# Design of a Propeller-Driven Airplane



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# Introduction

- propeller is a type of fan that transmits power by converting rotational motion into thrust.
- a mechanical device for propelling a boat or aircraft, consisting of a revolving shaft with two or more broad, angled blades attached to it.


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# Requirement

- In order to  designing a light, business transport aircraft .

(1) Maximum level speed 250 mi/h

(2) Range 1,200 mi

(3) Ceiling 25,000 ft

(4) Rate of climb at sea level:1000ft/min

(5) Stalling  speed 70 mi/h

(6) Landing distance  2,200 ft

(7) Talk off distance 2,500

# Weight of airplane

## Can be divided into

**Crew weight Wcrew:** people necessary to operate the airplane in flight.

**payload weight Wpayload:** the airplane is intended to transport

**Fuel weight Wfue:** weight of the fuel in the fuel tanks

**Empty weight Wempty:** everything else structure in the aircraft(radar, computers, communication device…etc)

# Cont..

- The design takeoff gross weight **W0** is the weight of the airplane at the instant it begins its mission. It includes the weight of all the fuel on board at the beginning of the flight. Hence,

**Wo = Wcrew + Wpayload +Wfuel + Wempty**
**Wo = Wcrew + Wpayload + Wt + We**
**Wo = Wcrew + Wpayload + - Wo + -Wo**

$$W_0 = \frac{W_{crew} + W_{payload}}{1 - W_f/W_0 - W_e/W_0}$$

# Estimation

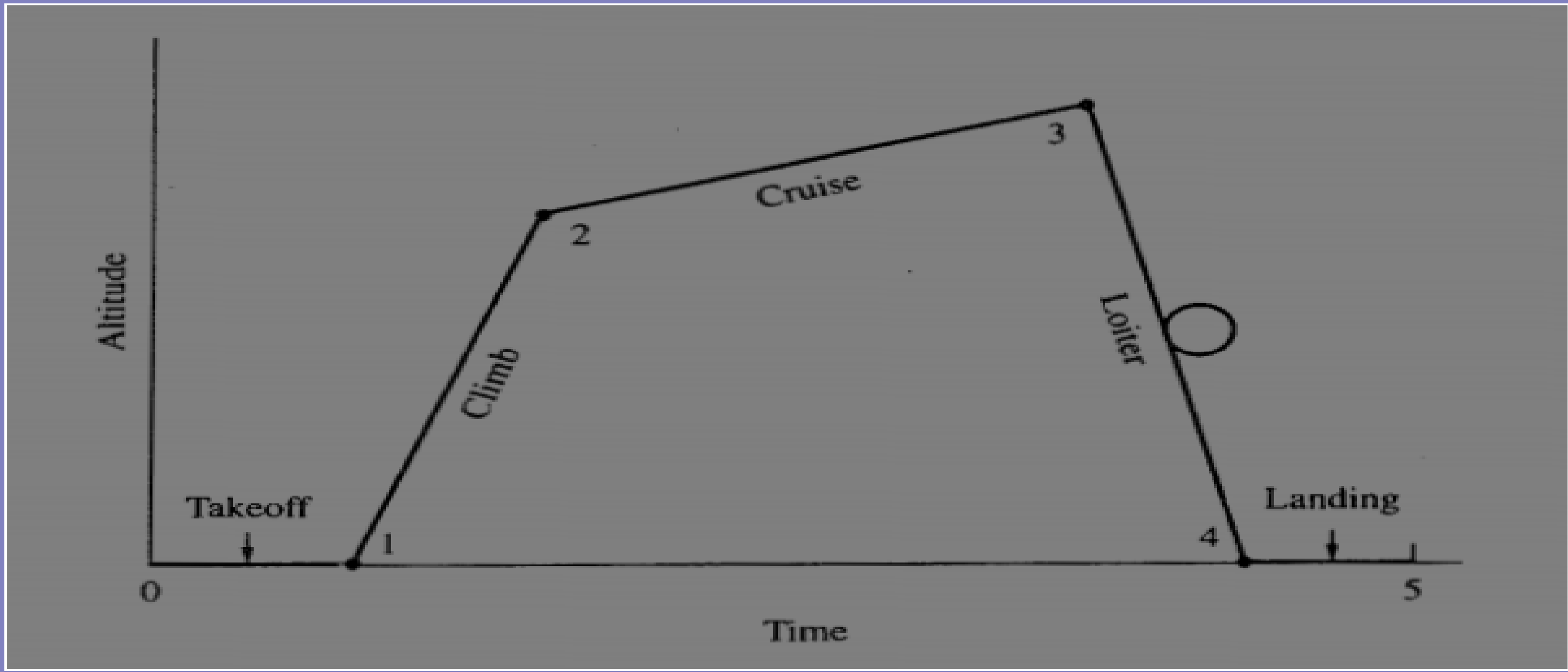
- Most airplane designs are evolutionary rather than revolutionary.

