Chapter 2

Data collection
and
preliminary three-view drawing.

2.1 Data Collection.

We assume that the specifications of the airplane to be designed have already been arrived at . In this chapter we discuss data collection and preparation of a preliminary three view drawing.

Airplane design is an evolutionary process. Data on existing similar airplanes provides the necessary guidance for arriving at appropriate initial design values. The sources of design data are:

1. Janes All The World's Aircraft (Ref 1.2)
2. Books cited in chapter 1
3. www.arnoldpublishers.com/aerodata
4. Websites of aircraft manufacturers such as Boeing and Airbus Industries.

A typical format for collection of aircraft data is given below.

It may be mentioned that this format includes information about (a) general features of the airplanes (b) geometrical parameters of major components of the airplane (c) various types of weights of the airplane and (d) performance of parameters. Meanings of some of the terms are given in Appendix 2.1 at the end of this chapter. This somewhat detailed data collection would be useful during subsequent steps of preliminary design and we should try to obtain as much data as possible. Appendix 'C' presents the data collected for the jet airplane in the form of a table. The student is advised to follow it.

Condensed Airplane Data Sheet

Name of the airplane:

Type* :

Name of manufacturer and country of origin:

Power Plant:

Type*:

Name:

Engine rating*:

---

* See Appendix 2.1 for definition

Specific fuel consumption:

Oil consumption:

Weight of power plant:

Overall dimensions:

diameter (m):

length (m) :

Engine centre of gravity:

Special accessories and controls:

No. of engines and locations:

Intake/propeller details:

Wing:

Planform shape (Fig.2.1)

Airfoil section:

