

## Chapter 8

### Weights and centre of gravity - 2

#### Lecture 33

#### Topics

##### Example 8.1

##### Example 8.2

##### Example 8.1

For the sixty seater airplane considered in examples 3.1, 4.19, 5.1, 6.1, 6.2 and 6.3, obtain the following.

- (i) Weights and c.g. locations of (a) wing, (b) fuselage, (c) h.tail, (d) v.tail, (e) landing gear, (f) installed engine, (g) all else empty (h) fuel (i) payload.
- (ii) Location of wing such that the c.g. of the entire airplane with MTOW is at quarter chord of m.a.c.
- (iii) Shift in the c.g. of the airplane for the following cases.
  - (a) Full payload but no fuel.
  - (b) No payload and no fuel.
  - (c) No payload but full fuel.
  - (d) Full fuel but half of the payload in the front half of passenger cabin.
  - (e) Full fuel but half of the payload in the rear half of passenger cabin.

#### **Solution :**

From example 3.1 the gross weight of the airplane is 21,280 kgf or 208,757 N

l)The weights and c.g. locations of various components are estimated below.

(A) Wing

From examples 5.1 and 6.1 the following data are obtained.

Wing area = 58.48 m<sup>2</sup>

Root chord of wing = 2.636 m

Tip chord of wing = 1.318 m

Wing span = 26.49 m ; semispan = 13.245 m

Constant chord of 2.636 m upto 4.636 m from FRL

Fuselage width = 2.88 m

Mean aerodynamic chord = 2.295 m

Location of the leading edge of m.a.c. from the leading edge of wing = 0.237 m

Location at the a.c. of the wing from the wing root chord = 0.811 m

Referring to Fig.E5.1 and using the above data the area of the exposed wing is :

$$(S_{\text{exposed}})_{\text{wing}} = 2 \left\{ 2.636 \left( 4.636 - \frac{2.88}{2} \right) + \frac{(13.245 - 4.636)}{2} (2.636 + 1.318) \right\}$$
$$= 2 \{ 8.425 + 17.02 \} = 50.89 \text{ m}^2$$

**Remark :**

A simpler way to get the area of exposed wing in this case, where, the chord is constant in the inboard portion of the wing, is :

$$58.48 - 2.88 \times 2.636 = 50.89 \text{ m}^2$$

Using Table 8.1, the estimated weight of the wing is :

$$50.89 \times 49 = 2493.6 \text{ kgf} = 24,462.3 \text{ N}$$

$$\text{Or } \frac{W_{\text{wing}}}{W_g} = 24462.3 / 208757 = 11.72 \%$$

From Table 8.1, the c.g. of wing is at 40% of m.a.c.

Hence, the location of the c.g. of wing from the leading edge of the root chord of the wing is at :  $0.237 + 0.4 \times 2.295 = 1.155 \text{ m}$

(B) Horizontal tail

The horizontal tail is mounted on V.tail. Hence, its exposed area is taken roughly equal to planform area which equals  $11.11 \text{ m}^2$ .

Hence, weight of h.tail =  $11.11 \times 27 = 300 \text{ kgf} = 2943 \text{ N} = 1.41 \%$  of  $W_g$

To arrive at the location of the c.g. of the horizontal tail, the following are noted from example 6.2.

Mean aerodynamic chord of h.tail = 1.52 m

The distance between the leading edge of the root and the leading edge of m.a.c. is  $1.711 \times \tan 11.24 = 0.34 \text{ m}$

From Table 8.1, the c.g. of the h.tail is at 40% of its m.a.c. Consequently, the

distance between the leading edge of the root chord of h.tail and the c.g. of h.tail is :

$$0.34 + 0.4 \times 1.52 = 0.95 \text{ m}$$

(C) Vertical tail

The contribution of dorsal fin to the weight of v.tail is ignored at this stage of preliminary design.

$$\text{Area of v.tail} = 12.92 \text{ m}^2$$

$$\text{Hence, weight of v.tail} = 12.92 \times 27 = 348.8 \text{ kgf} = 3422 \text{ N} = 1.64 \% \text{ of } W_g$$