  We/W0 evolutionary (different companies)

  Wf/wo

The amount of fuel required to carry out the mission depends critically on the ef-ficiency of the propulsion device-the engine specific fuel consumption and the propeller efficiency. It also depends critically on the aerodynamic efficiency-the lift-to-drag ratio.

# Wf/wo



# E.Critical parameter performance

- Can be determined as maximum speed , range , ceiling , rate of climb ,stalling speed ,landing distance and take of distance.
- Maximum lift coefficient: this is the stage in the design process where we make an initial choice for the air foil shape of the wing.

# parametr of aircraft design

(a) Maximum lift cofficient (CL)Max

(b) Maximum Lift -to- drag ratio(L/D)max

(c) wing loading W/S

(d) Power Loading W/P

(e) Trust to weight ratio

A.

$$C_L = \frac{L}{q\,S} = \frac{L}{\frac{1}{2}\rho u^2\,S} = \frac{2L}{\rho u^2 S}.$$

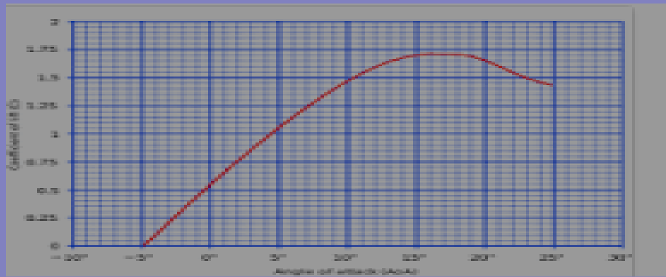
where L=lift Force

q=fluid dynamic

p=desnsity

s=surface area

u=flow speed



# cont..

- wing loading is determined by concideration of Vstall and landing distance as Vstall increases W/S increase.

$$V_{\text{stall}} = \sqrt{\frac{2}{\rho_\infty}\frac{W}{S}\frac{1}{(C_L)_{\max}}}$$

- **Trust-to-weight ratio** it is determined by takeoff distance, rate of climb and maximum speed

**Power loading**: The inverse of power-to-weight, weight-to-power ratio (power loading) is a calculation commonly applied to aircraft, cars, and vehicles in general, to enable the comparison of one vehicle's performance to another. Power-to-weight ratio is equal to thrust per unit mass multiplied by the velocity of any vehicle.

# summrization

| | |
|---|---|
| Maximum lift coefficient | $(C_L)_{\max} = 2.34$ |
| Maximum lift-to-drag ratio | $\left(\frac{L}{D}\right)_{\max} = 14$ |
| Wing loading | $\frac{W}{S} = 29.3 \text{ lb/ft}^2$ |
| Power loading | $\frac{W}{P} = 14.3 \text{ lb/hp}$ |
| Takeoff gross weight | $W_0 = 5,158$ lb |
| Fuel weight | $W_f = 820$ lb |
| Fuel tank capacity | 145.4 gal |
| Wing area | $S = 176 \text{ ft}^2$ |
| High-lift device | Single-slotted trailing-edge flaps |
| Zero-lift drag coefficient | $C_{D,0} = 0.017$ |
| Drag-due-to-lift coefficient | $K = 0.075$ |
| Aspect ratio | $AR = 7.07$ |
| Propeller efficiency | 0.8 |
| Engine power, supercharged to 20,000 ft | 362.5 hp |