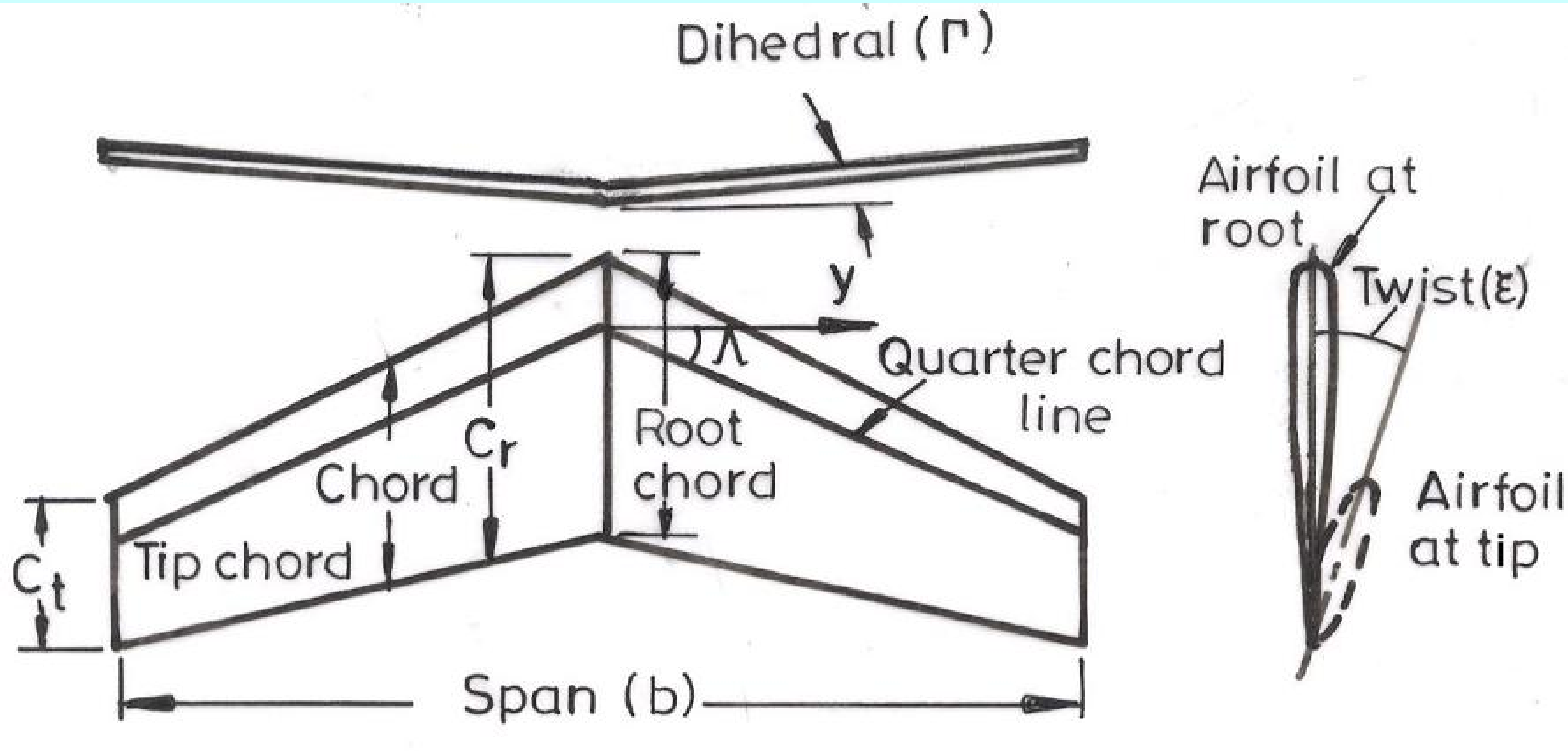

Fig 2.1 Wing planform

Span(m) :

Root chord(m) :

Tip chord(m) :

Area (S) (m^2) :

Mean chord* (m) :

Mean adn. chord* (m) :

Sweep(Λ^0):

Dihedral. (Γ^0) :

Twist (ε^0)* :

Incidence (i_w)* :

Flap area (m^2) :

Aileron area (m^2) :

Type of high-lift devices :

Location of Spars :

Taper ratio (λ)* :

Aspect Ratio (A)* :

Flap area/Wing area:

Aileron area/wing area:

Location on fuselage (high/mid/low):

Construction and other details:

Horizontal Tail surface

Type of tail (Fig 2.2):

Platform shape:

Airfoil:

Span (m):

Root chord (m) :

Tip chord(m):

Area (m^2) :

Sweep:

Incidence (i_t)* (^{0}):

