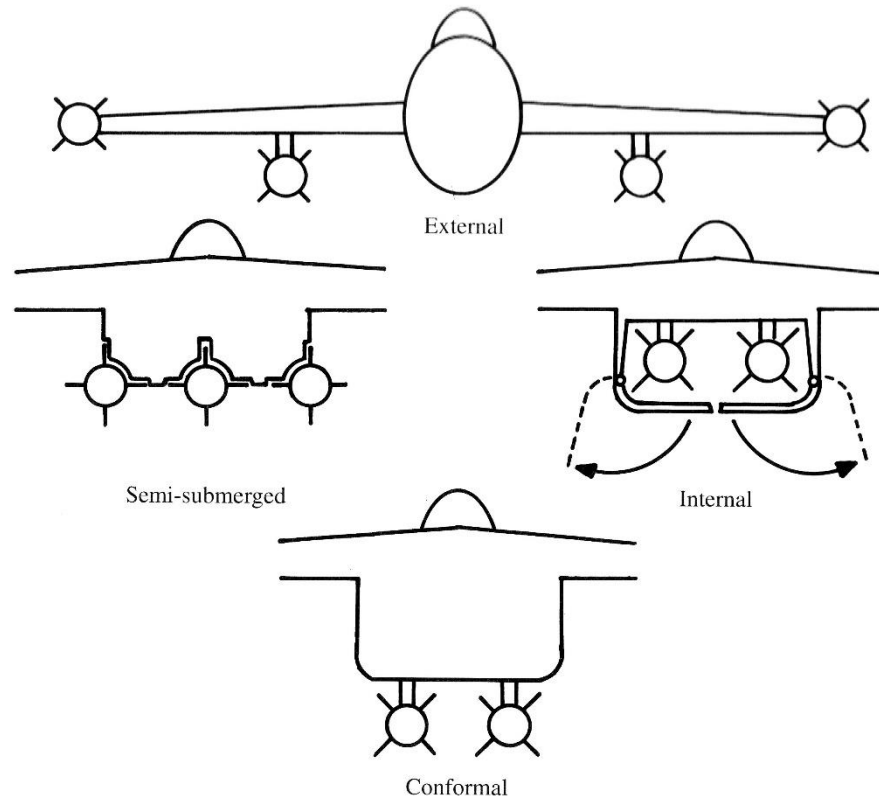


Fig. 9.6 Weapon carriage options.

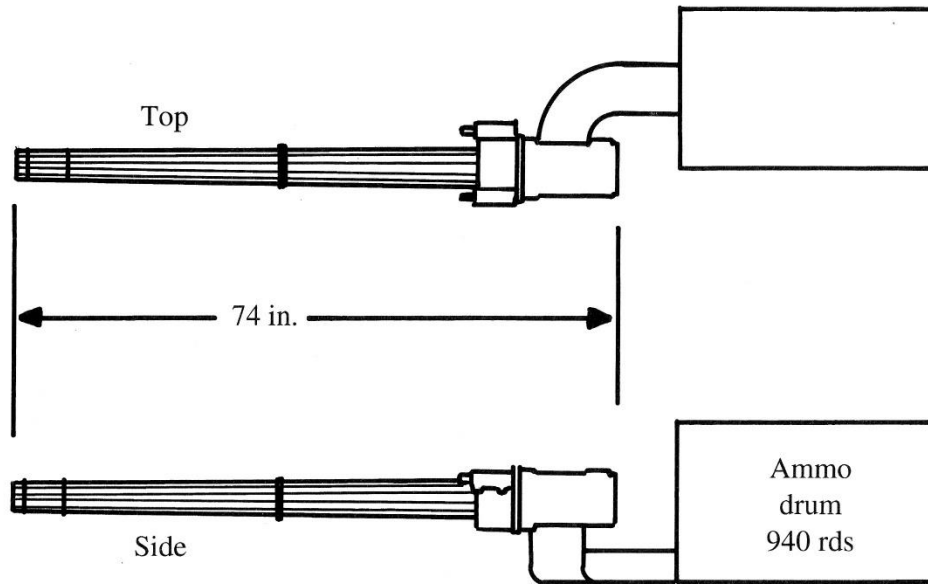
# External stores

- To ensure that the weapons never strike the ground, there should be at least 3" clearance to the ground at all attitudes.
- If weapons are placed near each other, there should be minimum distance of 3" between them.
- There should be at least 30 cm clearance between a weapon and propeller disk.
- A gun should be located at the centerline of an airplane as much as possible, otherwise the recoil force of the gun will produce a significant yawing moment.

# External stores



# Weapons carriage



**Fig. 9.9 M61 Vulcan gun.**

# External stores

- The carriage drag of the stores is often of the same order of magnitude as the total minimum drag of the aircraft itself.
- Store carriage on modern tactical aircraft is extremely important, particularly as one approaches the transonic regime, where the interference effects of the stores and pylons are highest and most detrimental to performance.

# External stores

- Not only must external stores be carried efficiently by tactical aircraft, but they must release cleanly and follow a predictable trajectory through the vehicle's flowfield.
- The store trajectory is governed by the highly unsteady forces and moments acting on the store produced by the nonuniform flowfield about the configuration and the aerodynamic characteristics and motions of the store itself.
- The problem is complicated by realistic combat requirements for jettison or launch at maneuver conditions and multiple release conditions where the weapons must not 'fly' into one another.

# Multiple release of weapons



# Weapon carriage

<b>Store carriage concepts</b>	<b>Advantages</b>	<b>Disadvantages</b>
1. Wing pylon carriage	Most flexible carriage mode - large payloads, inefficient store shapes	High drag High radar cross section
2. Internal carriage	Low drag Low radar cross section	Limited weapon flexibility Increased fuselage volume
3. Semisubmerged carriage	Low drag Low radar cross section	“Holes” must be covered up after weapons drop Severely restricted payload flexibility
4. Conformal carriage	Most flexible of low drag carriage concepts	Size restrained

# Wing pylon carriage



# Internal carriage



# Semi-submerged carriage



# Conformal carriage