# Configuration

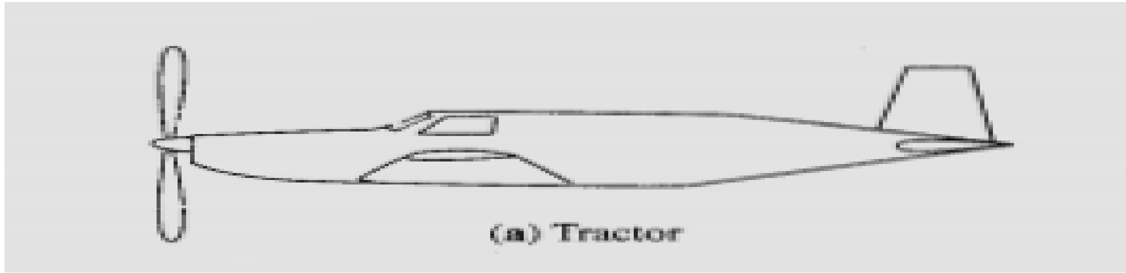
**mainly classified in to 2**

**tractor**

1. The heavy engine is at the front, which helps to move the center of gravity forward and therefore allows a smaller tail for stability considerations.
2. The propeller is working in an undisturbed free stream.
3. There is a more effective flow of cooling air for the engine.

Disadvantages:

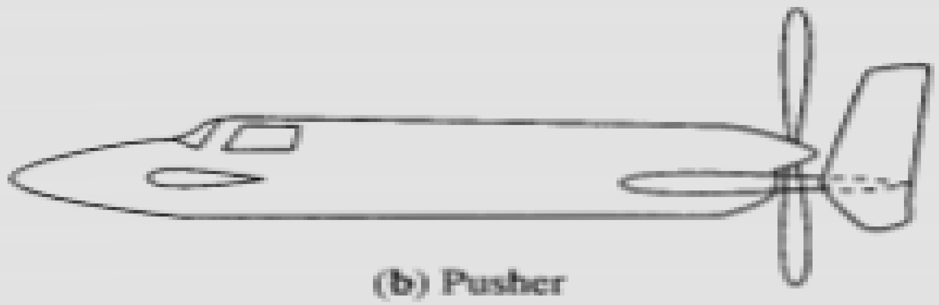
1. The propeller slipstream disturbs the quality of the airflow over the fuselage and wing root.