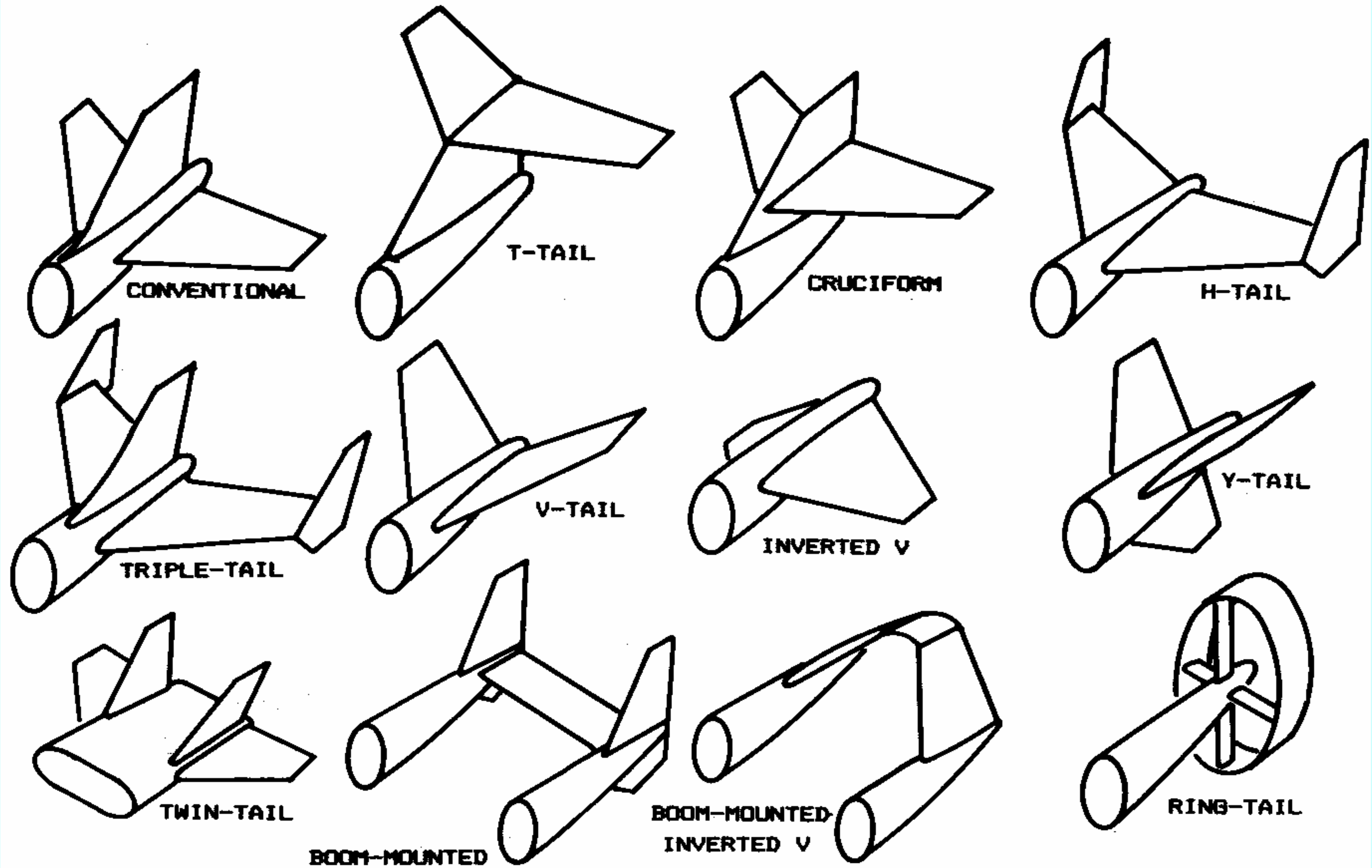

Fig 2.2 Horizontal and vertical tail configurations
(Adapted from Ref.1.11, chapter 4)

Elevator area(m^2) : Tab area (m^2):

Aspect ratio: Taper ratio:

Elevator area/Tail area: Tab area/elevator area:

Tail area/wing area:

Location:

Type of control and aerodynamic balancing*:

Construction and other details :

Vertical Tail Surface:

Airfoil:

Height (m): Root chord (m) :

Tip chord (m):

Area (m^2): Sweep (^{0}) :

Off-set angle(^{0})*:

Rudder area(m^2) : Tab area(m^2):

Aspect ratio (A_V)*: Taper ratio:

Rudder area/tail area:

Tab area/rudder area:

Tail area/wing area: Location:

Type of control and aerodynamic balancing:

Construction and other details:

Fuselage:

Length (m) :

Shape and size of cabin:

