FLIGHT VEHICLES DESIGN

III B. Tech V semester (Autonomous IARE R-16)

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Course outcome

COs	Course outcome
CO1	Describe different phases of aircraft design , weight estimation and few basics of aerodynamics
CO2	Differentiating size estimation fuel system and understanding the installation of engine systems
CO3	Estimation of lift curve slopes maximum lift coefficient and different material selection can be found
CO4	Understanding the concepts of stability for different control surfaces and also understanding the methods of structural analysis
CO5	Acquiring knowledge on cost estimation research, Development, Test, and Evaluation and Product cost for designing an aircraft

UNIT - I

OVERVIEW OF THE DESIGN PROCESS

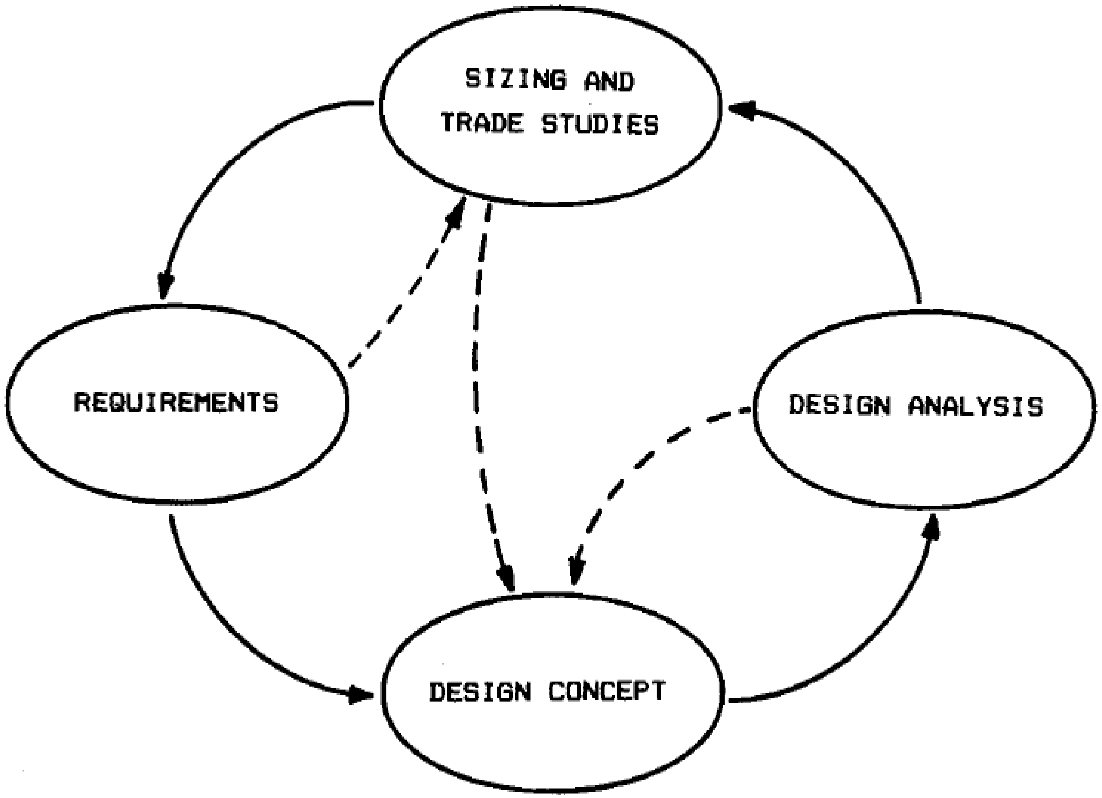
UNIT - I

CLOs	Course Learning Outcome
CLO1	Demonstrate the concept of supersonic flow, how it is different from incompressible flow.
CLO2	Understand governing equations of supersonic flow in various form and thermodynamics properties.
CLO3	Describe the governing equations required for compressible flows.

Introduction

- Those involved in design can never quite agree as to just where the design process begins.
- The designer thinks it starts with a new airplane concept. The sizing specialist knows that nothing can begin until an initial estimate of the weight is made.
- The customer, civilian or military, feels that the design begins with requirements. They are all correct. Actually, design is an iterative effort, as shown in the "Design Wheel" of Fig. 1.1.

The Design Wheel



The design wheel

Preliminary Design

- Preliminary design can be said to begin when the major changes are over. The big questions such as whether to use a canard or an aft tail have been resolved.
- The configuration arrangement can be expected to remain about as shown on current drawings, although minor revisions may occur.
- At some Point late in preliminary design, even minor changes are stopped when a decision is made to freeze the configuration.

Detail Design

- Assuming a favorable decision for entering full-scale development, the detail design phase begins in which the actual pieces to be fabricated are designed.
- For example, during conceptual and preliminary design the wing box will be designed and analyzed as a whole., spars, and skins, each of which must be separately designed. Another important part of detail design is called production design. Specialists determine how the airplane will be fabricated, starting with the smallest and simplest subassemblies and building up to the final assembly process.

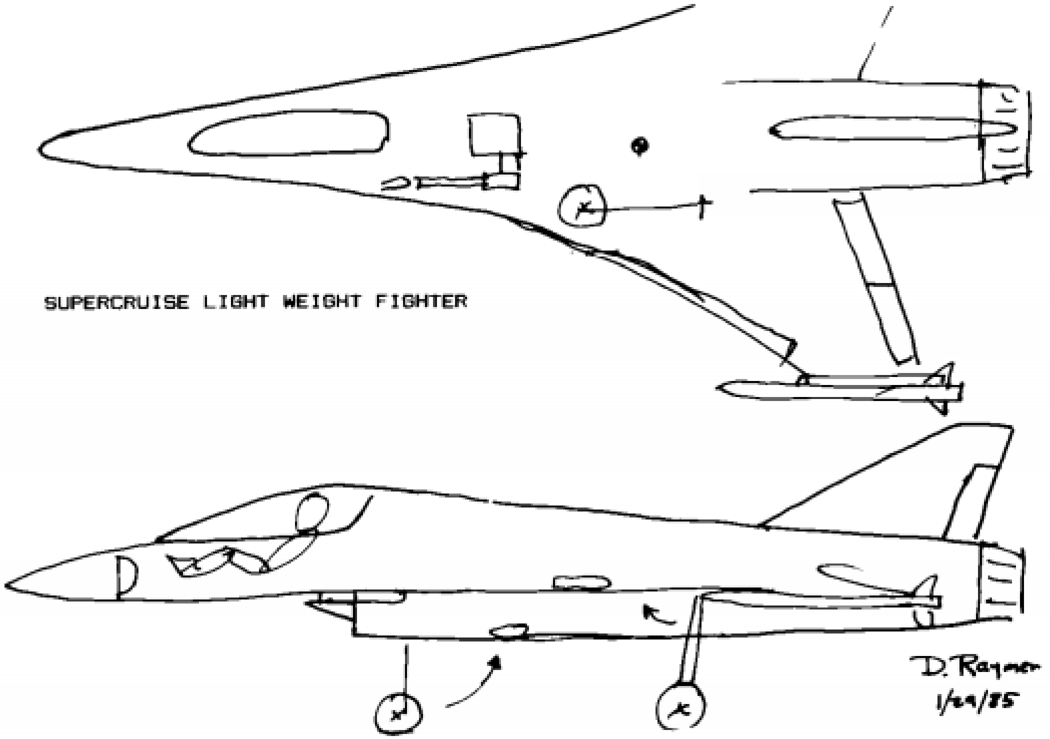
Detail Design

- Production designers frequently wish to modify the design for ease of manufacture; that can have a major impact on performance or weight. Compromises are inevitable, but the design must still meet the original requirements.
- Detail design ends with fabrication of the aircraft. Frequently the fabrication begins on part of the aircraft before the entire detail-design effort is completed. Hopefully, changes to already-fabricated pieces can be avoided.
- The further along a design progresses, the more people are involved. In fact, most of the engineers who go to work for a major aerospace company will work in preliminary or detail design.

Aircraft conceptual design process

- Conceptual design will usually begin with either a specific set of design requirements established by the prospective customer or a company-generated guess as to what future customers may need. Design requirements include parameters such as the aircraft range and payload, takeoff and landing distances, and maneuver.
- The design requirements also include a vast set of civil or military design specifications which must be met. These include landing sink-speed, stall speed, structural design limits, pilots' outside vision angles, reserve fuel, and many others. Sometimes a design will begin as an innovative idea rather than as a response to a given requirement ability and speed requirements.

Initial sketch



Initial Sketch

Initial Layout

- This initial layout is analyzed to determine if it really will perform the mission as indicated by the first-order sizing.
- Actual aerodynamics, weights, and installed propulsion characteristics are analyzed and subsequently used to do a detailed sizing calculation.
- Furthermore, the performance capabilities of the design are calculated and compared to the requirements mentioned above

Sizing From A Conceptual Sketch

- There are many levels of design procedure.
- The simplest level just adopts past history. For example, if you need an immediate estimate of the takeoff weight of an airplane to replace the Air Force F-15 fighter, use 44,500 lb.
- That is what the F-15 weighs, and is probably a good number to start with. To get the "right" answer takes several years, many people, and lots of money.
- Actual design requirements must be evaluated against a number of candidate designs, each of which must be designed, analyzed, sized, optimized, and redesigned any number of times.

Sizing From A Conceptual Sketch

- Analysis techniques include all manner of computer code as well as correlations to wind-tunnel and other tests.
- Even with this extreme level of design sophistication, the actual airplane when flown will never exactly match predictions.
- In between these extremes of design and analysis procedures lie the methods used for most conceptual design activities.

Takeoff-Weight Buildup

- Design takeoff gross weight" is the total weight of the aircraft as it begins the mission for which it was designed.
- This is not necessarily the same as the "maximum takeoff weight." Many military aircraft can be overloaded beyond design weight but will suffer a reduced maneuverability.
- Unless specifically mentioned, takeoff gross weight, or "W0 ," is assumed to be the design weight.
- Design takeoff gross weight can be broken into crew weight, payload (or passenger~ weight, fuel weight, and the remaining (or "empty") weight.

Takeoff-Weight Buildup

- The empty weight includes the structure, engines, landing gear, fixed equipment, avionics, and anything else not considered a part of crew, payload, or fuel. Equation summarizes the takeoff-weight buildup
- $W_o = W_{Crew} + W_{payload} + W_{fuel} + W_{empt}$
- The crew and payload weights are both known since they are given in the design requirements. The only unknowns are the fuel weight and empty weight. However, they are both dependent on the total

Takeoff-Weight Buildup

$$W_0 = W_{\text{crew}} + W_{\text{payload}} + W_{\text{fuel}} + W_{\text{empty}}$$

This can be solved for W0 as follows:

$$W_0 = W_{\text{crew}} + W_{\text{payload}} + \left(\frac{W_f}{W_0}\right) W_0 + \left(\frac{W_e}{W_0}\right) W_0$$

$$W_0 - \left(\frac{W_f}{W_0}\right) W_0 - \left(\frac{W_e}{W_0}\right) W_0 = W_{\text{crew}} + W_{\text{payload}}$$

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

Empty weight estimation

- The empty-weight fraction (We/W0) can be estimated statistically from historical trends as shown in developed by the author from data taken.
- Empty-weight fractions vary from about 0.3 to 0.7, and diminish with increasing total aircraft weight.
- As can be seen, the type of aircraft also has a strong effect, with flying boats having the highest empty-weight fractions and long-range military aircraft having the lowest. Flying boats are heavy because they need to carry extra weight for what amounts to a boat hull

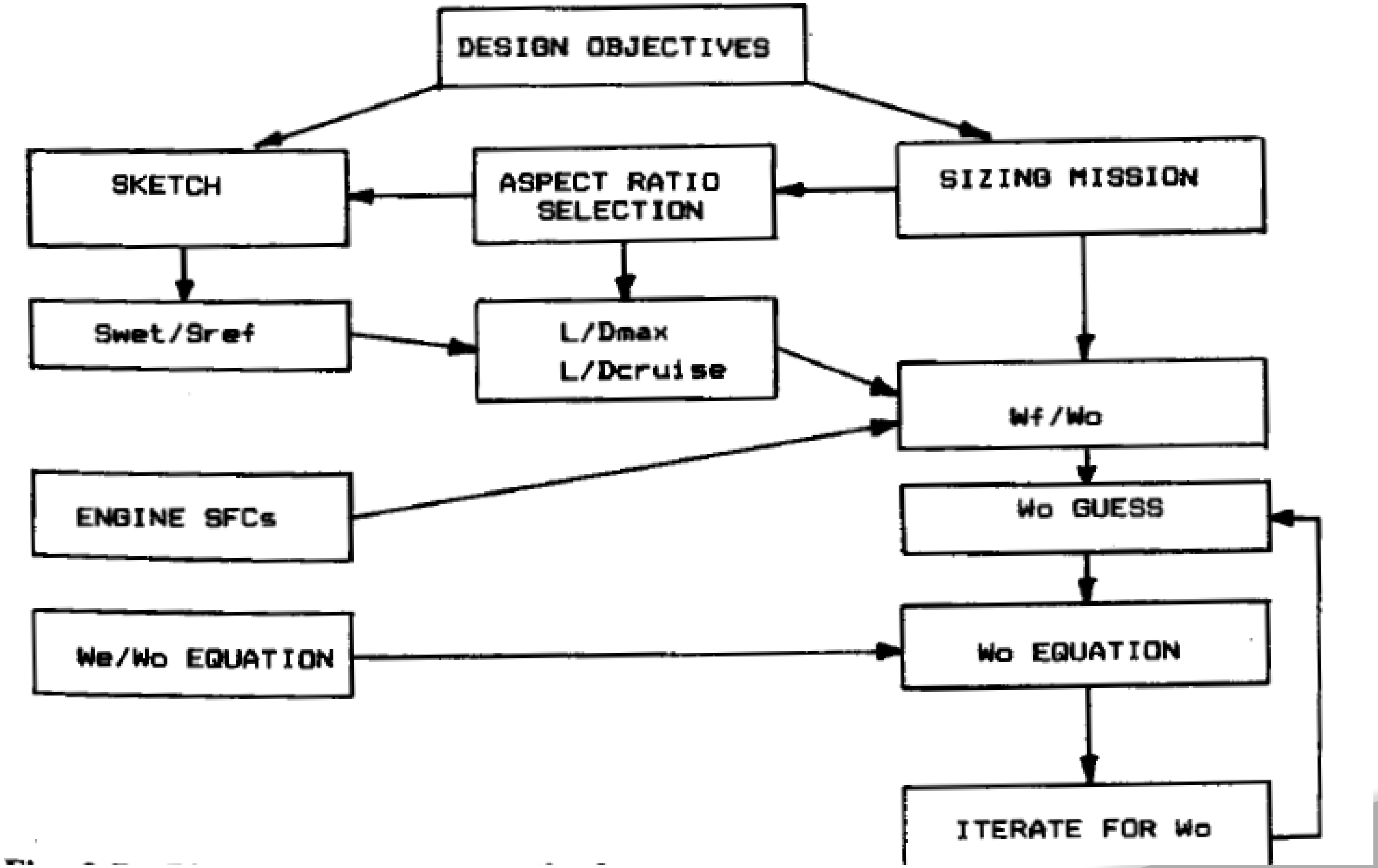
Fuel-Fraction Estimation

Using historical values from Table 3.2 and the equations for cruise and loiter segments, the mission-segment weight fractions can now be estimated. By multiplying them together, the total mission weight fraction, Wx/Wo, can be calculated. Since this simplified sizing method does not allow mission segments involving payload drops, all weight lost during the mission must be due to fuel usage. The mission fuel fraction must therefore If you assume, typically, a 6% allowance for reserve and trapped fuel, the total fuel fraction can be estimated

Takeoff-weight Calculation

- Using the fuel fraction found with above Eq .and the statistical empty weight equation selected
- From the takeoff gross weight can be found iteratively. This is done by guessing the takeoff gross weight, calculating the statistical empty-weight fraction, and then calculating the takeoff gross weight. If the result doesn't match the guess value, a value between the two is used as the next guess.
- This will usually converge in just a few iterations. This first-order sizing process is diagrammed.

First order design method



L/D Estimation

- For initial sizing, a wing aspect ratio of about 11 was selected. With the area of the wing and canard both included, this is equivalent to a combined aspect ratio of about 8.
- From, initial values for SFC are obtained. For a subsonic aircraft the best SFC values are obtained with high-bypass turbofans, which have typical values of about 0.5 for cruise and 0.4 for loiter.

Takeoff-Weight Sizing

- From, initial values for SFC are obtained. For a subsonic aircraft the best SFC values are obtained with high-bypass turbofans, which have typical values of about 0.5 for cruise and 0.4 for loiter.
- Does not provide an equation for statistically estimating the empty weight fraction of an antisubmarine aircraft. However, such an aircraft is basically designed for subsonic cruise efficiency so the equation for military cargo/bomber can be used. The extensive ASW avionics would not be included in that equation, so it is treated as a separate payload weight.

Trade studies

- An important part of conceptual design is the evaluation and refinement with the customer, of the design requirements.
- In the ASW design the required 1500 n.mi. example range 1500n.mi. (Each way) is probably less than the customer would really like.
- A "range trade" can be calculated to determine the increase m design takeoff gross weight if the required range is increased

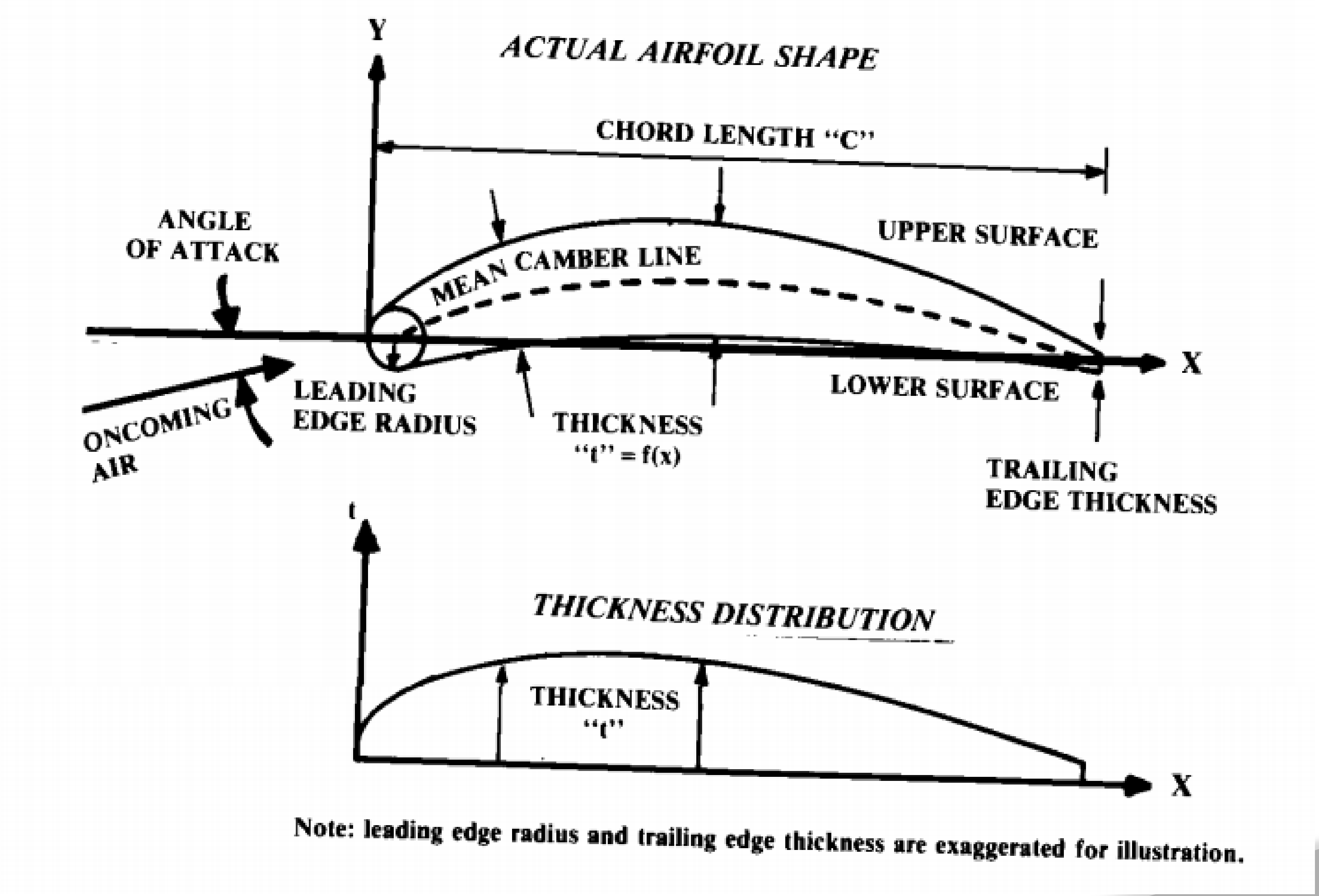
Airfoil Selection

- The airfoil, in many respects, is the heart of the airplane.
- The airfoil affects the cruise speed, takeoff and landing distances, stall speed, handling qualities (especially near the stall), and
- Overall aerodynamic efficiency during all phases of flight

Airfoil Selection

- An airfoil designed to operate in supersonic flow will have a sharp or nearly-sharp leading edge to prevent a drag-producing bow shock.
- (As discussed later, wing sweep may be used instead of a sharp leading edge to reduce the supersonic drag.)
- The chord of the airfoil is the straight line from the leading edge to the trailing edge.
- It is very difficult to build a perfectly sharp trailing edge, so most airfoils have a blunt trailing edge with some small finite thickness.

Airfoil geometry

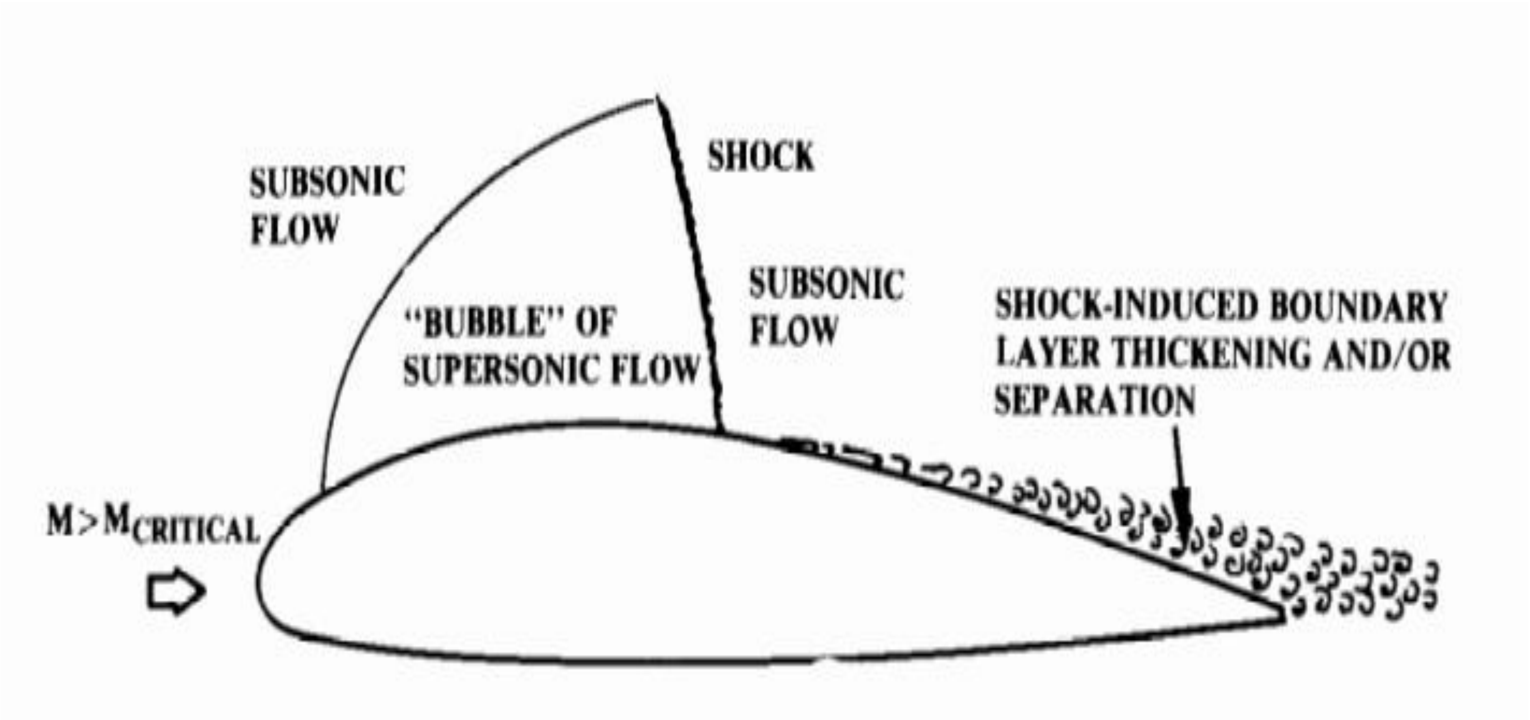


Note: leading edge radius and trailing edge thickness are exaggerated for illustration.

Design Lift Coefficient

- For early conceptual design work, the designer must frequently rely upon existing airfoils.
- From existing airfoils, the. One should be selected a comes closest to having the desired characteristics
- Aircraft should be designed so that it flies the design milestone at or near the design lift coefficient
- To maximize the aerodynamic efficient equals the airfoil lift

Transonic effects

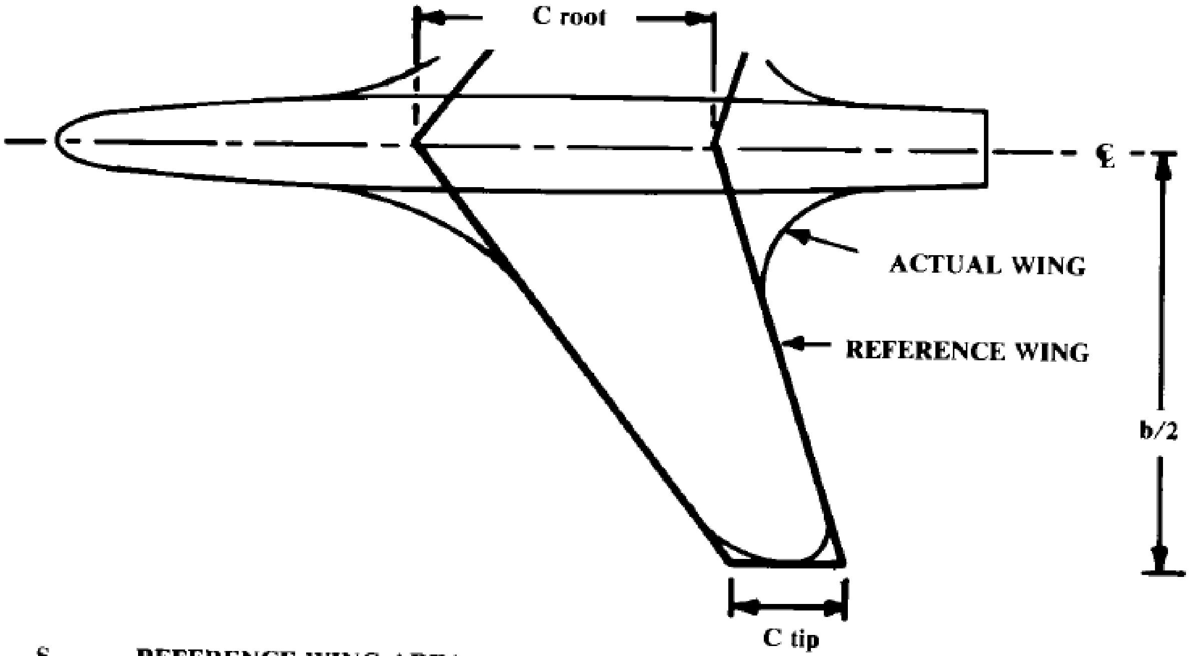


Transonic effects

Wing Geometry

- The "reference" ("trapezoidal") wing is the basic wing geometry used to began the layout. Following Figures
- How the key geometric parameters of the reference wing. Note that the reference wing is fictitious, and extends through the fuselage to the aircraft centerline.
- For the reference wing, the root airfoil is the airfoil of the trapezoidal reference wing at the centerline of the aircraft, not where the actual wing connects to the fuselage.

Wing Geometry



S = REFERENCE WING AREA

C = CHORD (DISTANCE L.E. TO T.E.)

A = ASPECT RATIO = b^2/S

t/c = AIRFOIL THICKNESS RATIO (MAXIMUM THICKNESS/CHORD)

λ = TAPER RATIO = C tip/C root

b = SPAN

GIVEN: W/S, A , λ

$S = W/(W/S)$ $b = \sqrt{A \cdot S}$ $C_{root} = 2 \cdot S/[b(1+\lambda)]$ $C_{tip} = \lambda \cdot C_{root}$

Aspect Ratio

- The first to investigate aspect ratio in detail were the Wright Brothers, using a wind tunnel they constructed. They found that a long, skinny wing(high aspect ratio) has less drag for a given lift than Wing Sweep
- Wing sweep is used primarily to reduce the adverse effects of transonic and supersonic flow.
- Theoretically, shock formation on a swept wing is determined not by the actual velocity of the air passing over the wing, but rather by the air velocity in a direction perpendicular to the leading edge of the wing.
- This result, first applied by the Germans during World War II Allows an increase in Critical Mach Number by the use of sweep.

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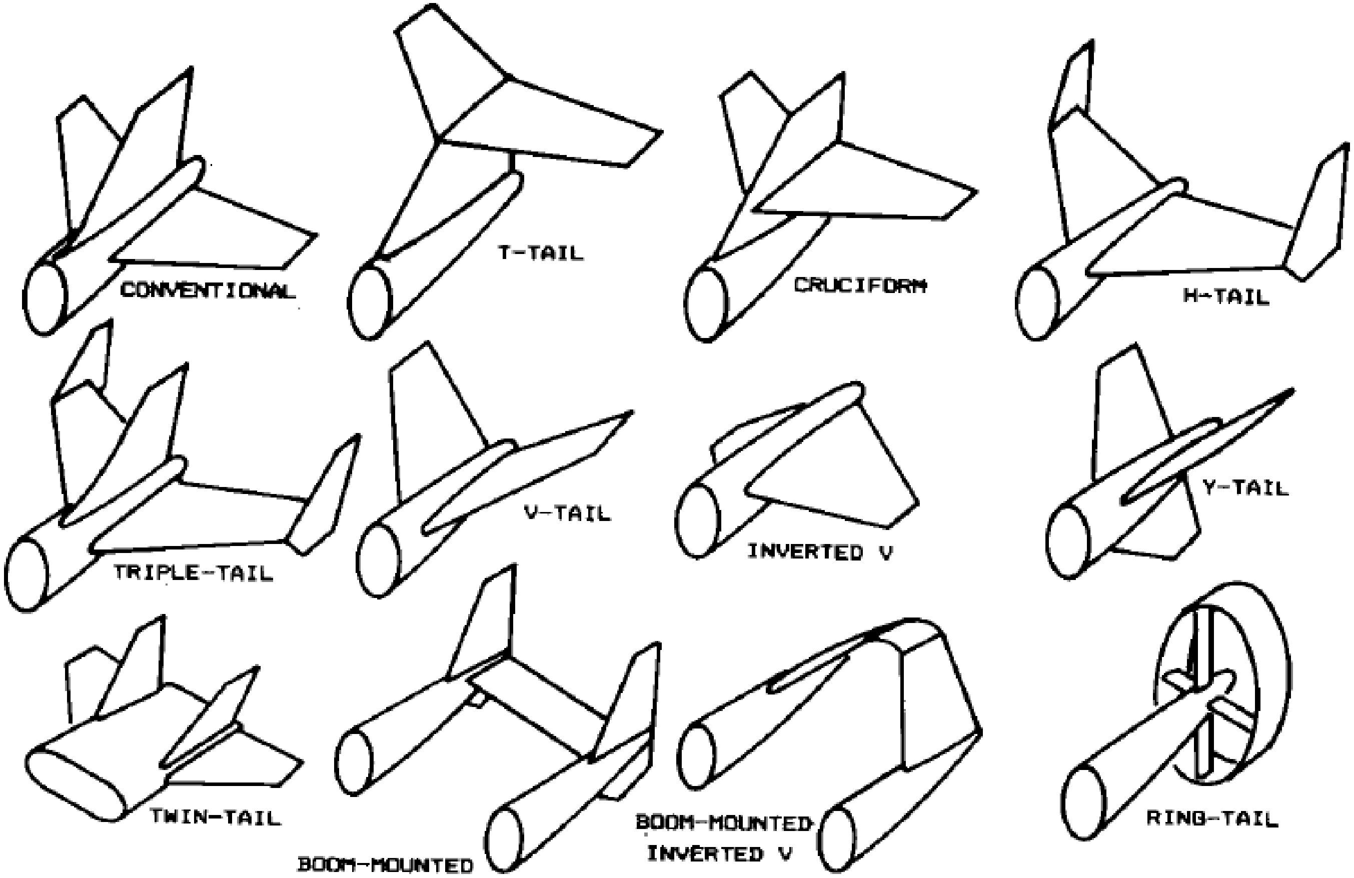
Taper Ratio

- Wing taper ratio is the ratio between the tip chord and the centerline root chord. Most wings of low sweep have a taper ratio of about 0.4-0.5.
- Most swept wings have a taper ratio of about 0.2-0.3.Taper affects the distribution of lift along the span of the wing..

Taper Ratio

- Tail Functions Tails are little wings. Much of the previous discussion Concerning wings can also be applied to tail surfaces. The major Difference between a wing and a tail is that, while the wing is Designed routinely to carry a substantial amount of lift, a tail is Designed to operate normally at only a fraction of its lift Potential. Any time in flight that a tail comes close to its Maximum lift potential, and hence its stall angle, something is Very wrong Tails provide for trim, stability, and control. Trim
- Refers to the generation of a lift force that, by acting through Some tail moment arm about the center of gravity, balances some 0ther moment produced by the aircraft.

Aft tail configuration



Aft tail configuration

Thrust-to-weight Ratio

- T/W directly affects the performance of the aircraft. An aircraft With a higher T/W will accelerate more quickly, climb more rapidly, reach a higher maximum speed, and sustain higher turn rates. On the other hand, the larger Engines will consume more Fuel throughout the mission, which will drive up the aircraft's Takeoff gross weight to perform the design mission.
- It is very important to avoid confusing the takeoff T/ W with the T/W at other conditions in the calculations below. If a required T/W is calculated at some other condition, it must be adjusted Back to takeoff conditions for use in selecting the number and Size of the engines. These T/W adjustments will be discussed later.

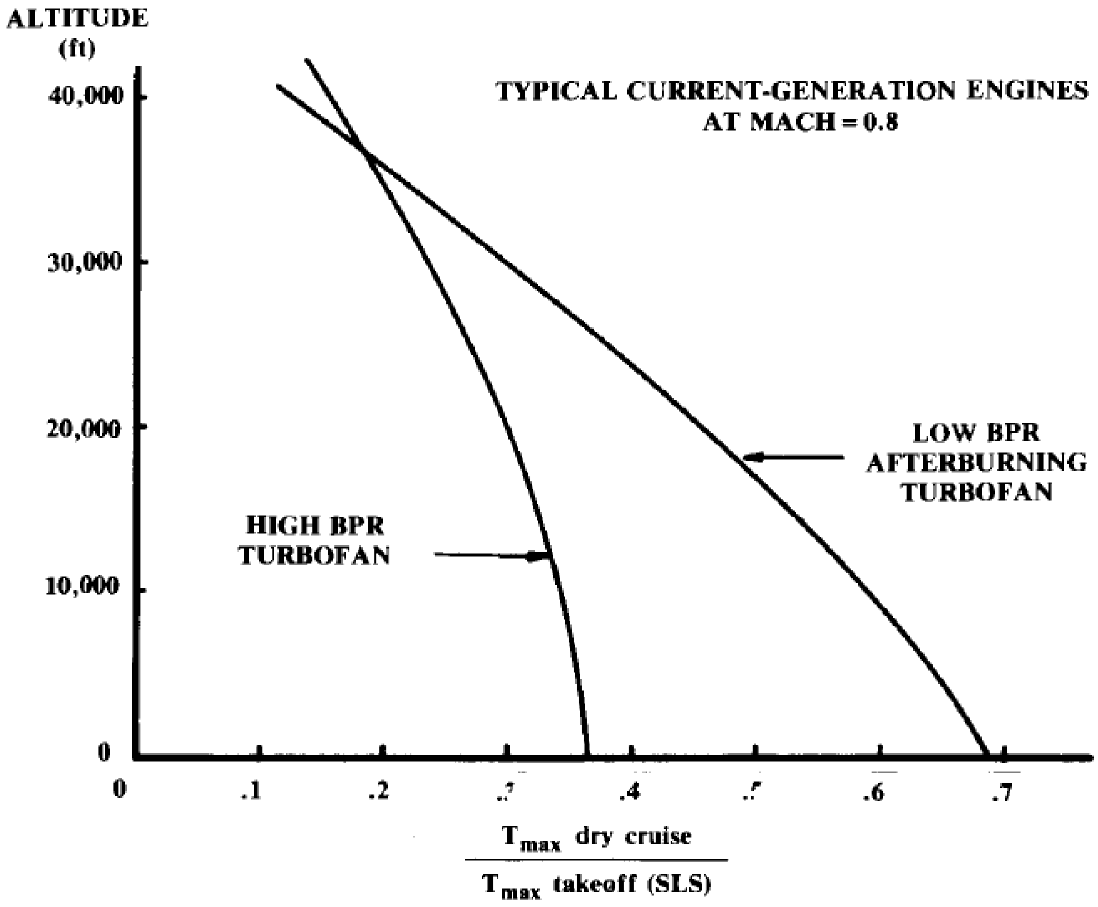
Power Loading and Horsepower-to-Weight

- The term &quote thrust-to-weight& ratio is associated with jet-engine
- Aircraft. For propeller-powered aircraft, the equivalent term has
- Classically been the ratio power loading &quote expressed as the weight of The aircraft divided by its horsepower (W/hp).

Thrust Matching

- For aircraft designed primarily for efficiency during cruise, a
- Better initial estimate of the required TIW can be obtained by
- Thrust matching. Quota
- This refers to the comparison of the selected
- Engine is thrust available during cruise to the estimated aircraft
- Drag. In level unaccelerating flight, the thrust must equal the drag.

Thrust Lapse At Cruise



Thrust Lapse At Cruise

Wing Loading

- The wing loading is the weight of the aircraft divided by the area of the reference (not exposed) wing. As with the thrust-to-weight ratio, the term wing loading normally refers to the takeoff wing loading, but can also refer to combat and other flight conditions.
- Wing loading affects stall speed, climb rate, takeoff and landing distances, and turn performance. The wing loading determines the design lift coefficient, and impacts drag through its effect upon wetted area and wingspan.

Wing Loading

- This material generally assumes that an initial estimate of T/W has been made using the methods presented in the last section. However, most of the equations could also be used to solve for T/W
- if the wing loading is defined by some unique requirement (such as stall speed).These methods estimate the wing loading required for various performance conditions. To ensure that the wing provides enough lift in all circumstances, the designer should select the lowest of the estimated wing loadings.

UNIT-II

INITIAL SIZING &CONFIGURATION LAYOUT

UNIT-II

CLOS	Course Learning Outcome
CLO 4	Estimation of wing geometry and wing vertical location, wing tip shapes, tail geometry and arrangements, thrust to weight ratio- statistical estimation
CLO 5	Apply a theories and to predict the maximum lift coefficient, and complete drag build up, installed performance of an engine
CLO 6	Calculating the velocity, angle of Attack, angle of attack rate, pitch rate, elevator angle. Development of configuration lay out from conceptual sketch.
CLO 7	Calculating the velocity, angle of Attack, angle of attack rate, pitch rate, elevator angle.