2. The increased velocity and flow turbulence over the fuselage due to the propeller slipstream increase the local skin friction on the fuselage.



# Pusher Configuratior

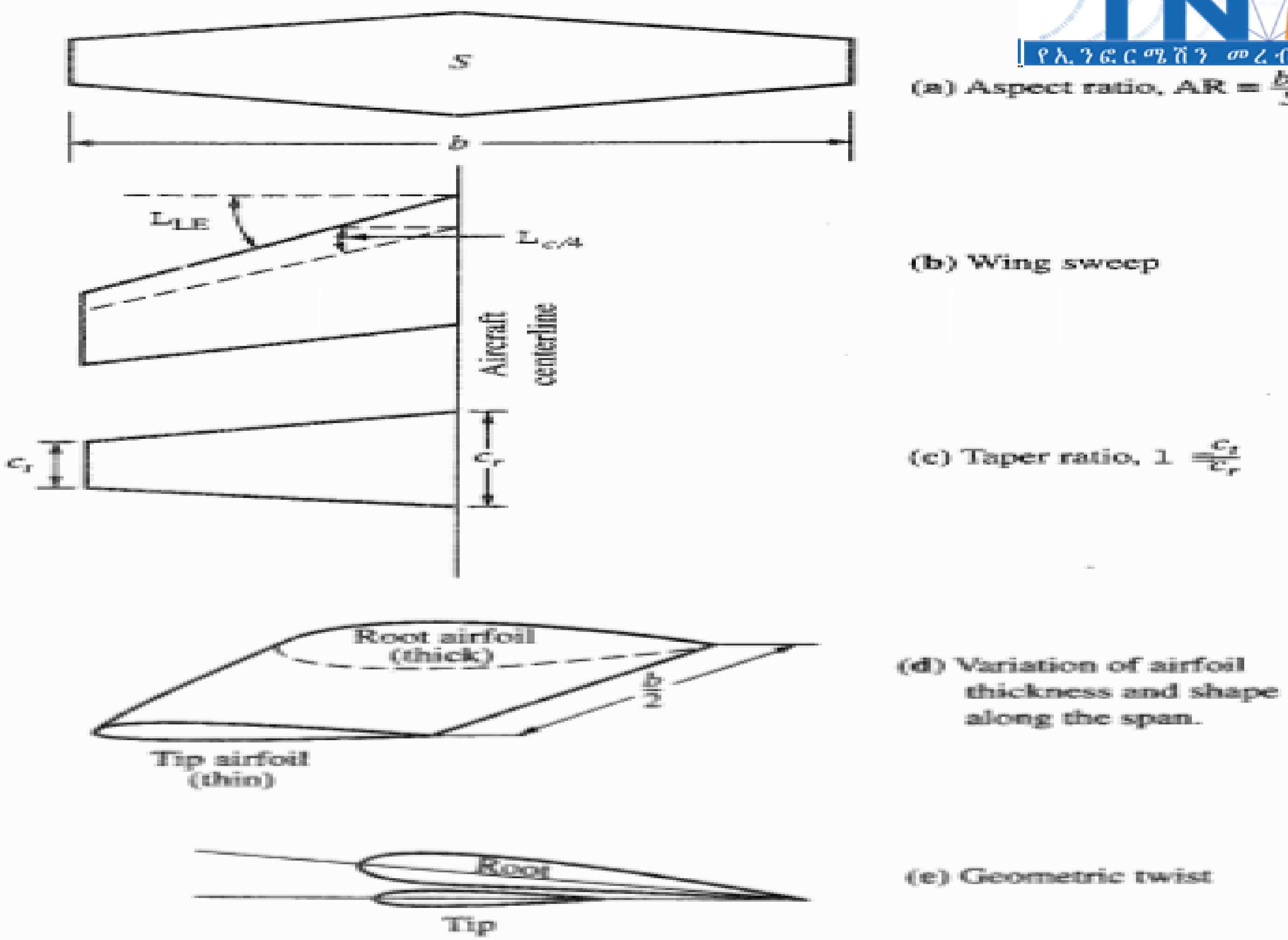
Pusher Configuration  Advantages:
1. Higher-quality (clean) airflow prevails over the wing and fuselage.
2. The inflow to the rear.propeller induces a favorable pressure gradient at the rear
3. Engine noise in the cabin area is reduced.
4. The pilot's front field of view is improved.