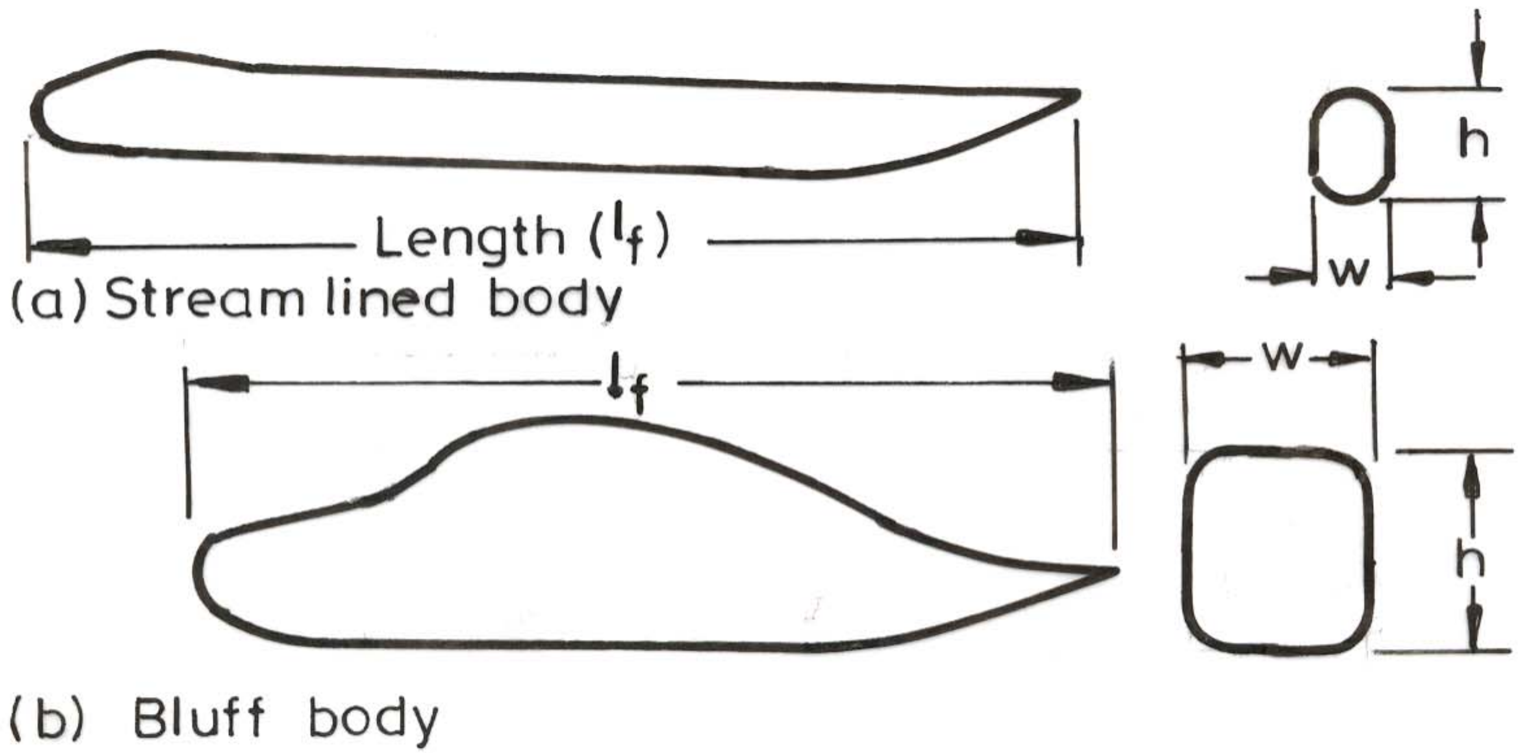

Fig 2.3 Fuselage parameters

Arrangement of payload and auxiliary equipment:

Construction:

Cockpit:

Number and arrangement of seats:

Cockpit instruments:

Vision (angle)   :

Landing gear

Type* :

Number and size of wheels:

Tyre pressure :

Wheel base* (m) :

Wheel tread* (m) :

Location of landing gears:

Means to reduce landing run and other details:

Overall Dimensions:

Length (m) :

Span (m) :

Height (m) :

Tread(m) :

Length/span:

Height/span:

Tread/span:

Weights:

Pay load* (kgf):

Empty weight* (kgf) :

Fuel Weight (kgf) :

Structural weight (kgf) :

Disposable load* (kgf) :

Landing weight (kgf) :

Normal gross weight(kgf) :

Maximum gross weight (kgf) :

Payload/gross weight:

Empty weight/gross weight:

Fuel weight/gross weight:

Structural weight/gross weight:

Wing loading* :

Power (or thrust) loading* :

Performance:

Maximum speed (kmph) at Sea level:

at Altitude :

Landing speed (kmph) :

Cruise speed (kmph) and altitude (km):

Maximum sea level rate of climb (m/min):

Service ceiling (km) :

Range* or radius of action* (km) :

Endurance* (hours): Take-off run* (m) :

Landing run* (m) :

Remark :

It would be noticed that from various items of raw data we deduce the ratios like l_t/b, S_t/S, S_{vt} / S etc.. These ratios are obtained because, as would be seen later, for similar airplanes such ratio lie in a narrow band and help in arriving at ball park figures for airplane under design.