To arrive at the location of the c.g. of the v.tail, the following are noted from example 6.2.

$$\text{Mean aerodynamic chord of v.tail} = 2.60 \text{ m}$$

The distance between leading edge of the root chord of v.tail and leading edge of m.a.c. =  $2.366 \tan 30^\circ = 1.366 \text{ m}$

From Table 8.1 the c.g. of v.tail is at 40% of its m.a.c. Consequently, the distance between the root chord of v.tail and c.g. of v.tail is :

$$1.366 + 0.4 \times 2.6 = 2.41 \text{ m}$$

(D) Engine

As mentioned in example 6.3, the weight of each engine is 450 kgf.

Hence, from Table 8.1, the installed weight of the two engines is :

$$2 \times 1.3 \times 450 = 1170 \text{ kgf} = 11478 \text{ N} = 5.5 \% \text{ of } W_g$$

As regards the location of c.g. of the engine, Ref.1.24, chapter 11, mentions that for gas turbine engines the location of c.g. from the engine inlet is between 30 to 45% of engine length.

In the present case the engine length is 2.13 m. From Fig.6.7a it is assumed that the engine inlet is just behind the boss of the propeller. From example 6.3 the boss of the propeller is at 1.58 m from the leading edge of the wing. Taking c.g. of engine to be at 40 % of engine length, the location of engine c.g. from the leading edge of the wing is :

$$-1.58 + 0.4 \times 2.13 = -0.728 \text{ m i.e. } 0.728 \text{ m ahead of the leading edge of the root chord of the wing.}$$

(E) Landing gear

From Table 8.1 the weight of the nose wheel plus the main landing gear is 4.3 % of  $W_G$  i.e.  $0.043 \times 208757 = 8977$  N

Out of this total weight, the nose wheel and main wheel account for 15 % and 85 % respectively. Hence, nose wheel weighs  $0.15 \times 8977 = 1347$  N and the main wheels weigh  $0.85 \times 8977 = 7630$  N.

As regards the locations of the c.g.'s of nose wheel and main wheels, it is recalled that the nose wheel and main wheels share respectively 10 % and 90 % of the airplane weight. From example 6.3, the wheel base is chosen as 9.78 m. Hence, the c.g. of the nose wheel is  $0.9 \times 9.78 = 8.802$  m ahead of the c.g. of the airplane. The c.g. of the main wheels, as a group, is :

$$0.1 \times 9.78 = 0.978 \text{ m behind the c.g. of the airplane.}$$

(F) Fuselage and systems

Wetted area of fuselage is obtained as follows. Various dimensions are obtained from Fig.6.8c

(a) Nose portion

Length of nose = 0.7 m

Diameter at the end of nose = 1.64 m

Hence, average diameter =  $1.64/2 = 0.82$  m

Consequently, wetted area or surface area of nose  $\approx \pi \times 0.82 \times 0.7 = 1.80 \text{ m}^2$

(b) Cockpit portion

Length of cockpit = 2.54 m

Diameter at the end of cockpit = 2.88 m

Hence, wetted area of cockpit portion  $\approx \pi \times \left( \frac{1.64 + 2.88}{2} \right) \times 2.54 = 18.03 \text{ m}^2$

(c) Midfuselage portion

Length of midfuselage = 12.83 m

Diameter of midfuselage = 2.88 m

Hence, wetted area of midfuselage =  $\pi \times 2.88 \times 12.83 = 116.08 \text{ m}^2$

(d) Tail cone

Average diameter  $\approx 2.88 / 2 = 1.44$  m

Length of tail cone = 9 m

Hence, wetted area of tail cone  $\approx \pi \times 1.44 \times 9 = 40.72$  m<sup>2</sup>

Consequently, wetted area of fuselage is :

$$1.80 + 18.03 + 116.08 + 40.72 = 176.63 \text{ m}^2$$

Using value in Table 8.1, the weight of fuselage is :

$$176.63 \times 24 = 4239.1 \text{ kgf} = 41585.84 \text{ N or } 19.92 \% \text{ of } W_g$$

**Remarks:**

(i) An expression for quicker, but approximate, estimation of fuselage wetted area is :

$$0.75 \times l_f \times (\text{Perimeter of the cross section with maximum area})$$

In the present case the approximate estimate would be:

$$0.75 \times \pi \times 2.88 \times 25.07 = 170.12 \text{ m}^2$$

This value is 96.3 % of the value obtained earlier.