Sizing With Fixed Engine And With Rubber Engine

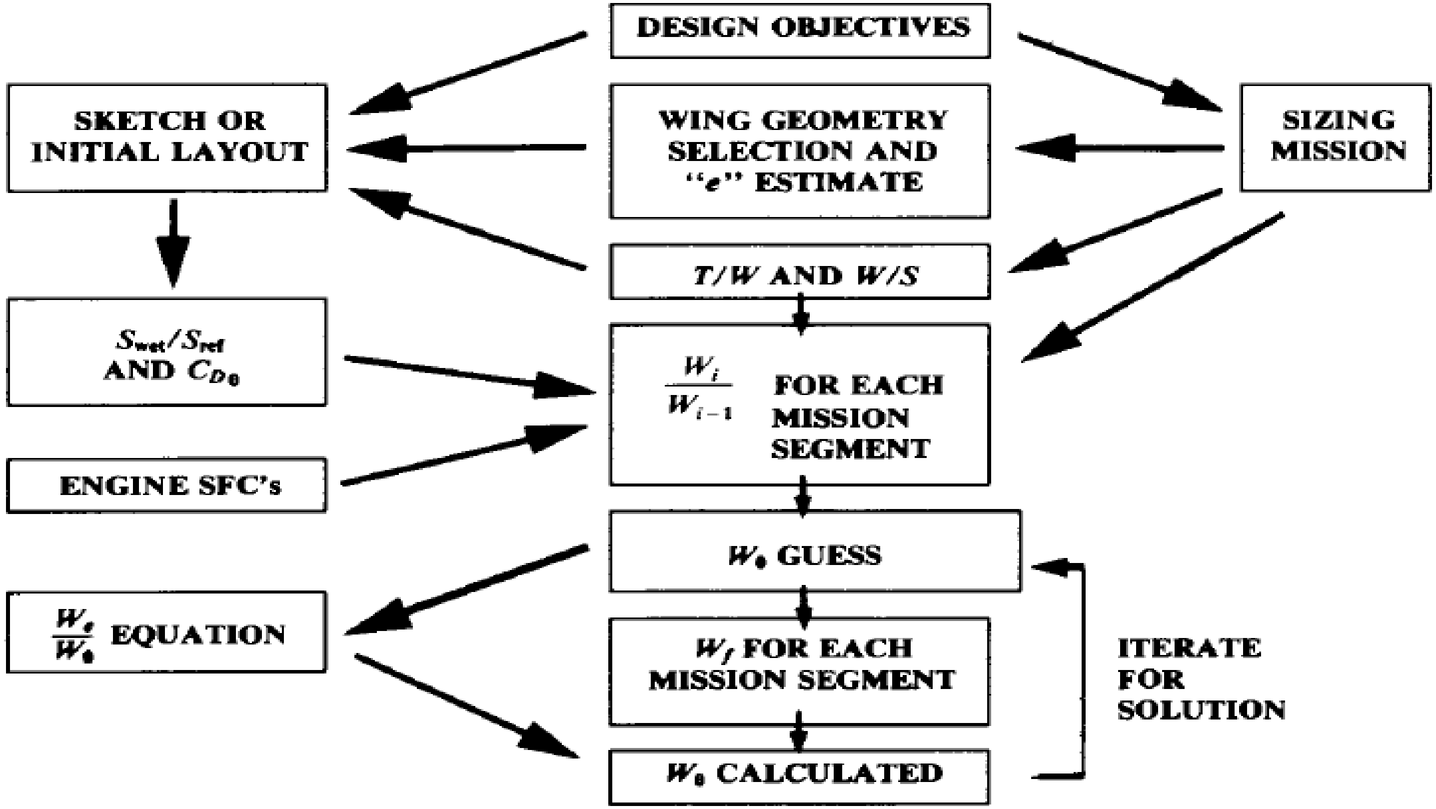
- This information a crude estimate of the maximum L/D was obtained. Using approximations of the specific fuel consumption, the changes in weight due to the fuel burned during cruise and loiter mission segments were estimated, expressed as the mission-segment weight fraction.
- Using these fractions and the approximate fractions for takeoff, climb, and landing which were provided, the total mission
- weight fraction (W i+1 /W i) was estimated. For different classes of aircraft, statistical equations for the aircraft empty-weight fraction were provided.

In Refined Sizing Equation

- For missions with a payload drop or other sudden weight change, as lightly different sizing equation must be used.
- The takeoff weight is calculated by summing the crew weight, payload weight, fuel weight, and empty weight.
- This is shown which resembles Equation except that the payload now includes a fixed payload and a dropped payload. The empty weight is again expressed as an empty-weight fraction, but the fuel weight is determined directly.

Refined Sizing Method

The design and sizing method presented above, as summarized resembles in many respects the first-order method presented as below



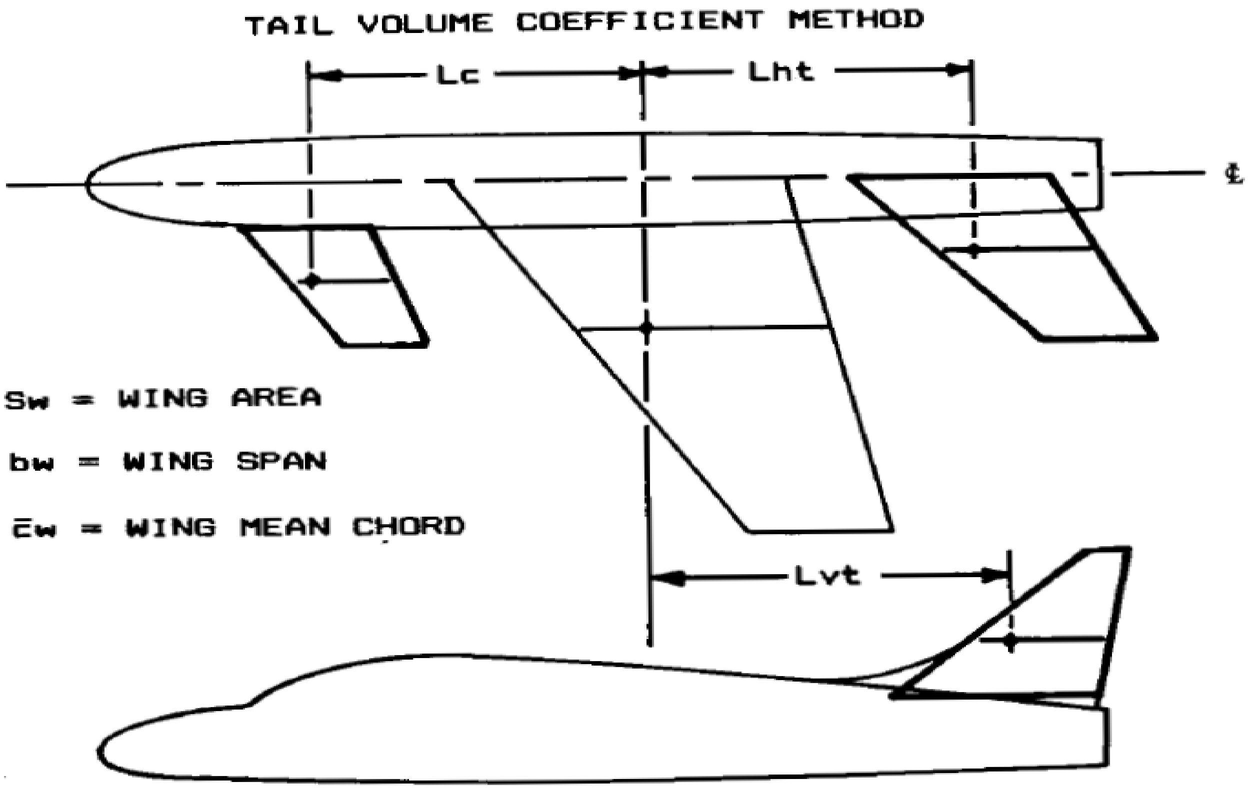
Geometry Sizing

Fuselage Once the takeoff gross weight has been estimated, the fuselage, wing, and tails can be sized. Many methods exist to initially estimate the required fuselage Wing The actual wing size can now be determined simply as the takeoff gross weight divided by the takeoff wing loading. Remember that this is the reference area of the theoretical, trapezoidal wing, and includes the area extending into the aircraft a large passenger aircraft

Geometry Sizing

- Tail Volume Coefficient For the initial layout, a historical approach is used for the estimation of tail size.
- The effectiveness of a tail in generating a moment about the center of gravity is proportional to the force (i.e., lift) produced by the tail and to the tail moment arm.

Initial Tail Sizing



Initial Tail Sizing

Control Surface Sizing

- The primary control surfaces are the ailerons (roll), elevator (pitch), and rudder (yaw).
- Final sizing of these surfaces is based upon dynamic analysis of control effectiveness, including structural bending and control-system effects.
- For initial design the following guidelines are offered.
- Those involved in design can never quite agree as to just where the design process begins.

Control Surface Sizing

- The designer thinks it starts with a new airplane concept.
- The sizing specialist knows that nothing can begin until an initial estimate of the weight is made.
- The customer, civilian or military, feels that the design begins with requirements.
- They are all correct. Actually, design is an iterative effort, as shown in the "Design Wheel“.

End Products Of Configuration Layout

- The outputs of the configuration layout task will be design drawings of several types as well as the geometric information required for further analysis.
- The design layout process generally begins with a number of
- Conceptual sketches.

End Products Design Sketch

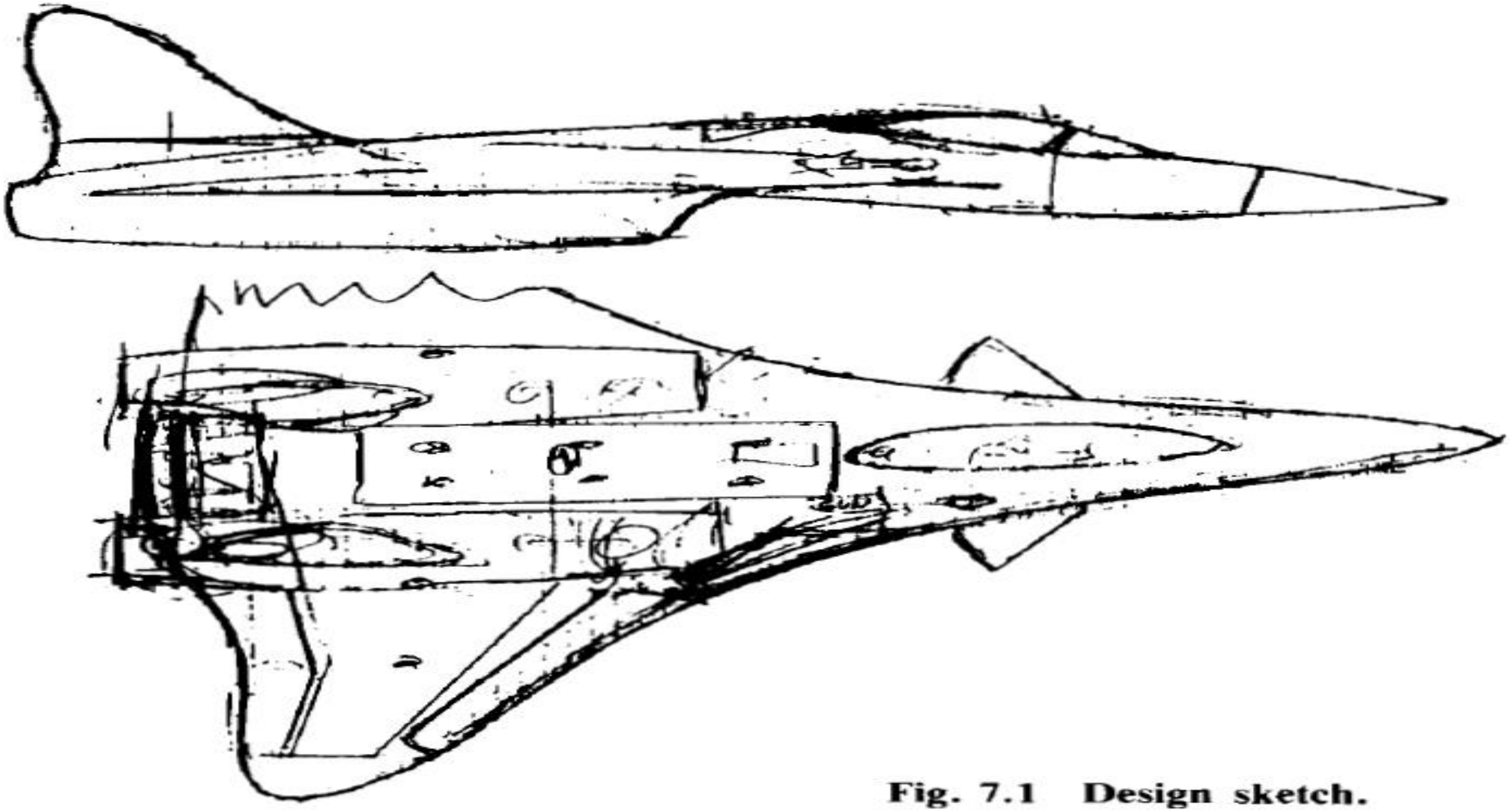
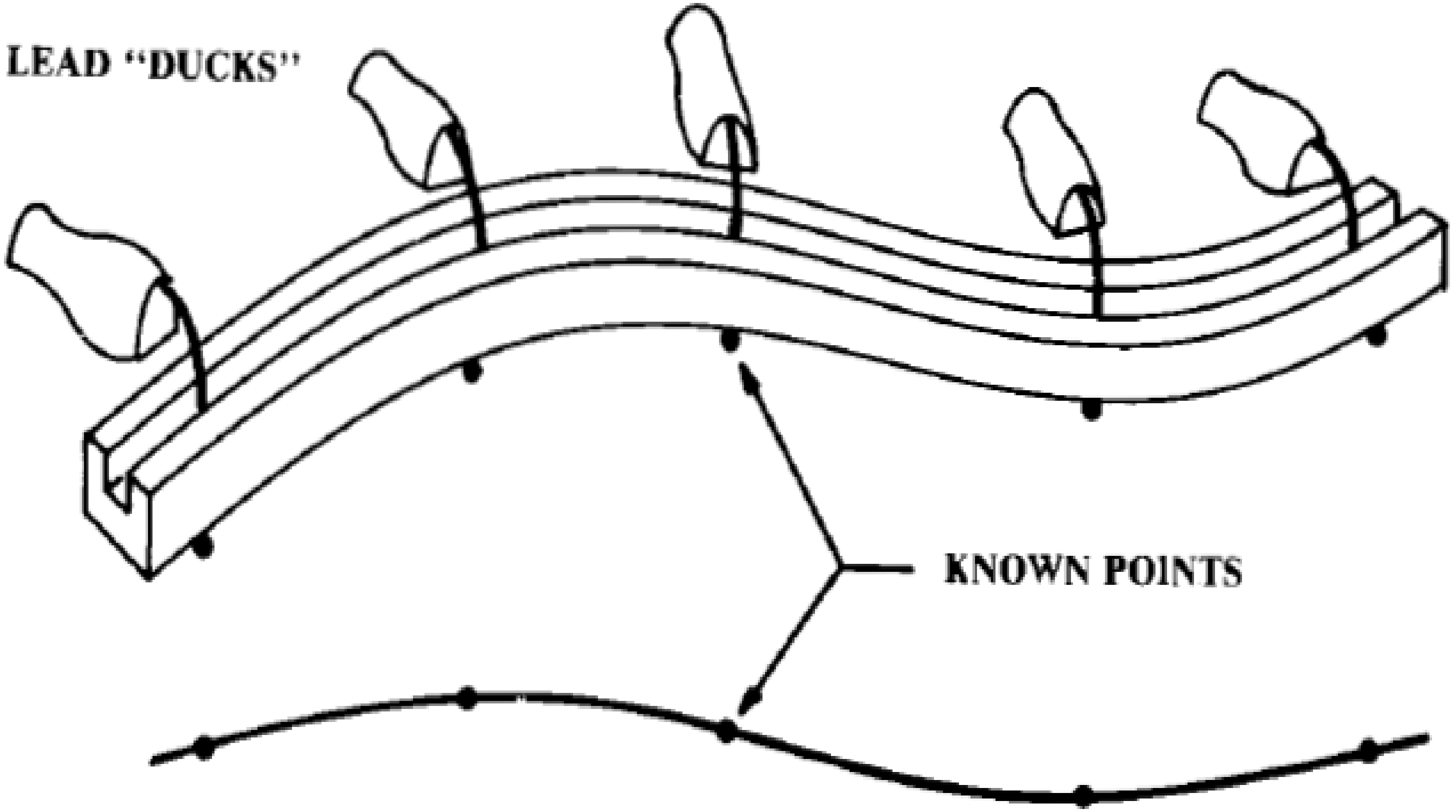


Fig. 7.1 Design sketch.

Conic Lofting ,Flat Wrap Lofting

It is the process of defining the external geometry of the aircraft. Quote Production lofting, quote; the most detailed form of lofting, provides an exact, mathematical definition of the entire aircraft including such minor details as the intake and exhaust ducts for the air conditioning. A production-loft definition is expected to be accurate to within a few hundredths of an inch (or less) over the entire aircraft.

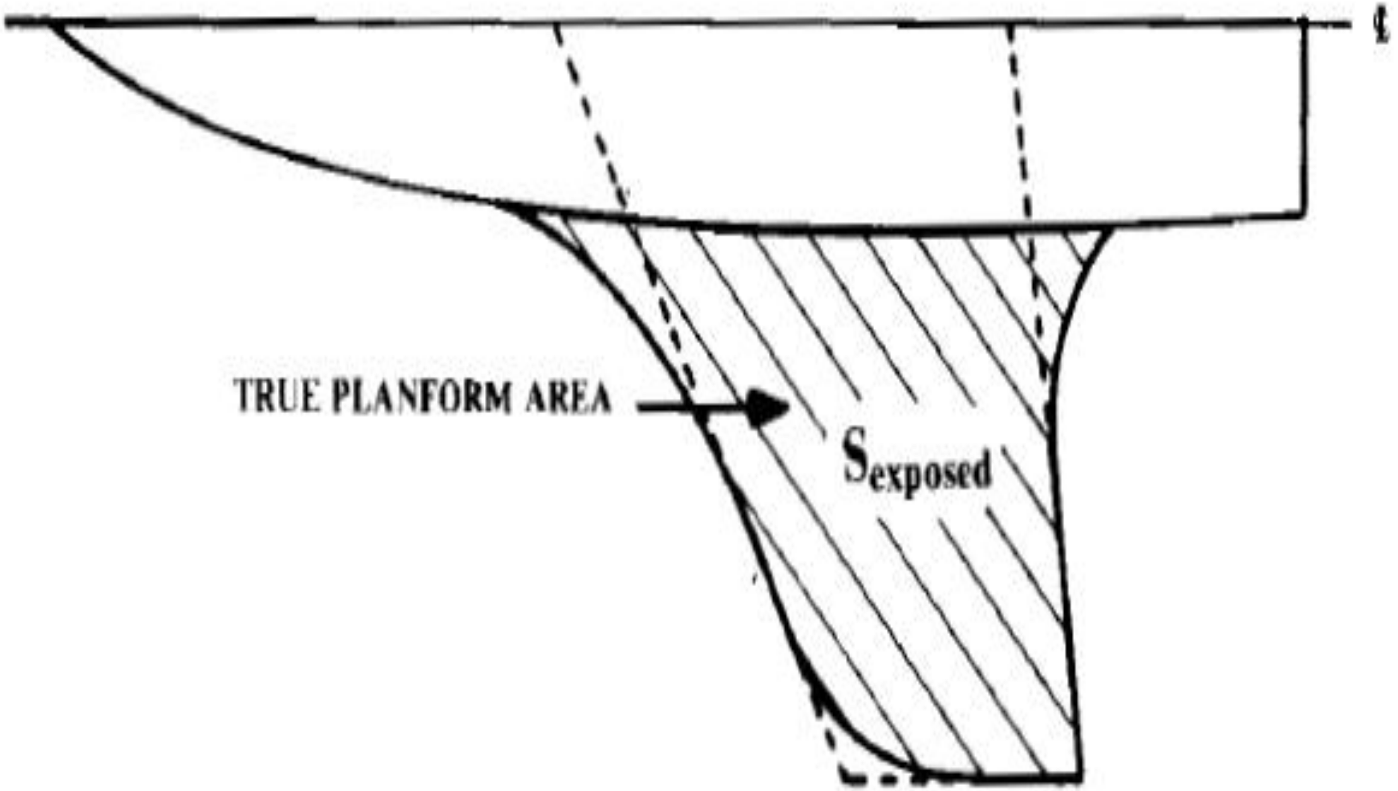
Spline Lofting



Wetted Area

Aircraft wetted area (S wet), the total exposed surface area, can be visualized as the area of the external parts of the aircraft that would get wet if it were dipped into water. The wetted area must be calculated for drag estimation, as it is the major contributor to friction drag.

Estimation Of Wetted Area(wing/ Tail Wetted Area)



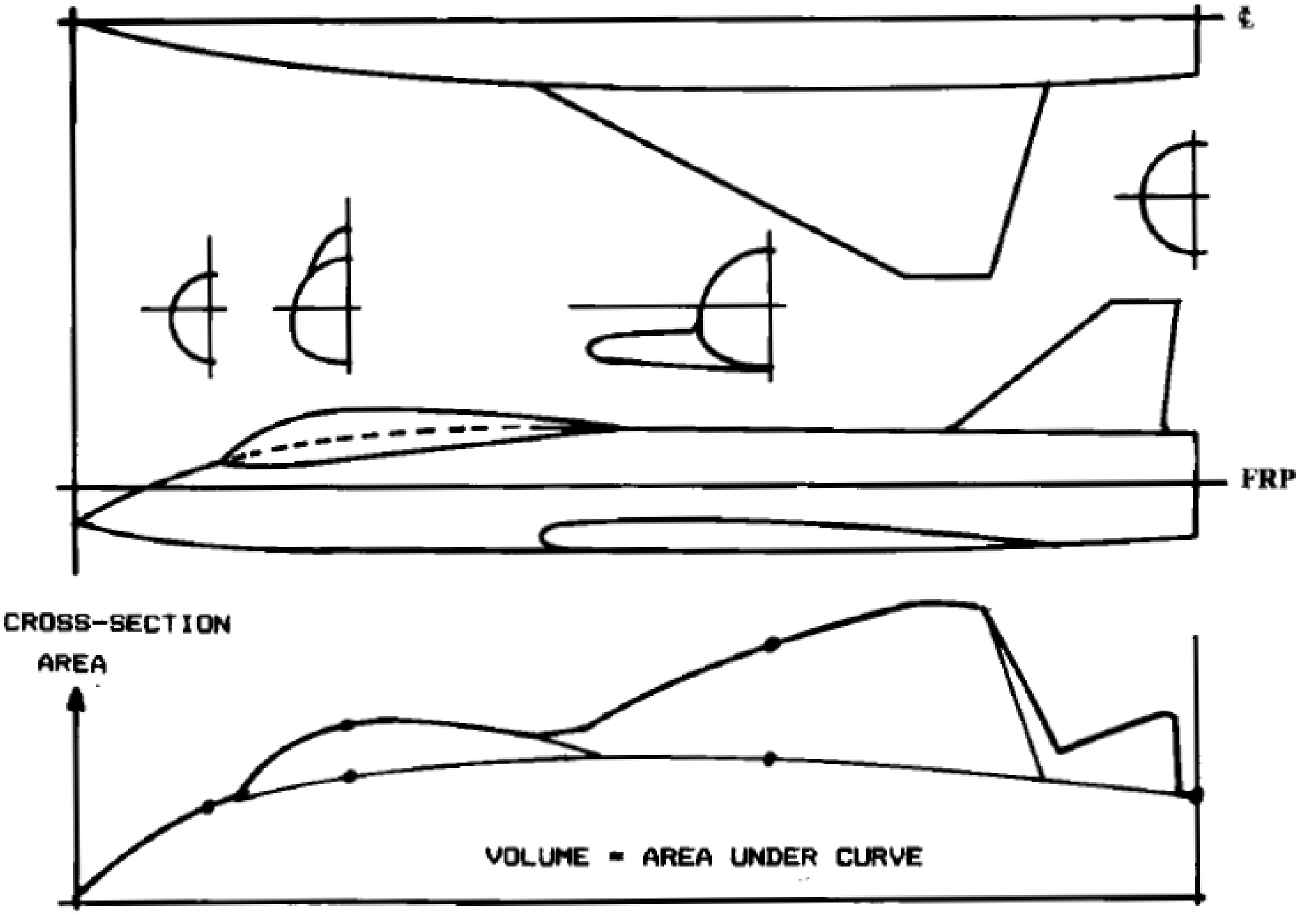
Estimation Of Wetted Area(wing/ Tail Wetted Area)

Volume Distribution And Fuel Volume Plots

The aircraft internal volume can be used as a measure of the reasonableness of a new design, by comparing the volume to existing aircraft of similar weight and type.

This is frequently done by customer engineering groups, using statistical data bases which correlate internal volume with takeoff gross weight for different classes of aircraft.

Aircraft Volume Plot



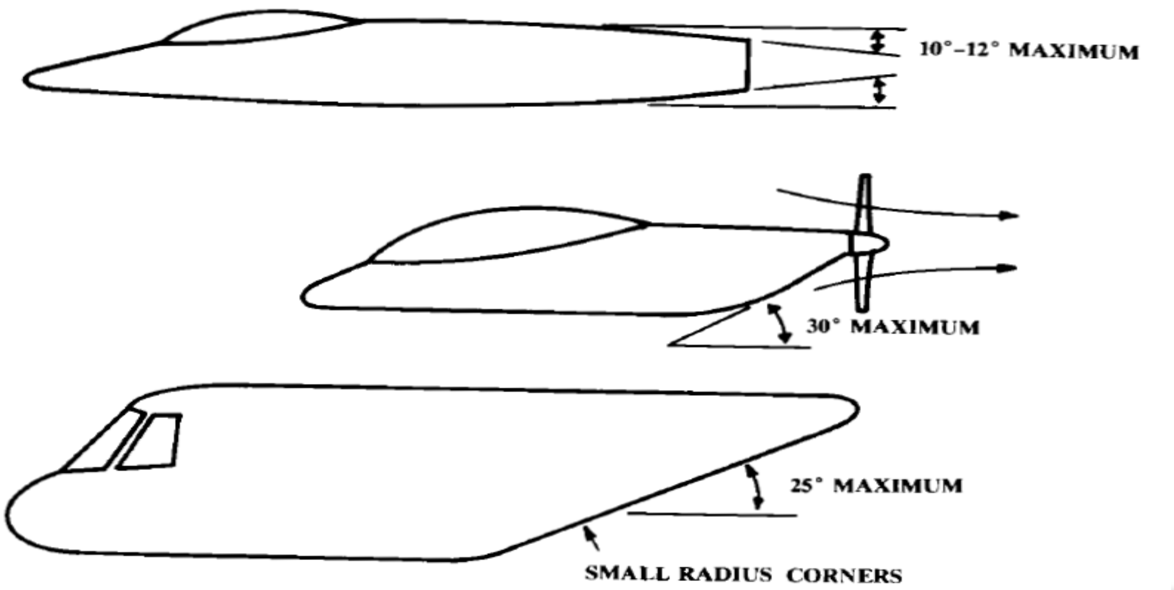
Aircraft Volume Plot

Special Consideration In Configuration Lay Out

This will focus on the required provisions for specific internal components, such as the crew station and landing gear. All of these are numerically analyzed in later stages of the design process. During configuration layout the designer must consider their impact in a qualitative sense.

Aerodynamic Considerations

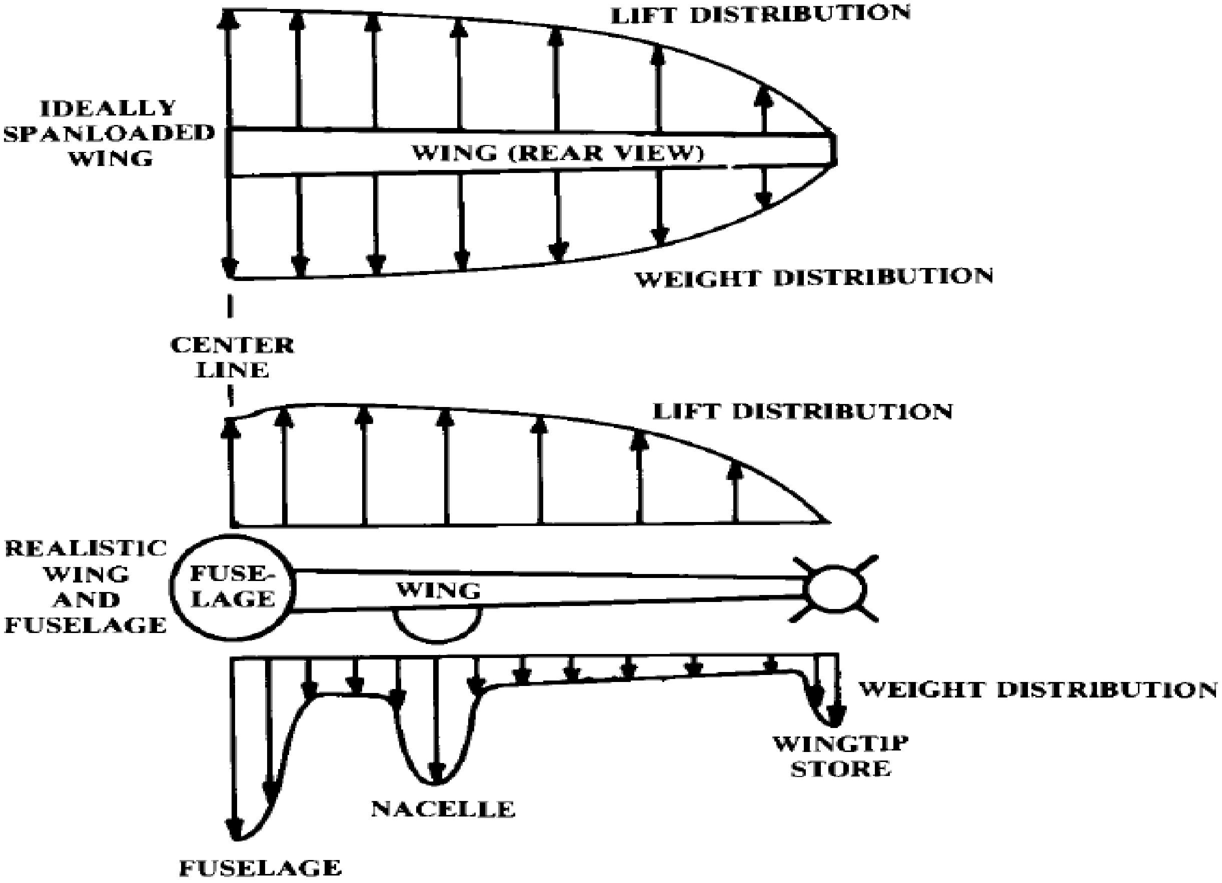
- The overall arrangement and smoothness of the fuselage can have a major effect upon aerodynamic efficiency. A poorly designed aircraft can have excessive flow separation, transonic drag rise, and supersonic wave drag



Structural Considerations,structural Load Paths

In most larger companies, the configuration designer is not ultimately responsible for the structural arrangement of the aircraft. That is the responsibility of the structural design group. However, a good configuration designer will consider the structural impacts of the general arrangement of the aircraft, and will in fact have at least an initial idea as to a workable structural arrangement. The primary concern in the development of a good structural arrangements the provision of efficient the structural elements by which opposing forces are connected.

Span loading For Weight Reduction



Span loading For Weight Reduction

Radar, IR, Visual Detect-ability,

- Ever since the dawn of military aviation attempts have been made to reduce the detectability of aircraft. During World War I, the only in use was the human eyeball.
- Camouflage paint in mottled patterns was used on both sides to reduce the chance of detection.
- Radar (acronym for Radio Detection And Ranging), the primary sensor used against aircraft today, consists of a transmitter antenna that broadcasts a directed beam of electromagnetic radio waves and a receiver antenna which picks up the faint radio waves that bounce off objects &quote illuminated" by the radio beam.
- Usually the transmitter and receiver antennas are collocated

Aural Signature

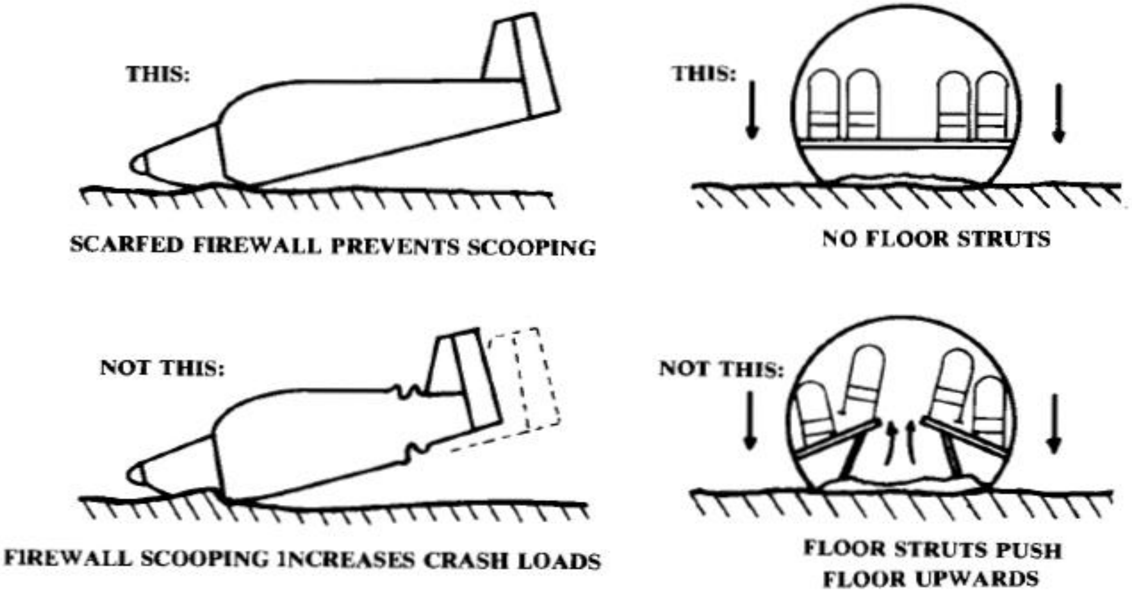
- Aural signature (noise) is important for civilian as well as military aircraft. Commercial airports frequently have an ordinances that restrict some aircraft. Aircraft noise is largely caused by airflow shear layers, primarily due to the engine exhaust.
- A small-diameter, high-velocity jet exhaust produces the greatest noise, while a large-diameter propeller with a low tip-speed produces the least noise.

Considerations of Vulnerability,

- Vulnerability concerns the ability of the aircraft to sustain battle damage, continue flying, and return to base. An aircraft can be in many ways.
- A single bullet through a non-redundant elevator actuator is as bad as a big missile up the tailpipe is a key concept.
- This refers to the product of the projected area (square feet or meters) of the aircraft components, times the probability that each component

Crashworthiness

Airplanes crash. Careful design can reduce the probability of injury in a moderate crash. Several suggestions have been mentioned above, including positioning the propellers so that the blades will not strike anyone if they fly off during a crash.



Crashworthiness

Ability, Maintainability

- Maintainability means simply the ease with which the aircraft can be fixed.
- Reliability and Maintainability frequently bundled together and measured Maintenance range
- less than one for a small private aircraft to well over a hundred for a sophisticated supersonic bomber or interceptor.

Passenger Compartment:

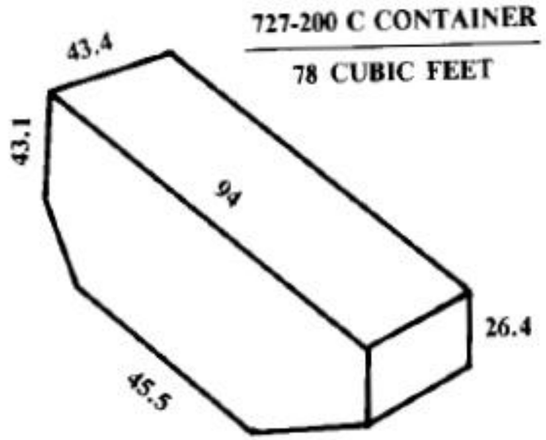
- General-aviation cockpits are designed to whatever range of pilot sizes the marketing department feels is needed for customer appeal, but typically are comfortable only for those under about 72 in.
- Commercial-airliner cockpits are designed to accommodate pilot sizes similar to those of military Aircraft.

Passenger Compartment

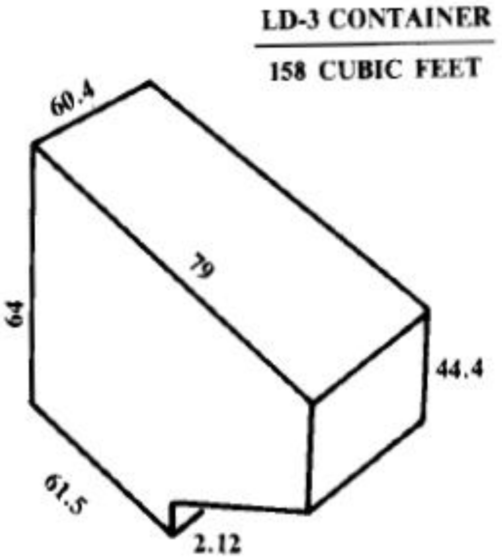
- The actual cabin arrangement for a commercial aircraft is determined more by marketing than by regulations.
- Defines the dimensions of interest. of the seats is defined as the distance from the back of one seat to the back of the next. Pitch includes fore and aft seat length as well as leg room.
- Is the height from the floor to the roof over the seats. For many smaller aircraft the sidewall of the fuselage cuts off a portion of the outer headroom, as shown.
- In such a case it is important to assure that the outer passenger has a 10-in. clearance radius about the eye position.

Cargo Provisions

Cargo must be. carried in a secure fashion to prevent shifting while in flight. Large civilian transports use standard cargo containers that are pre-loaded with cargo and luggage and then placed into the belly of the aircraft.


727-200 C CONTAINER

78 CUBIC FEET


LD-3 CONTAINER

158 CUBIC FEET

Weapons Carriage,

- Carriage of weapons is the purpose of most military aircraft.
- Traditional weapons include guns, bombs, and missiles.
- Lasers and other exotic technologies may someday become feasible as airborne weapons but will not be discussed here.
- Center of gravity. Otherwise the aircraft would pitch up or down when the weapons are released.