2.2 Premilinary three-view drawing

An idea about the possible shape and size of the airplane forms the next step after the data collection.

To draw the preliminary three-view drawing, we need approximate dimensions of the wing, fuselage, tail and other components . We proceed as follows to get these ball park values . Example 2.1 illustrates the procedure.

1. The payload i.e. weight of passengers, cargo or ammunition or the weight of the items the airplane is being designed for, is prescribed. Let us denote this by $W_{\mathbf{pay}}$.

2. From data collection on similar airplanes we choose the ratio W_g / W_{pay}; W_g being the design gross weight. Then

$$W_g = W_{pay} \times (W_g / W_{pay})$$

Remark: This weight will be refined in the next stage of preliminary design (see chapter 3).

3. From data collection on similar airplanes we choose a wing loading(W/S).
   Then S = W/(W/S)
4. From data collection on similar airplanes we choose an aspect ratio (A). Then Wing span (b) is given by

$$b = (S \times A)^{1/2}$$

5. We choose a wing planform from data collection. Let taper ratio be λ then:

$$S = b/2(c_r + c_t)$$

but $c_t = \lambda c_r$

Hence $S = (b/2)(1+ \lambda)\ c_r$

Hence, $c_r = 2S/b(1+\lambda)$, $c_t = c_r\ \lambda$

Also choose sweep angle of the wing from data on similar airplanes.

6. Choose from data collection on similar airplanes the ratio (l_f/b); l_f= length of fuselage. Then:

$$l_f = b \times (l_f /b)$$

7. Choose from data collection on similar airplanes , the cross-sectional size of the fuselage, position where payload is located. Also find the ratios $l_{\mathbf{nose}} /l_{\mathbf{f}}$, $l_{\mathbf{cockpit}} /l_{\mathbf{f}}$ and $l_{\mathbf{tailcone}}/l_{\mathbf{f}}$. Obtain $l_{\mathbf{nose}}$, $l_{\mathbf{cockpit}}$ and $l_{\mathbf{tailcone}}$ as l_f is known in step 6. Obtain the length of the payload section as difference between l_f and and the sum of the lengths of l_{nose} , $l_{cockpit}$ and $l_{tailcone}$.

8. Choose from data on similar airplanes the values of collection S_{ht}/S , S_{vt}/S. Also choose the values of aspect ratio, taper ratio and sweep of horizontal and vertical tails.

Then:

$$S_{ht} = \frac{S_{ht}}{S} S$$

$$b_{ht} = \sqrt{S_{ht} A_{ht}}$$

$$(c_r)_{ht} = \frac{2 S_{ht}}{b_{ht}(1 + \lambda_{ht})}$$

$$(c_t)_{ht} = (c_r)_{ht} \lambda_{ht}$$

$$S_{vt} = \frac{S_{vt}}{S} S$$

$$b_{vt} = \sqrt{S_{vt} A_{vt}}$$

$$(c_r)_{vt} = \frac{2 S_{vt}}{b_{vt}(1 + \lambda_{vt})}$$

$$(c_t)_{vt} = (c_r)_{vt} \lambda_{vt}$$

9. From data collection on similar airplanes choose the values of $S_{elevator} / S_t$, S_{rudder} / S_{vt} , $S_{ailemon} /S$, S_{flap} / S , $c_{elevator} / c_{ht}$, c_{rudder} / c_{vt} , $c_{aileron}/ c_{wing}$, c_{flap}/c_{wing} . Hence obtain the areas and chords of elevator, rudder , flap and aileron.

10 . Choose From data collection on similar airplanes the value of T/W or W/P.

Then T = (T/W) x W or P = W/(W/P)

Choose the number of engines to be used and obtain the rating of engine.

Obtain approximate dimensions of engine and the size of propellers/intake as appropriate.