(ii) The weight of the fuselage as percentage of gross weight ( $W_f/W_g$ ) appears high. However, as noted below Table 8.1, the quantity ( $W_f/W_g$ ) includes weights of fuselage, furnishing, consumables etc. Reference 1.19, chapter 8 presents information on weights of various items, as percentage of  $W_g$ , for different types of airplanes. For the turboprop airplane the data indicates that the weight of fuselage structure, furnishings and consumables would respectively be 9 to 11 %, 4 to 6 % and 1.5 to 2 % of gross weight. These would add up to 15 to 17 % of gross weight. Further as noted in Remark (i), after the subsection 8.2.2, the weight of fuselage, along with furnishing etc., and the systems is taken as one unit. Accordingly,

$$\frac{W_{\text{fuselage}} + W_{\text{system}}}{W_g} = \frac{W_{\text{empty}}}{W_g} - \left( \frac{W_{\text{wing}}}{W_g} + \frac{W_{\text{h.tail}}}{W_g} + \frac{W_{\text{v.tail}}}{W_g} + \frac{W_{\text{engine}}}{W_g} + \frac{W_{\text{landinggear}}}{W_g} \right)$$

From example 3.1, ( $W_{\text{empty}}/W_g$ ) is 0.559.

Hence,

$$\frac{W_{\text{fuselage}} + W_{\text{system}}}{W_g} = 0.559 - (0.117 + 0.0141 + 0.0164 + 0.055 + 0.043) = 0.3135$$

Or  $(W_{\text{fuselage}} + W_{\text{systems}}) = 0.3135 \times 208.757 = 65,445 \text{ N}$

From Table 8.1, the c.g. of the fuselage and systems can be taken to be at  $0.45 l_f$  or  $0.45 \times 25.07 = 11.28 \text{ m}$  from the nose of the fuselage.

(G) Fuel

From example 3.1,  $\frac{W_f}{W_g} = 0.143$

Hence,  $W_f = 0.143 \times 208,757 = 29,852 \text{ N}$

The mass of the fuel is  $29852 / 9.81 = 3043 \text{ kg}$

Taking density of fuel as 0.8, the volume of fuel is 3804 litres. From Ref.1.21 (1999-2000 edition) the airplanes in this category have integral fuel tanks in the wing with capacity of around 5000 litres. It may be pointed out that some space for additional fuel is intentionally provided. This permits increasing the range when needed. However, it should be noted that the design gross weight of the airplane cannot be exceeded and consequently, the payload has to be reduced correspondingly. The item III entitled "Range performance" in section 10.2.1 presents further details.

As regards the c.g. of fuel, Ref. 1.15, chapter 8 mentions that for fuel stored in the wing, the c.g. of fuel can be taken at the same location as the c.g. of the wing. As mentioned earlier, the c.g. of the wing is at 1.155 m behind the leading edge of the root chord of the wing.

(H) Payload and crew

These two items are generally clubbed together for passenger airplanes. In general aviation aircraft the flight crew can be separately considered.

From example 3.1, the weight of the crew and passengers plus the baggage is 6340 kgf as 62,195 N. The c.g. of these items is taken in the middle of the passenger cabin. From Fig.6.8c this location is :

$$0.7 + 2.54 + \left( \frac{12.83 + 2.11}{2} \right) = 10.71 \text{ m from the nose of fuselage.}$$

II) Determination of wing location and c.g. of the airplane

As mentioned in section 8.3, the position the wing is chosen such that the c.g. of the entire airplane with the gross weight is at 25% of the mean aerodynamic

chord of the wing. Before arriving at the location of wing which satisfies this condition, the following points are noted.