Missile carriage/launch

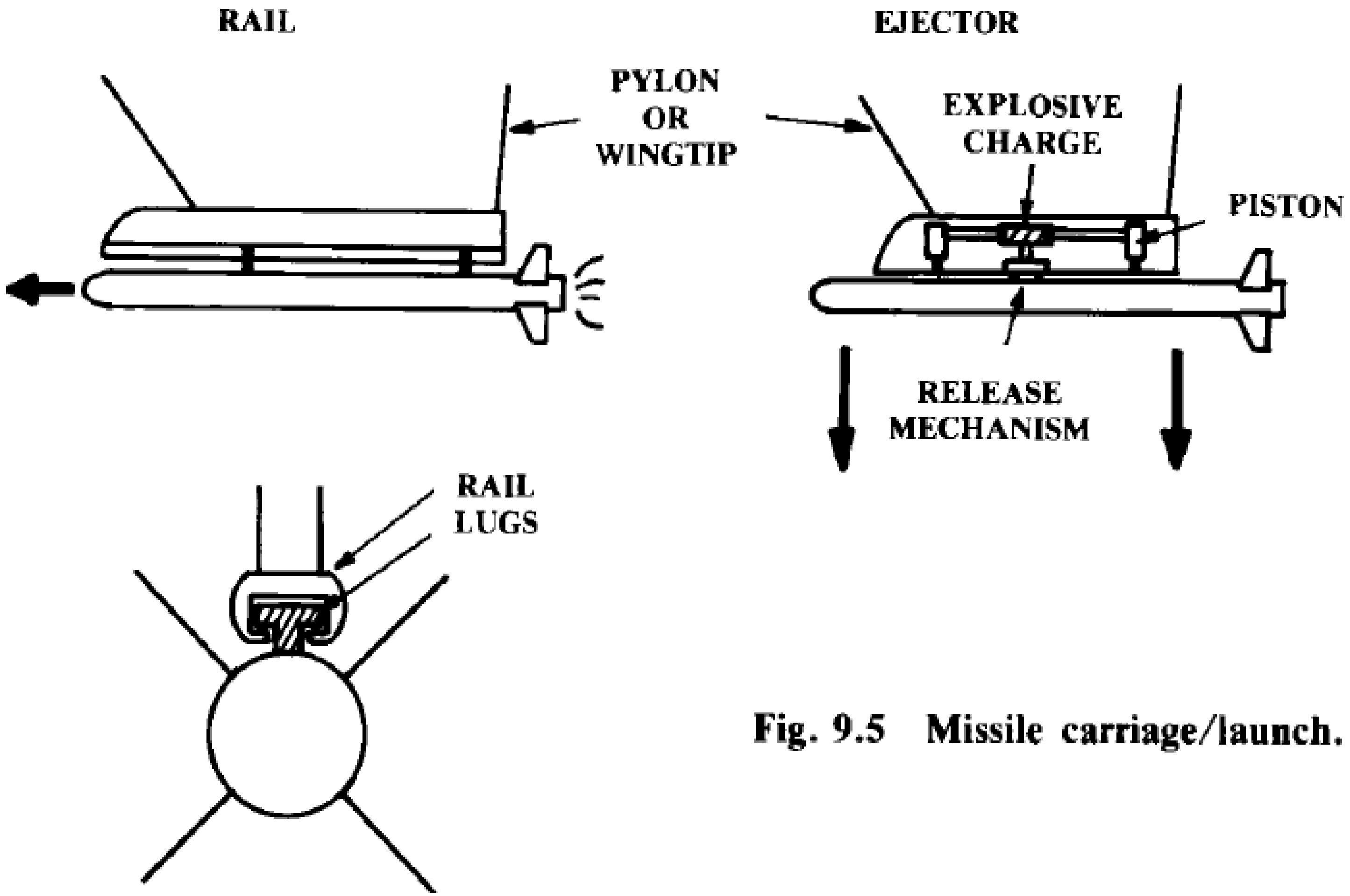
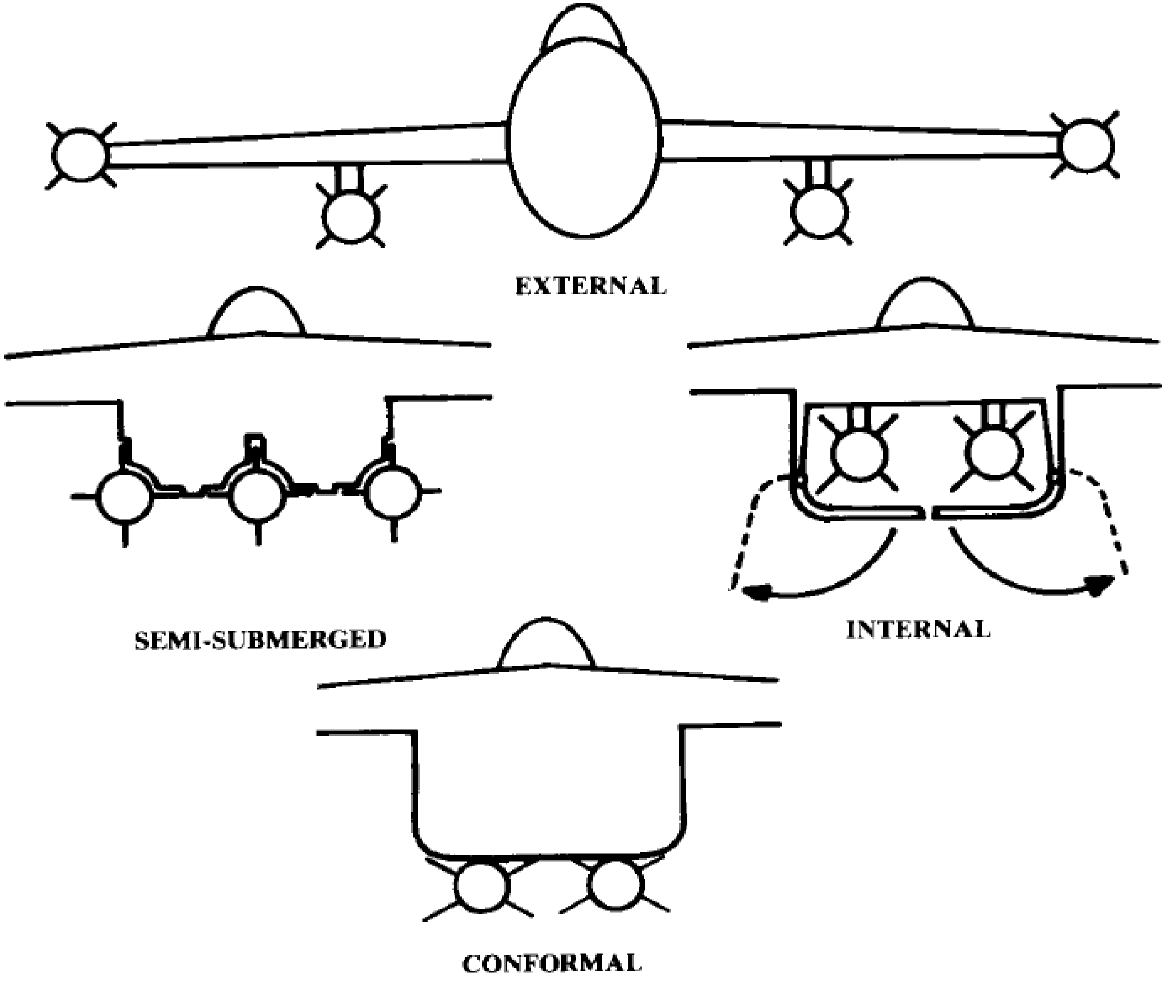


Fig. 9.5 Missile carriage/launch.

Weapon Carriage Options



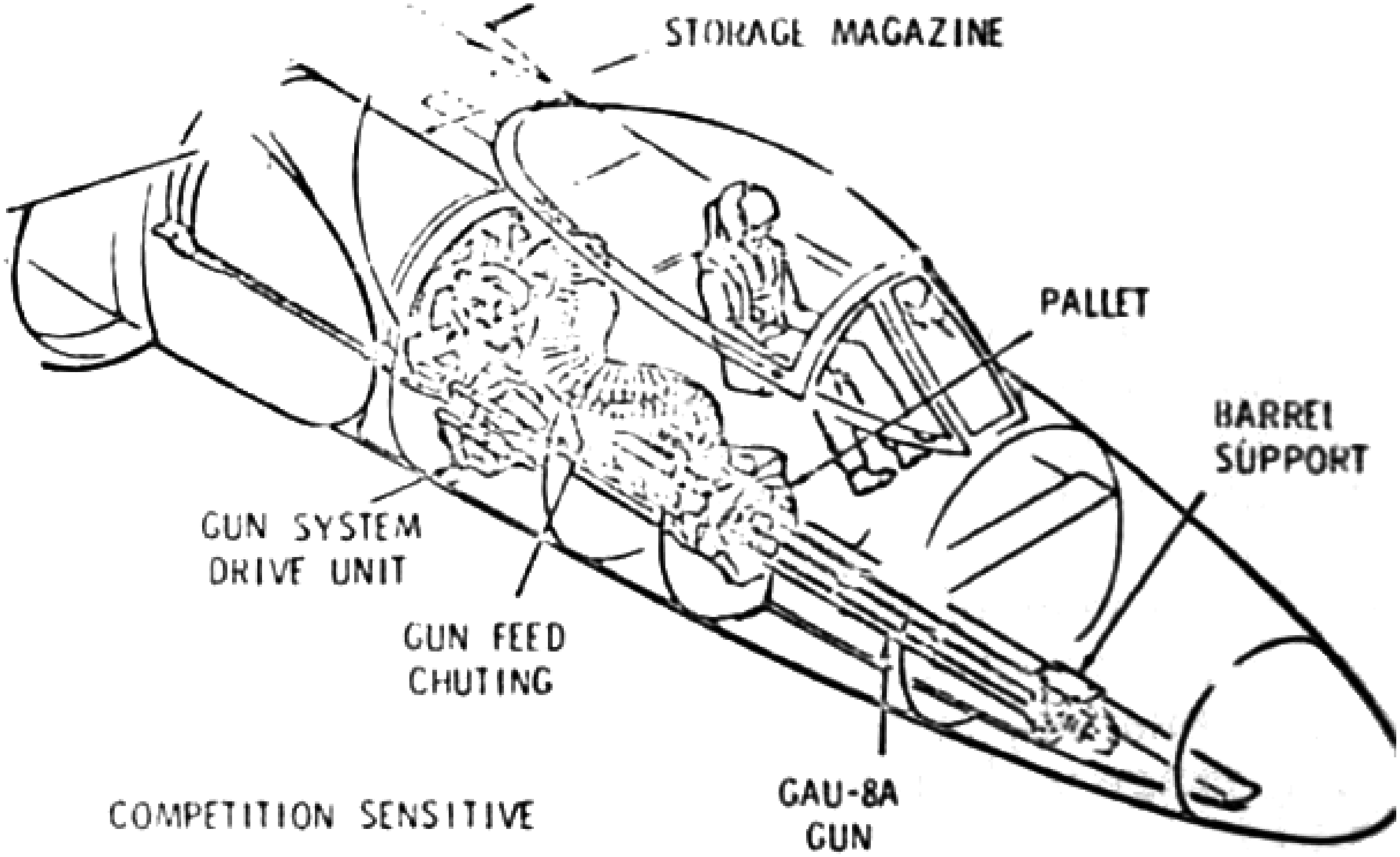
Weapon Carriage Options

Gun Installation

The gun has been the primary weapon of the air-to-air fighter since the first World War-I scout pilot took a shot at an opposing scout pilot with a handgun. For a time during the 1950.

it was felt that the then- new air-to-air missiles would replace the gun, and in fact several fighters

Gun Installation



UNIT-III

PROPULSION AND FUEL SYSTEM INTEGRATION, LANDING GEAR AND SUBSYSTEMS

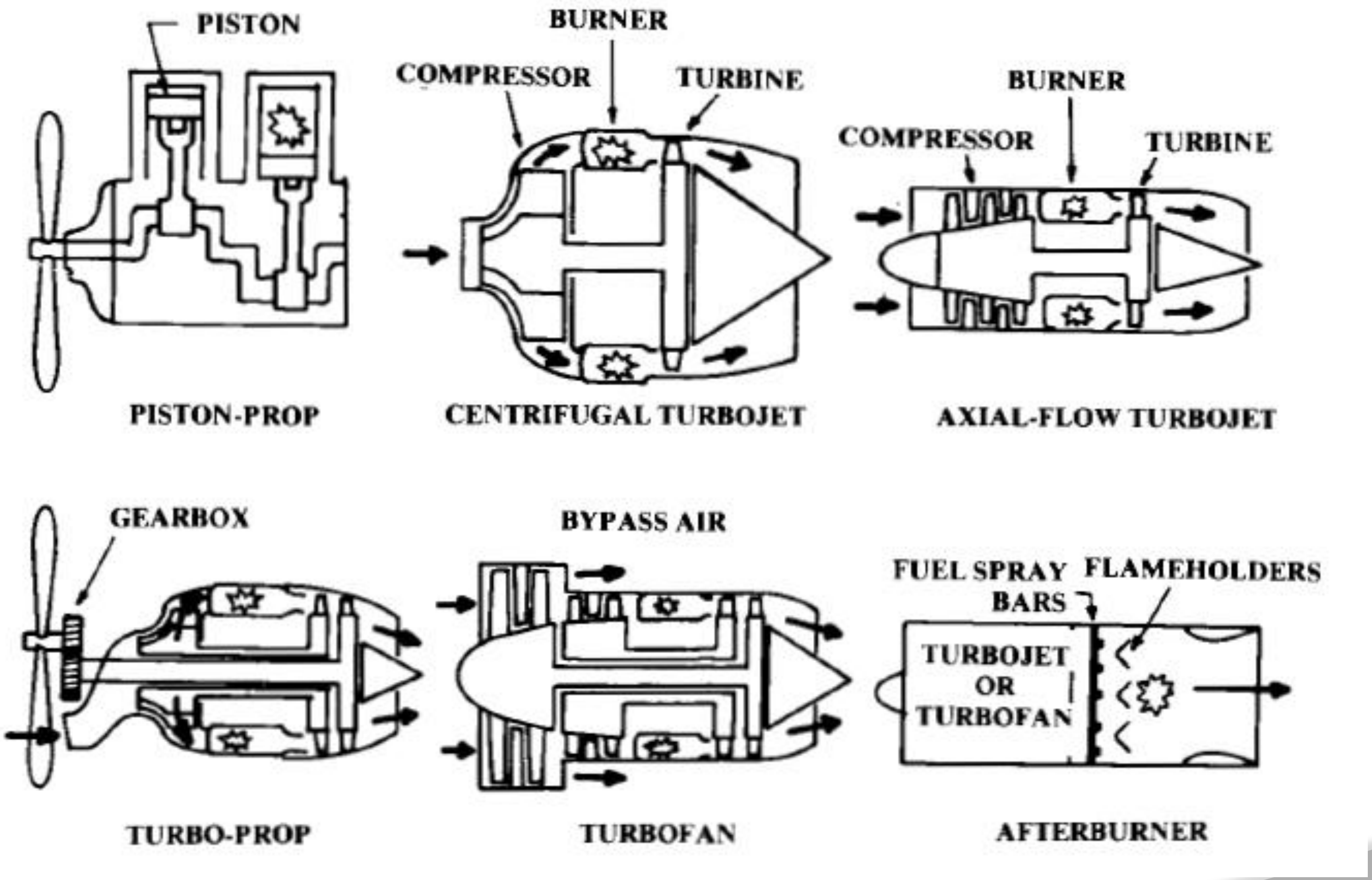
UNIT-III

CLOS	COURSE LEARNING OUTCOMES
CLO 8	Constructing v-n diagram, air load distribution on lifting surfaces
CLO 9	Developing the concept of Propulsion selection fuel selection
CLO 10	Plotting the mission segment with different weight fractions

PROPULSION SELECTION

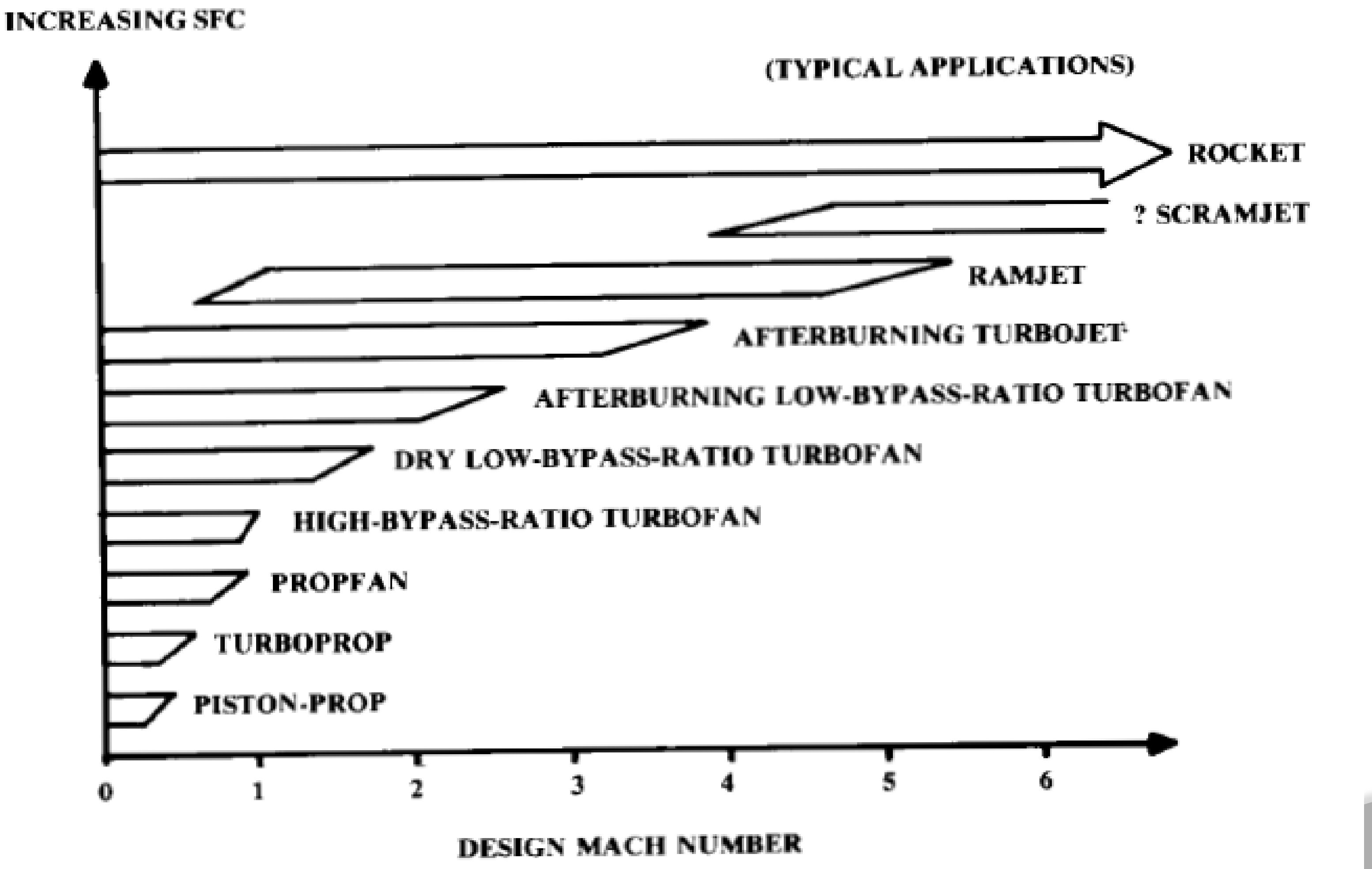
- Illustrates the major options for aircraft propulsion. All aircraft engines operate by compressing outside air, mixing it with fuel, burning the mixture, and extracting energy from the resulting high-pressure hot gases.
- In a piston-prop, these steps are done intermittently in the cylinders via the reciprocating pistons. In a turbine engine, these steps are done continuously, but in three distinct parts of the engine.
- The turbine engine consists of a "compressor," a "burner," and a "turbine”. These separately perform the three functions of the reciprocating piston in a piston engine.

Propulsion System Options



Propulsion System Options

Propulsion System Speed Limits

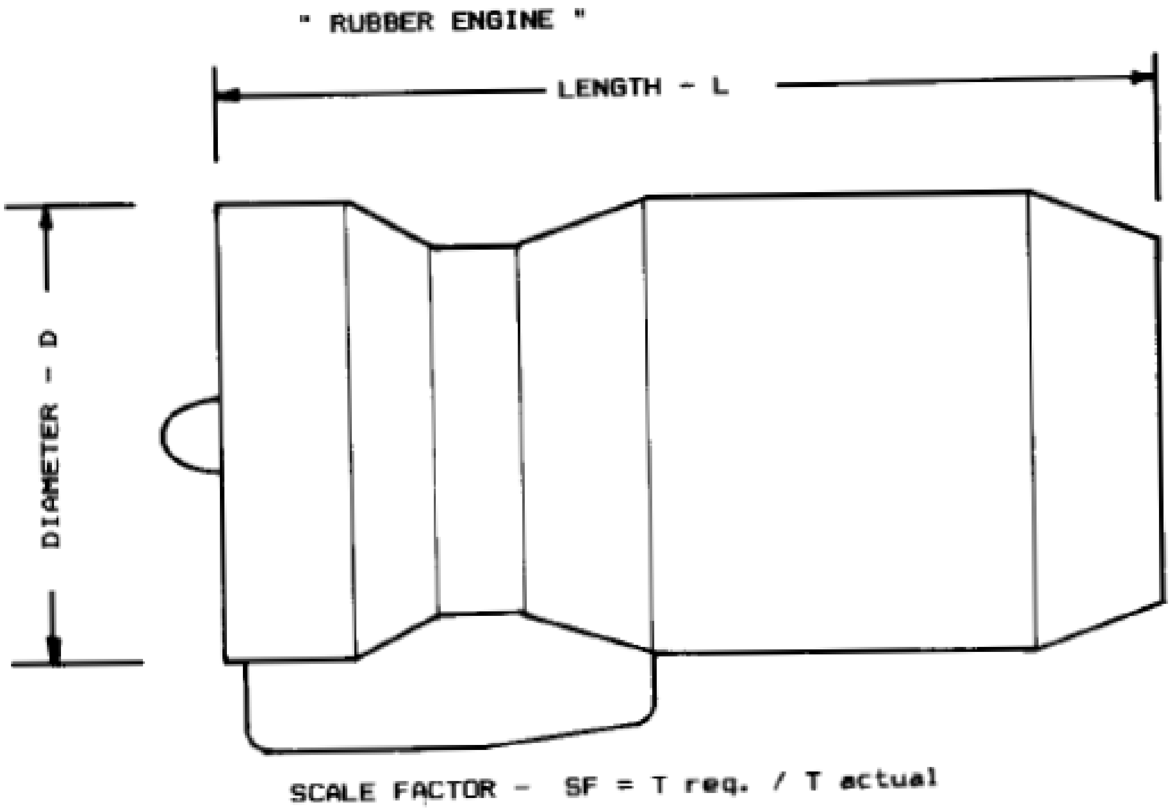


Propulsion System Speed Limits

Jet Engine Integration Engine Dimensions

- If the aircraft is designed using an existing, off-the-shelf engine, the dimensions are obtained from the manufacturer.
- If a "rubber" engine is being used, the dimensions for the engine must be obtained by scaling from some nominal engine size by whatever scale factor is required to provide the desired thrust.
- The nominal engine can be obtained by several methods. In the major aircraft companies, designers can obtain estimated data for hypothetical "rubber" engines from the engine companies.

Engine Scaling

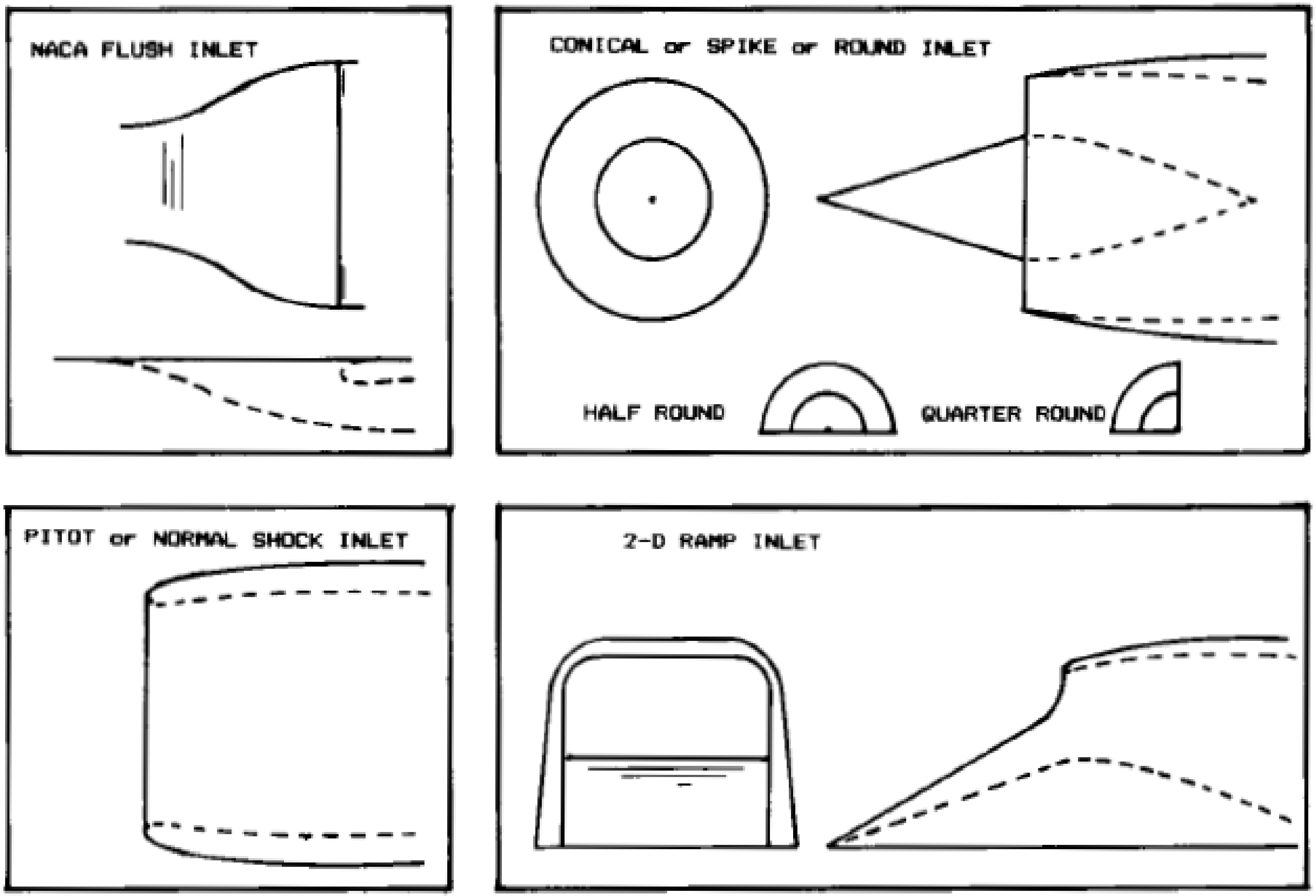


Engine Scaling

Inlet Geometry

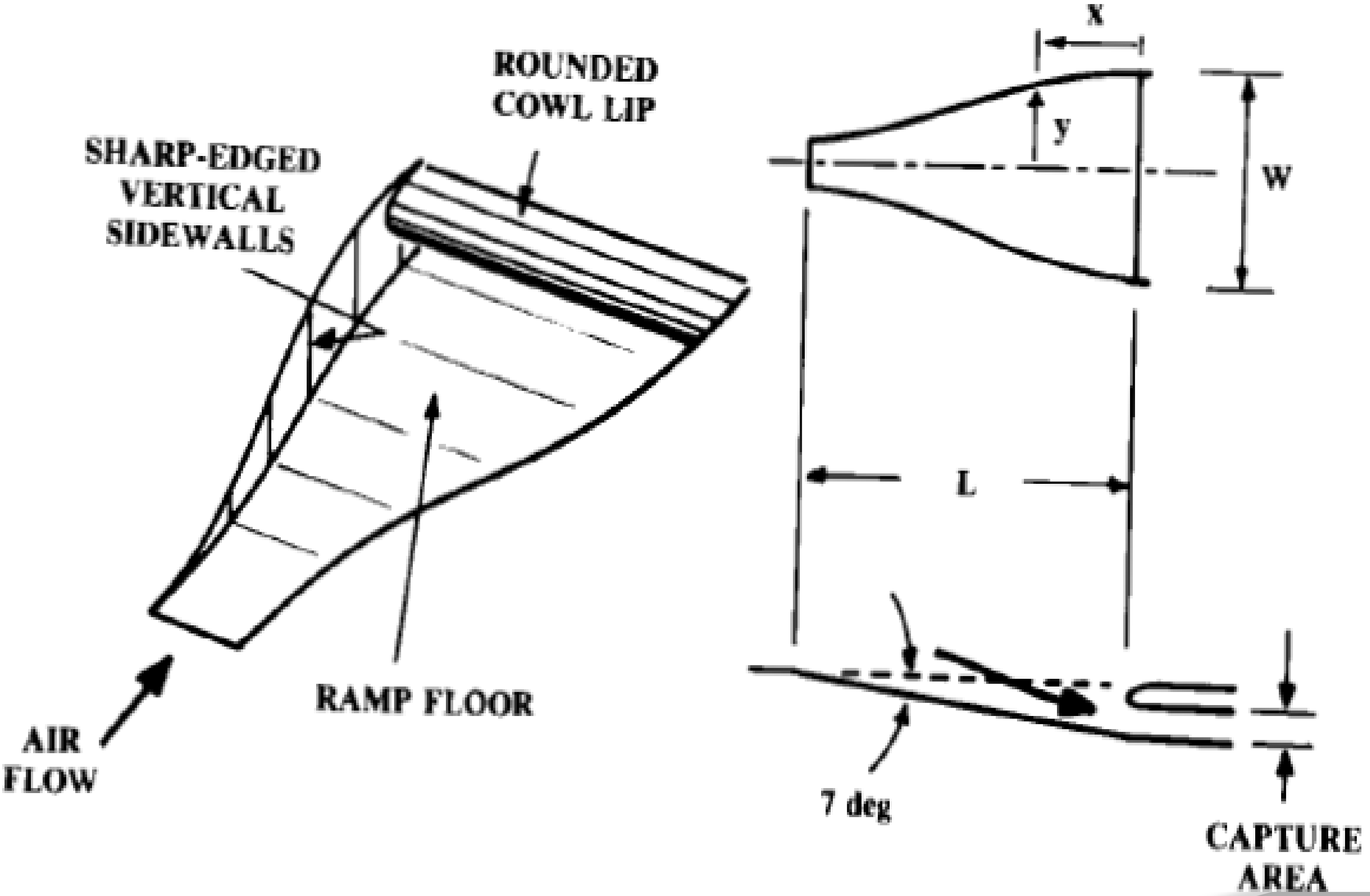
- Turbojet and turbofan engines are incapable of efficient operation unless the air entering them is slowed to a speed of about Mach 0.4-0.5.
- This is to keep the tip speed of the compressor blades below sonic speed relative to the incoming air.
- Slowing down the incoming air is the primary purpose of an inlet system.
- The installed performance of a jet engine greatly depends upon the air inlet system.