11. From data collection on similar airplanes choose the locations of the wing, the horizontal tail and the vertical tail on the fuselage.

12. Choose from data on similar airplane landing gear type and obtain (wheel base) /l_f and (wheel tread)/ l_f. Obtain wheel base and wheel tread as l_f is known.

With these data a preliminary three-view can be prepared. An example is given below.

Example 2.1

Obtain the preliminary three view of the following airplane .

Type: Short haul STOL (Short Take Off and Landing).

No. of seats = 50

V_{cruise} = 420 kmph at 4.5 km altitude,

Range = 1300 km.

Solution: In this example we mentioned various values without giving data on similar airplanes. However example in Appendix ‘C’ refers to relevant data collection.

It is seen from information on similar airplanes that:

$W_g \approx 400 \times$ No. of passengers .Hence

$W_g \approx 20{,}000$ kgf $\approx 200{,}000$N

The wing loading for such airplanes lies roughly between 2000 to 3000 N/m^2.

Taking $W/S \approx 2500\ N/m^2$ gives:

$$S = W/(W/S) = 200{,}000/2500 = 80m^2.$$

The aspect ratio for such airplanes lies between 10 to 12.

Taking $A \approx 10$ gives:

$$b = \sqrt{(S \times A)} = 28.28 \text{ m}$$

Taking $\lambda = 0.3$ gives:

$$c_r = 2S / b(1+ \lambda) = 4.35m$$

$$c_t = 0.3 \times 4.35 = 1.3m$$

Taking $l_f/b \approx 0.85$ gives:

$l_f = 0.85 \times 28.28 = 24.04$m

Taking $S_{ht}/S = 0.15$, $A_{ht} = 6$, $\lambda_{ht}=0.5$ gives:

$S_{ht} = 0.15 \times 80 = 12m^2$

$b_{ht} = 8.48$m, $c_{rht}=1.89$m, $c_{tht} = 0.95$m

Taking $S_{vt}/S = 0.08$, $A_{vt} = 2$, $\lambda_{vt}=1$ gives:

$S_{vt} = 6.4\ m^2$, $b_{vt}=3.58$m

$c_{rvt} = c_{tvt} =(2 \times 6.4)/(2 \times 3.56) = 1.79$m

Taking configuration with 4 engines and

W/P = 60 N/kW gives :

Total engine power = 200,000/60 = 3,300 kW or

Power per engine ≈ 825 kW. This example is based on the data for four engined / medium range transport airplanes using turboprop engines.

The values of weights and geometric parameters obtained above are very close to those of “de Havilland Canada Dash 7” airplane. Three view drawing of this airplane taken from 1987 -88 edition of Ref.1.2 is shown in Fig.2.4.

Remark:

Chapter 1 of Appendix 10.2 illustrates the above process for a medium range jet transport. It also contains information on design philosophy and data collection on airplanes in this category.