(i) The distance of the leading edge of the root chord of the wing from the nose of the fuselage is denoted by  $x_{lew}$ .

(ii) The 25% of the mean aerodynamic chord (m.a.c.) of wing is 0.811 m behind  $x_{lew}$  (example 5.1). Hence, the chosen location of the c.g. of the entire airplane is at  $(x_{lew} + 0.811)$  m from the nose of fuselage (Table E8.1)

(iii) The c.g. of the wing, as calculated in item 'A' of this example is at :  
 $(x_{lew} + 1.155)$  m

The c.g. of the two engines as mounted on the wings, and as calculated in item 'D' of this example is at :  $(x_{lew} - 0.728)$  m.

The c.g. of the fuel, as mentioned in item 'C' of this example is at :  
 $(x_{lew} + 1.155)$  m.

(iv) The tail arm of the horizontal tail i.e. the distance between the a.c. of the wing and the a.c. of h.tail is 13.31 m. Further the c.g. of the h.tail is at 40% of its m.a.c. and the m.a.c. being 1.52 m. Hence, the location of the c.g. of the h.tail is at :  
 $x_{lew} + 0.811 + 13.31 + (0.4 - 0.25) \times 1.52 = (x_{lew} + 14.349)$  m

In a similar manner, noting that the tail arm of v.tail is 11.99 m and its m.a.c. is 2.6 m, the location of the c.g. of v.tail is at :  
 $x_{lew} + 0.811 + 11.99 + (0.4 - 0.25) \times 2.6 = (x_{lew} + 13.191)$  m

(v) The nose wheel and main wheels, as mentioned in item 'E' of this example, are respectively 8.802 m ahead and 0.978 m behind the c.g. Hence, the c.g. of nose wheel is at :

$$x_{lew} + 0.811 - 8.802 = (x_{lew} - 7.991) \text{ m}$$

The c.g. of the main wheels, taken together is at :

$$x_{lew} + 0.811 + 0.978 = (x_{lew} + 1.789) \text{ m}$$

(vi) The fuselage plus the systems as a unit have the c.g. at 11.28 m from the nose of fuselage (item 'F' of this example).

The full payload plus the crew together have the c.g. at 10.71 m from the nose of the fuselage (item 'H' of this example).

The weights of various items and their c.g. locations are presented in Table E 8.1a.

Item	W (N)	x (m)	W.x (Nm)
Wing	24,462	$x_{lew} + 1.155$	$24462 x_{lew} + 28,254$
Engines	11,478	$x_{lew} - 0.728$	$11478 x_{lew} - 8,356$
Fuel	29,852	$x_{lew} + 1.155$	$29852 x_{lew} + 34,479$
H.tail	2,943	$x_{lew} + 14.349$	$2,943 x_{lew} + 42,229$
V.tail	3,422	$x_{lew} + 13.191$	$3,422 x_{lew} + 45,140$
Nose Wheel	1,347	$x_{lew} - 7.991$	$1,347 x_{lew} - 10,764$
Main Wheels	7,630	$x_{lew} + 1.789$	$7,630 x_{lew} + 13,650$
Fuselage + Systems	65,445	11.28	738,220
Payload + Crew	62,195	10.71	666,108
			$\sum W_i .x_i = 81134 x_{lew} + 1,548,960$
Airplane with c.g. at $0.25 \bar{c}_w$	$2,08,774^{\$}$	$x_{lew} + 0.811$	

<sup>§</sup> As per example 3.1, the take-off weight is 21280 kgf or 208757 N. The value of 208774 N shown in the table is obtained by adding the weights of individual components. The negligible difference between the two values is due to round-off errors. For the sake of consistency,  $W_g = 208774$  N is used in subsequent calculations.