Inlet Types



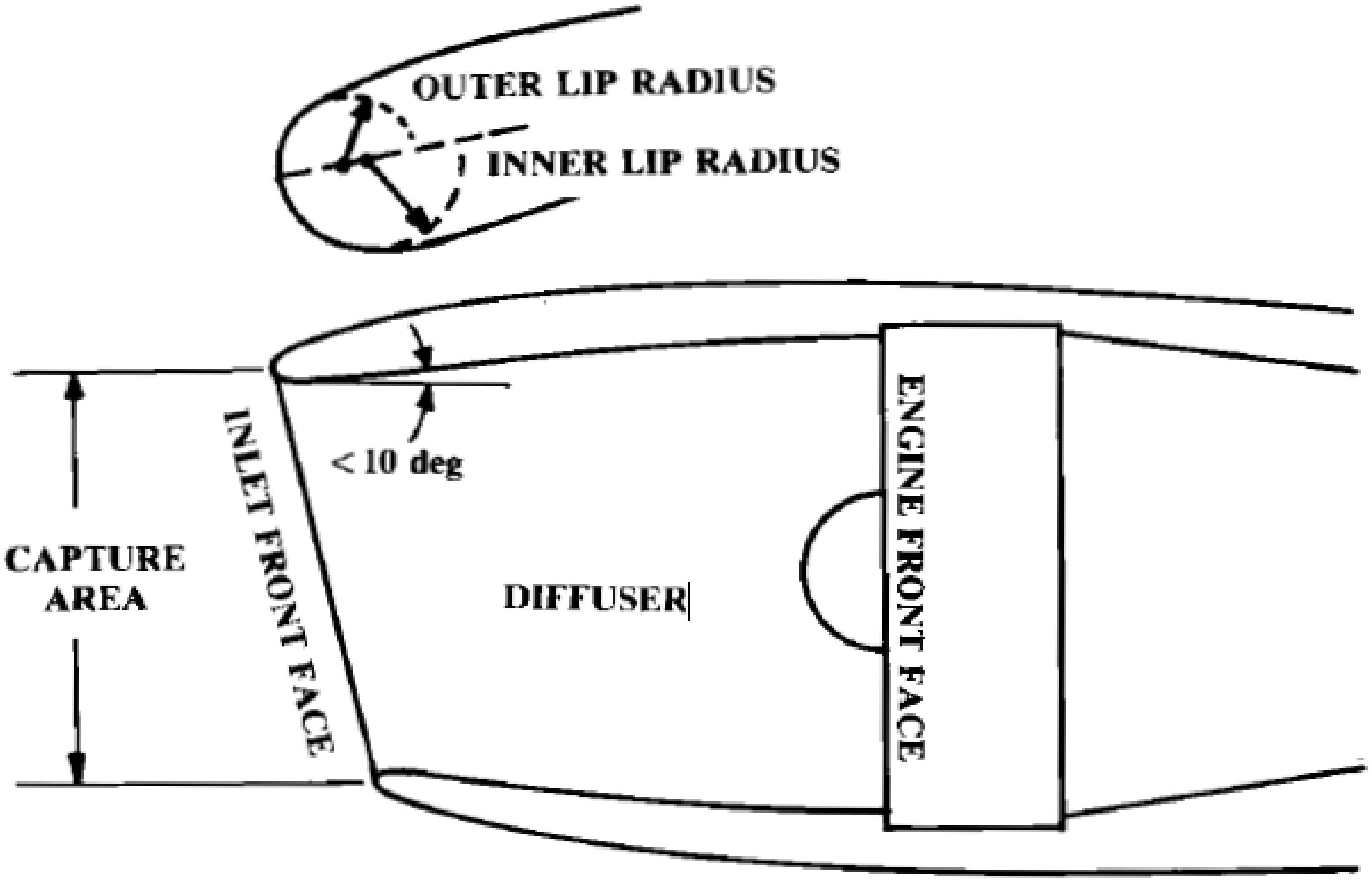
Inlet Types

Flush Inlet Geometry



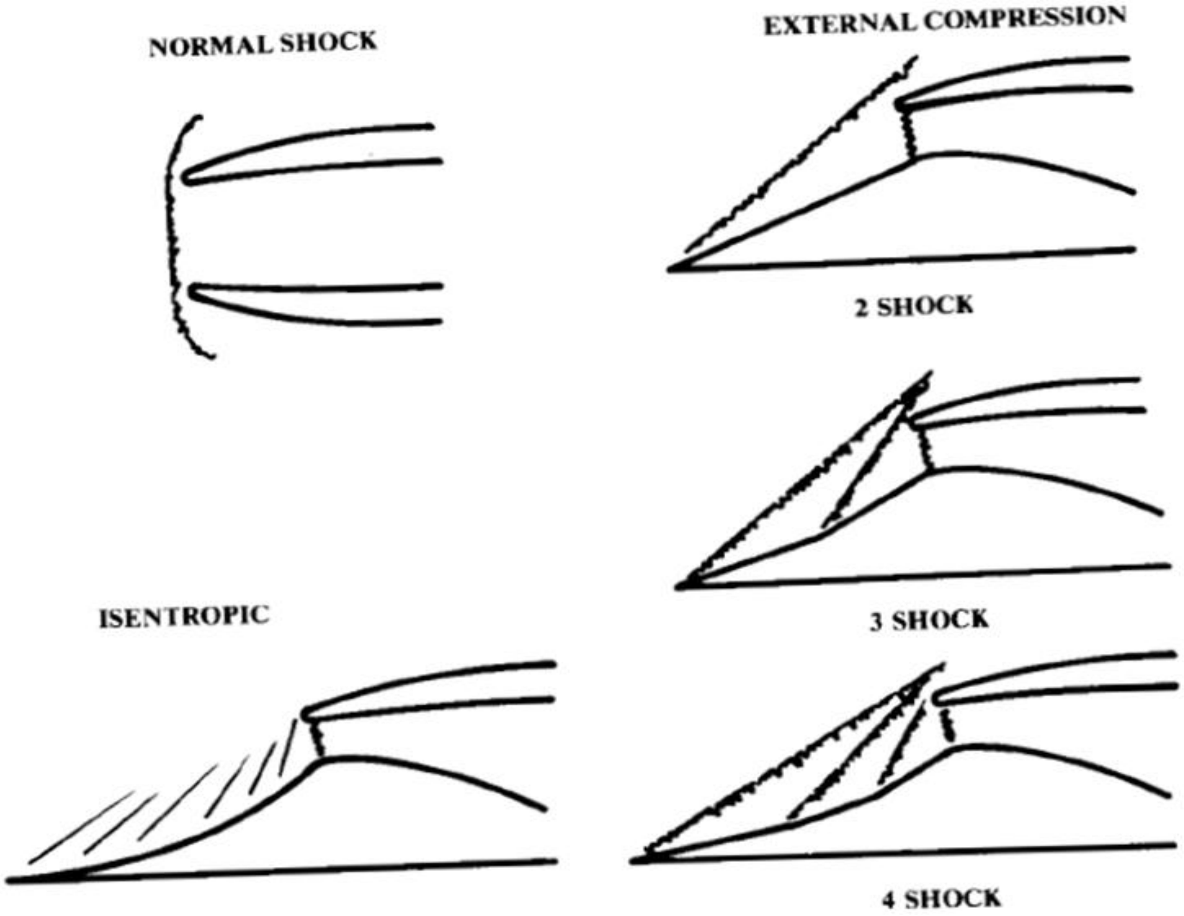
Flush Inlet Geometry

pilot (normal shock) inlet layout



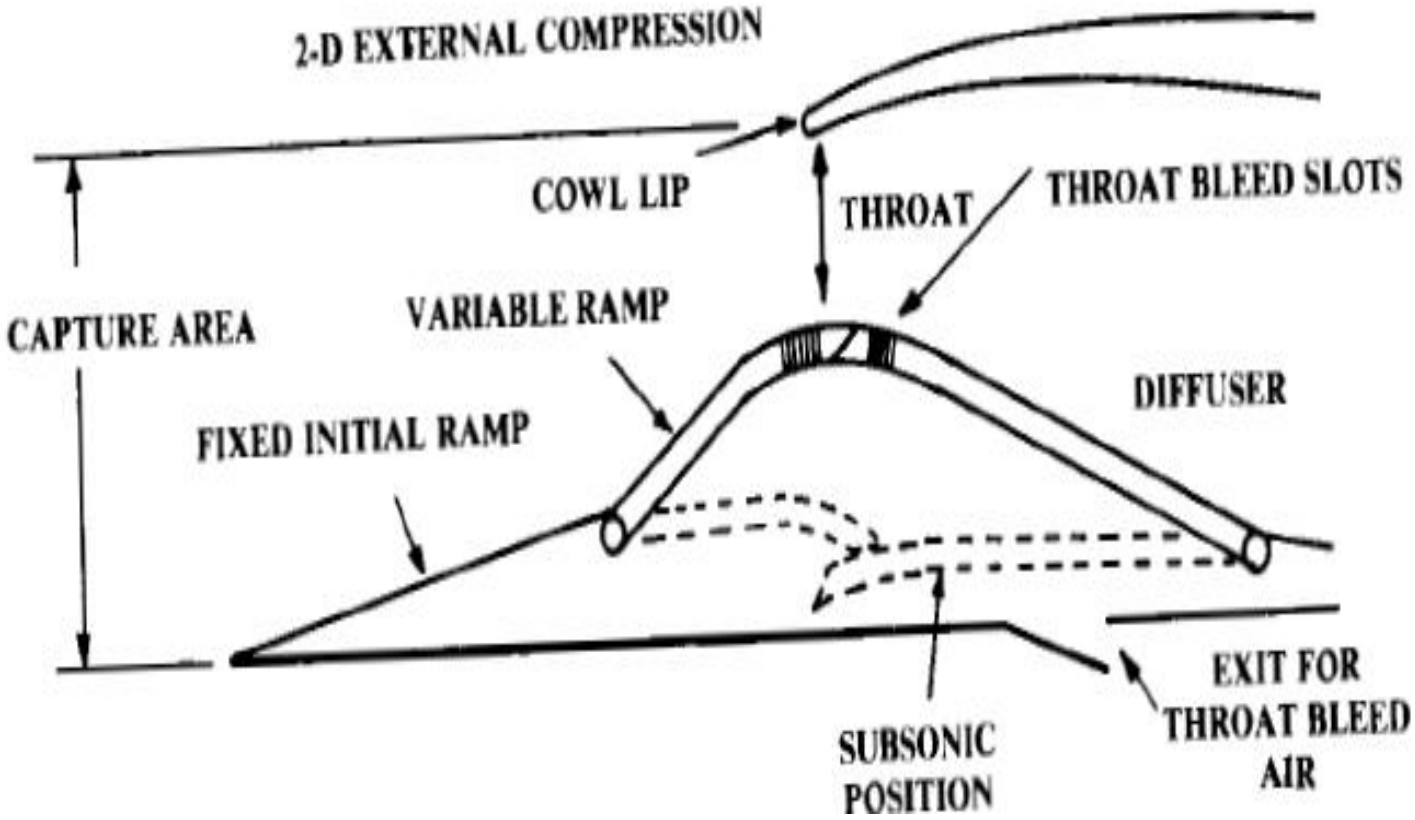
Pilot (normal shock) inlet layout

Supersonic Inlets-external Shocks



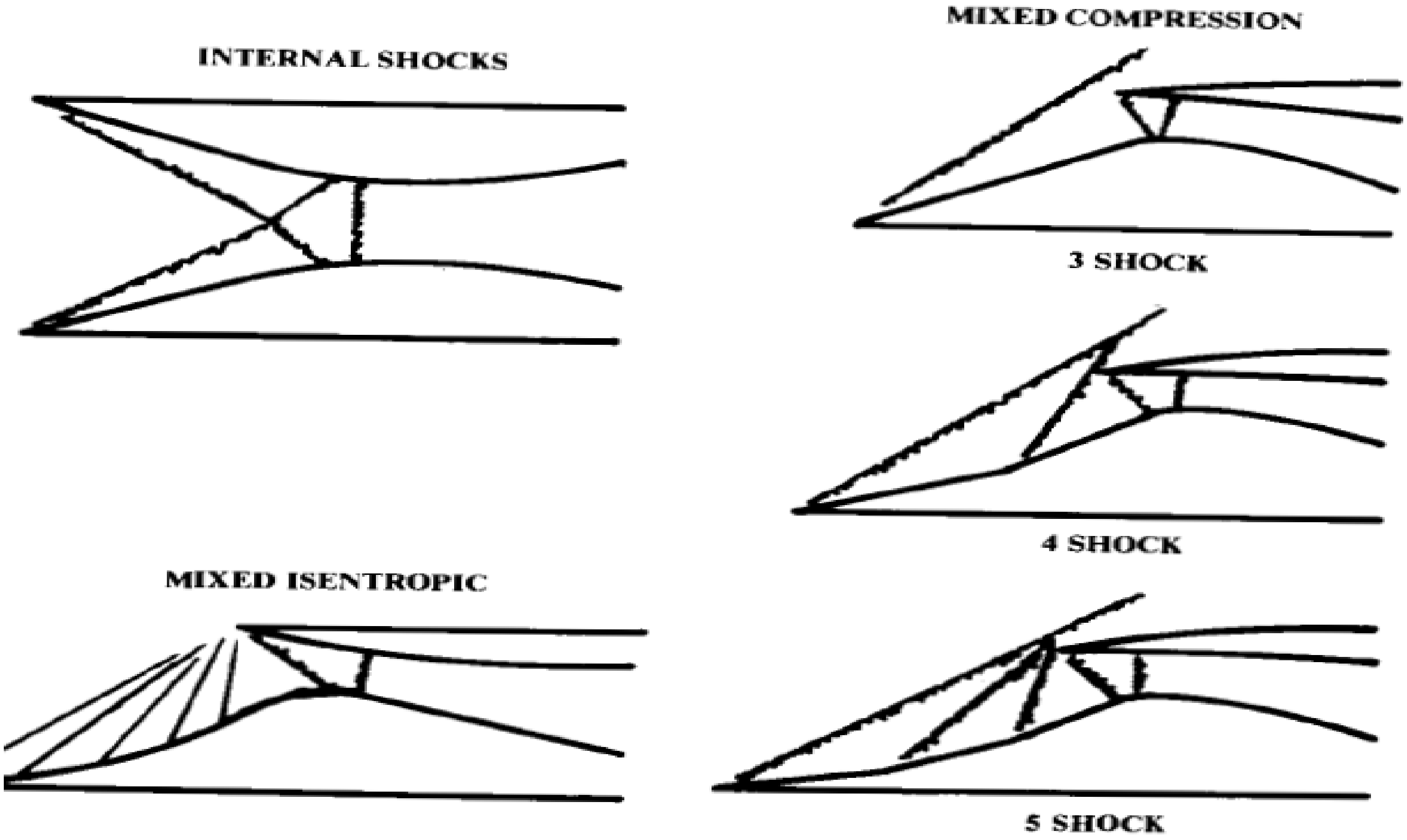
Supersonic Inlets-external Shocks

Variable Inlet Geometry



Variable Inlet Geometry

Supersonic Inlets-internal And Mixed

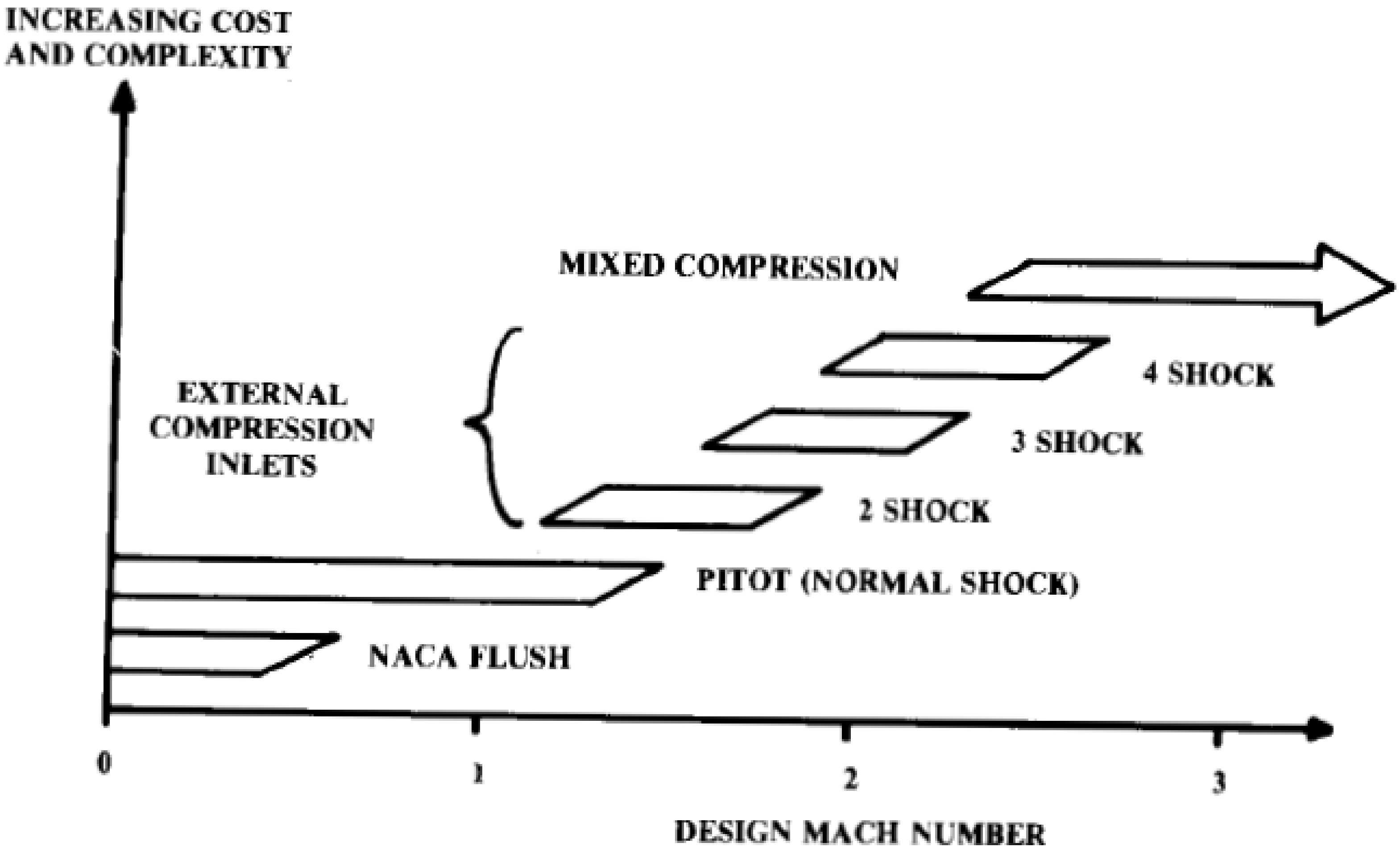


Supersonic Inlets-internal And Mixed

Inlet Location

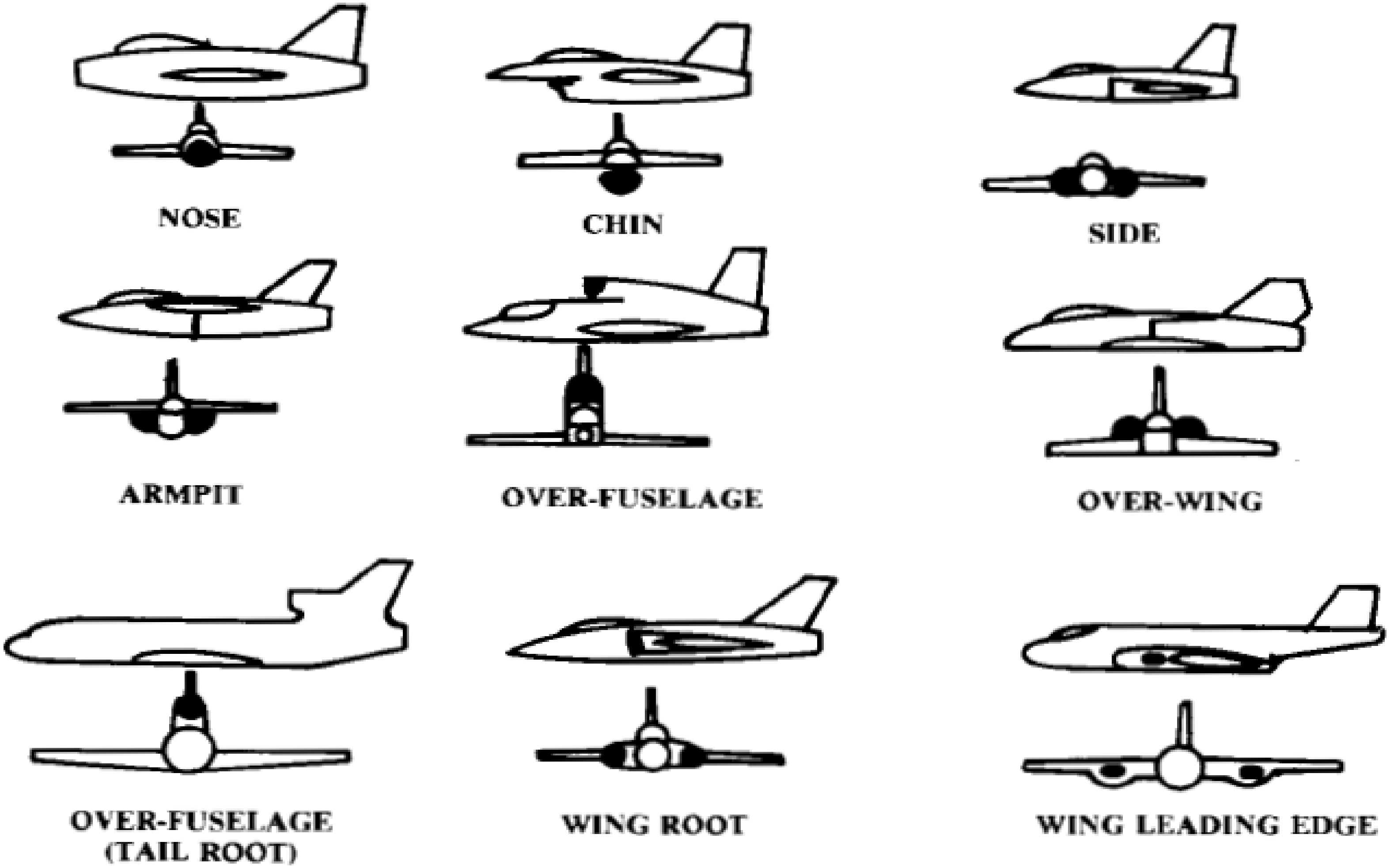
- The inlet location can have almost as great an effect on engine performance as the inlet geometry. If the inlet is located where it can ingest vortex off the fuselage or a separated wake from a wing, the resulting
- An over-fuselage inlet is much Tike an inverted chin inlet, and has a short duct length but without the problems of nose-wheel location. This was used on the unusual F-107. The upper-fuselage inlet is poor at high angle of attack because the fore body blanks the airflow.

Inlet Applicability



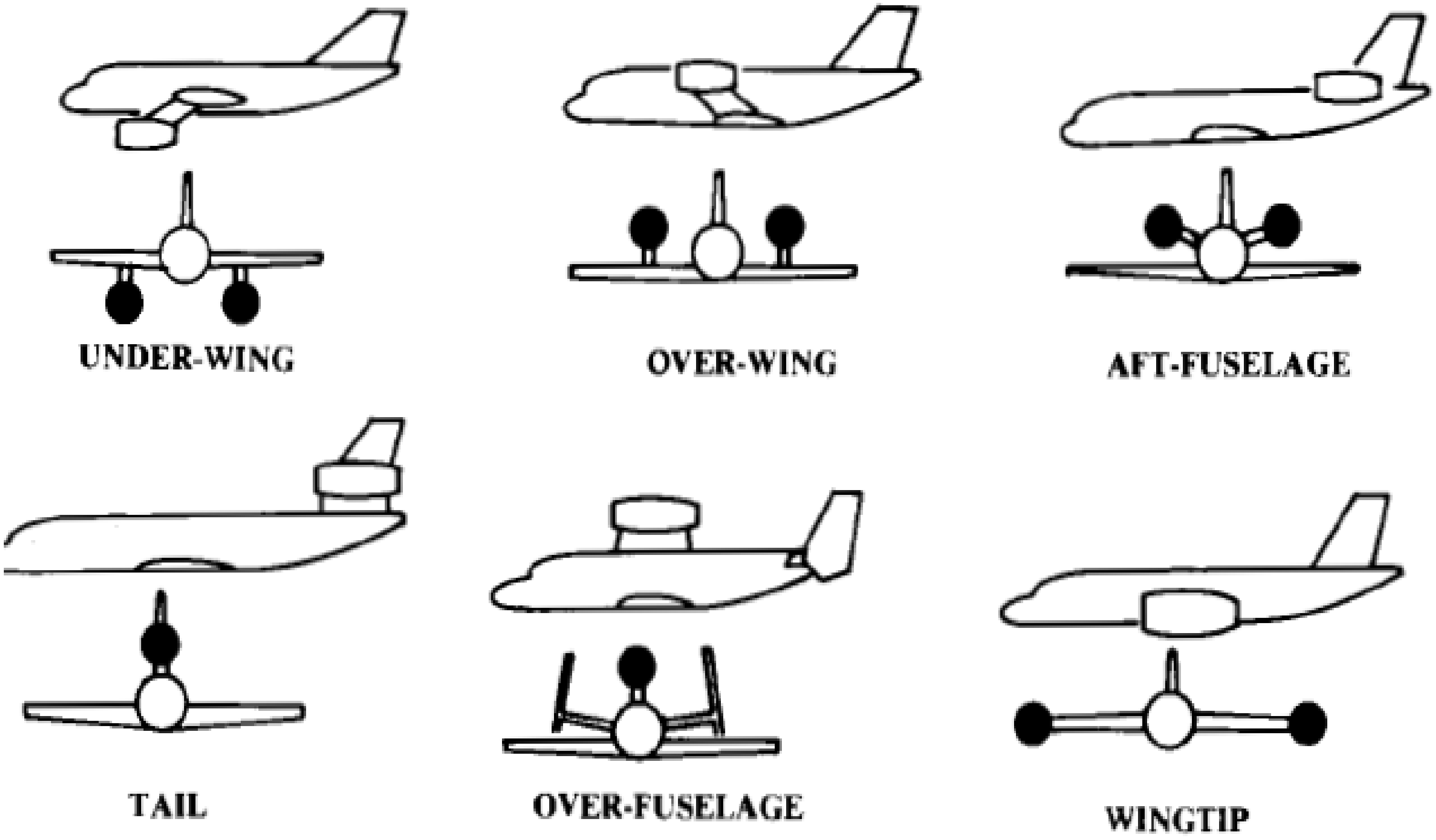
Inlet Applicability

Inlet Locations-buried Engines



Inlet Locations-buried Engines

Inlet Location-podded Engines



UNDER-WING

OVER-WING

AFT-FUSELAGE

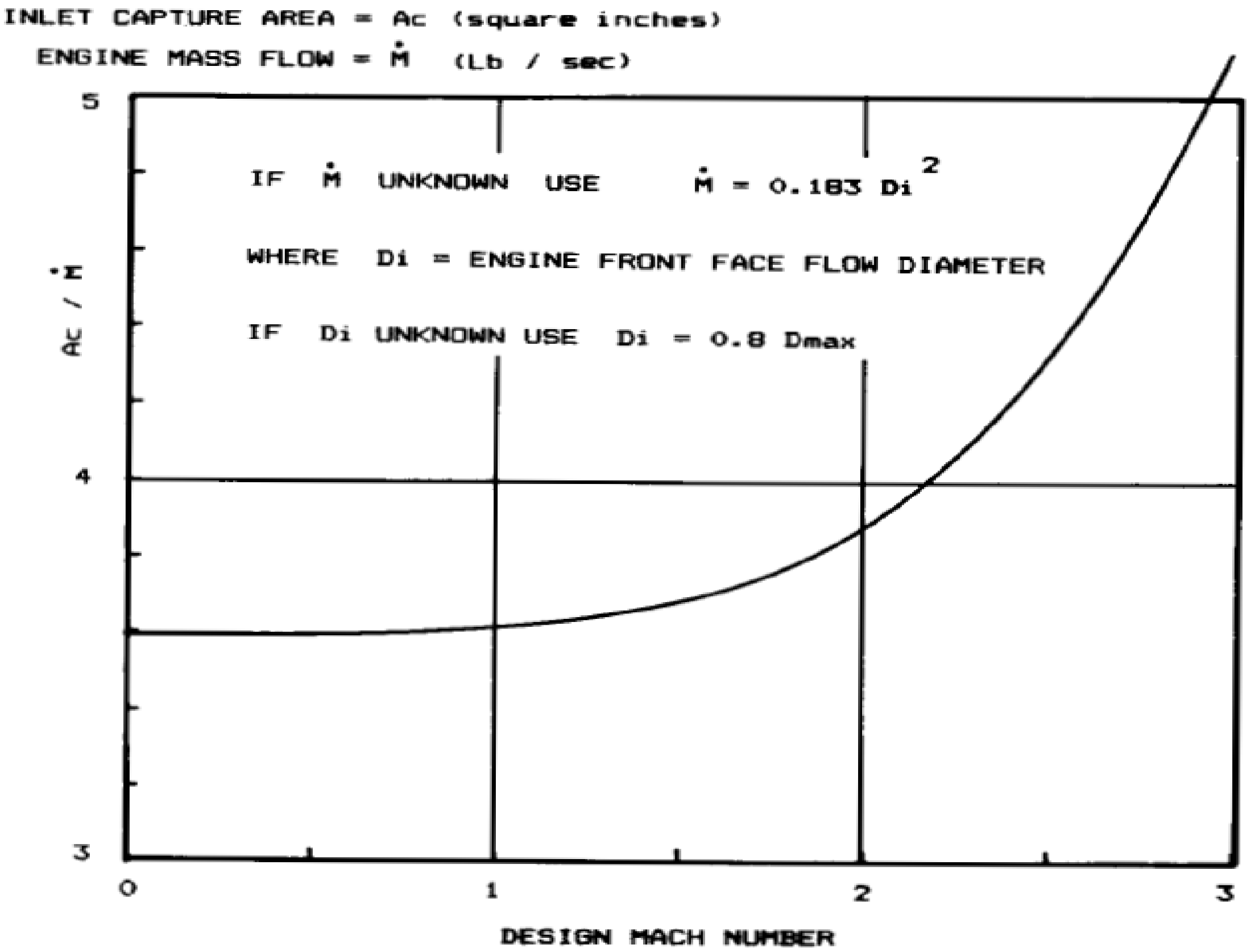
TAIL

OVER-FUSELAGE

WINGTIP

Inlet Location-podded Engines

Capture Area Calculation



INLET CAPTURE AREA = Ac (square inches)

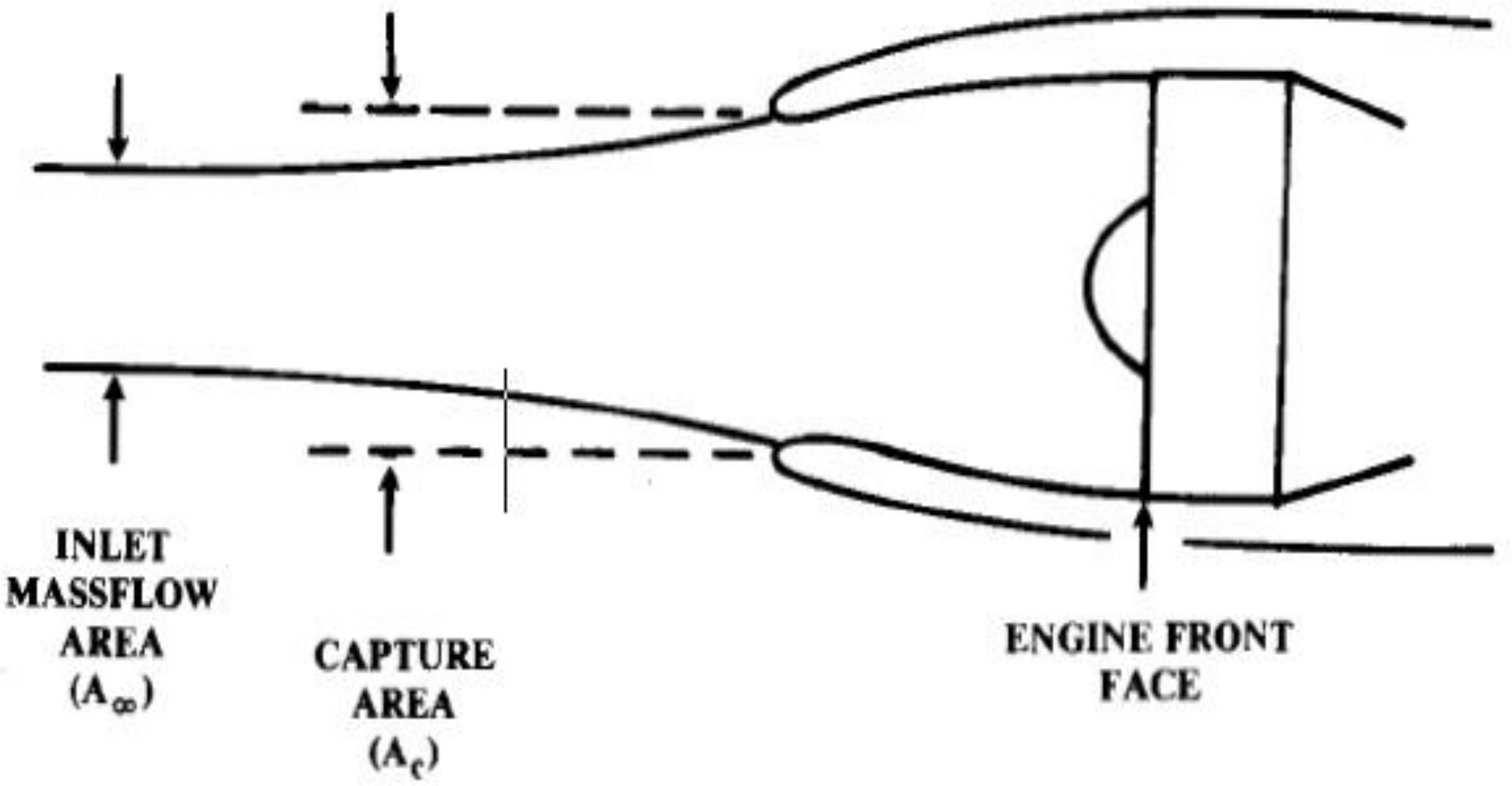
ENGINE MASS FLOW = $\dot{M}$ (Lb / sec)

IF $\dot{M}$ UNKNOWN USE $\dot{M} = 0.183 \; Di^2$

WHERE Di = ENGINE FRONT FACE FLOW DIAMETER

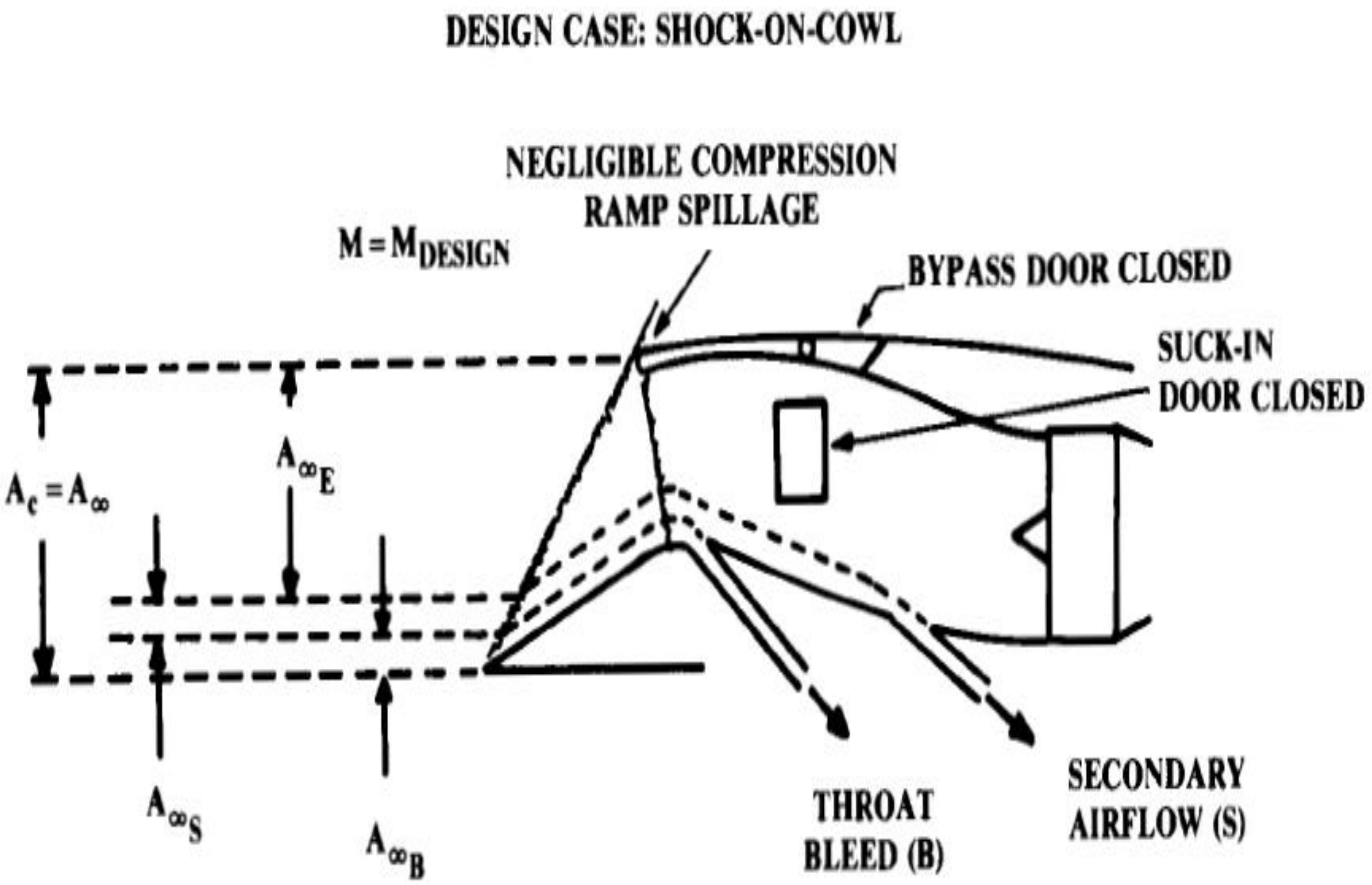
IF Di UNKNOWN USE Di = 0.8 Dmax

Subsonic Inlet Capture Area



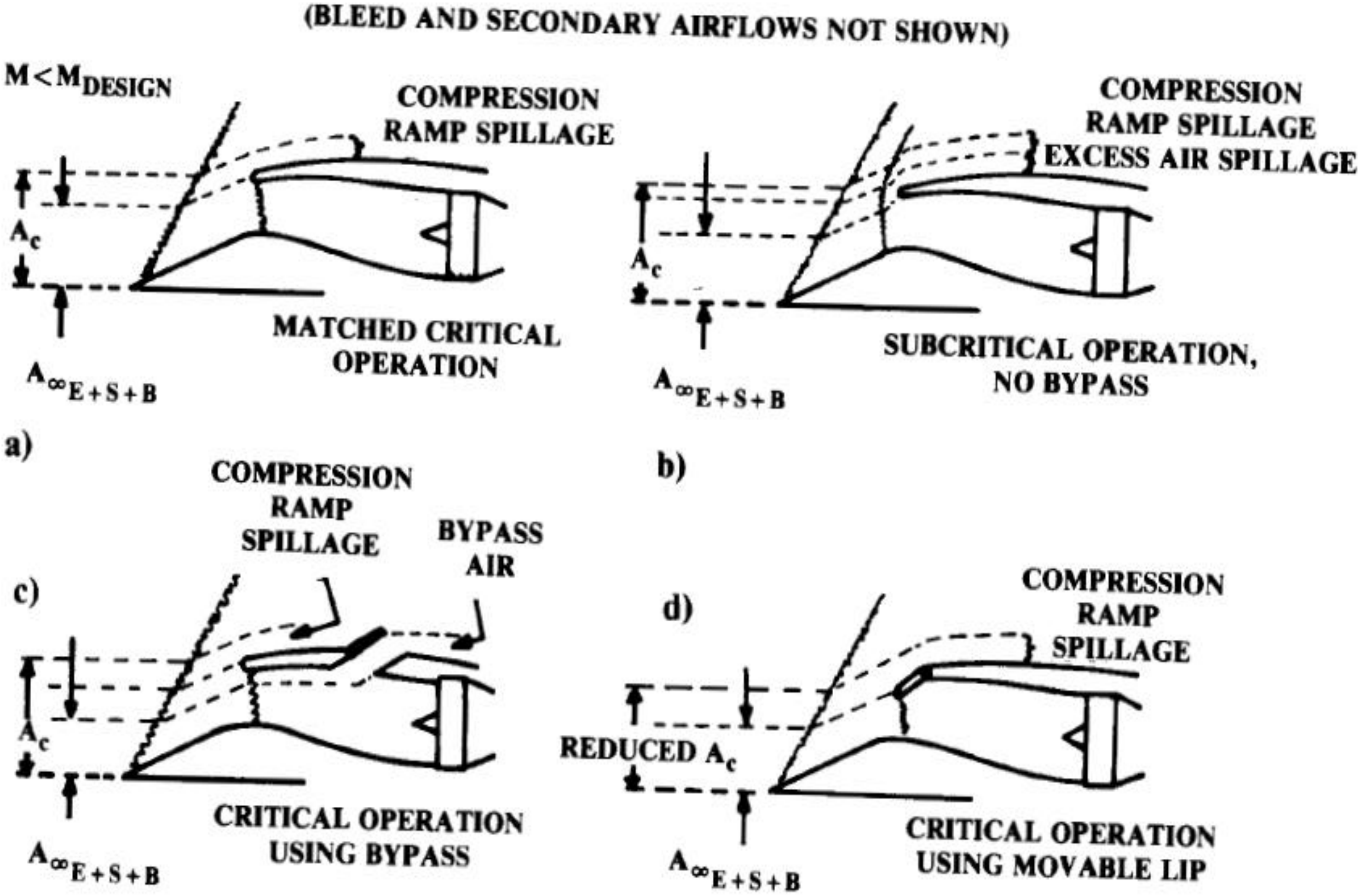
Subsonic Inlet Capture Area

Supersonic Inlet Capture Area-on Design



Supersonic Inlet Capture Area-on Design

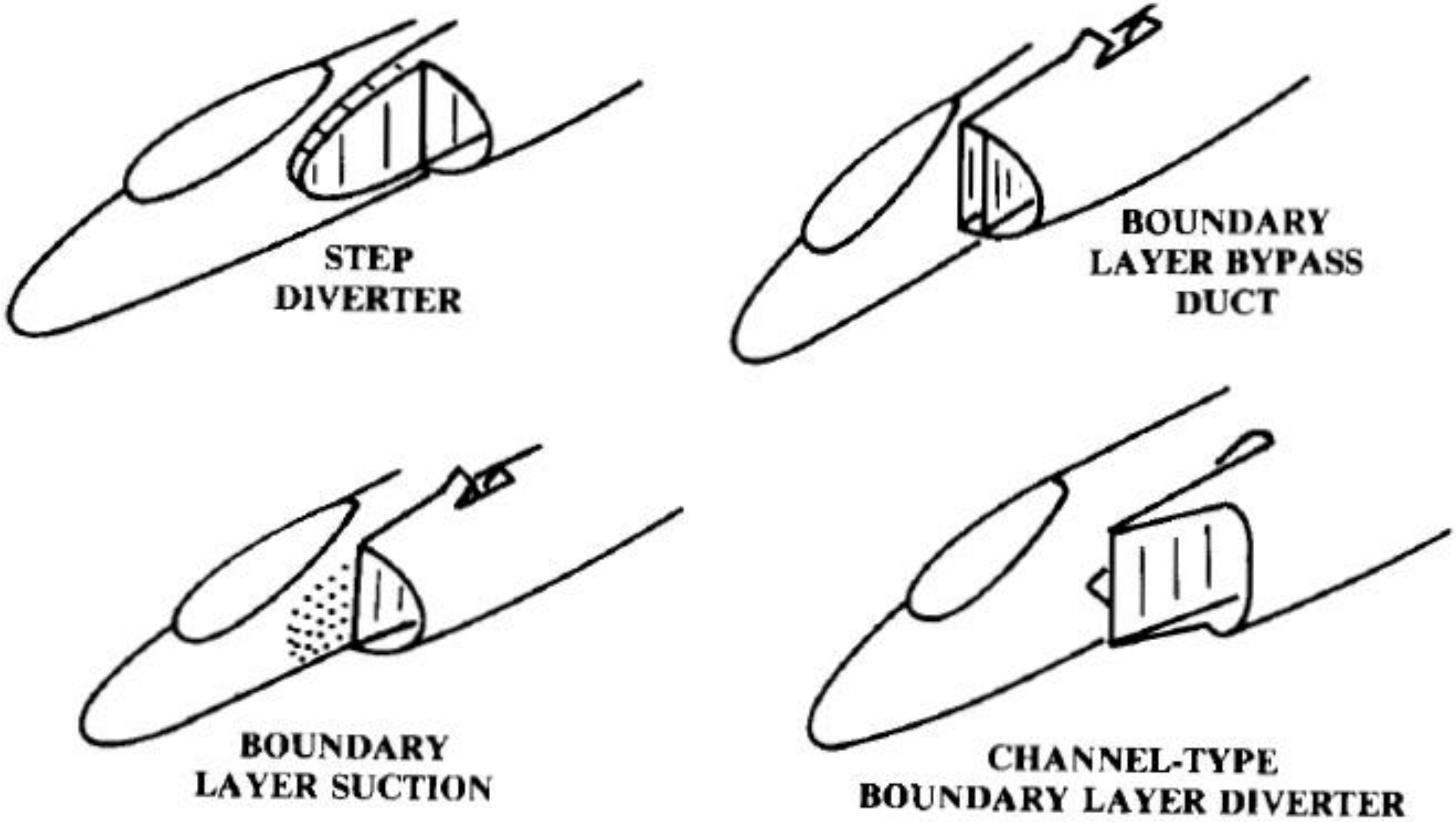
Off-design inlet operations



BOUNDARY LAYER DIVERTERS

- Any object moving through air will build up a boundary layer on its surface. In the last section, boundary-layer bleed was included in the capture area calculation.
- This boundary-layer bleed was used to remove the low-energy boundary layer air from the compression ramps, to prevent shock-induced separation.
- The aircraft's fore body builds up its own boundary layer. If this low-energy, turbulent air is allowed to enter the engine, it can reduce engine performance sub sonically and prevent proper inlet operation supersonically