Disadvantages:
l. The heavy engine is at the back, which shifts the center of gravity rearward, hence reducing longitudinal stability.
2. Propeller is more likely to be damaged by flying debris at landing.
3. Engine cooling problems are more severe



(b) Pusher

# wing configuration



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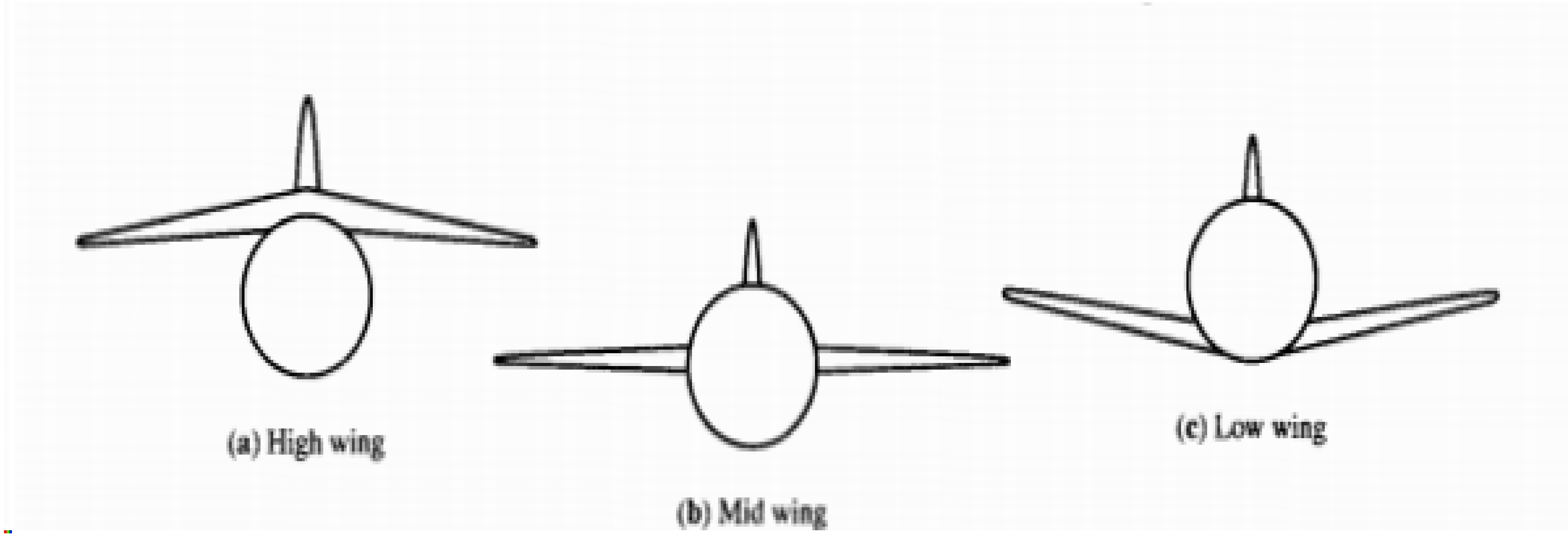