Table E 8.1a Balance table

To satisfy the choice, that the c.g. of the entire airplane is at  $0.25 \bar{c}_w$ , leads to the following equation.

$$208774 (x_{lew} + 0.811) = 81134 x_{lew} + 1,548,960$$

$$\text{Or } x_{\text{lew}} = \frac{1548960 - 208774 \times 0.811}{208774 - 81134} = 10.81 \text{ m}$$

Hence, the c.g. of the airplane is at :

$$10.81 + 0.811 = 11.62 \text{ m from nose of the fuselage}$$

Since, the c.g. lies at a.c. of wing, the latter is also at 11.62 m from the nose of the fuselage.

**Remarks:**

(i) In example 6.2, the distance between the nose of fuselage and the a.c. of wing ( $l_{\text{ntacw}}$ ) was assumed as 10.53 m. The value obtained above is 11.62 m or 1.09 m behind earlier assumed value. This has implications for locations of the aerodynamic centres of v.tail and h.tail. To retain the same tail arms of v.tail and h.tail ( $l_{\text{vt}}$  and  $l_{\text{ht}}$ ) respectively as 11.99 m and 13.31 m, the empennage needs to be shifted aft by 1.09 m as compared to the earlier location (Fig.E6.2b).

Incidentally, in the trailing edge of the root chord of the v.tail in Fig.E6.2b is at  $(22.52+3.028-2.016)$  or 23.712 m from the nose of the fuselage. Shifting aft the empennage by 1.09 m would shift the trailing edge of the root chord of the v.tail to  $23.712 + 1.09 = 24.802$  m which is still inside the rear end of fuselage (note:  $l_f = 25.07$  m). However, the trailing edge of the tip chord of v.tail will project further behind the rear end of the fuselage. The overall length of the airplane ( $l_{\text{overall}}$ ) would go up from 25.483 to  $25.483 + 1.09 = 26.573$  m. This would give  $l_{\text{overall}} / l_f = 26.573 / 25.07 = 1.06$ . This value of  $l_{\text{overall}} / l_f$  is almost the same as that for IPTN N-250-100 and Dash 8 – Q300 (Table 6.2). It may be pointed out that rudder has the chord of 0.3 m and as such the rear spar of the v.tail is further ahead of the rear end of the fuselage. Figure 6.7a shows the features of the attachment between fuselage and v.tail for ATR-72-200. The cutaway drawing of Dash 8-Q300 can be seen in Ref.1.21(1999-2000 edition) and on the website of Flight global.

(ii) In the balance table (Table E8.1) the distances of the c.g. of h.tail,v.tail landing gears, engines and fuel are with reference to  $x_{\text{lew}}$ . Hence, the shifting empennage is automatically taken care-off. However, it must be added that the locations of wing, h.tail, v.tail and landing gears are still tentative. Final locations

are arrived at after various components are optimised and more accurate weights and c.g. location are determined.

(III) c.g. shift for different loading conditions

To carry out these calculations, the balance table with  $x_{lew} = 10.81$  m is presented as table E8.1b

Case (a) Full payload, but no fuel

In this case, the values from Table E8.1b are :

$$W = 208774 - 29852 = 178,922 \text{ N}$$

It may be added that the weight and moment due to trapped fuel is ignored.

$$\sum W_i \cdot x_i = 2426017 - 357179 = 2068838 \text{ Nm}$$

Hence, c.g. location in this case is at :

$$2068838 / 178922 = 11.56 \text{ m}$$

Hence, c.g. shift as fraction of  $\bar{c}_w$  is  $= (1156 - 1162) / 2.295 = - 2.61 \%$  of  $\bar{c}_w$

Or the c.g. is at  $0.224 \bar{c}_w$

Case(b) No payload and no fuel.

It may be noted that, while calculating c.g. location with  $W = W_g$ , the weights of passengers and crew were clubbed together. However, for no payload case only the weight of passengers is considered as payload.