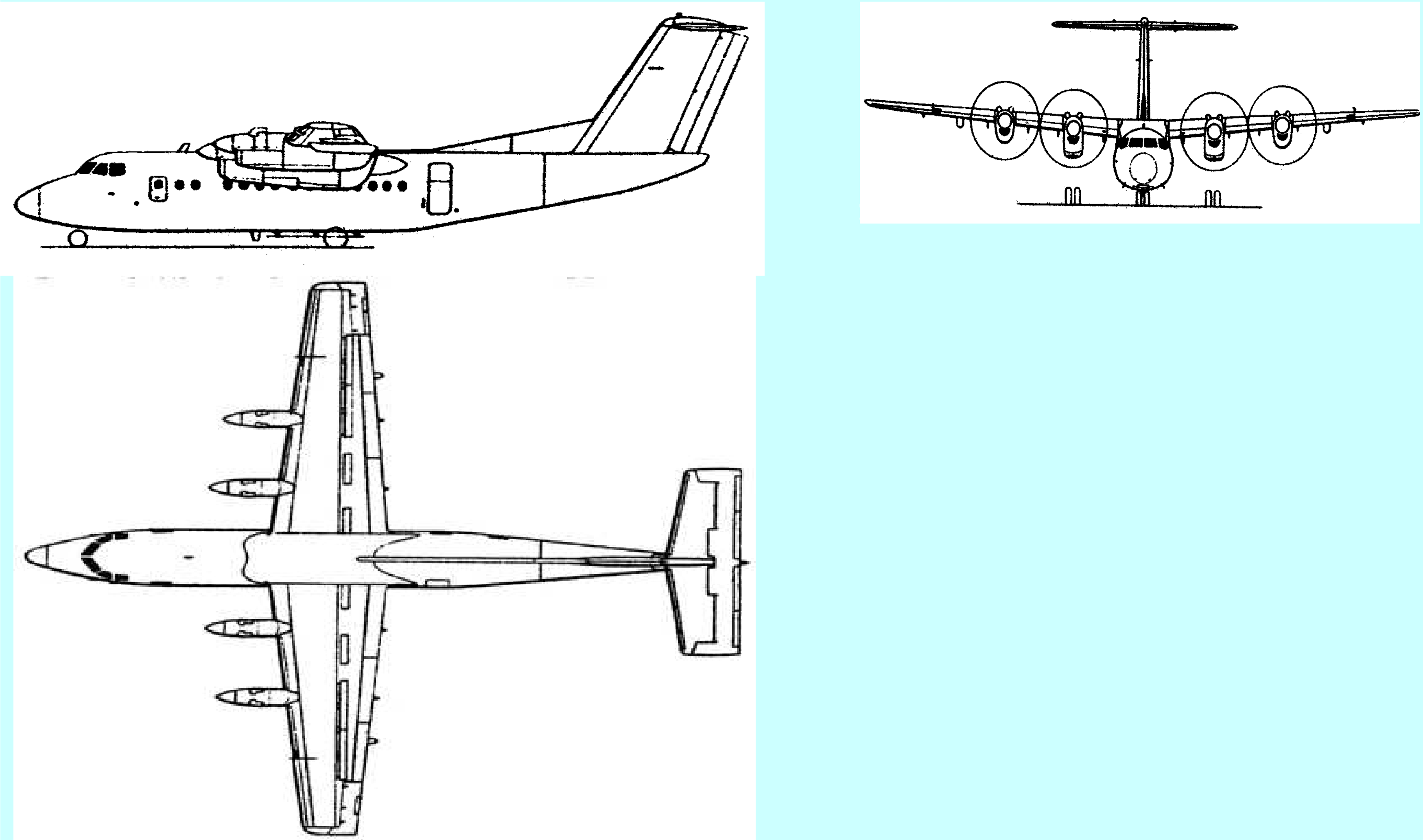

Fig.2.4 Preliminary 3 view
(Adapted from Ref. 1.2, Chapter 8)

References:

1) Gunston.B, “The Cambridge Aerospace Dictionary”, Cambridge University Press, 2004.
2) Viswanathan M, “Dictionary of Aeronautical and Engineering Terms”, Himalayan Books , New Delhi ,2004 .

EXERCISES

2.1 Dassault Mirage 2000 has the following features. Draw a neat three-view sketch of the airplane.

Type	: Single seat multi-role fighter
Wing	: Low wing cropped delta planform(λ =0.1), area= 41.0 m^2,span = 9.0 m, leading edge sweep 57^o (approx.) leading edge slat; flaps; ailevons from tip to about semispan.

Fuselage : Pointed nose;length of fuselage ≅ 15m; maximum

height (at canopy) ≅ 1.5 m.

Engine : One engine in rear fuselage.

Empennage : No horizontal tail. Vertical tail of height ≅ 2.75 m, root chord ≅ 3.9 m,

tip chord ≅ 1.15 m, quarter chord sweep ≅ 40^o.