Boundary Layer Removal



STEP DIVERTER

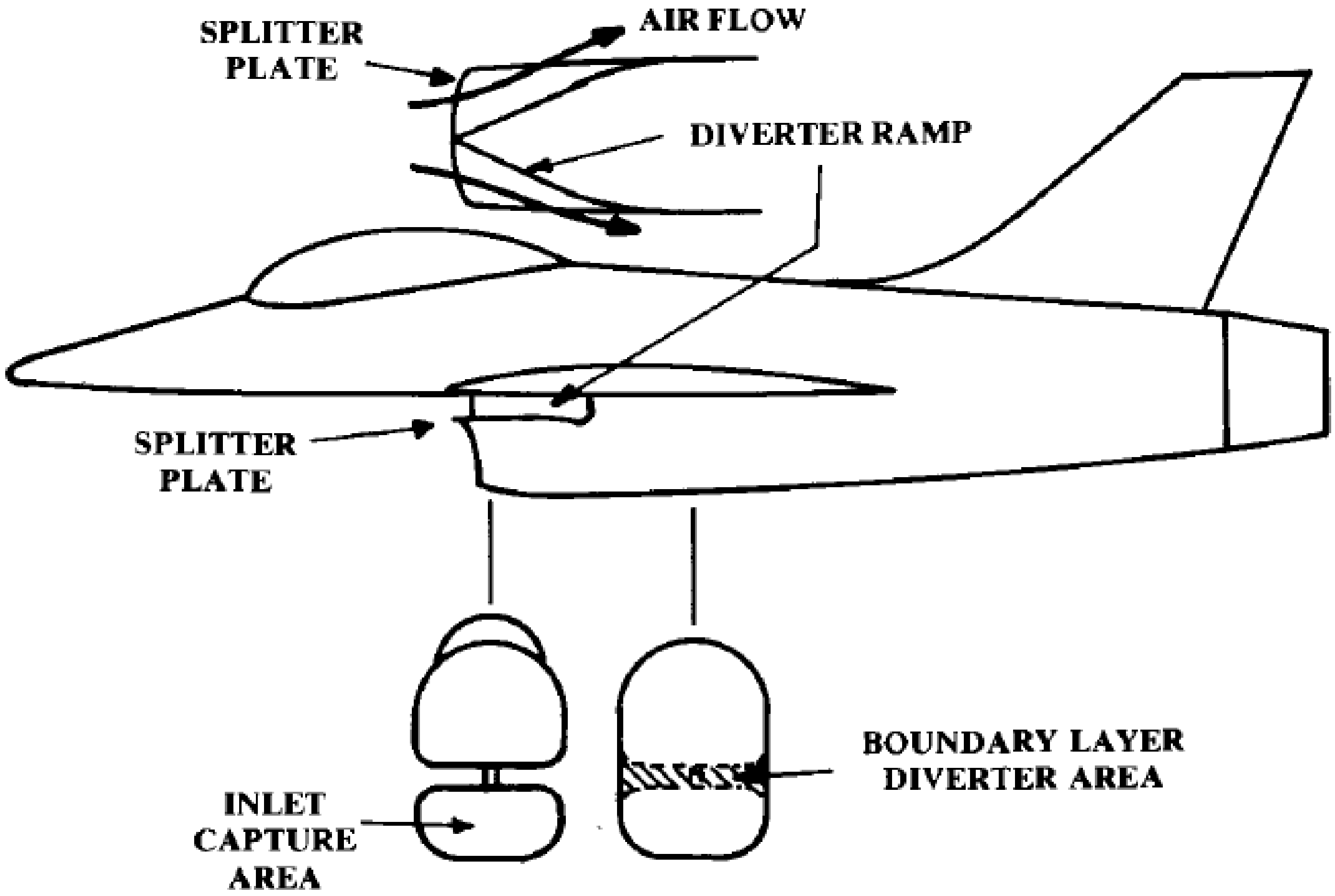
BOUNDARY LAYER BYPASS DUCT

BOUNDARY LAYER SUCTION

CHANNEL-TYPE BOUNDARY LAYER DIVERTER

Boundary Layer Removal

Boundary Layer Diverter

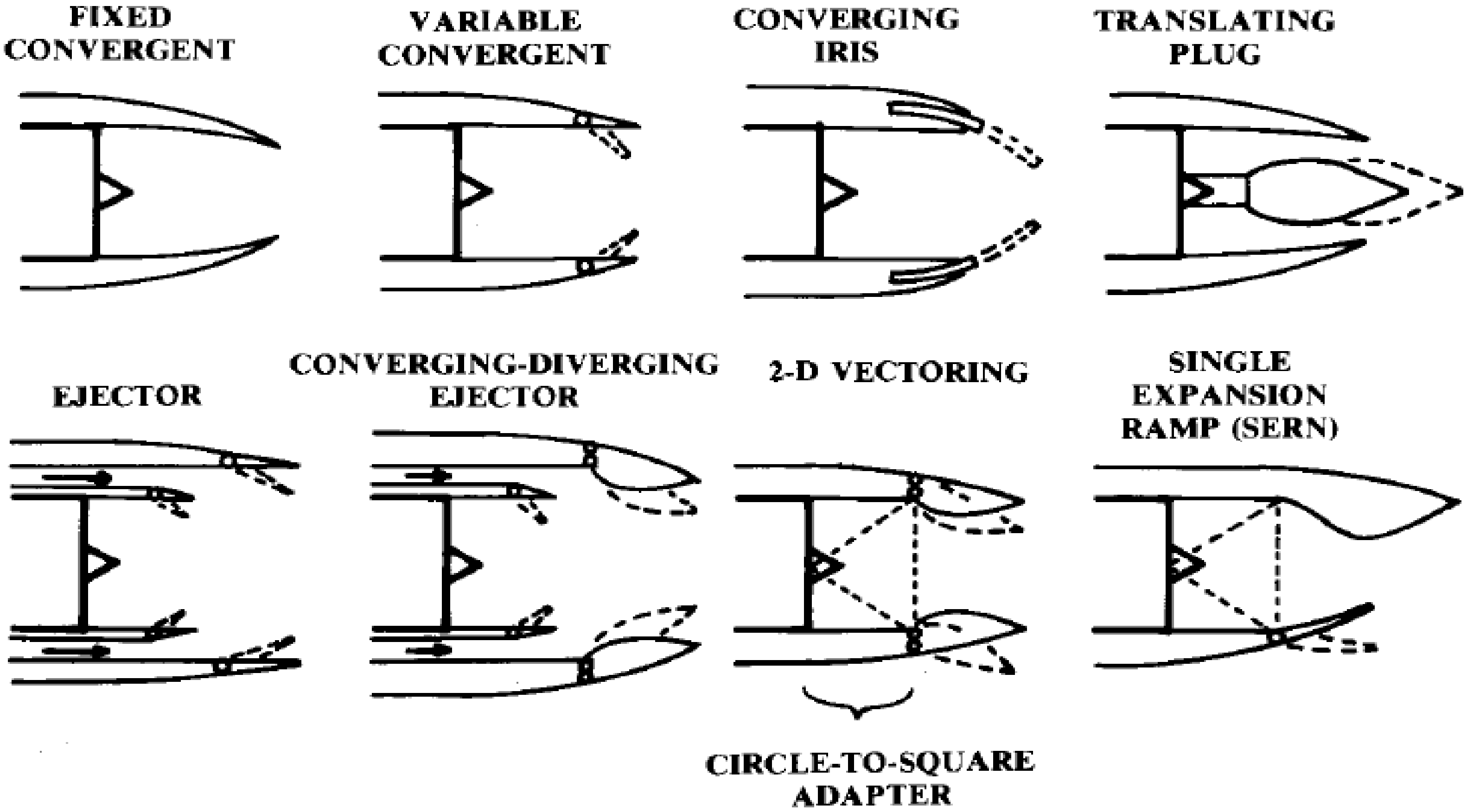


Boundary Layer Diverter

Nozzle Integration

- The fundamental problem in jet engine nozzle design is the mismatch in desired exit areas at different speeds, altitudes, and thrust settings. The engine can be viewed as a producer of high-pressure subsonic gases.
- The nozzle accelerates those gases to the desired exit speed, which is controlled by the exit area. The nozzle must converge to accelerate the exhaust gases to a high subsonic exit speed.
- If the desired exit speed is supersonic, a converging-diverging nozzle is required. Another means to vary the exit area of a convergent nozzle is the translating plug. This was used on the engine for the Me-262, the first jet to be Employed in combat in substantial numbers.

Types Of Nozzles



Types Of Nozzles

Engine Cooling Provisions

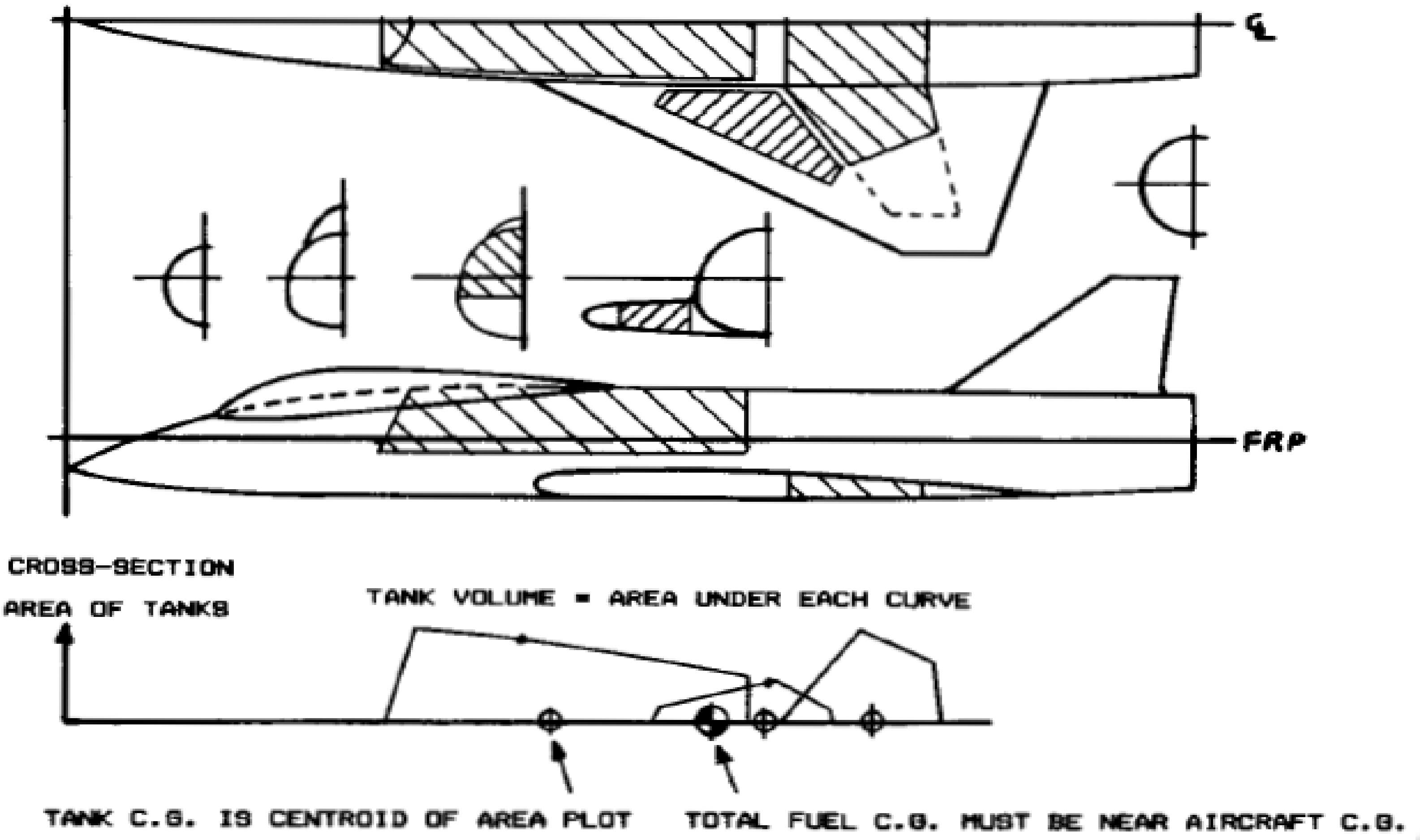
Engine Size Estimation

The required horsepower has previously been calculated. The dimensions of an engine producing this power must now be determined. In propeller aircraft design it is far more common to size the aircraft to a known, fixed-size engine as opposed to the rubber-engine aircraft sizing more common in jet-aircraft design.

Fuel System

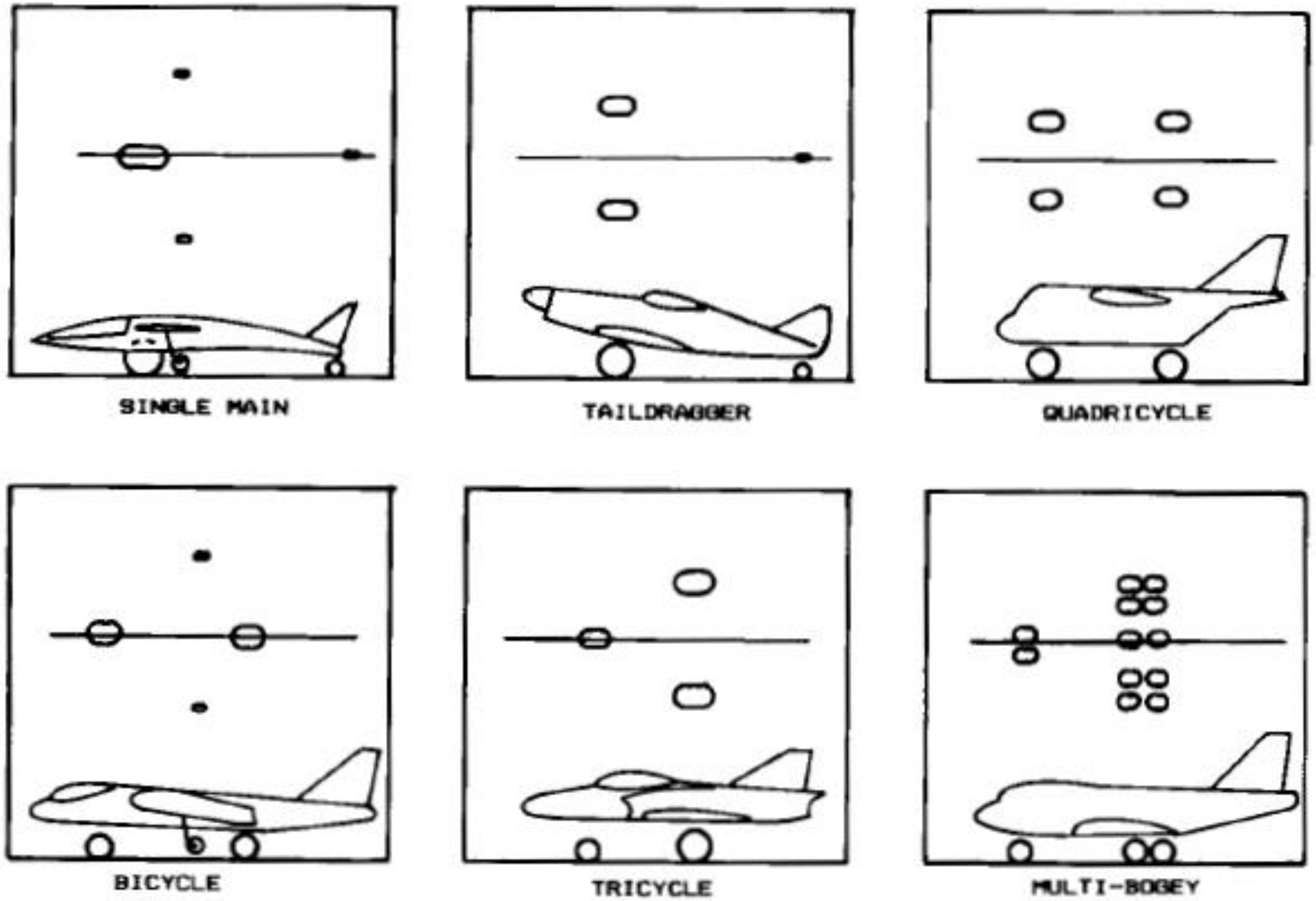
An aircraft fuel system includes the fuel tanks, fuel lines, fuel pumps, vents, and fuel-management controls. Usually the tanks themselves are the only components that impact the overall aircraft layout, although the winglets on the round-the-world Rutan Voyager were added solely to raise the fuel vents above the wing tanks when the wing tips bent down to the runway on takeoff.

Fuel Tank Volume Plotting



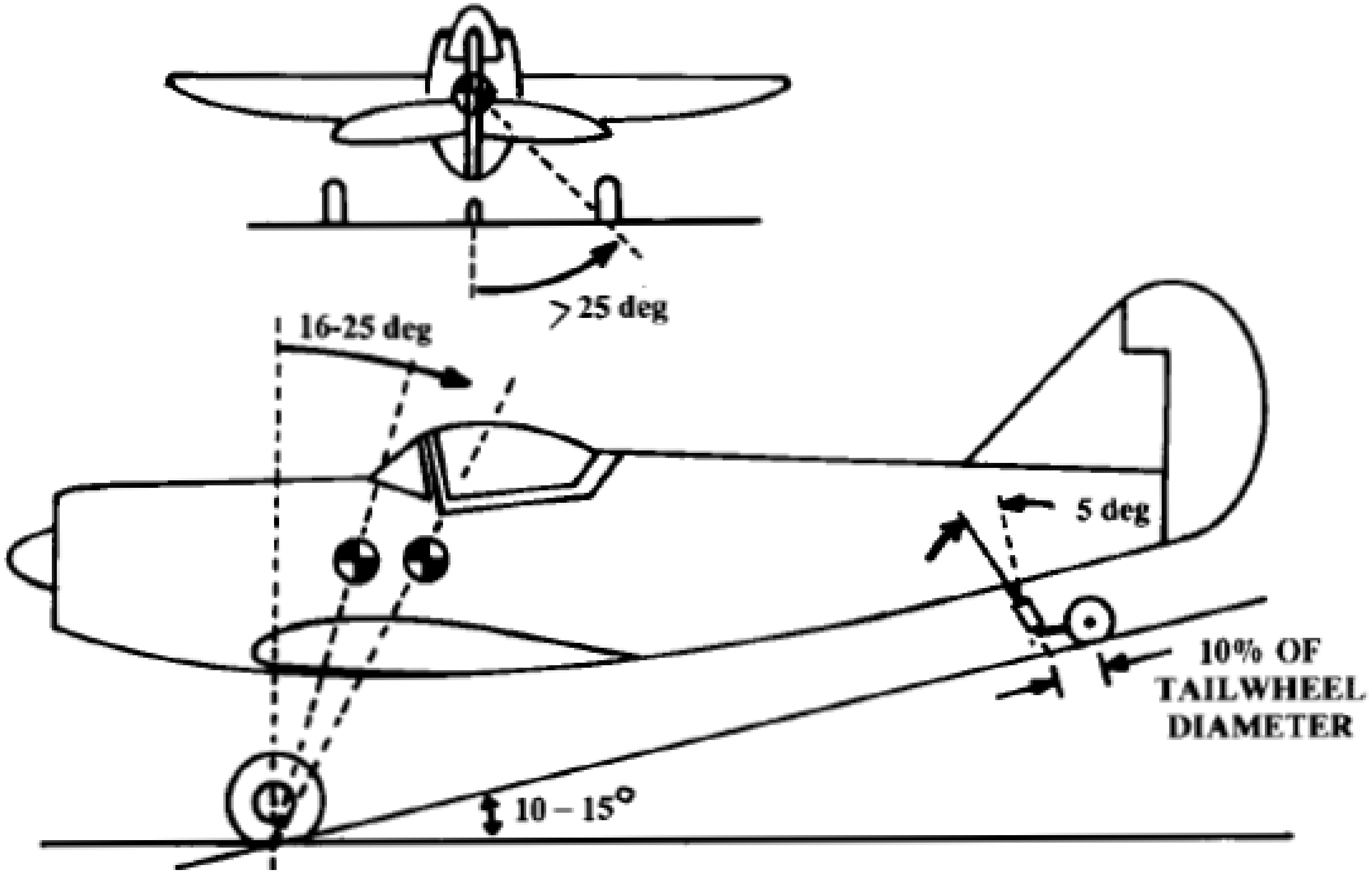
Fuel Tank Volume Plotting

Landing Gear Arrangements



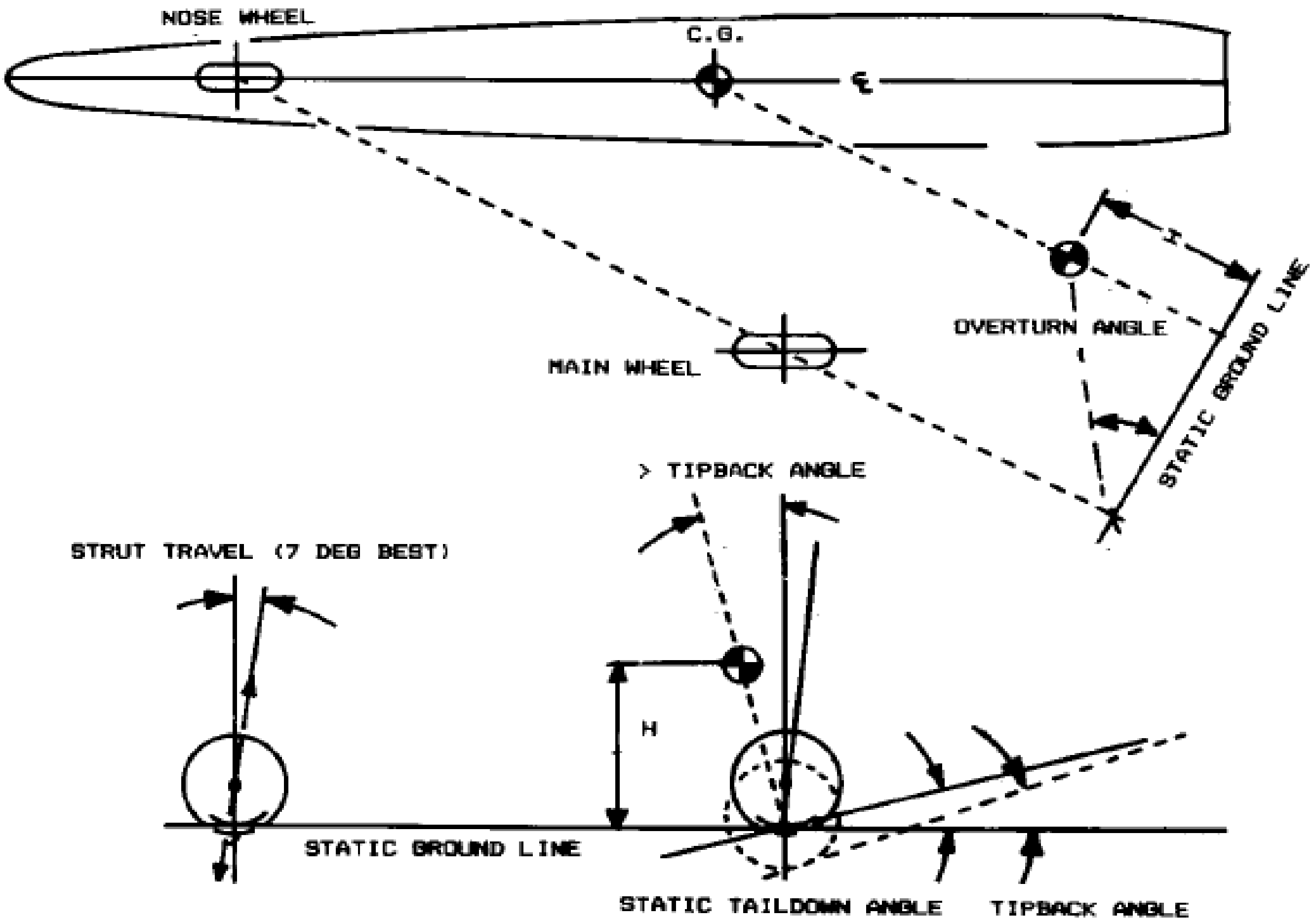
Landing Gear Arrangements

Tail dragger landing gear



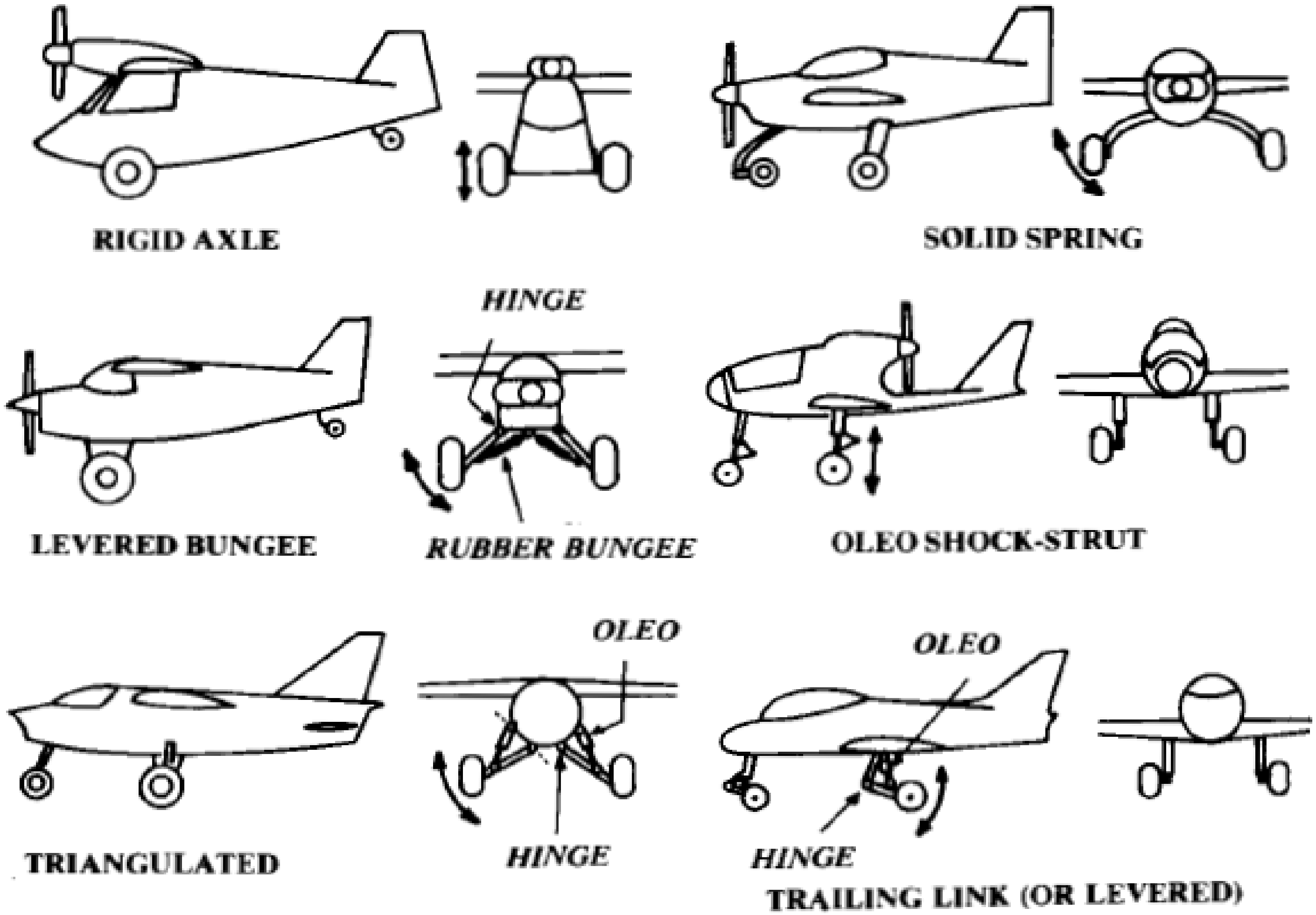
Tail dragger landing gear

Tricycle Landing Gear Geometry

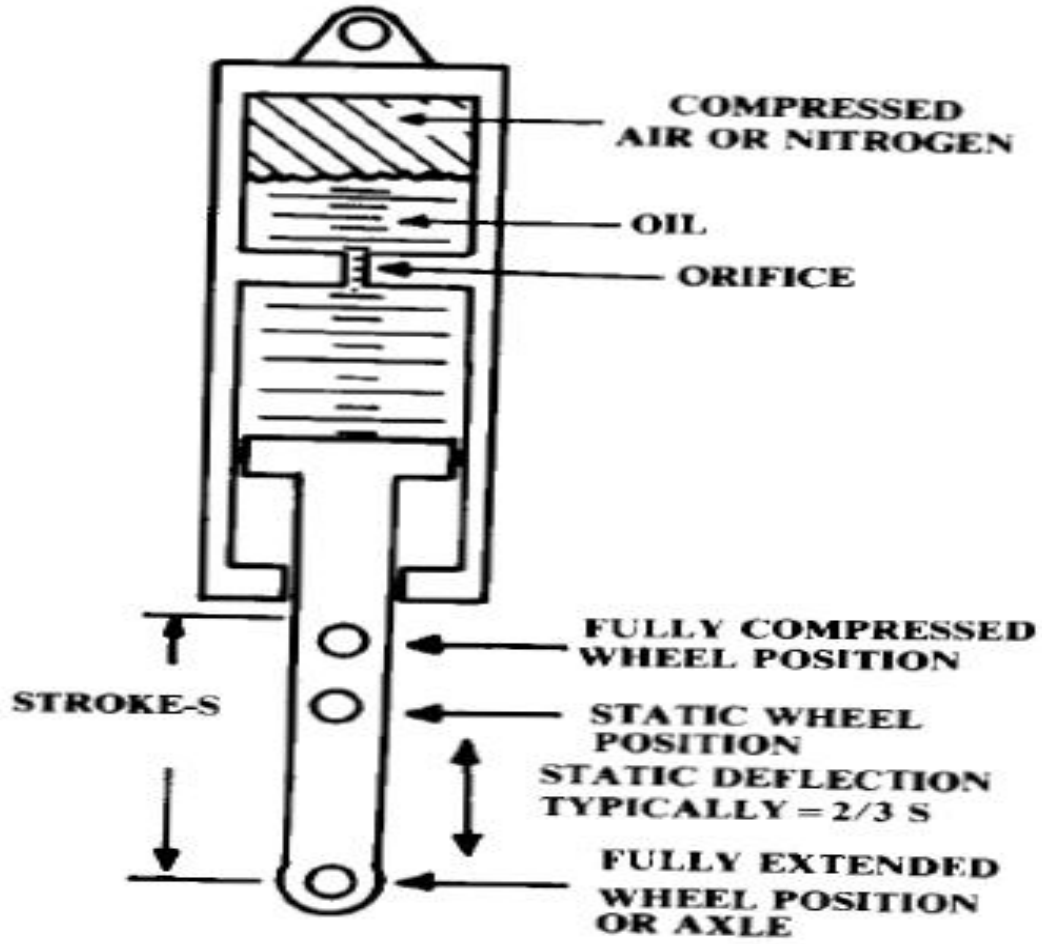


Tricycle Landing Gear Geometry

Gear/Shock Arrangements



Oleo Shock Absorber



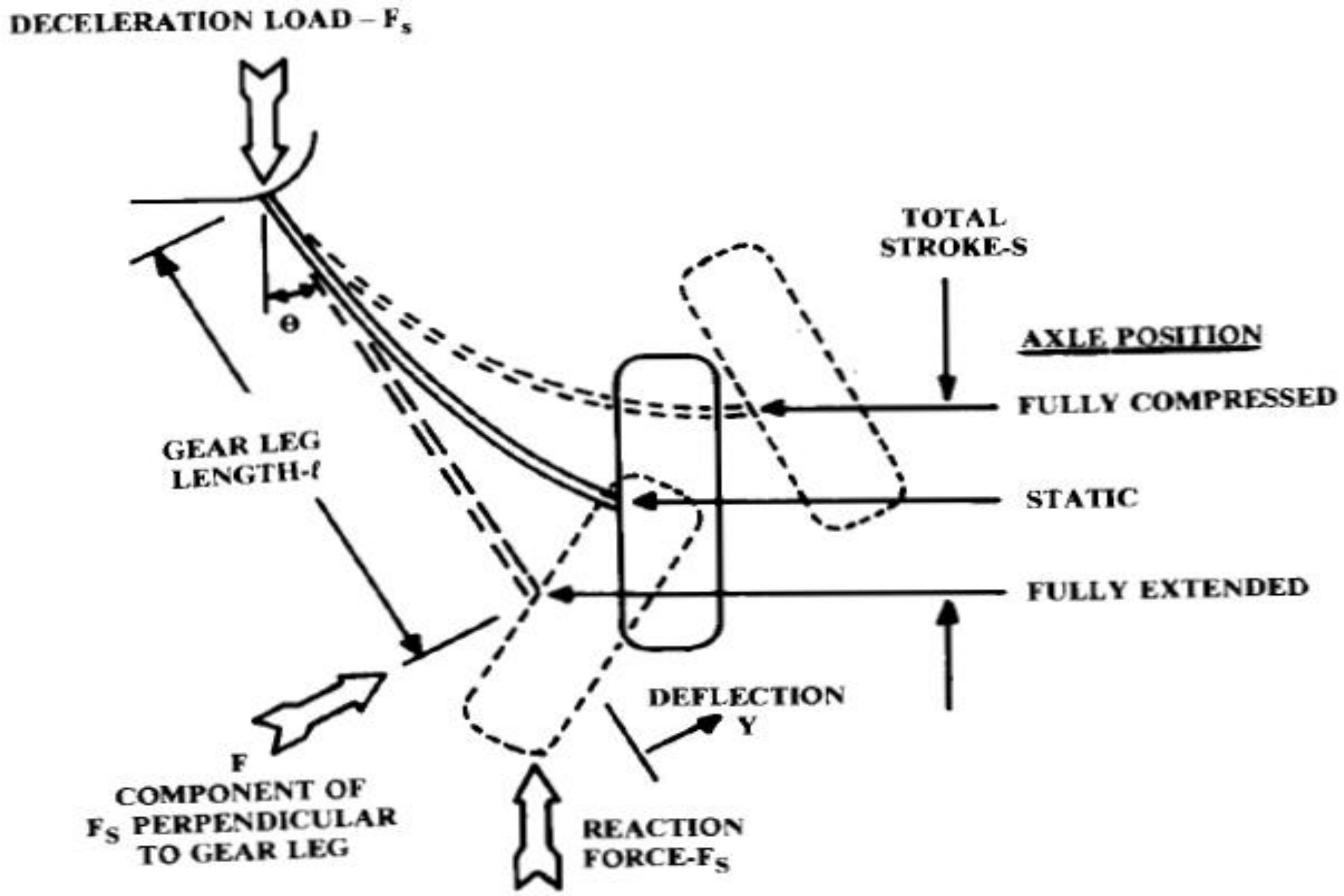
Oleo Shock Absorber

Stroke Determination

- The required deflection of the shock-absorbing system (the "stroke") depends upon the vertical velocity at touchdown, the shock-absorbing material and the amount of wing lift still available after touchdown.
- As rough rule-of-thumb, the stroke in inches approximately equals the vertical velocity at touchdown in (ft/s).

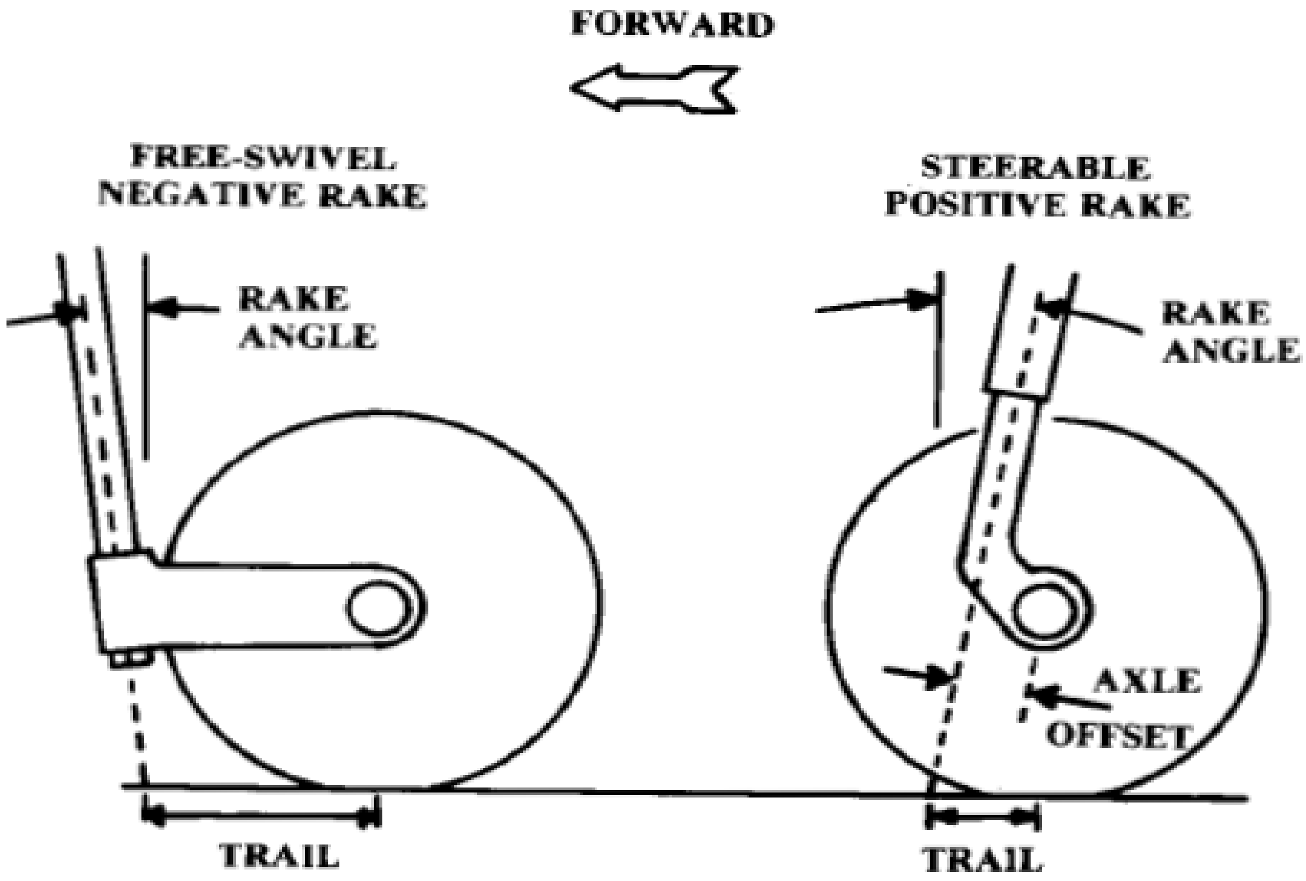
$$KE_{\text{vertical}} = \left(\frac{1}{2}\right)\left(\frac{W_{\text{landing}}}{g}\right) V_{\text{vertical}}^2$$