In this case :

$$W = 208774 - 29852 - 58860 = 120,062 \text{ N}$$

$$\sum W_i x_i = 2426017 - 357179 - (10.71 \times 58860) = 1438447 \text{ Nm}$$

Hence, c.g. is at  $= 1438447 / 120062 = 11.981 \text{ m}$

Item	W (N)	x (m)	W.x (Nm)
Wing	24,462	11.965	292,688
Engines	11,478	11.082	115,721
Fuel	29,852	11.965	357,179
H.tail	2,943	25.159	74,043
V.tail	3,422	24.001	82,131
Nose wheel	1,347	2.819	3,797
Main wheel	7,630	12.599	96,130
Fuselage+Sys	65,445	11.28	738,220
Payload + crew	62,195*	10.71	666,108

$$\sum W_i x_i = 2,426,017$$

\*Weight of 60 passengers = 58860 N ; Weight of 4 crew members = 3335 N

Table E 8.1b Weights and c.g. locations of various items

Or c.g. shift as fraction of  $\bar{c}_w$  is :  $(11.981-11.62) / 2.295 = + 15.7 \%$

Or the c.g. is at  $0.407 \bar{c}_w$  .

Case (c) No payload but full fuel

In this case the values from Table E8.1b are :

$$W = 208774 - 58860 = 149914 \text{ N}$$

$$\sum W_i x_i = 242607 - (10.71 \times 58860) = 1795626 \text{ Nm}$$

Hence, c.g. is at :  $1795626 / 149914 = 11.978 \text{ m}$

Or c.g. shift as fraction of  $\bar{c}_w$  :  $(11.979-11.62) / 2.295 = 15.6\%$

Or the c.g. is at  $0.406 \bar{c}_w$

Case (d) Full fuel but with half of passengers in front half of passenger cabin.

The weight of passengers is 58860 N

Half of this would be 29430 N

To obtain the c.g. of the airplane in this case, it is considered that the rear half of the passenger cabin is empty.

The c.g. of this (rear half of passenger cabin) is (Fig.6.8c) at  $0.7 + 2.54 + (12.83 + 2.11) \times 0.75 = 14.445$  m

Hence, in this case,

$$W = 208774 - 29430 = 179,344 \text{ N}$$

$$\sum W_i x_i = 2426017 - 29430 \times 14.445 = 2000901 \text{ Nm}$$

Hence, the c.g. is at :  $2000901/179344 = 11.16$  m

$$\text{Or c.g. shift as percentage of } \bar{c}_w = \frac{11.16-11.62}{2.245} = -20.04 \%$$

Or the c.g. is at  $0.0496 \bar{c}_w$ .

Case (e) Full fuel but with half of passengers in rear half of passenger cabin.

In this case  $W = 179,344$  N

It is considered that the front half of passenger cabin is empty.

The c.g. of the front half of passengers cabin is at :  $0.7 + 2.54 + (12.83 + 2.11) \times 0.25 = 6.975$  m

Consequently,

$$\sum W_i x_i = 2426017 - 29430 \times 6.975 = 2220743 \text{ Nm}$$

Hence,  $x_{cg} = 2220743 / 179344 = 12.38$  m

$$\text{Or the c.g. shift is : } \frac{12.38-11.62}{2.295} = 33.1\% \text{ of } \bar{c}_w$$

Or c.g. at  $0.581 \bar{c}_w$

#### Remarks:

(i) The cases (d) and (e) result in large shift of c.g.. They are hypothetical cases. These are avoided by allotting the window seats first, then aisle seat and later the rest.

The first three cases cause c.g. travel between  $0.224 \bar{c}_w$  and  $0.408 \bar{c}_w$  or c.g. shift

$\Delta(\text{c.g.}) = 0.184 \bar{c}_w$ . Reference 1.12, part II, chapter 10 gives range of c.g. shift for different types of airplanes. For regional transport airplanes with turboprop engines the value of  $\Delta(\text{c.g.})$  can be between 0.14 to 0.27 of  $\bar{c}_w$ .

(ii) When accurate estimates of the weights of various components and the locations of their c.g. are available, a diagram called “Weight-c.g. excursion diagram” (Ref.1.12, part II, chapter 10) is plotted. In this diagram the c.g. location, as fraction of  $\bar{c}_w$ , is plotted on the x-axis. The weight of airplane is plotted on the y-axis. The weight of the airplane under different loading conditions and the corresponding c.g. location provide the points on the diagram. Such a diagram covering the full range of weights and c.g. locations appears like a potato and is sometimes referred to(Ref.1.19,chapter 8) as “Potato curve”. This diagram indicates the most forward and most aft locations of c.g.