[Answer : See three view drawing in Jane's all the world's aircraft]

2.2 Gates Lear Jet airplane has the following features.

Type	:	Light business executive transport
Wing	:	Moderately swept (about 20^o), taper ratio about 0.4; winglets at tips
Fuselage	:	Circular cross section of length about 1.25 times wing span
Engine	:	Two engines mounted on rear fuselage
Horizontal	:	T-tail

Vertical tail with dorsal fin

Make a neat three-view sketch of the airplane.

[Answer : See three view drawing in Jane’s all the world’s aircraft]

2.3 An airplane has the following features.

Gross Weight : 160,000 N

Wing loading : 3760 N/m^2

Wing : $A = 8$, $\lambda = 0.3$, $\Lambda = 25^o$

Horizontal tail : $S_{ht}/S=0.2$, $A=5$, $\lambda=0.5$, $\Lambda=30^o$

Obtain the root chords of the wing and the tail.

[Answer : $(c_r)_{wing}$ = 3.548 m, $(c_r)_{tail}$ = 1.74 m]

Appendix 2.1
Definitions of some terms (source Refs.2.1 & 2.2)

- **Aerodynamic balance**: Method of reducing control-surface hinge moment.

Aspect ratio (A): It is equal to b^2/S, where b is the wing span measured from tip to tip perpendicular to the longitudinal axis and S is the gross wing area; gross wing area includes the wing area inside the fuselage.

- **Aspect ratio of vertical tail (A_v)**: It is equal to h^2/S_v, where h is height of vertical tail and S_v is reference area vertical tail .
- **Disposable load**: MRW (Maximum Ramp Weight) minus OEW (Operational Empty Weight).

- **Empty weight**: Weight of an operational airplane without fuel, payload, crew and other removable items. OEW (Operational Empty Weight) is also used in the same context.
- **Endurance**: Time in hours for which the airplane can remain in flight with a given amount of fuel.
- **Engine rating**: Output as permitted by regulations for specified use e.g. maximum takeoff (2.5 and 5 minute rating), climb (30 minute rating), cruise (maximum continuous rating).
- **Incidence of horizontal tail (i_t)**: Angle between reference chord of horizontal tail and fuselage reference line.

- **Incidence of wing (i_w)**: Angle between reference chord of the wing and the fuselage reference line.
- **Landing distance**: Horizontal distance covered in descending from screen height and come to a halt.
- **Landing gear types**: a) tricycle or nose wheel, (b) tail wheel and c) bicycle.
- **Landing run**: Horizontal distance covered from the point where the main wheels touch the ground to the point where the airplane comes to a halt.
- **Maximum ramp weight**: Maximum weight permissible for an aircraft. It equals MTOW (Maximum Take Off Weight) plus fuel allowance for running main engines and APU (Auxiliary Power Unit) during start, run-up and taxing operations.

- **Mean aerodynamic chord ($\bar{c}$)**: It is given by:

$$\bar{c} = \frac{1}{S} \int_{-b/2}^{b/2} c^2 \, dy$$

- **Mean chord (S/b)**: Ratio of gross wing area to span.
- **Offset angle**: Angle in plan-view between reference chord of vertical tail and FRL (Fuselage Reference Line).
- **Payload**: That part of useful load from which revenue is derived.

- **Take off distance**: Field length measured from brake-release to the point of attaining screen height; screen height is generally 15m.
- **Take off run**: Field length measured from brake-release to the point where main wheels leave the ground.
- **Taper ratio (λ)**: Ratio of tip chord (c_t) to root chord (c_r).
- **Thrust loading (T/W)**: Maximum sea level static thrust divided by MTOW of jet-propelled vehicle.
- **Type of Airplane** : Main classification is civil and military. Among civil we have passenger, cargo, agricultural, sports, ambulance etc. In military category there are fighter, bomber, reconnaissance,

transport etc.

- **Type of power plant**: piston engine-propeller combination, turboprop, turbofan and turbojet.
- **Twist (ε)**: Variation in angle of incidence along the wing span.
- **Wheel base**: Distance in side elevation between wheel centers of nose and main landing gears.
- **Wheel tread**: Lateral spacing between the left and the right main landing gears.
- **Wing loading (W/S)**: Gross weight or MTOW divided by wing area.