SOLID-SPRING GEAR SIZING



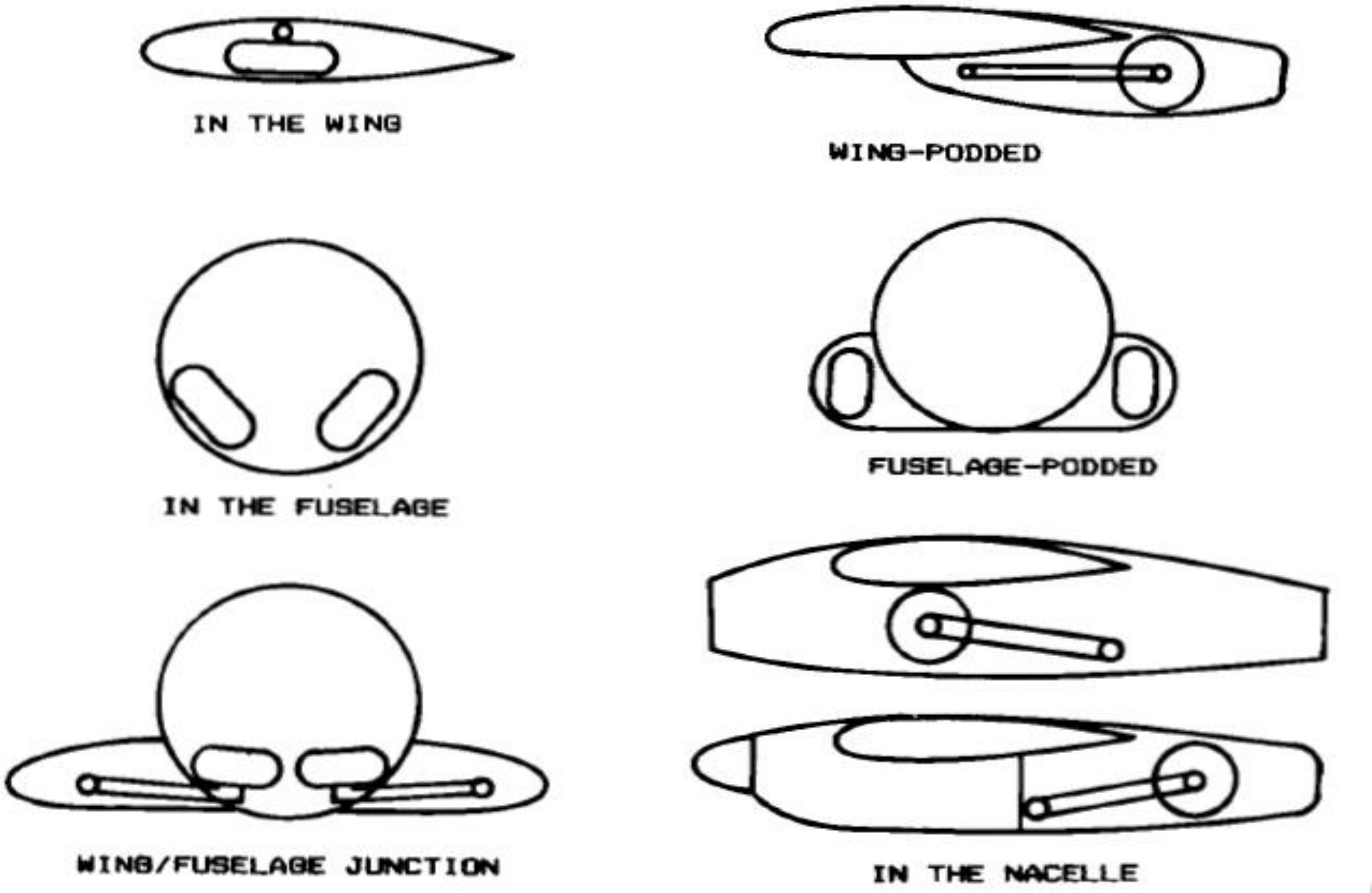
Solid-spring Gear Sizing

STROKE DETERMINATION, GEAR LOAD FACTORS



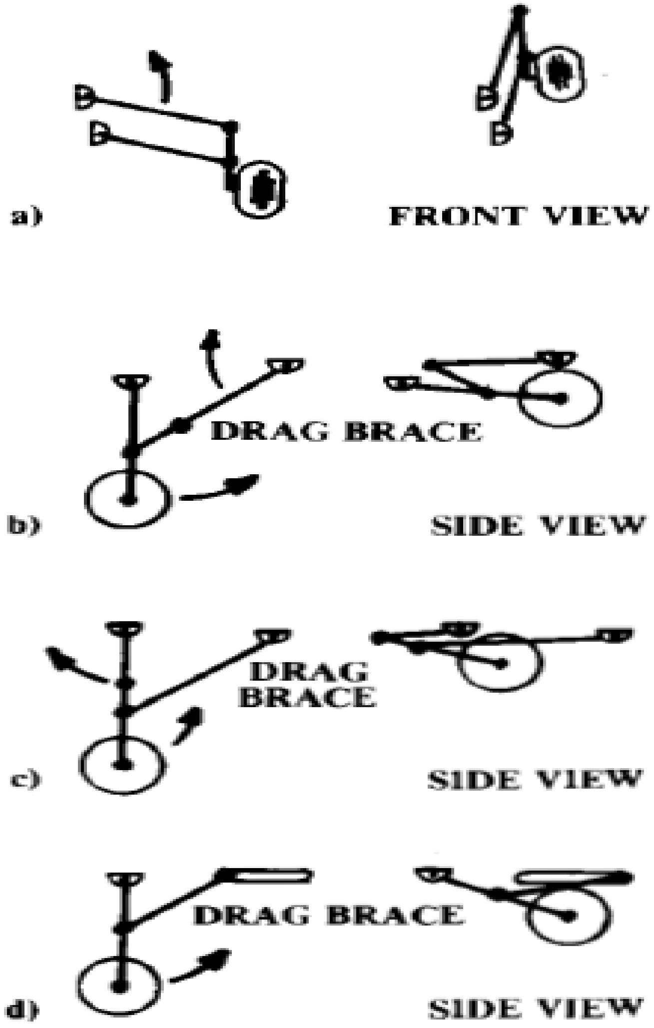
Stroke Determination, Gear Load Factors

Gear Retraction Geometry



Gear Retraction Geometry

Landing Gear Retraction

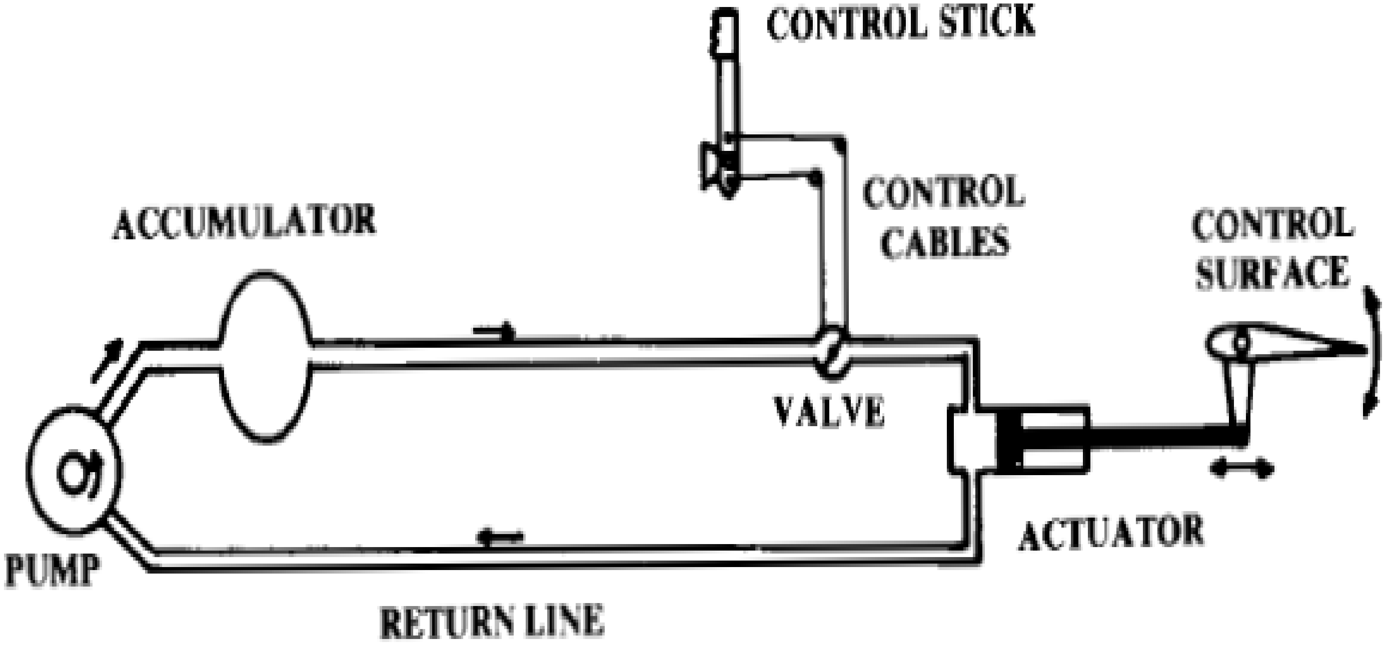


Landing Gear Retraction

AIRCRAFT SUBSYSTEMS

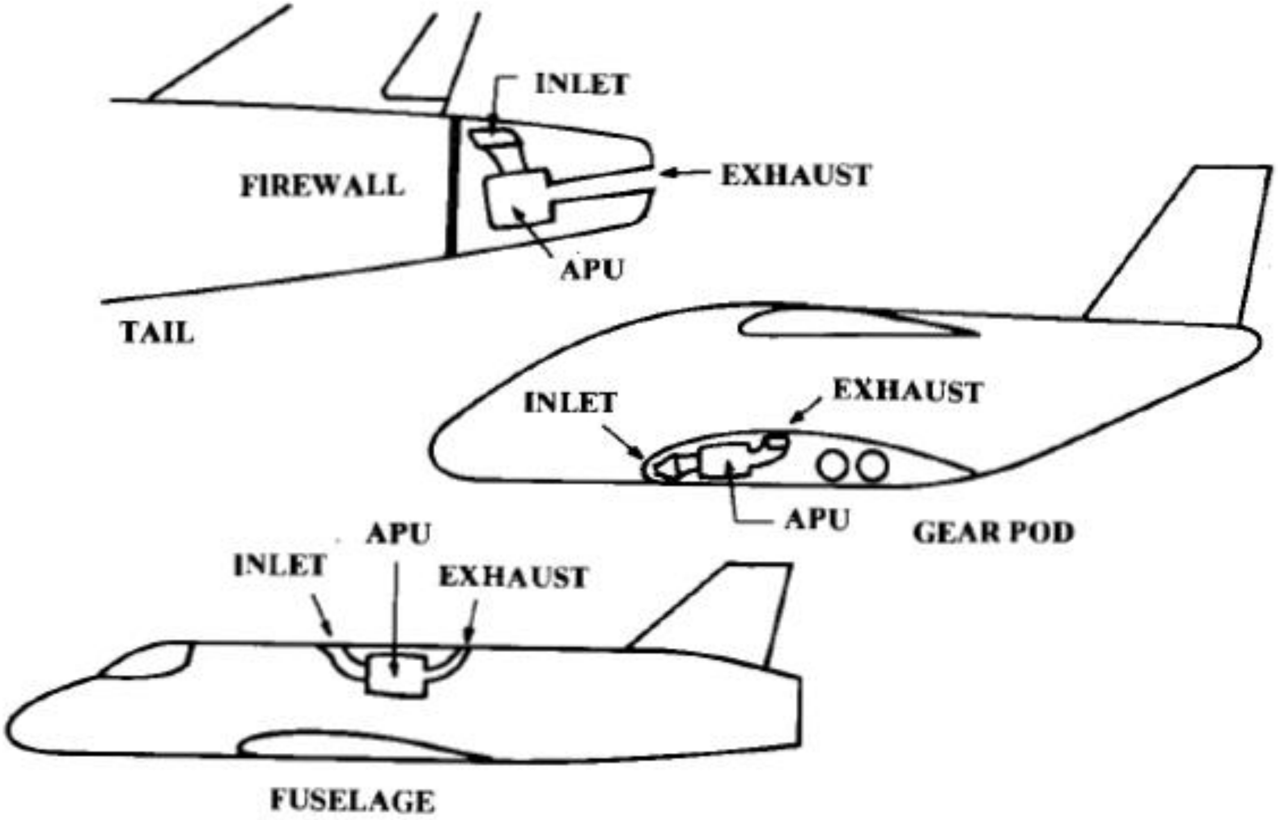
- Aircraft subsystems include the hydraulic, electrical, pneumatic, and auxiliary emergency power systems. Also, the avionics can be considered a subsystem (although to the avionics engineers, the airframe is merely the "mobility subsystem" of their avionics package)
- In general, the subsystems do not have a major impact on the initial design layout. However, later in the design cycle the configuration designer will have to accommodate the needs of the various subsystems, so a brief introduction is provided below.

Hydraulics



Hydraulics

Electrical System



Electrical System

Pneumatic System

- The pneumatic system provides compressed air for pressurization, environmental control, anti-icing, and in some cases engine starting. Typically the pneumatic system uses pressurized air bled from the engine compressor.
- This compressed air is cooled through a heat exchanger using outside air. This cooling air is taken from a flush inlet inside the inlet duct (i.e., inlet secondary airflow) or from a separate inlet usually located on the fuselage or at the front of the inlet boundary-layer diverter

Auxiliary/Emergency Power

- The three major forms of emergency power.
- The ram-air turbine (RAT) monopropellant emergency power unit (EPU), and Jet-fuel EPU.
- The ram-air turbine is a windmill extended into the slipstream. Alternatively, a small inlet duct can open to admit air into a turbine.
- The monopropellant EPU uses a monopropellant fuel such as hydrazine to drive a turbine.

Avionics

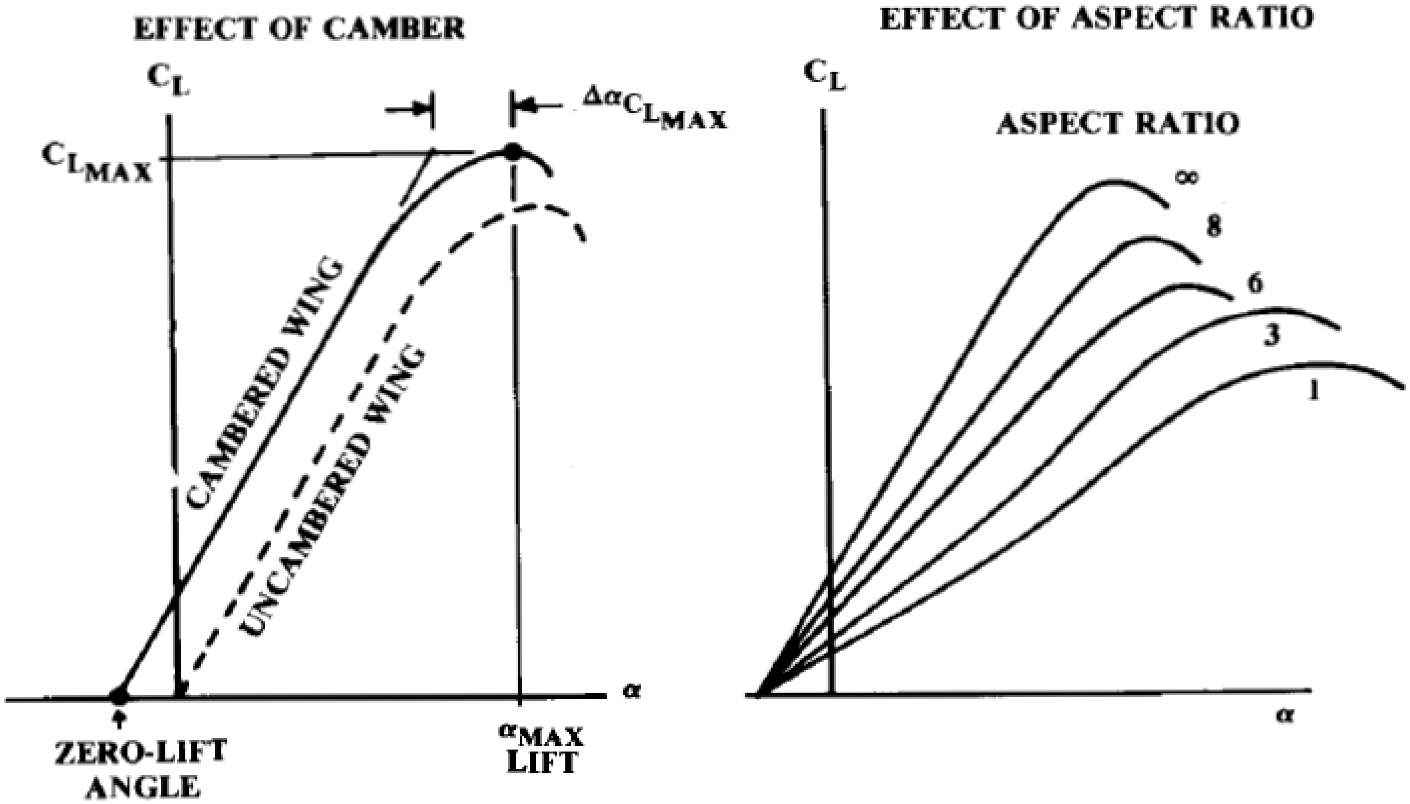
- Avionics (a contraction of "aviation electronics") includes radios, flight instruments, navigational aids, flight control computers, radar, and other aircraft sensors such as infrared detectors.
- For initial layout, it is necessary to provide sufficient volume in the avionics bays. Also, the nose of the aircraft should be designed to hold the radar.
- On the average, avionics has a density of about 30-45 lb/ft3
- The required avionics weight can be estimated from the aircraft empty weight (We),which is known at this point

Significance to Configuration Lay Out, The Baseline De Layout And Report Of Initial Specifications

Aerodynamics 261

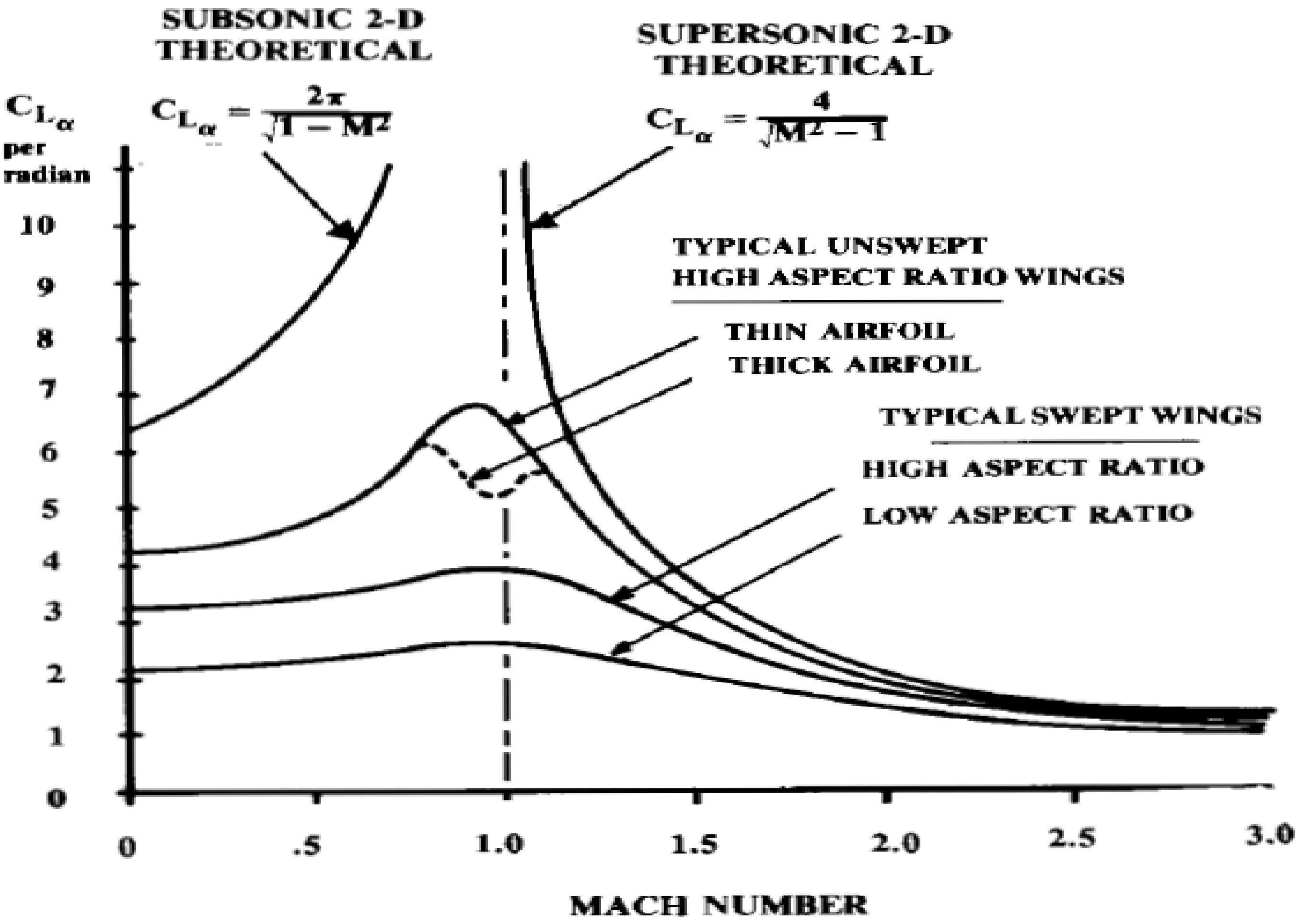
- Viscous separation is largely responsible for the drag of irregular bodies such as landing gear and boundary-layer diverters. It also produces base drag, the pressure drag created by a "cut-off" aft fuselage.
- The subsonic drag of a streamlined, nonlifting body consists solely of skin friction and viscous separation drag and is frequently called the "profile drag.“
- If the body. Also, the separation point is affected by the amount of energy m the flow.
- Turbulent air has more energy than laminar air, so a turbulent boundary layer actually tends to delay separation.

Wing Lift Curve



Wing Lift Curve

Subsonic Lift-curve Slope

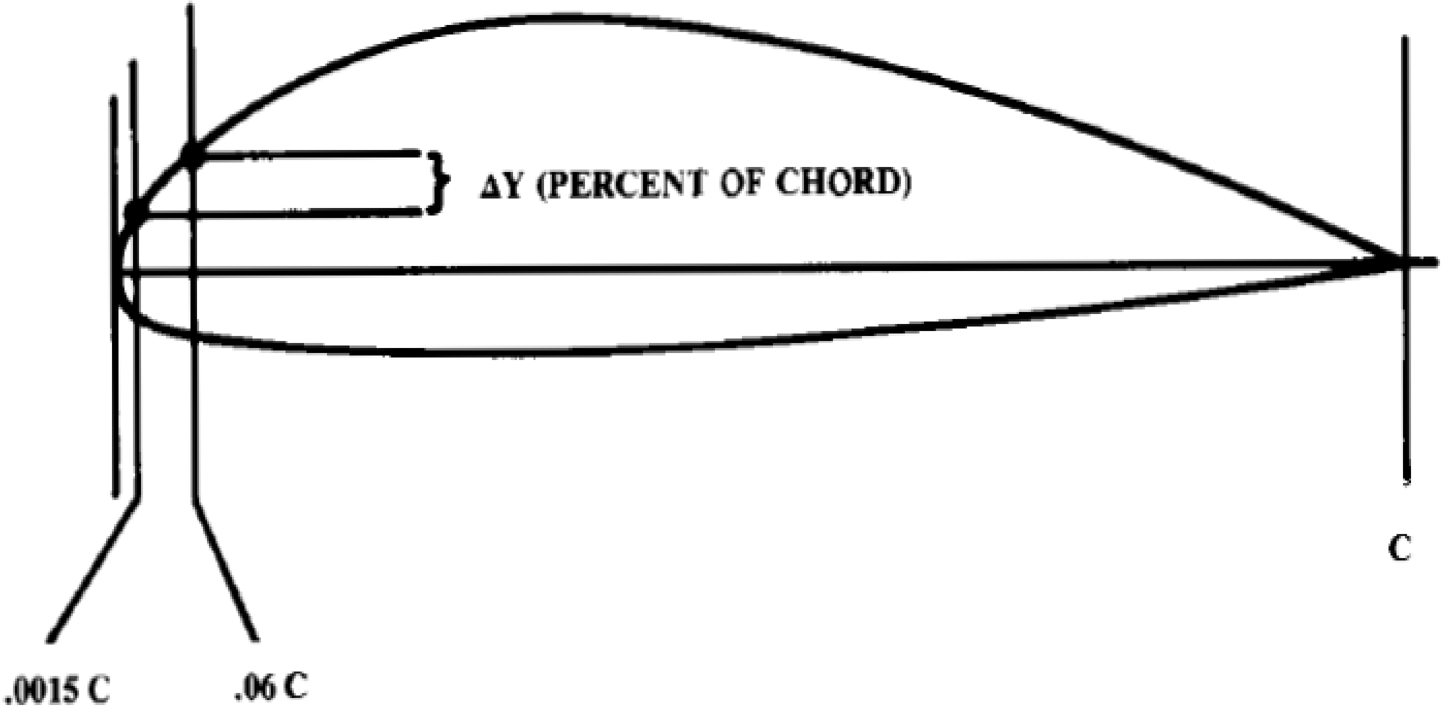


Subsonic Lift-curve Slope

MAXIMUM LIFT COEFFICIENT

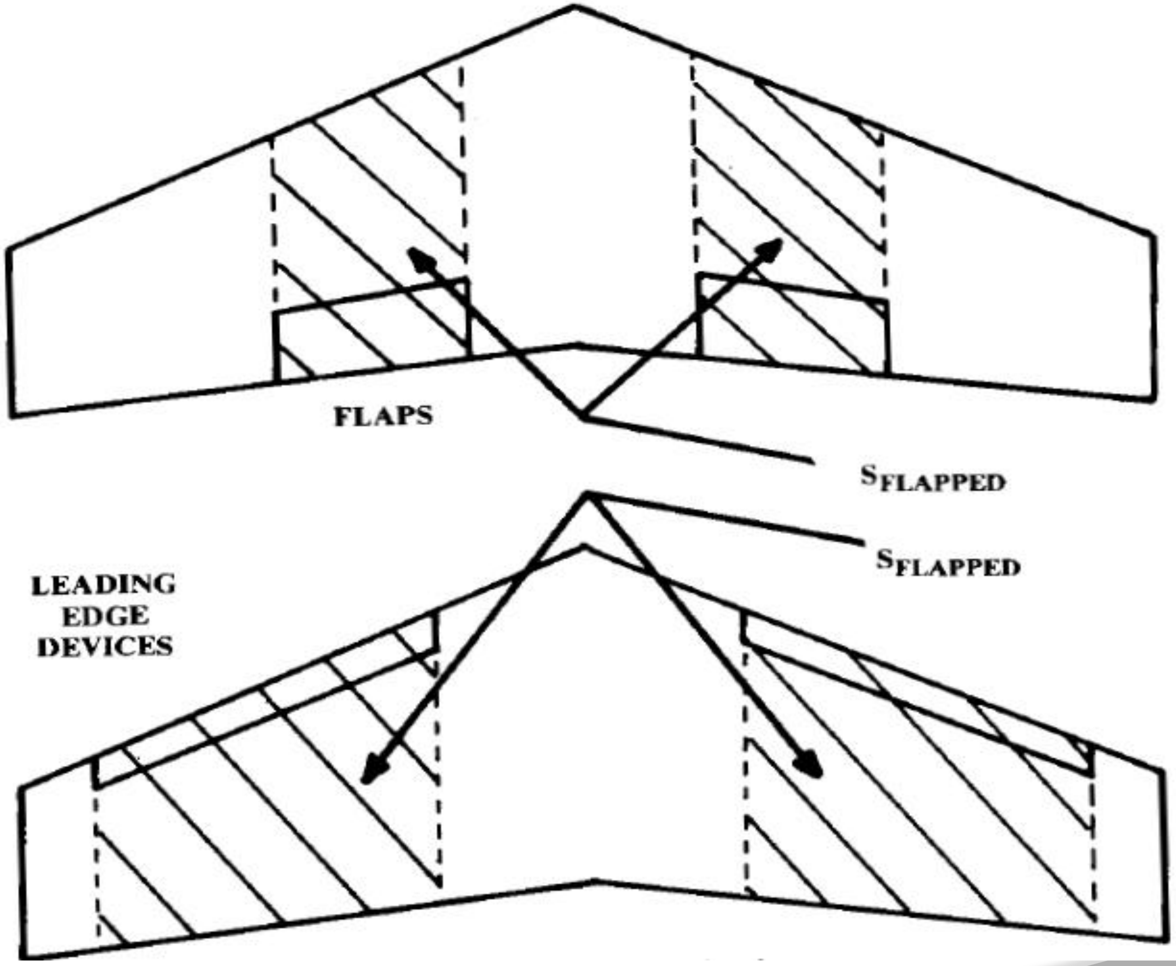
- The maximum lift coefficient of the wing will usually determine the wing area.
- This in turn will have a great influence upon the cruise drag.
- This strongly affects the aircraft takeoff weight to perform the design mission.
- Thus, the maximum lift coefficient is critical in determining the aircraft weight;
- Yet the estimation of maximum lift is probably the least reliable of all of the calculations used in aircraft conceptual design

Airfoil Leading Edge Sharpness Parameter



Airfoil Leading Edge Sharpness Parameter

Flapped Wing Area

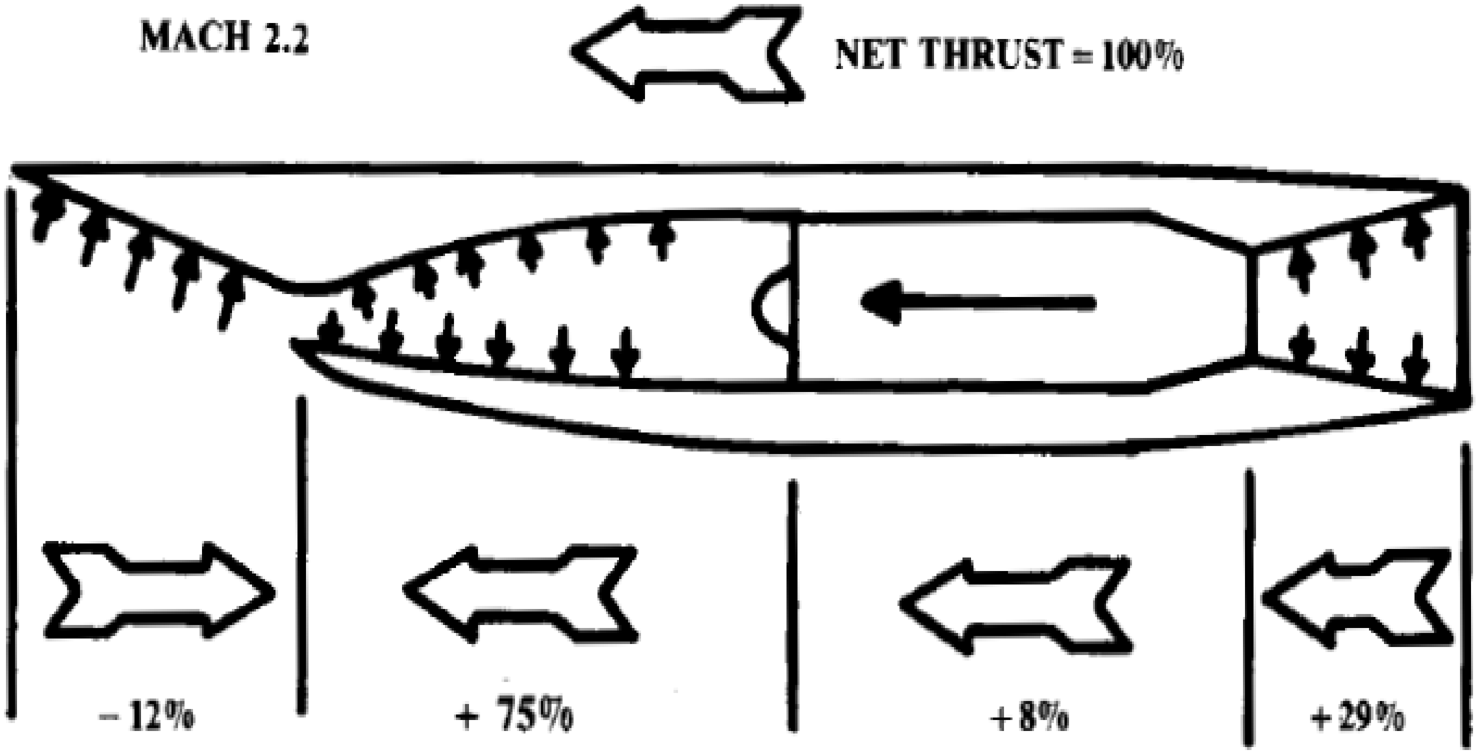


Flapped Wing Area

Installed Performance Of An Engine And Installation

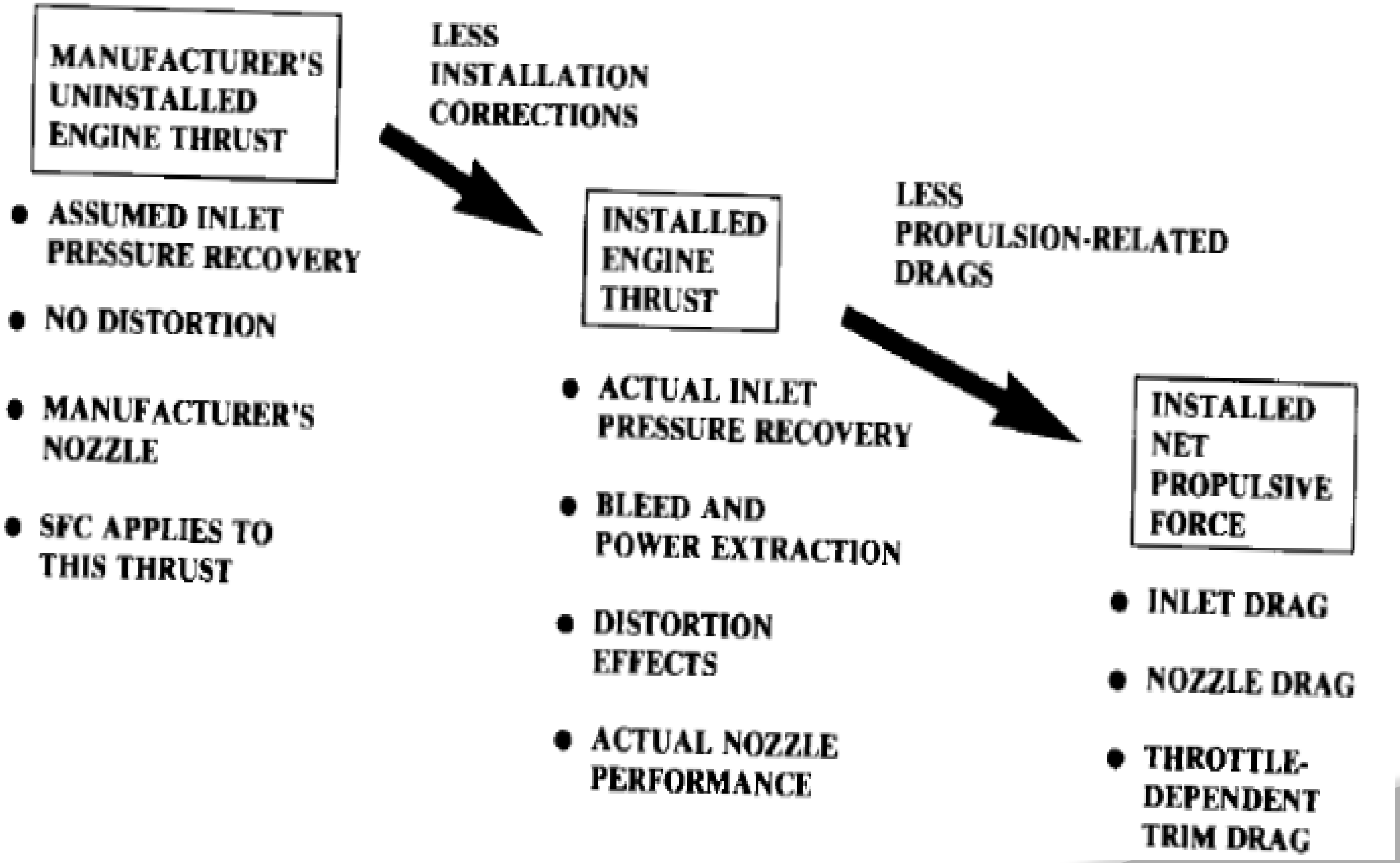
- Aircraft propulsion develop thrust by pushing air (or hot gases) backward. In a simplified case the force obtained can be determined using Newton's equation (F =ma) by summing all the accelerations imparted to the air.
- The analysis above is too simplistic for actual thrust calculation. It falsely assumes that the fluid velocity is constant throughout the exhaust and that all of the accelerations experienced by the air mass occur at the propeller plane or within the jet engine.