(iii) The airplane is symmetric about x-z plane and c.g. lies in the plane of symmetry. The vertical location of c.g. is calculated after taking into account the heights of various components above the ground. This location is needed for the design of landing gear.

### Example 8.2

A preliminary three view drawing was obtained in example 2.1, for the sixty seater regional airplane with turboprop engines.

Revised estimates of the parameters of wing, fuselage, h.tail, v.tail, engine and landing gear have been obtained in chapters 3 to 8. Based on these data, obtain a revised 3-view drawing of the airplane at this stage of the preliminary design.

### Solution:

The following points are noted from the calculations carried out in chapters 3 to 8.

1) Wing parameters

a) The geometrical parameters of the wing are presented in Fig.E5.1.

b) A high wing configuration is chosen

c) The leading edge of the root chord of the wing is at 10.81 m from the nose of fuselage (example 8.1). The wing dihedral is  $3^\circ$ .

II) Fuselage parameters

a) The geometrical parameters of the fuselage are presented in Fig.6.8c and d. The cabin layout is presented in Fig.6.8b.

b) The cross section of the midfuselage is circular. The top portion of the rear fuselage, on which the v.tail is located, is parallel to the fuselage axis.

c) Based on data in table 2.1 for IPTN, ATR-72 and Dash-8 the height of the belly of the fuselage above ground is chosen as 0.7 m.

III) The geometric parameters of the empennage are shown in Fig.E6.2.

However, after the calculation of c.g., the empennage is shifted rearwards by 1.09 m as compared to that shown in Fig.E6.2. A T-tail configuration is chosen.

IV) The two engines are located in nacelles on each wing half. The spanwise extent of each nacelle ends at 35% of wing semi-span. The maximum width and depth of nacelle are 1.03 m and 1.37 m respectively (Example 6.3). The propeller diameter is 3.93 m. The boss of the propeller is at 1.58 m ahead of the leading edge of wing (example 8.1)

V) A tricycle landing gear is chosen. The main wheels are retracted in pods attached to fuselage. The tentative locations of the nose wheel and the main wheels are respectively at 2.819 m and 12.599 m from the nose of the fuselage. The revised three view drawing for the airplane under design is shown in Fig.E8.2.