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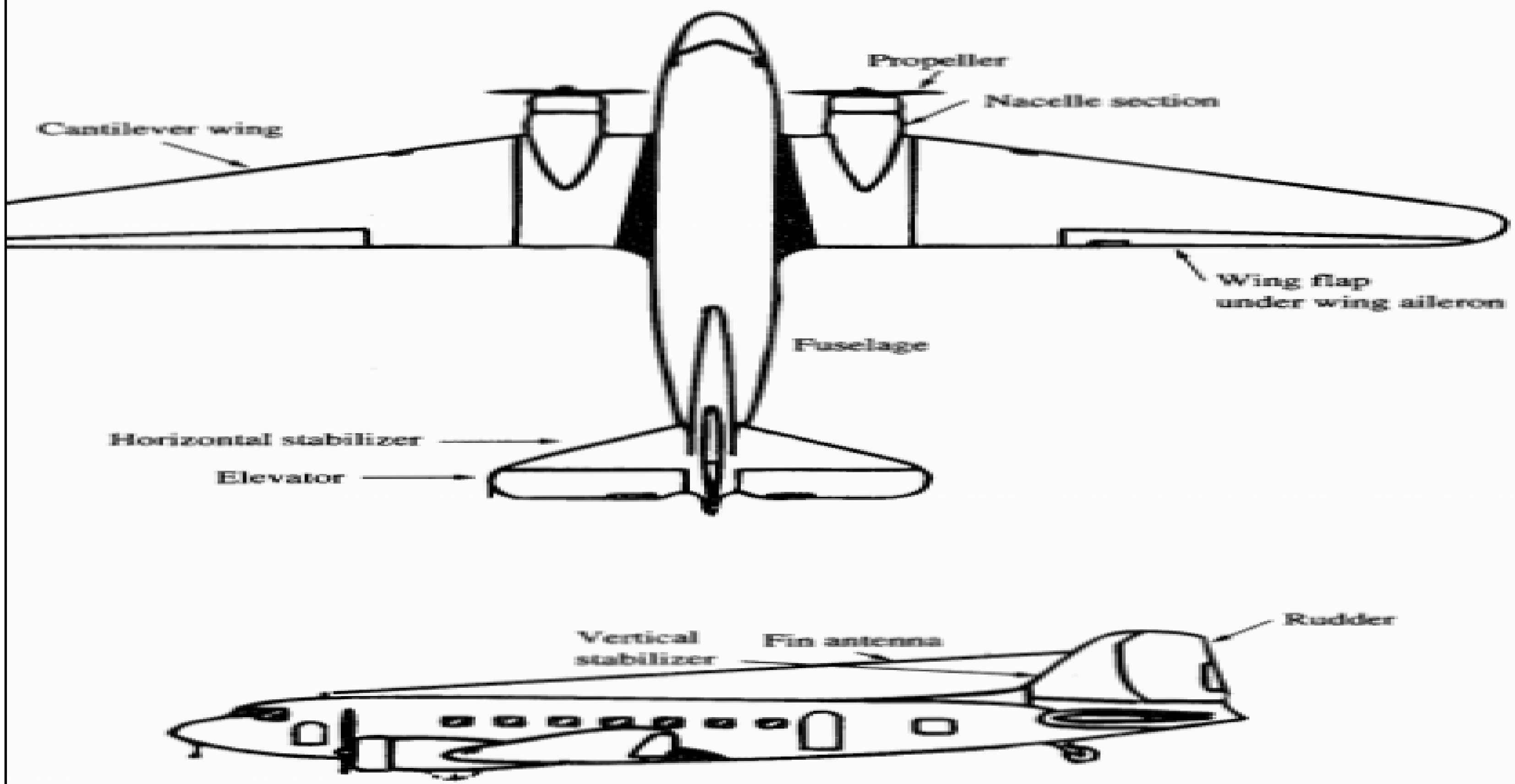
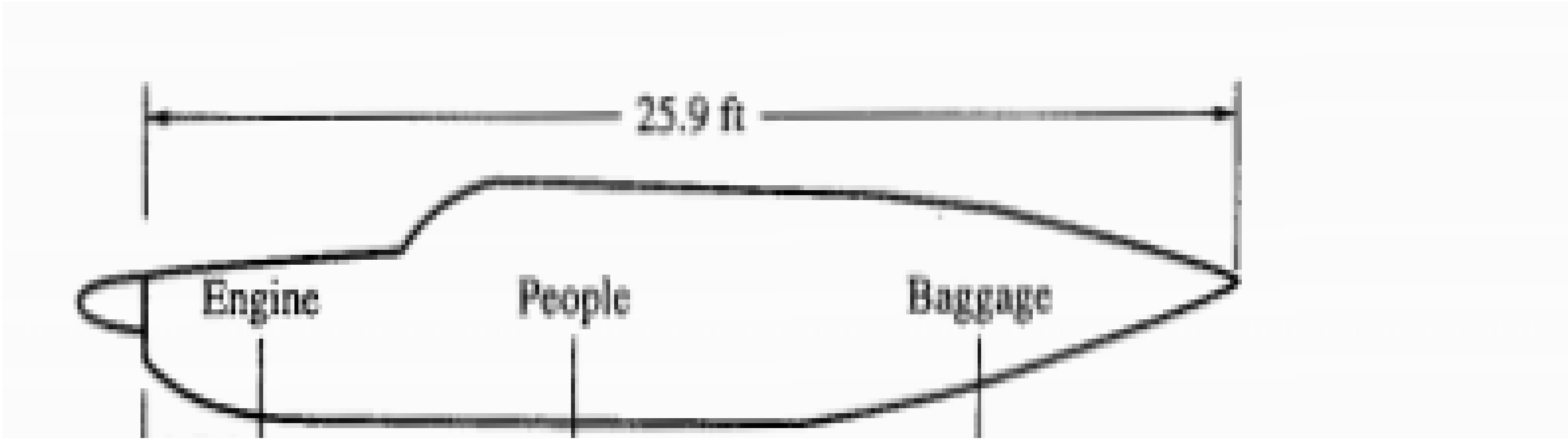