Turbojet Thrust Contributors



Turbojet Thrust Contributors

Installed Thrust Methodology



MANUFACTURER'S UNINSTALLED ENGINE THRUST

- ASSUMED INLET PRESSURE RECOVERY
- NO DISTORTION
- MANUFACTURER'S NOZZLE
- SFC APPLIES TO THIS THRUST

LESS INSTALLATION CORRECTIONS

INSTALLED ENGINE THRUST

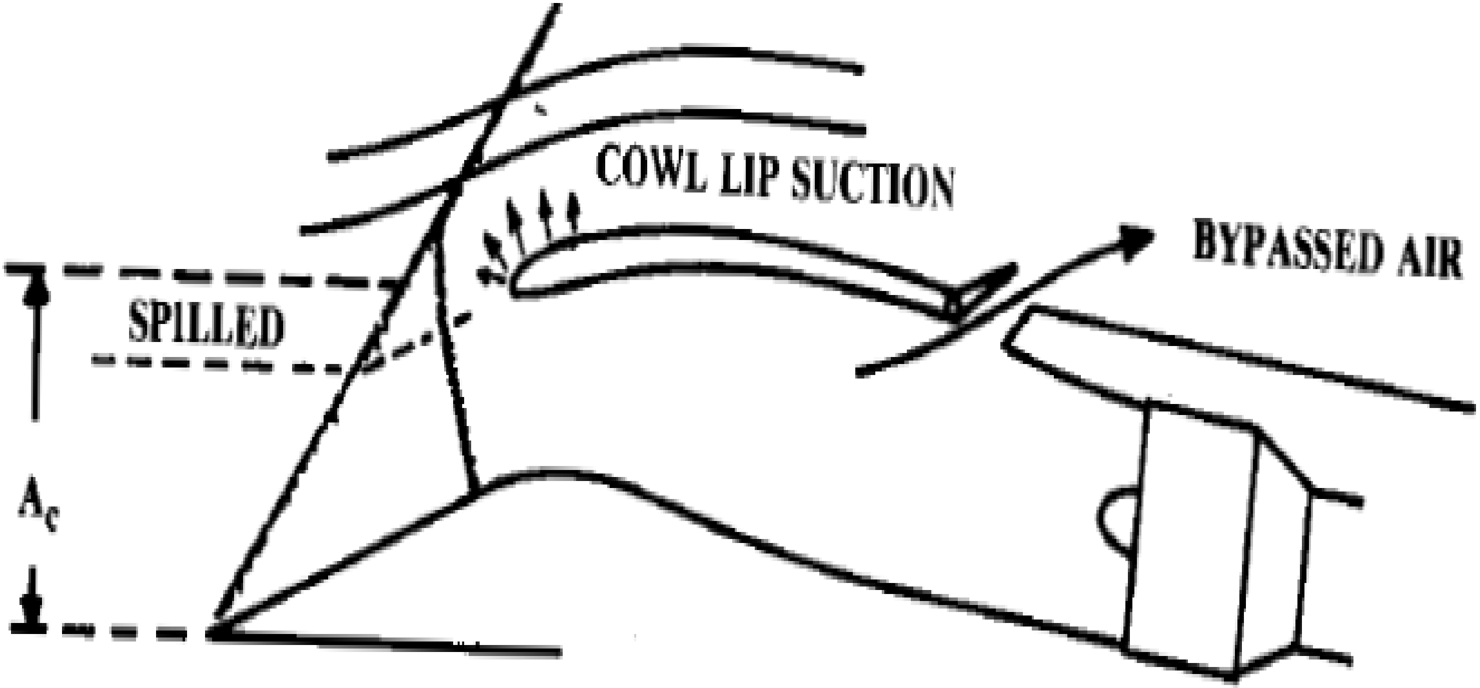
- ACTUAL INLET PRESSURE RECOVERY
- BLEED AND POWER EXTRACTION
- DISTORTION EFFECTS
- ACTUAL NOZZLE PERFORMANCE

LESS PROPULSION-RELATED DRAGS

INSTALLED NET PROPULSIVE FORCE

- INLET DRAG
- NOZZLE DRAG
- THROTTLE-DEPENDENT TRIM DRAG

Additive Drag, Cowl Lip Suction And Bypass Subcritical Operation

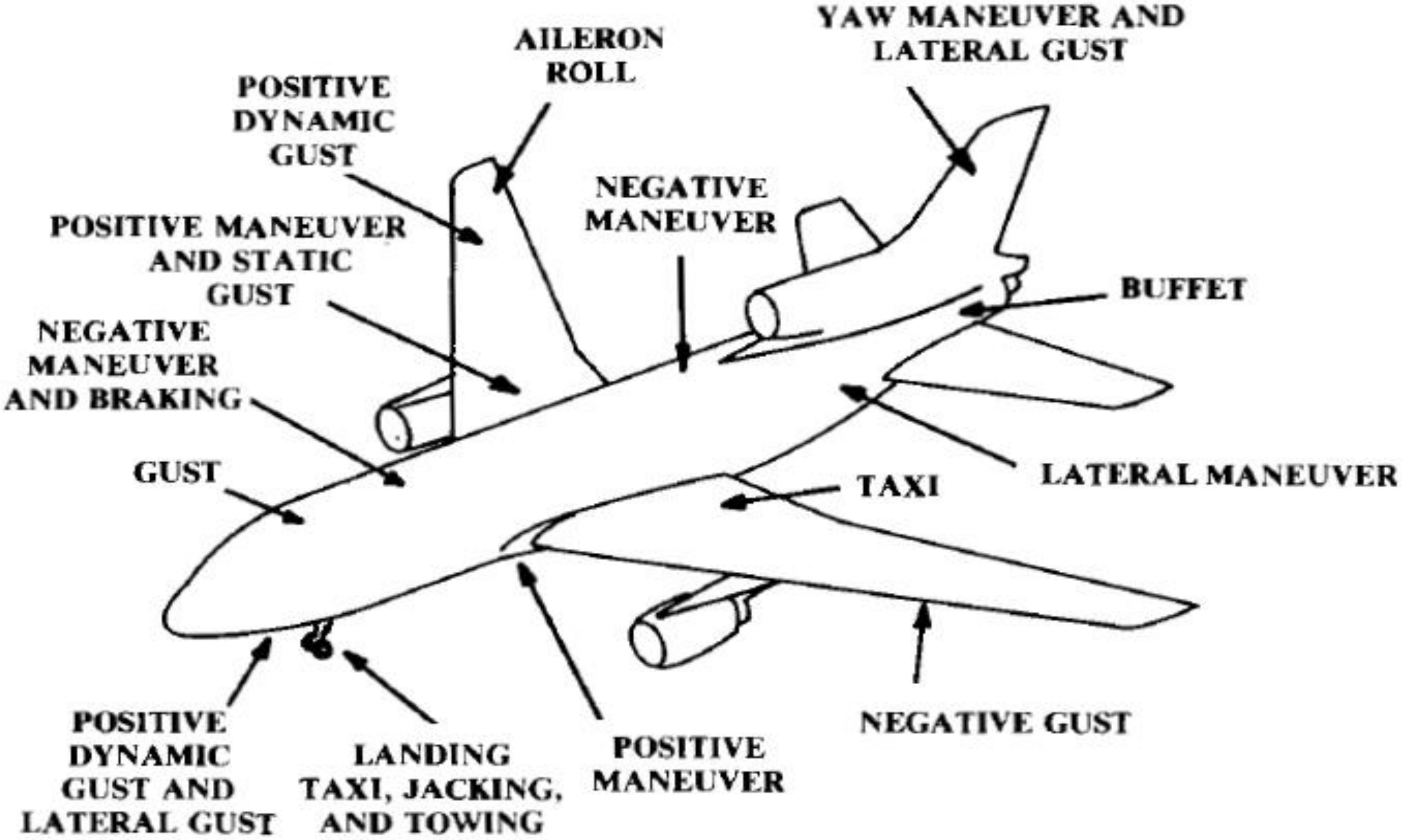


Additive Drag, Cowl Lip Suction And Bypass Subcritical Operation

Maneuver Loads

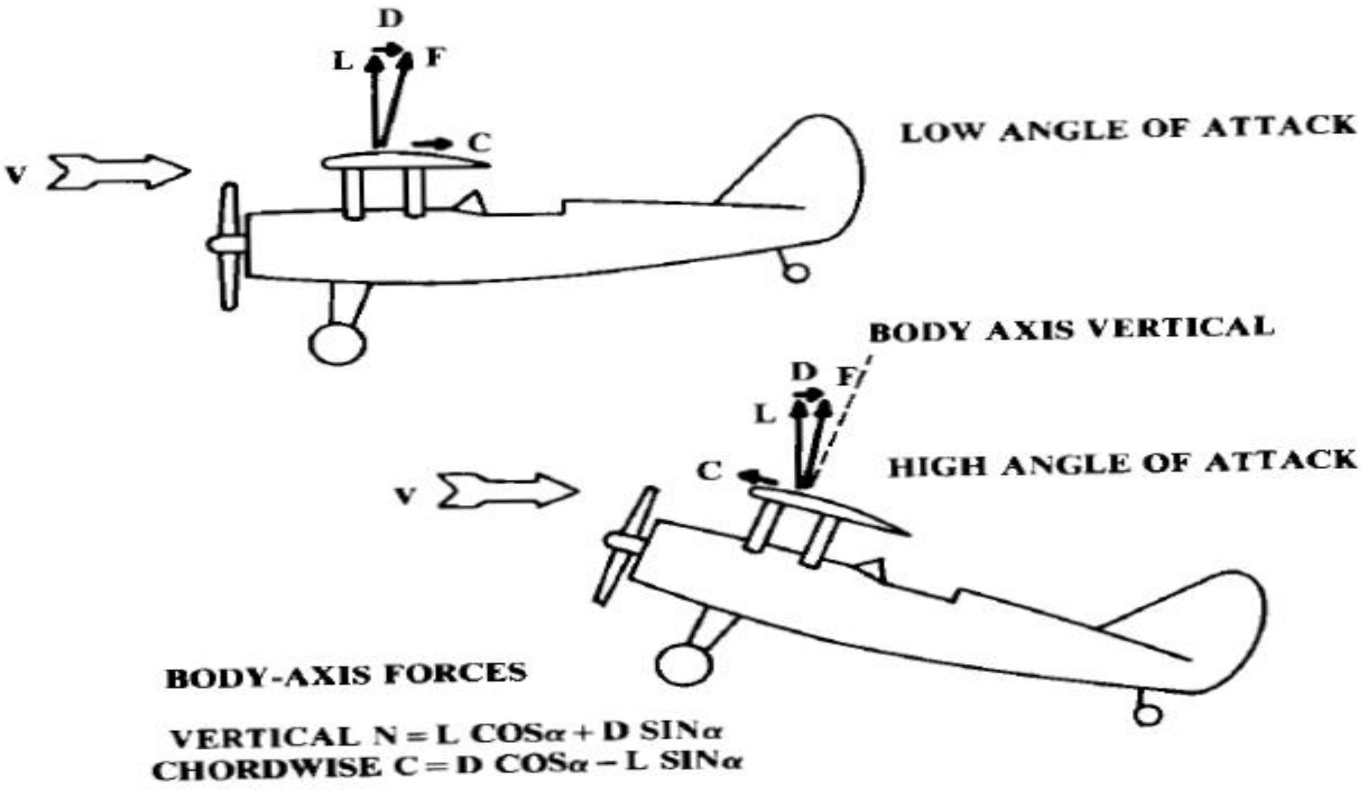
- The greatest air loads on an aircraft usually come from the generation of lift during high-g maneuvers.
- Even the fuselage is almost always structurally sized by the lift of the wing rather than by the air pressures produced directly on the fuselage.
- Aircraft load factor (n) expresses the maneuvering of an aircraft as a multiple of the standard acceleration due to gravity

L1011 Critical loads



Critical loads

Wing Load Direction At Angle Of Attack



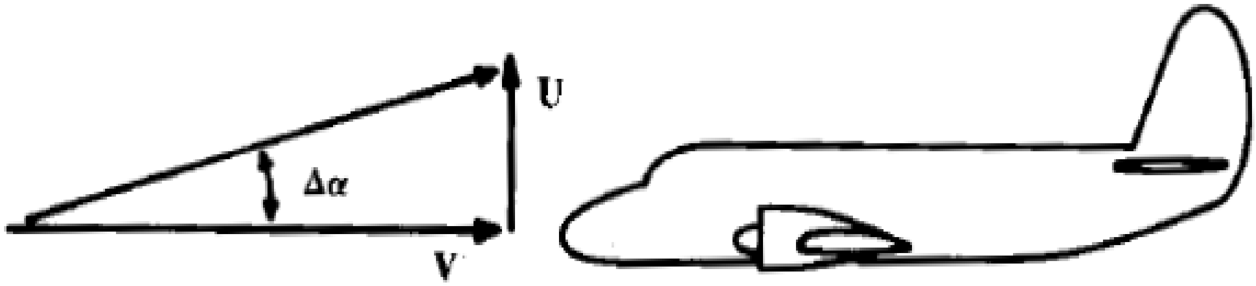
BODY-AXIS FORCES

VERTICAL $N = L\ COS\alpha + D\ SIN\alpha$
CHORDWISE $C = D\ COS\alpha - L\ SIN\alpha$

Wing Load Direction At Angle Of Attack

GUST LOADS

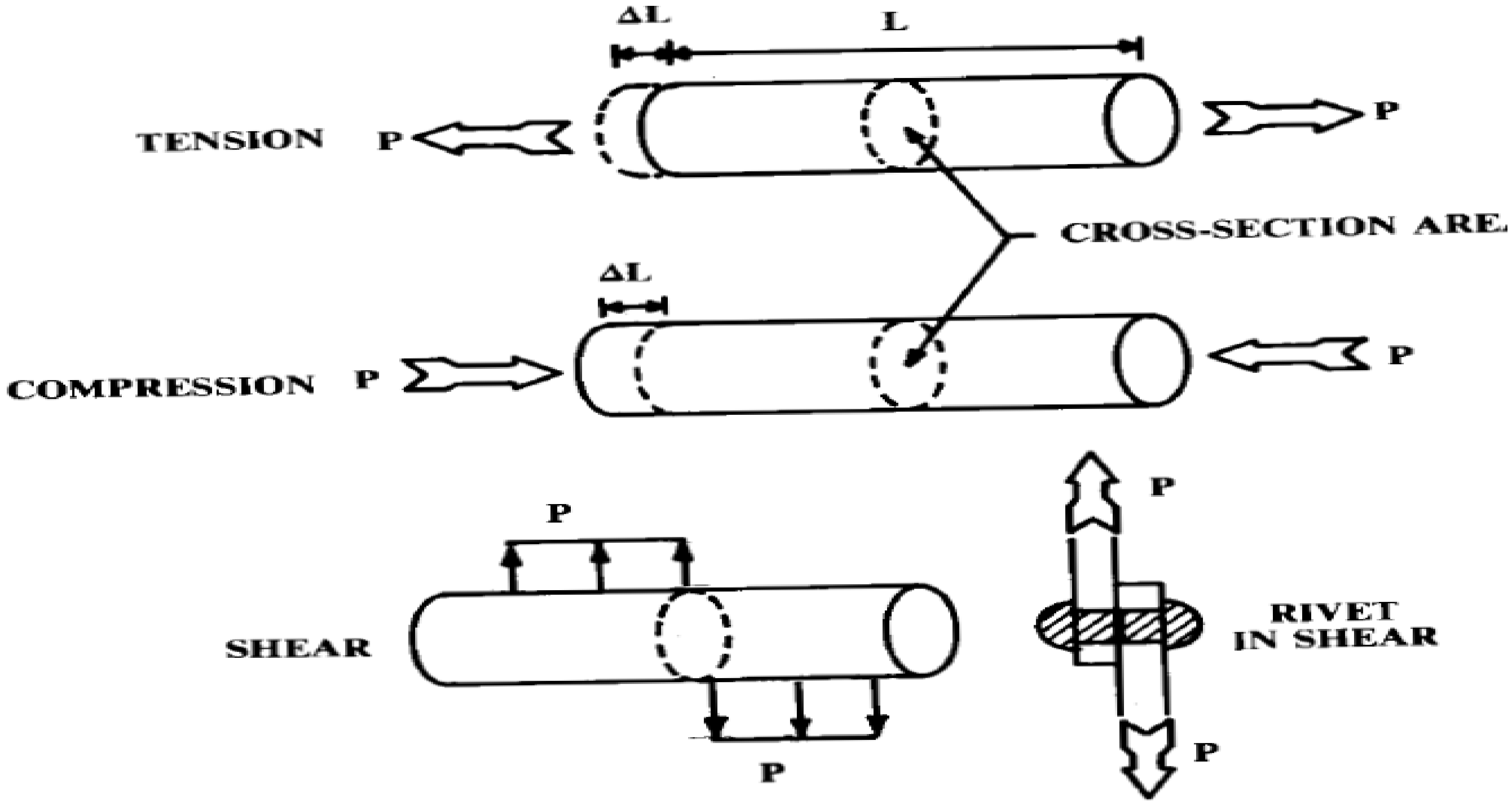
The loads experienced when the aircraft encounters a strong gust can exceed the maneuver loads in some cases. For a transport aircraft flying near thunderstorms or encountering high-altitude "clear air turbulence," it is not unheard of to experience load factors due to gusts ranging from a negative 1.5 to a positive 3.5 g or more.



POWER-PLANT LOADS

- The engine mounts must obviously be able to withstand the thrust of the engine as well as its drag when stopped or wind milling.
- The mounts must also vertically support the weight of the engine times the design load factor.
- The engine mounts are usually designed to support a lateral load equal to one-of the vertical design load.
- The mounts must withstand the gyroscopic loads caused by the rotating machinery (and propeller) at the maximum pitch and yaw rates

Three basic structural loadings



Three basic structural loadings

Air Load Distribution on Lifting Surfaces

- The first step involves a stability-and-control calculation to determine the required lift on the horizontal tail to balance the wing pitching moment at the critical conditions.
- Note that the required tail lift will increase or decrease the required wing lift to attain the same load factor.
- Complicated methods for estimating the lift on the trimmed tail and wing for a given load factor.
- These can be initially approximated by a simple summation of wing and tail moments about the aircraft center of gravity, ignoring the effects of downwash, thrust axis, etc.

Wing lift distribution

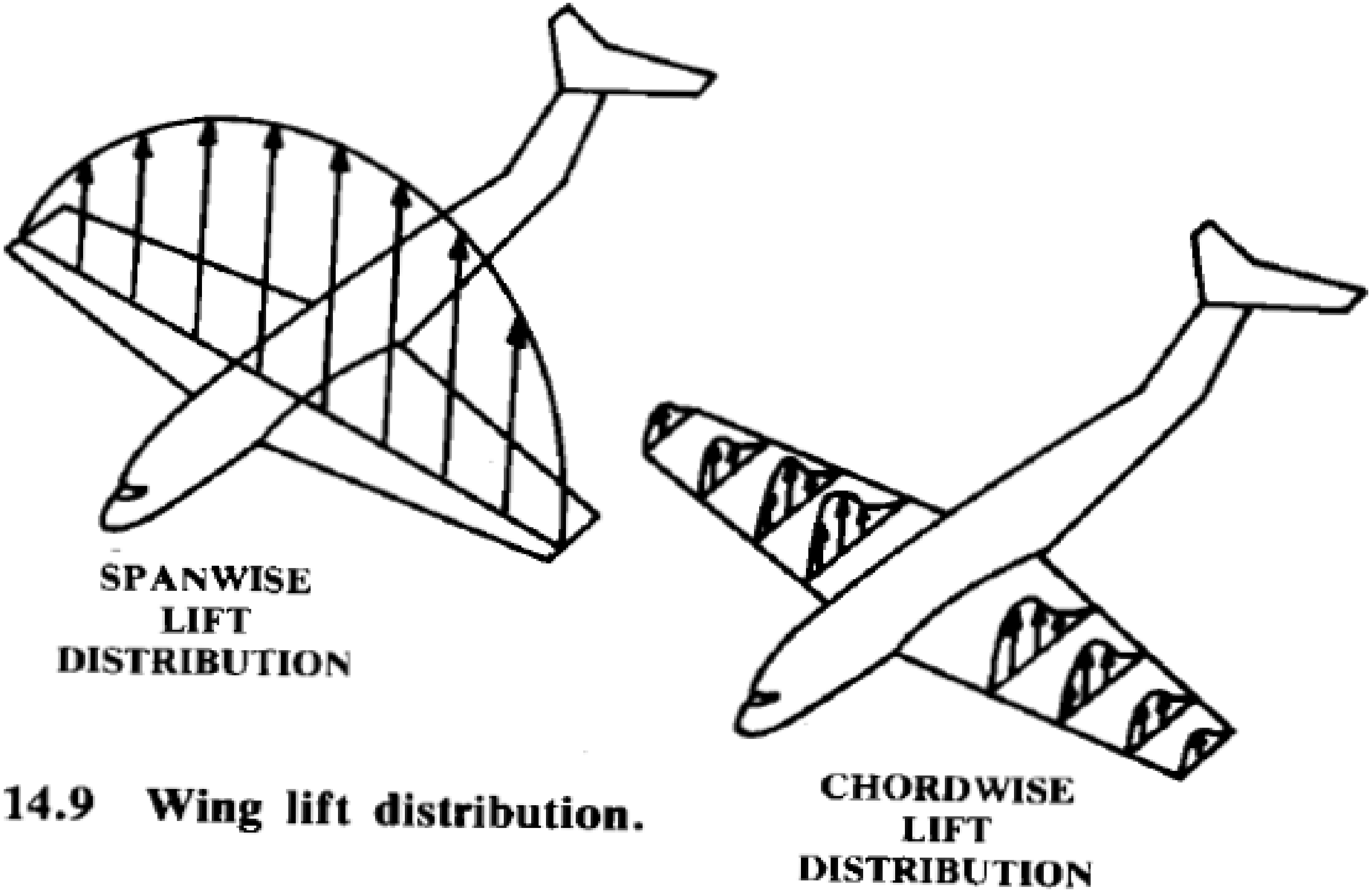
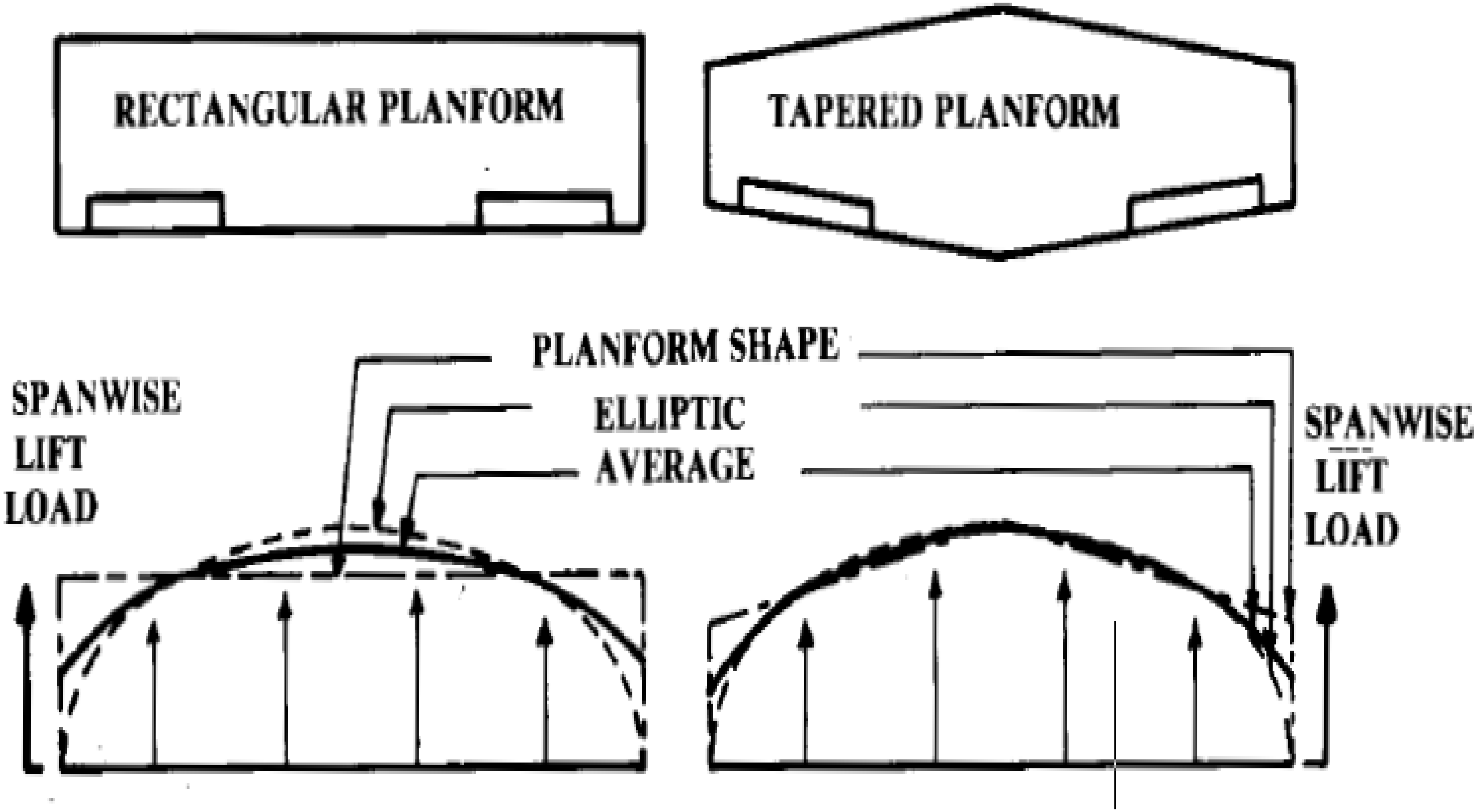


Fig. 14.9 Wing lift distribution.

Schrenk’s approximations



Schrenk’s approximations

Material Selection

- A number of properties are important to the selection of materials for an aircraft. The selection of the "best" material depends upon the application.
- Actors to be considered include yield and ultimate strength, stiffness, density, fracture toughness, fatigue crack resistance, creep, corrosion resistance, temperature limits, producibility, reparability, cost, and availability. Strength, stiffness, and density have been discussed already.

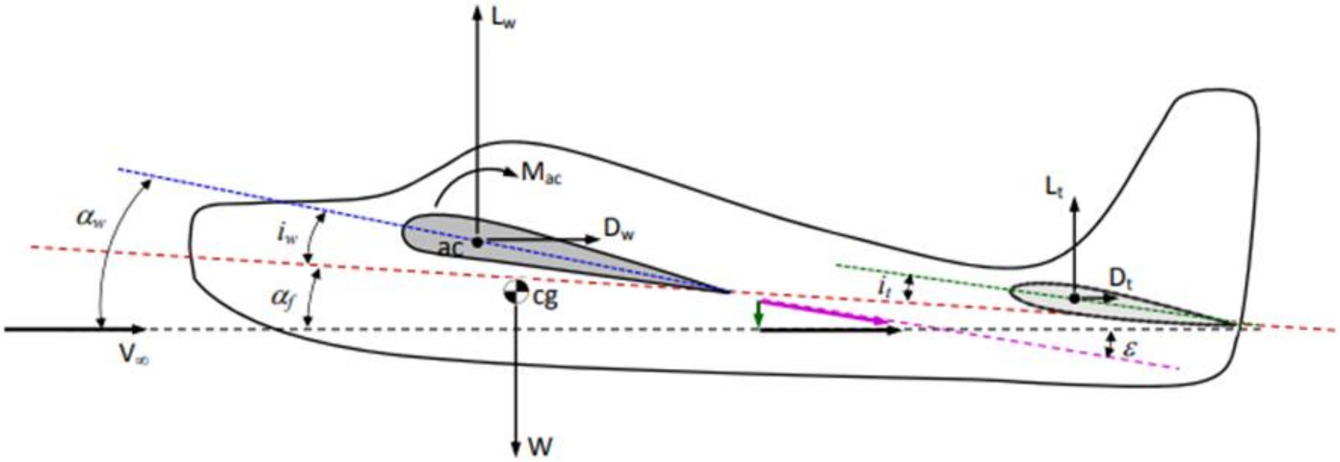
UNIT-IV

BASELINE DESIGN ANALYSIS - II

UNIT-IV

CLOs	Course Learning Outcome
CLO11	Understanding the concepts of different landing gear system
CLO12	Estimation of design-stability and control
CLO13	Analysis of performance under constrained conditions constraint

Estimation of static pitch stability



Longitudinal (pitch) stability requires a moment

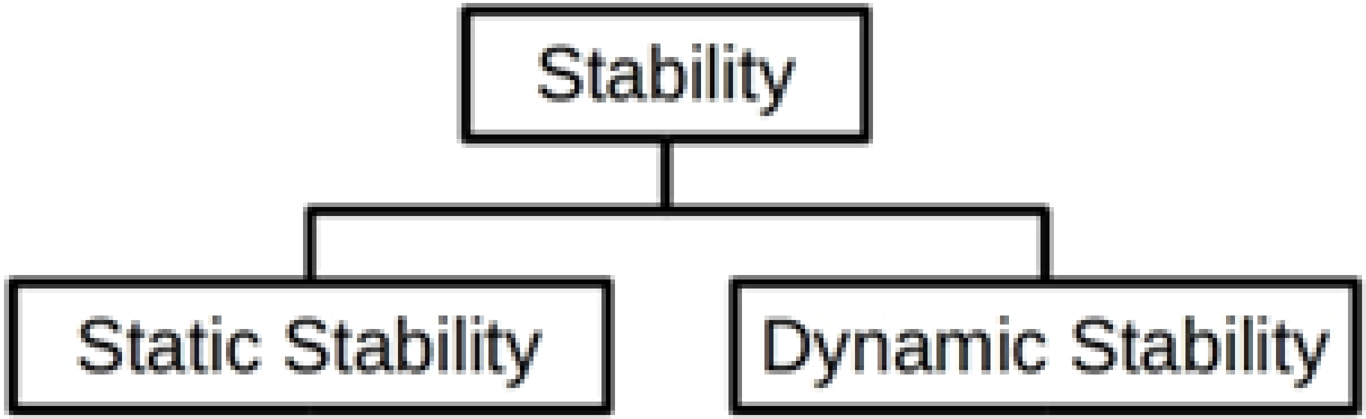
Static Pitch Stability

- Negative slope of the moment curve provides the static stability such that if the AoA increases (say, due to a momentary gust).
- A negative pitching moment brings the airplane AoA back to the equilibrium point.
- There is a certain equilibrium AoA at which the pitching moment about cg becomes zero.
- This corresponds to level flight conditions without any pitching.

STATIC PITCH STABILITY

- Note that if the airplane is designed for a level cruising flight along the fuselage axis (red dotted line)
- Then the AoA of airplane becomes zero.
- Therefore, in such a design, equilibrium point has to be achieved at zero AoA in the moment curve(i.e., $\alpha_e = 0$)

VELOCITY STABILITY AND TRIM


Stability

Static Stability

Dynamic Stability

Static Stability

- If an airplane disturbed from equilibrium state has "Initial Tendency" to return to its equilibrium state, then the aircraft is assumed to have static stability.
- Static equilibrium occurs whenever there is no acceleration (linear or angular) of the aircraft. Un-accelerated flight requires that the summations of forces and moments acting on the aircraft are zero.

Dynamic Stability

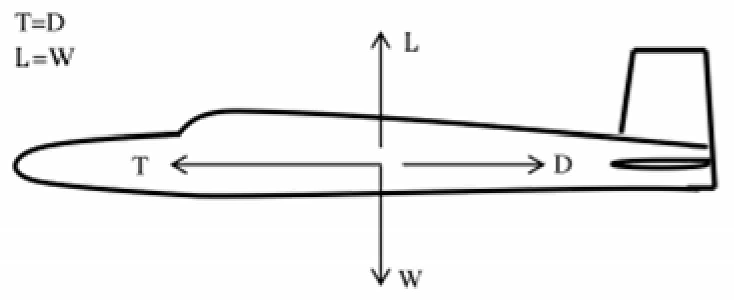
- Not only initial tendency, but also the amplitudes of the response due to disturbance decay in finite time to attain the equilibrium state.
- Static equilibrium also requires that the side force acting on the airplane is also zero.
- Additionally, the summation of moments about the center of gravity (CG) in roll, pitch and yaw must all be zero for equilibrium (Trimmed flight).

Stable Trim (longitudinal Axial)

- An object moving through the air will experience drag that opposes the motion.
- If angle of attack remains fixed, this drag will increase with speed. (Drag opposes increase in speed)
- Thrust developed by engine is either constant with airspeed or decrease with increasing air speed. (Drag increase in speed)
- In static equilibrium with regard to translational in the direction of motion, the forward component of thrust must balance the drag (T = D)

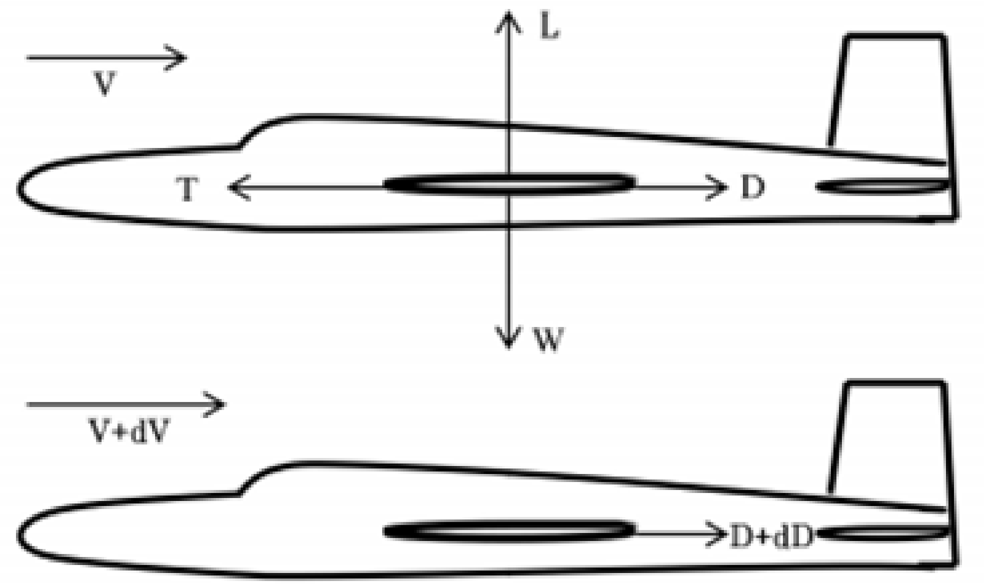
Pitch stability

- At constant angle of attack, a small increase in airspeed will result in
- Increase in Drag
- Either a decrease in Thrust or No change in Thrust a decrease



Pitch stability

dD will oppose dv



If dV is positive; dD will act to reduce/marginalize dV .If dV is negative; dD will tend to increase the speed as in that case T > D.

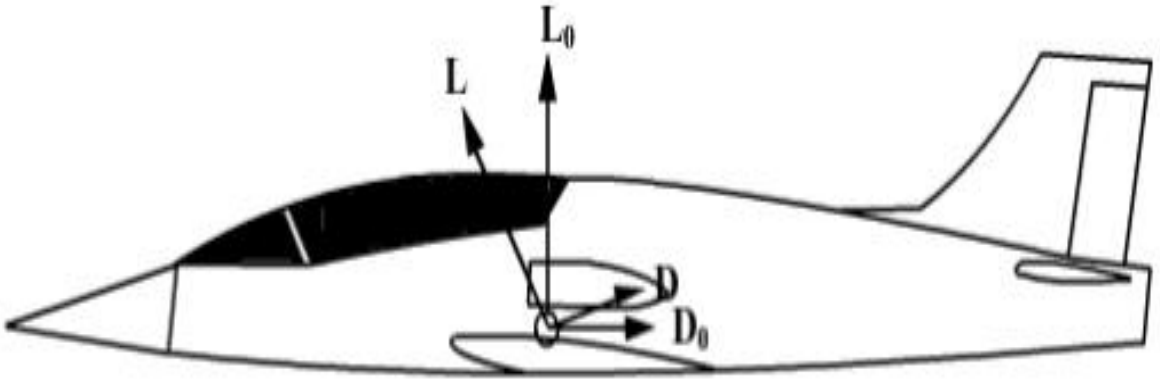
Estimation of Stability and Control Derivatives

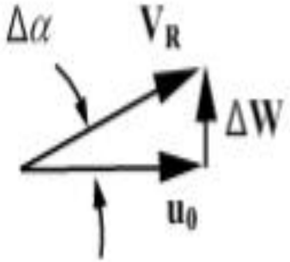
The solution of small perturbation equations for longitudinal motion would be taken up in chapter 8 and for the lateral motion in However, to solve these equations the stability derivatives are required. The following subsections deal with their estimation

∂X / ∂u

$$C_{Lu} = M_1 \frac{dC_L}{dM_1} = M_1 \alpha \frac{dC_{L\alpha}}{dM_1}$$

Stability derivatives due changes of w





Stability derivatives due changes of weight

Static Lateral, Directional Stability And Trim

- ❑ Stability is the tendency of an airplane to fly a prescribed flight course. Dynamic longitudinal stability concerns the motion of a statically stable airplane, one that will return to equilibrium after being disturbed.
- ❑ Basically, there are two primary forms of longitudinal oscillations with regard to an airplane attempting to return to equilibrium after being disturbed.
- ❑ The first form is the phuagoid mode of oscillation, which is a long-period slow oscillation of the airplane's flight path. The pilot generally can control this oscillation himself.

Estimation of Aircraft Dynamical Characteristics

- In this section we relate the dimensionless derivatives of the preceding section to the usual aerodynamic derivatives, and provide simple formulas for estimating them.
- It is natural to express the axial and normal force coefficients in terms of the lift and drag coefficients, but we must take into account the fact that perturbations in angle of attack will rotate the lift and drag vectors with respect to the body axes.

$$C_X = C_T - C_D \cos\alpha + C_L \sin\alpha \approx C_T - C_D + C_L\alpha$$

$$C_Z = -C_D \sin\alpha - C_L \cos\alpha \approx -C_D\alpha - C_L$$

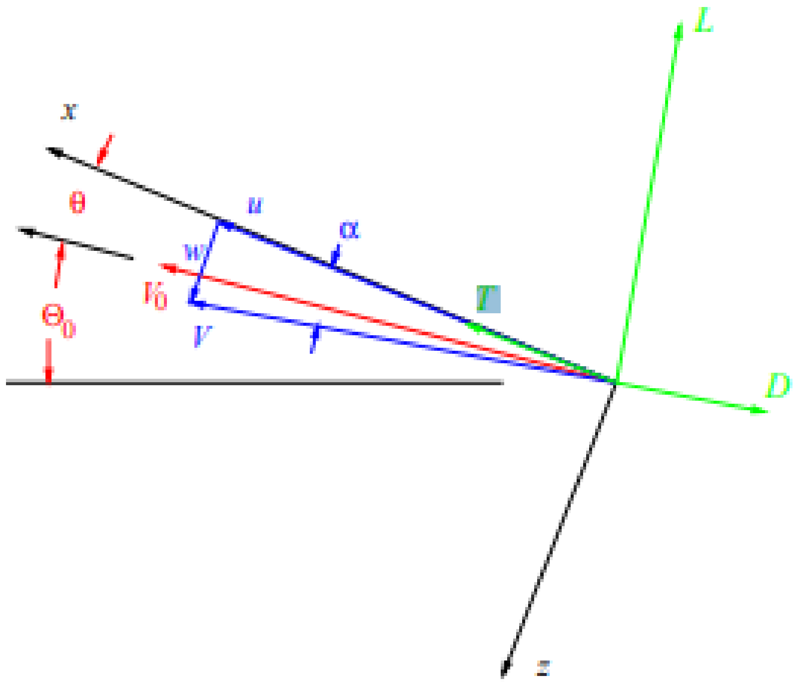
Speed Derivatives

- We first consider the derivatives with respect to vehicle speed u. The derivative Represents the speed damping, and

$$CDu = M \frac{\partial Cd}{\partial M}$$

- Orientation of body axes with respect to instantaneous and equilibrium vehicle velocity, illustrating relation between force components in body axes and lifts, drag, and thrust forces.
- The angle of attack α denotes the angle between the x-axis and the instantaneous velocity vector V

Orientation of body axes with respect to instantaneous and equilibrium vehicle velocity



Orientation of body axes with respect to instantaneous and equilibrium vehicle velocity

HANDLING QUALITIES

- We are continuing our lecture on how to model stick force and try to understand the importance of Hinge moment coefficients on designing a system, reversible control system for aircraft, so the stick force is well within the capability of the pilot, the pilot can fly at ease, right.
- So, if you recall before I come to stick force modeling let me write few statements.

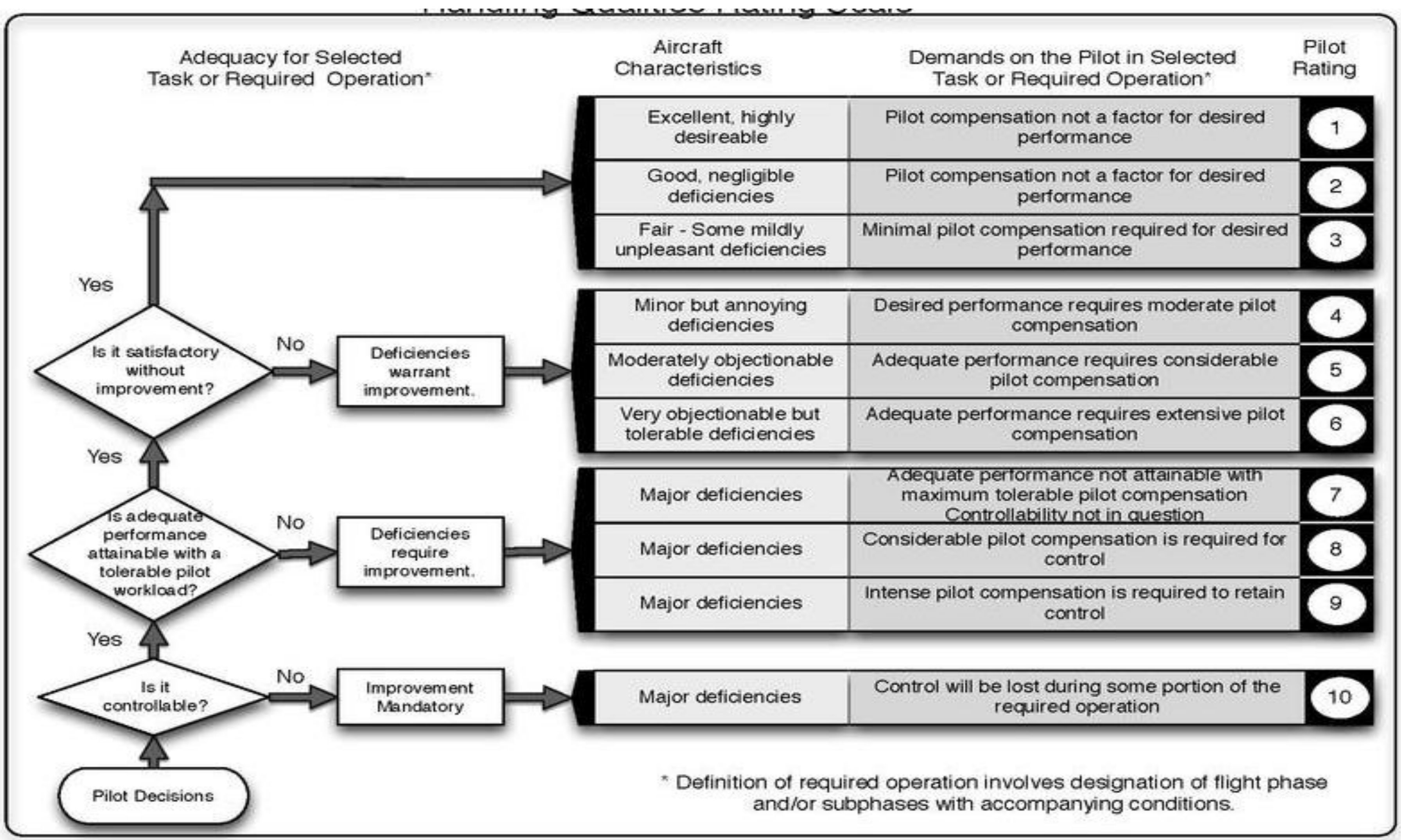
Handling Qualities

- Precision of flight can be quantified in terms of rounds on target for gun tracking, circular error probability for bombing or sink rate for landing, for example.
- Workload is more difficult to quantify, and for the time being we simply ask the pilot how easy or difficult his job is.
- Much of the achievement of handling-qualities practitioners has been in acquiring reliable information on pilot workload from pilots

Cooper Harper Scale

- The Cooper-Harper Rating Scale is the current standard for evaluating aircraft handling qualities. It makes use of a decision tree that assesses adequacy for task, aircraft characteristics, and demands on the pilot to calculate and rate the handling qualities of an aircraft.
- George Cooper's standardized system for rating an aircraft's flying qualities. Cooper developed his rating system over several years as a result of the need to quantify the pilot's judgment of an aircraft's handling in a fashion that could be used in the stability and control design process.