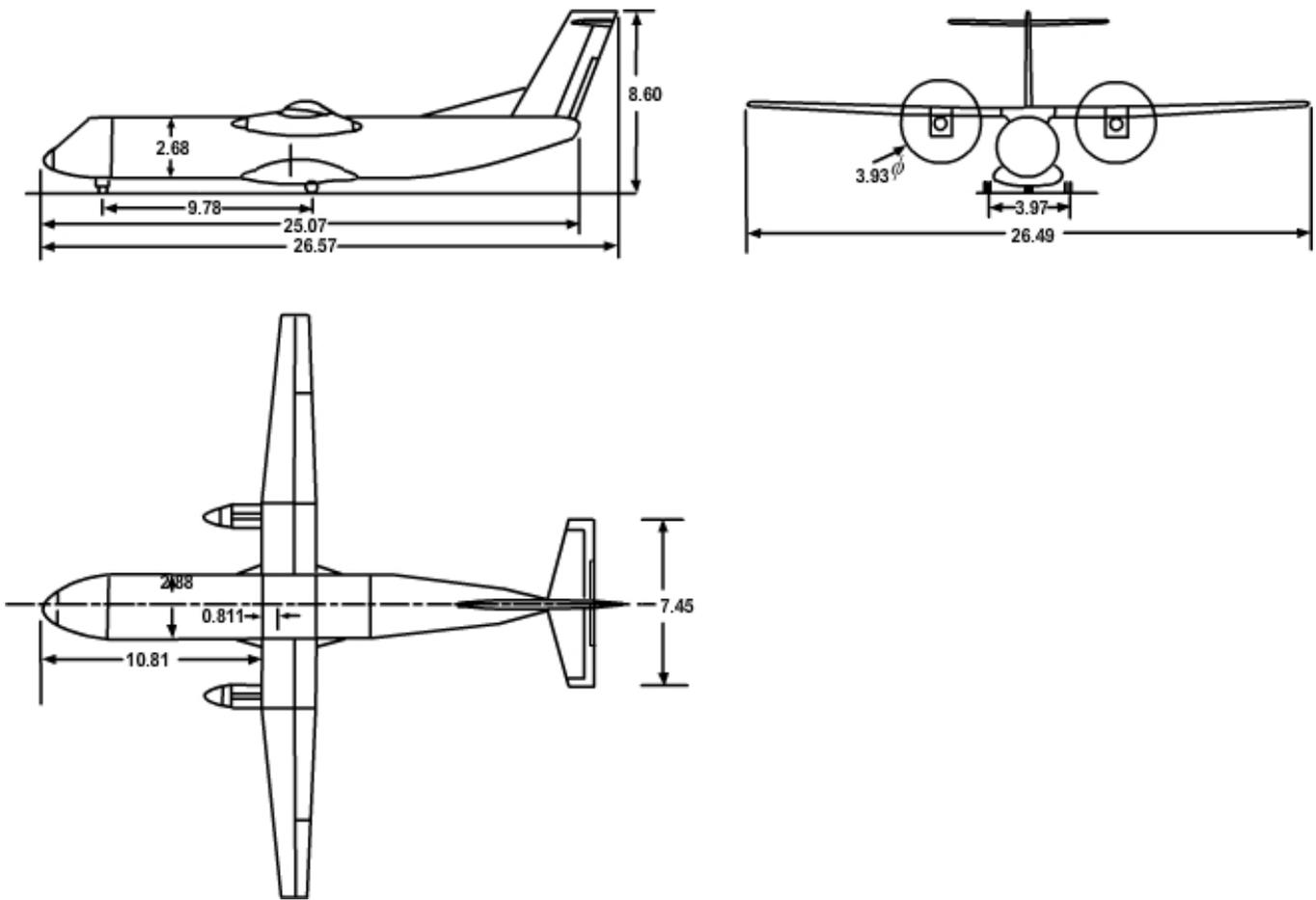


Fig.E8.2 Revised three-view drawing

**Remarks:**

(i) At this stage of the preliminary design, the structural design has not been done. Hence, guidelines from the three-view drawings of IPTN, ATR 72 and Dash-8 are taken for the tentative shapes of (a) wing-fuselage attachment, (b) pods in which main landing gear is retracted and (c) nacelles and their attachment.

(ii) The height of the airplane in Fig.2.1 is 7.7 m. However, the height in Fig.E8.2 is 8.6 m. The reasons for this increase are as follows.

The height of 7.7 m in Fig.2.1 is based on height of ATR-72 which is 7.65 m. In this airplane (ATR-72) and the airplane under design, the distance of the belly of the fuselage above the ground and the maximum height of fuselage are nearly

same. However, two differences between ATR 72 and the airplane under design are pointed out below.

(a) The shape of the vertical tail of ATR-72 is not trapazoidal. It is like a cranked wing.(Fig.6.7a) The sweep angle and the chord near the root of v.tail are large as compared to a conventional trapazoidal shape. This results in lower height of vertical tail for a given area of v.tail.

(b) The upper surface of the fuselage, where v.tail is located is curved. Hence, the root chord of the vertical tail lies along the centre line of the rear end of fuselage as shown in Fig.6.9b. Thus, the height of the v.tail above the fuselage is further lowered. If these concepts were used in the airplane under design, the overall height of the airplane would be comparable to that of ATR-72. Presently, the height is comparable to the overall height of IPTN which has a v.tail configuration similar to that of airplane under design.

In an actual design, the changes in vertical tail configuration and many other aspects would be brought out in later stages of design.