Propeller
Nacelle section
Cantilever wing
Wing flap
under wing aileron
Fuselage
Horizontal stabilizer
Elevator
Vertical
stabilizer
Fin antenna
Rudder

# Fuselage Configurati

The fuselage must be large enough to contain the engine in the nose, the pilot and five passengers in the cabin, the baggage, and the fuel if it is decided to store it in the fuselage. Let us first examine the question of where to put the fuel. For enhanced safety to the occupants, it is extremely desirable to store the fuel in the wings rather than the fuselage. Also, with the fuel storage in the wings, the shift in the airplane's center of gravity as fuel is consumed is usually much less than if fuel were stored in the fuselage. Is our wing large enough, with enough internal volume, to hold the fuel? and we have to identify center of gravity.



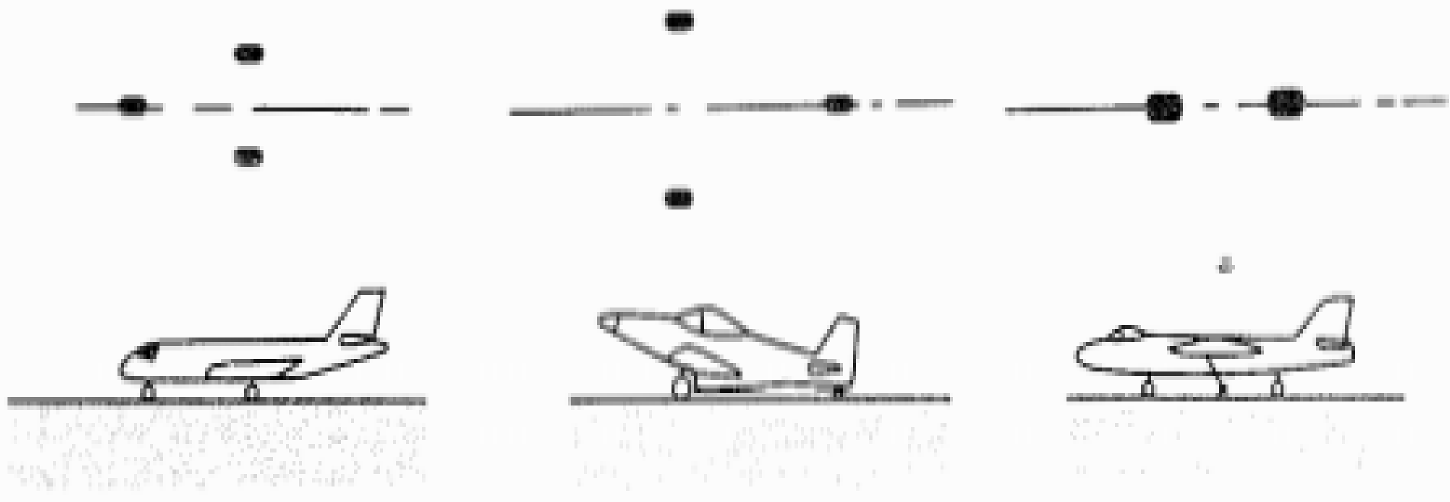
# Propeller Size

for a general aviation airplane of our
design type, the propeller would be bought off the shelf from a propeller manufacturer. However, for the configuration layout, we need to establish the propeller diameter, because that will dictate the length (hence weight) of the landing gear.
The function of the propeller is to take the shaft power from the reciprocating engine and turn it into thrust power to propel the airplane forward. This is never accomplished without some losses, hence the propeller efficiency 1"'/pr is always less than unity.

$$\eta_{pr} = \frac{\text{thrust power}}{\text{shaft power}} = \frac{T V_\infty}{P} < 1$$

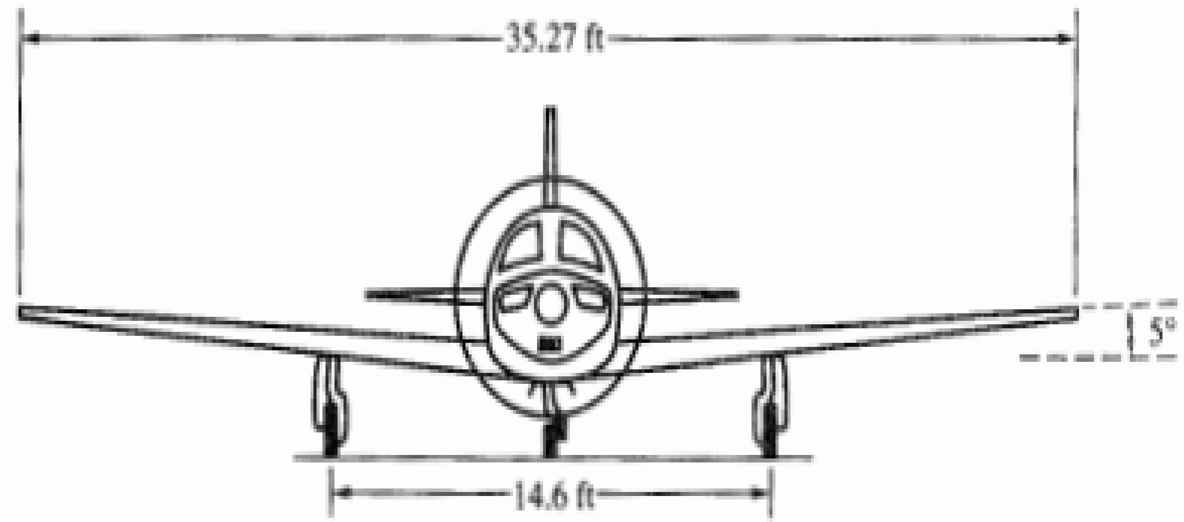
# Landing Gear, and Wing Placer

relative to our discussion on landing distance and how it affects W / S,
we made the decision to use a tA-icyde landing gear for our design"
the landing gear should be long enough to give the propeller tip at least 9-in clearance above the ground.



(a) Tricycle landing gear (b) Tail dragger (c) Bicycle landing gear

have been aimed at achieving the configuration layout-a drawing of our first iteration for the shape and size of the airplane. Our various
considerations-the wing's size, shape, and placement relative to the fuselage; the tail's size and placement; etc



this stage is a process of testing our aircraft configuration maches to the estimation of the model

such as

power loading
wing loading
rate of climb
range
stalling speed
landing distance
take of distance

# END