Handling qualities Rating scales



Adequacy for Selected Task or Required Operation*

Pilot Decisions

Is it controllable?
No → Improvement Mandatory
Yes ↑

Is adequate performance attainable with a tolerable pilot workload?
No → Deficiencies require improvement.
Yes ↑

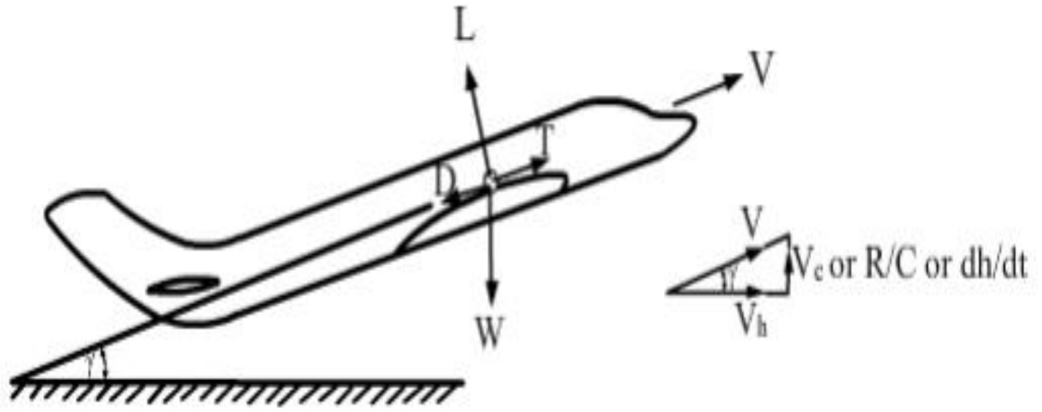
Is it satisfactory without improvement?
No → Deficiencies warrant improvement.
Yes ↑

Aircraft Characteristics	Demands on the Pilot in Selected Task or Required Operation*	Pilot Rating
Excellent, highly desireable	Pilot compensation not a factor for desired performance	1
Good, negligible deficiencies	Pilot compensation not a factor for desired performance	2
Fair - Some mildly unpleasant deficiencies	Minimal pilot compensation required for desired performance	3
Minor but annoying deficiencies	Desired performance requires moderate pilot compensation	4
Moderately objectionable deficiencies	Adequate performance requires considerable pilot compensation	5
Very objectionable but tolerable deficiencies	Adequate performance requires extensive pilot compensation	6
Major deficiencies	Adequate performance not attainable with maximum tolerable pilot compensation Controllability not in question	7
Major deficiencies	Considerable pilot compensation is required for control	8
Major deficiencies	Intense pilot compensation is required to retain control	9
Major deficiencies	Control will be lost during some portion of the required operation	10

* Definition of required operation involves designation of flight phase and/or subphases with accompanying conditions.

Steady Level Flight, Minimum Thrust Required For Level Flight

- During a steady climb the center of gravity of the airplane moves at a constant velocity along a straight line inclined to the horizontal at an angle γ The forces acting on the airplane are shown in



Steady climb

Thrust And Power Required For A Prescribed Rate Of Climb At A Given Flight Speed

- Here it is assumed that the weight of the airplane (W), the wing area (S) and the drag polar are given.
- The thrust required and power required for a chosen rate of climb (Vc) at a given altitude (h) and flight speed (V) can be obtained, for a general case, by following the steps given below.
- It may be pointed out that the lift and drag in climb are different from those in level flight.
- Hence, the quantities involved in the analysis of climb performance are, hereafter indicated by the suffix ‘c’ i.e. lift in climb is denoted by Lc

UNIT-V

COST ESTIMATION, PARAMETRIC ANALYSIS, OPTIMISATION, REFINED SIZING AND TRADE STUDIES

CLOs	Course Learning Outcome
CLO 14	Acquire Basic knowledge to solve real time problems in Aircraft propulsion and structure with different loading conditions
CLO 15	Apply the fundamental concepts in competitive examinations

Elements Of Life Cycle Cost ,Cost Estimating Method

Cost Estimating

- The purpose of cost estimating is to forecast the cost of a project prior to its actual construction. Cost estimating is a method of approximating the probable cost of a project before its construction.
- The exact cost of a project is known after completion of the project.
- Cost estimate is prepared at various stages during the life of a project on the basis of the information available during the time of preparation of the estimate.
- Generally for any construction project, three parties are involved namely owner, design professionals and construction professionals

Types of Estimates

- There are different types of estimates which are prepared at various stages during the life of a project starting from the initial phases to its final phase on the basis of the available information at the time of preparation of the estimates.
- The approximate estimates are prepared during initial stages of the project life cycle.
- These estimates are also known as preliminary, budget or order-of magnitude estimates and are prepared to determine the preliminary cost of the project.

Estimates during conceptual planning

- This estimate is prepared at the very initial stage i.e. during conceptual planning stage of a project.
- It is based on little information and on broad parameters namely size of the project, location and job site conditions and the expected construction quality of project as a whole.
- The size of the project may be expressed in terms of its capacity namely number of rooms for a hostel, number of beds for a hospital, length (km) of a highway etc.
- Owner of the project provides adequate input for defining scope of the project and this scope of the project forms the basis on which the conceptual estimate is prepared.
- This estimate is prepared to establish the preliminary budget of the project and accordingly project funding can be arranged.

Estimates during schematic design

- During this phase of the project, the cost estimate is prepared on the basis of preliminary design information along with required schematic documents.
- The designer may incorporate different design alternatives and the cost estimate is prepared for these design alternatives by the estimators depending on the available information.
- The cost estimates of different design alternatives are reviewed keeping in view the project scope and budget and the acceptable alternative(s) selected in this phase is analyzed in a detailed manner in the next phase of the project.

Estimates during design development

- During design development phase of the project, the cost estimate is prepared on the basis of more detailed design information and schematic documents.
- With the improved level of information, the most of the major project items namely volume of earthwork volume of concrete weight of steel etc.
- The project elements costing too high or too low as compared to past data should be reviewed and accordingly adjusted can be quantified

Estimates during procurement (i.e. estimates for construction of the project)

- During this phase of the project, the cost estimate is prepared on the basis of complete set of contract documents that defines the project.
- The contractors bidding for the project prepare the cost estimate in accordance with contract documents by taking into consideration the estimated project duration.
- As already mentioned in the previous lecture

RDT&E AND PRODUCTION COSTS

- RDT & E represent the cost towards research, development, test and evaluation of the airplane. It includes the cost of technology development and research, design engineering.
- The purchase cost of the civil airplane (civil purchase price) is arrived at based on expenses towards
    - RDT & E,
    - Production cost and
    - Fair amount of profit.

Operation And Maintenance Costs, Cost Measures of Merit

- In the case of military airplane the RDT & E cost may be paid by the government.
- Generally along with the airplane a certain amount of spares are also purchased which may amount to 10 -15% of the initial cost.

    (a) RDT & E,

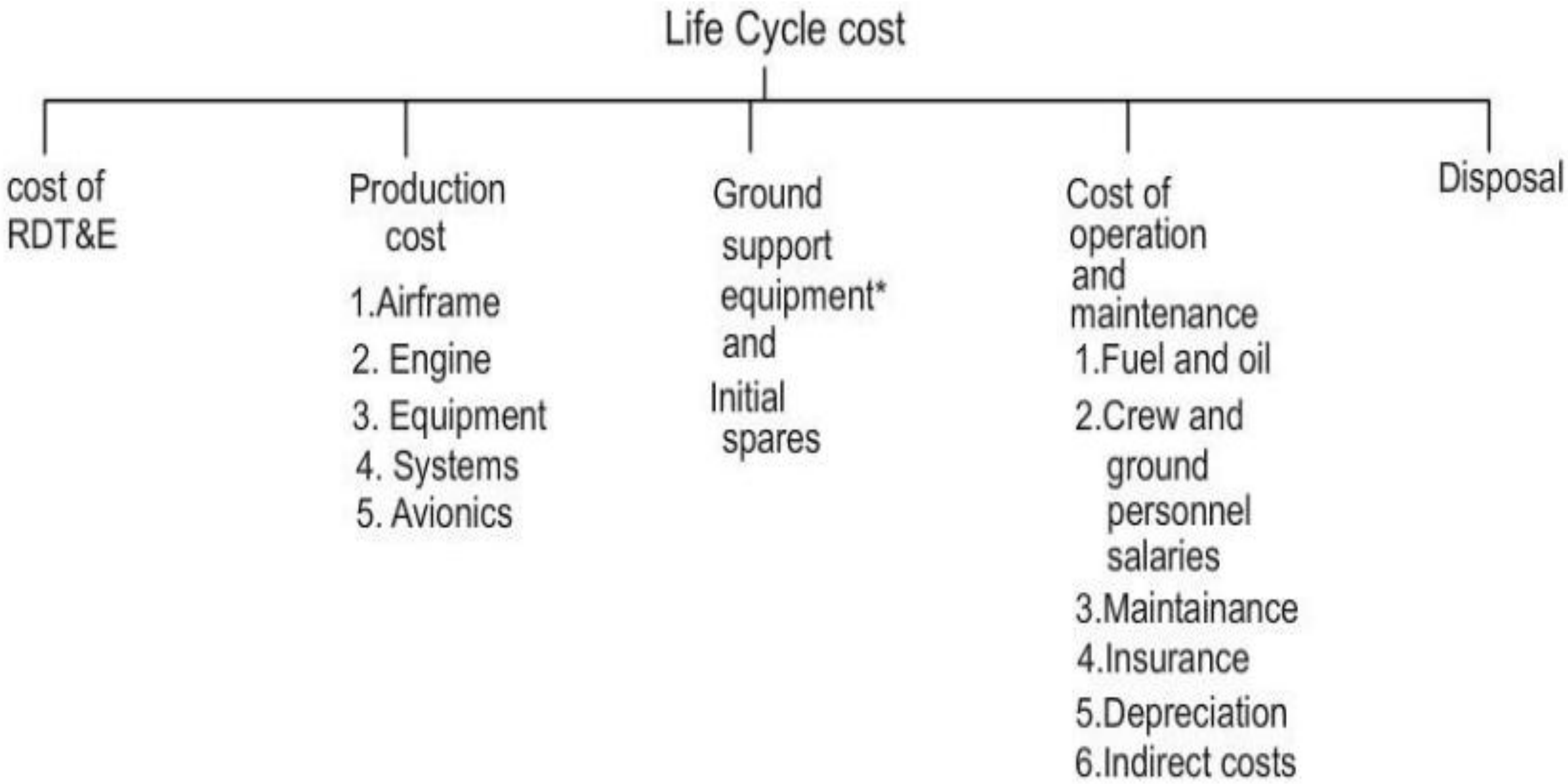
    (b) Production,

    (c) Ground support equipment,

    (d) Initial spares and

    (e) Special construction, constitute the program cost.

Subdivisions of life cycle cost



Life Cycle cost

- cost of RDT&E
- Production cost
  - 1.Airframe
  - 2. Engine
  - 3. Equipment
  - 4. Systems
  - 5. Avionics
- Ground support equipment* and Initial spares
- Cost of operation and maintenance
  - 1.Fuel and oil
  - 2.Crew and ground personnel salaries
  - 3.Maintainance
  - 4.Insurance
  - 5.Depreciation
  - 6.Indirect costs
- Disposal

The operations and the maintenance costs include

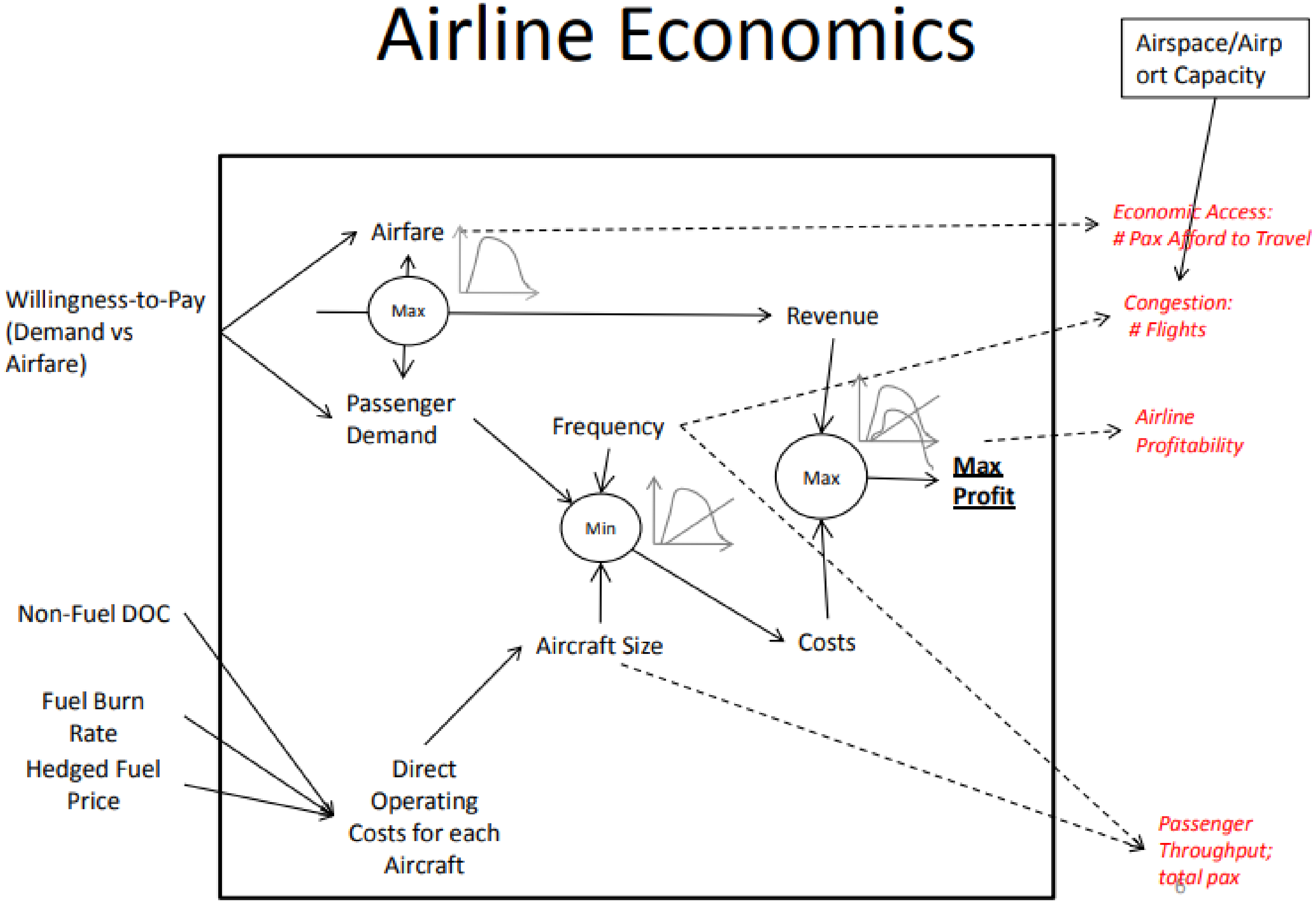
- The costs of fuel and oil,
- Salaries of crew and ground personnel,
- Cost of maintenance,
- Insurance
- Depreciation for civil airplane and
- Indirect costs.

Disposal cost

- For military aircraft the cost of taking to the disposal location is generally ignored. In the case of civil airplanes, the scrap value of the airplane is typically 10% of the purchase price.
- For military airplanes a life time of 20 years is assumed and the cost of operation, maintenance and disposal is added to the program cost of the airplane.
- This constitutes the life cycle cost.
- This cost along with the performance of the airplane decides the choice of the airplane.

Airline Economics

Airline Economics



Airspace/Airport Capacity

Airfare

Max

Revenue

Willingness-to-Pay (Demand vs Airfare)

Passenger Demand

Frequency

Min

Max

Max Profit

Aircraft Size

Costs

Non-Fuel DOC

Fuel Burn Rate

Hedged Fuel Price

Direct Operating Costs for each Aircraft

Economic Access: # Pax Afford to Travel

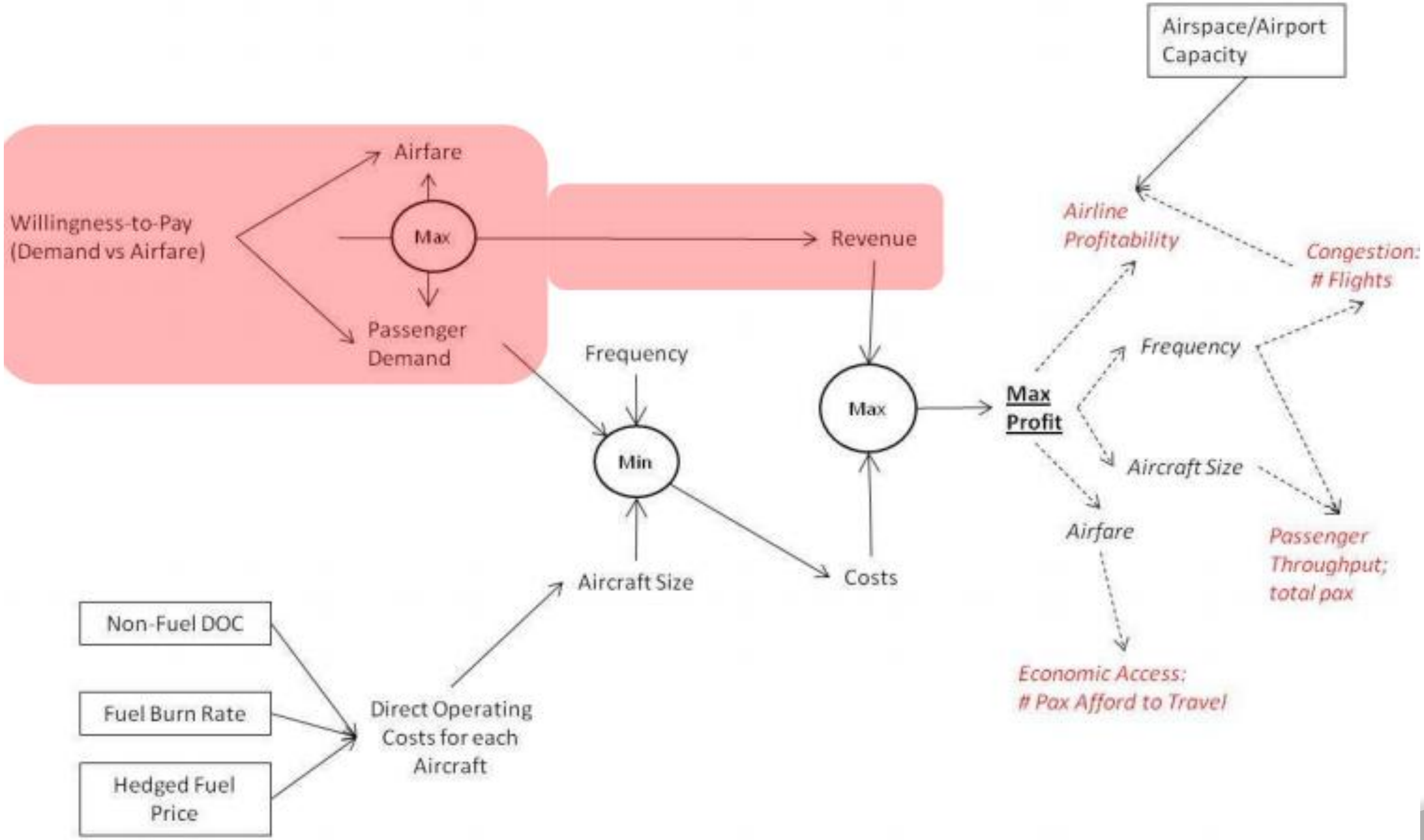
Congestion: # Flights

Airline Profitability

Passenger Throughput; total pax

Revenue of airline economics

Revenue

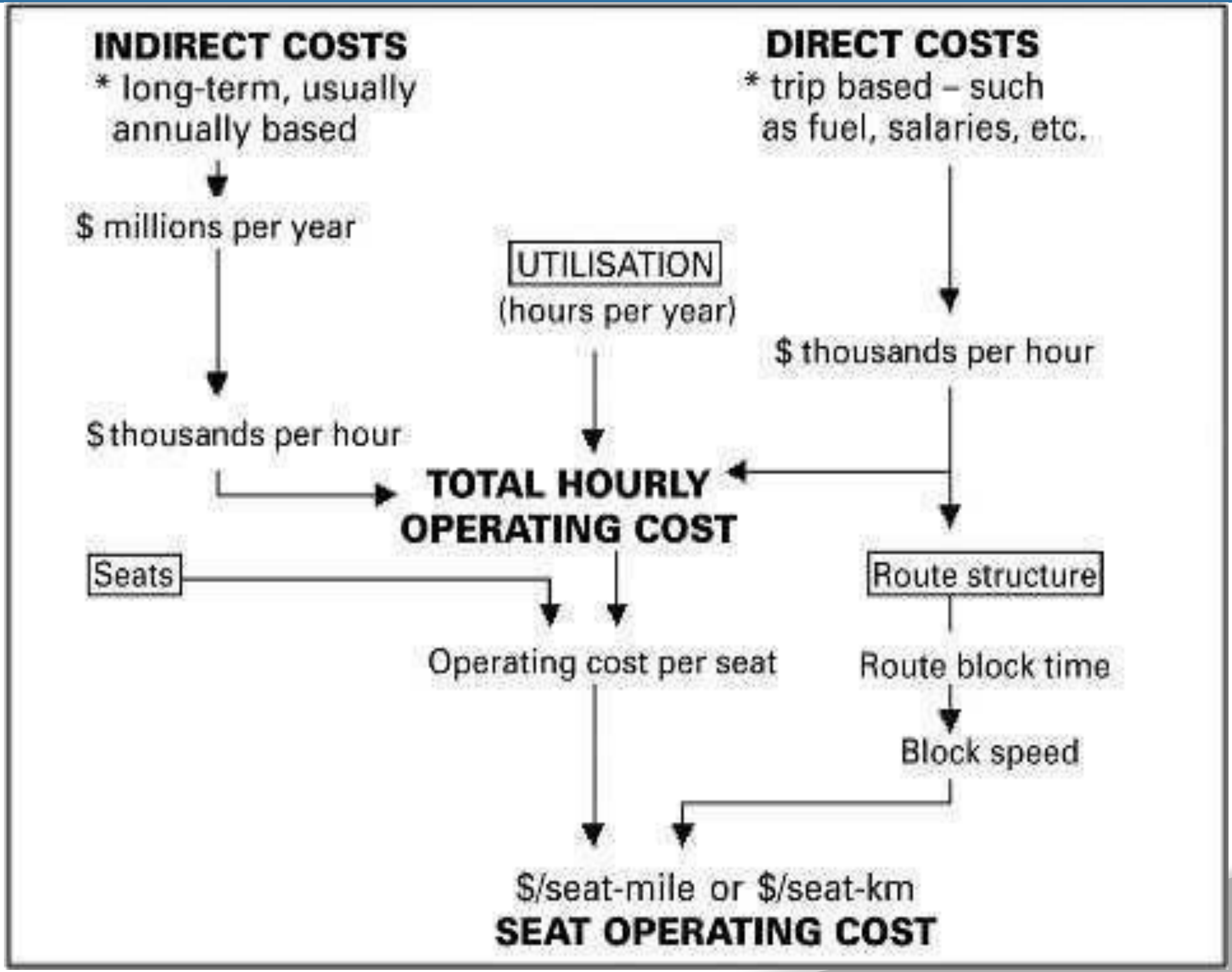


DOC And IOC, Airline Revenue, Breakeven Analysis, Investment Cost Analysis

When the mile cost (km cost) is divided by the maximum number of seats on the airplane, it gives the seat mile (or km) cost. It is expressed as cents per seat-km. This cost is an index of the efficiency of the design

- Direct Operating Cost (DOC)
- Indirect Operating Cost (IOC)

DOC AND IOC


INDIRECT COSTS
* long-term, usually annually based
$ millions per year
$ thousands per hour
DIRECT COSTS
* trip based – such as fuel, salaries, etc.
$ thousands per hour
UTILISATION
(hours per year)
TOTAL HOURLY OPERATING COST
Seats
Operating cost per seat
Route structure
Route block time
Block speed
$/seat-mile or $/seat-km
SEAT OPERATING COST

Direct Operating Cost (DOC):

The DOC is based on the expenses associated with the flying and maintenance of the airplane. Following these can be divided into

- Standing charges,
- Maintenance cost and,
- Flight operational cost,
- The standing charges include cost of depreciation.

The Indirect Operating Cost (IOC)

It is not dependent on the number of hours flown by the airplane. It includes

(a) Cost towards depreciation and maintenance on the ground equipment,

(b) Cost of administrative, technical and customer services,

(c) Advertising, promotion and sales, and

(d) Training. IOC is not an insignificant cost. It could be as high as DOC.

Parametric Analysis And Optimization

- The parametric cost estimate is based on cost-estimating relationships those use past cost data to obtain the current cost estimate.
- Cost estimating relationships are statistical models those relate the cost of a product or system to the physical attributes those define its characteristics.
- One of the most commonly used cost-estimating relationships is power-sizing model.

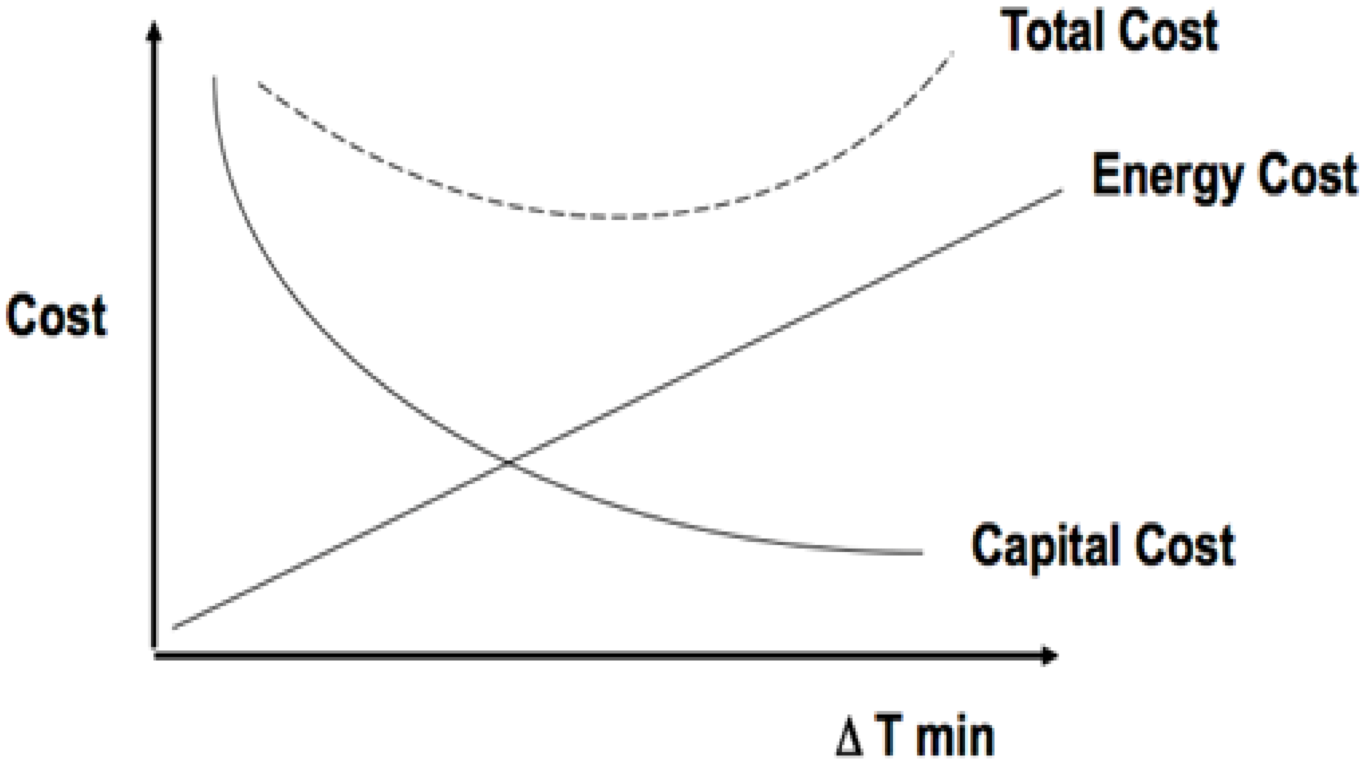
Improved Conceptual Sizing Methods

- Sizing matrix plot and carpet plot, trade studies, At the end of the preliminary design phase, a configuration of the airplane is available.
- This configuration is called base line configuration. Using this configuration the revised drag polar, fuel required and gross weight can be obtained.
- Further, parametric studies by varying certain parameters can be carried out to get near optimum shape/parameters. Such studies are called sizing and trade studies.

DESIGN TRADES

- Optimization of process design follows the general outline below:
- Establish optimization criteria: using an objective function that is an economic performance measure.
- Define optimization problem: establish various mathematical relations and limitations that describe the aspects of the design
- Design a process model with appropriate cost and economic data

Trade-off example



Trade-off example

CASE STUDIES ON DESIGN OF DC-3

Purpose

- The purpose of this exercise is to analyze the unique design of the DC-3 which as the first profit-making passenger aircraft revolutionized commercial aviation.
- So successful was the DC-3 that it served as the prototype for the design of all commercial propeller-driven aircraft, only to be superseded by the jets.
- It is still being used on airlines in the United States and abroad.

The Problem

In the early 1930s as well as the nature of the competition. The five essential elements are:

- speed
- reliability
- comfort
- safety
- profit

The following are among the most notable of the Trimotor's design features:

- A corrugated aluminum fuselage and wing
- Large, non-retractable landing gear
- 3 uncovered engines--one mounted at the front of the fuselage, the other two suspended from the wings.

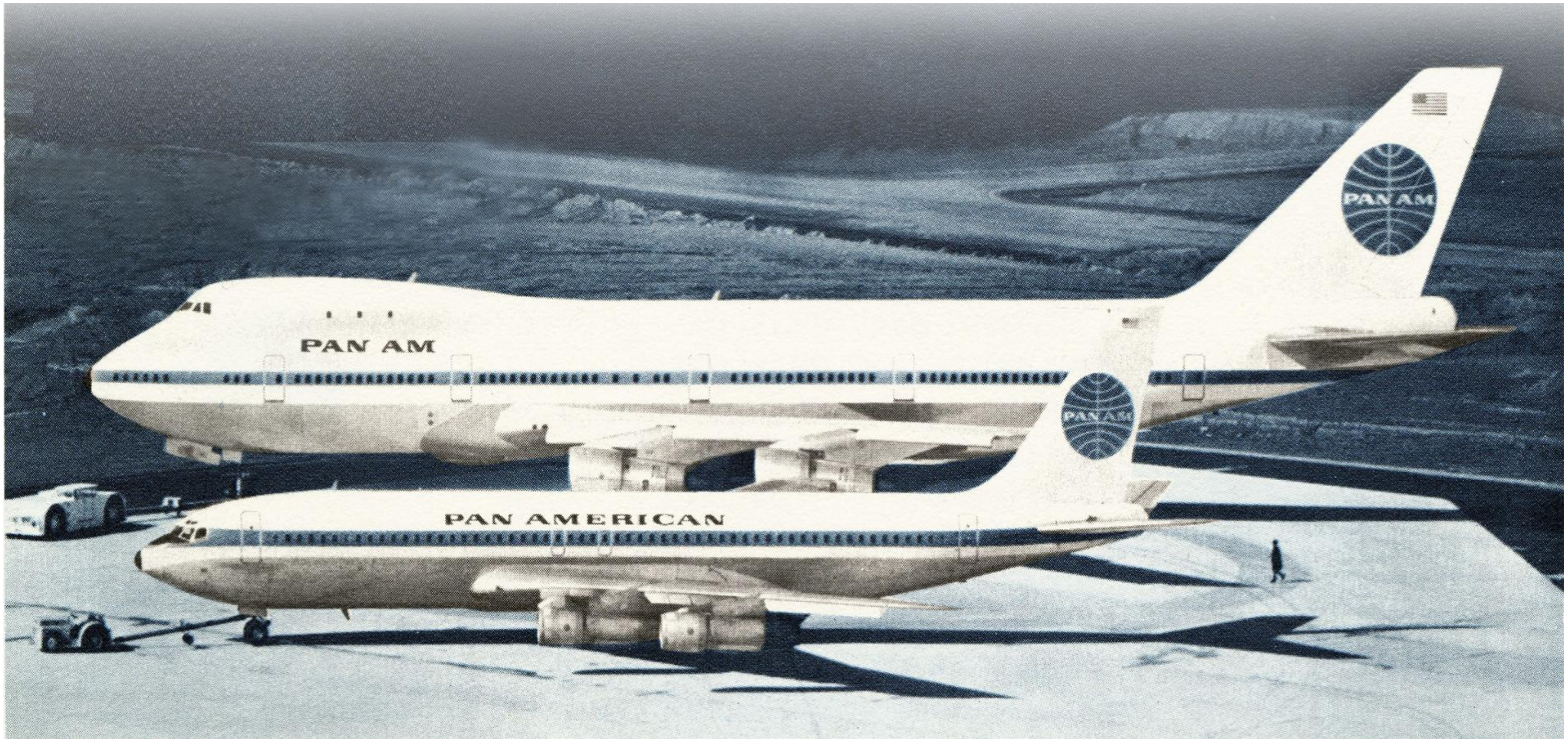
Conclusion

- It is the thesis of this abstract that while it is perfectly valid to "read" a machine
- It might be exciting for students to take this premise one step further-to "read" machines, define their problems, and
- Be encouraged to "solve" them to produce new machines.
- Indeed, there appears to be one pitfall inherent in this approach.

BOEING B-707&747;

- Since helping launch the commercial jet aircraft age with its 707 model in the 1950s
- The Boeing Company has taken very large risks (some might even say gambles) on developing new generations of wide-body commercial jet aircraft.
- This approach has historically been known as a “bet the company strategy.”

BOEING B-707&747;



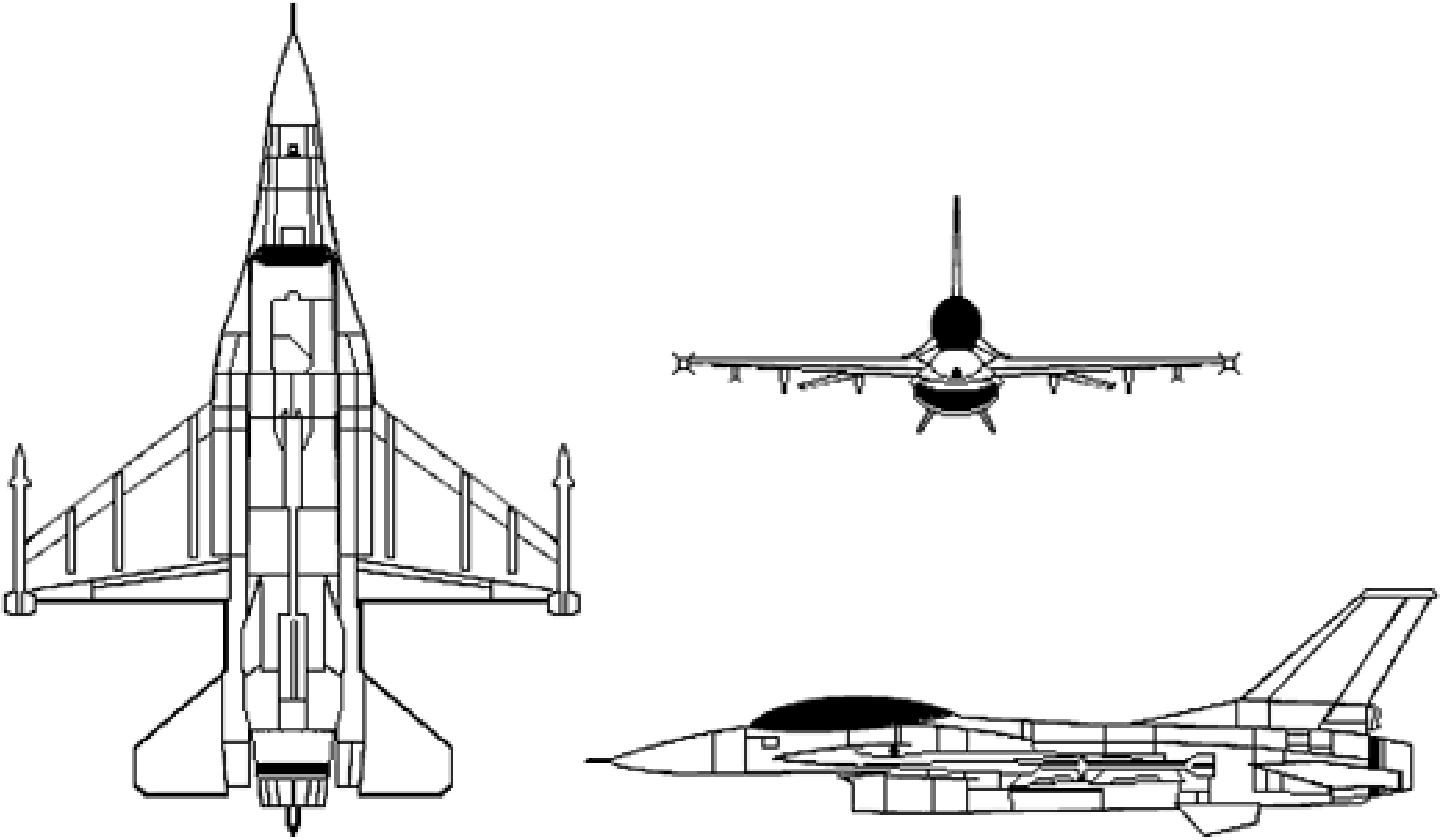
BOEING B-707&747;

- This includes, but is not limited to, accommodating unique customer demand requirements on a global scale, rationalization in down cycles, improvement of assembly and manufacturing processes and either buying out (e.g., acquiring McDonnell Douglas) or driving out (e.g., Lockheed) its major US commercial jet aircraft competitors.
- While Boeing’s stock price has been cyclical, investors have learned to be patient every time the company undertakes a bigger bet when launching a new generation of aircraft.
- In general, as shown in Exhibit II the price of stocks have been more in line with future orders rather than net profit.

GENERAL DYNAMICS F-16

Fighting Falcon

views of F-16 Fighting Falcon



views of F-16 Fighting Falcon

views of F-16 Fighting Falcon

- A computerized “fly-by-wire” stabilizing system issues continuous commands to control surfaces in the tail and wings, and a “heads-up-display” instrumentation system projects flying and combat data onto a transparent screen in front of the pilot.
- In addition, a highly sophisticated bomb-aiming system, using a laser range-finder and high-speed digital data processing permits ordinary “dumb” bombs to be dropped with precision accuracy from low altitudes.

SR-71 BLACKBIRD

SR-71 BLACKBIRD

- The Lockheed SR-71 "Blackbird" is a long-range, Mach3+ strategic reconnaissance aircraft that was operated by the United States Air Force
- American aerospace engineer Clarence "Kelly“ Johnsonwas responsible for many of the design's innovative concepts. During aerial reconnaissance missions, the SR-71 operated at high speeds and altitudes to allow it to outrace threats.
- If a surface-to-air missile launch were detected, the standard evasive action was simply to accelerate and outfly the missile. The shape of the SR-71 was based on the A-12 which was one of the first aircraft to be designed with a reduced radar cross-section

NORTHROP-GRUMMAN B-2 STEALTH BOMBER.

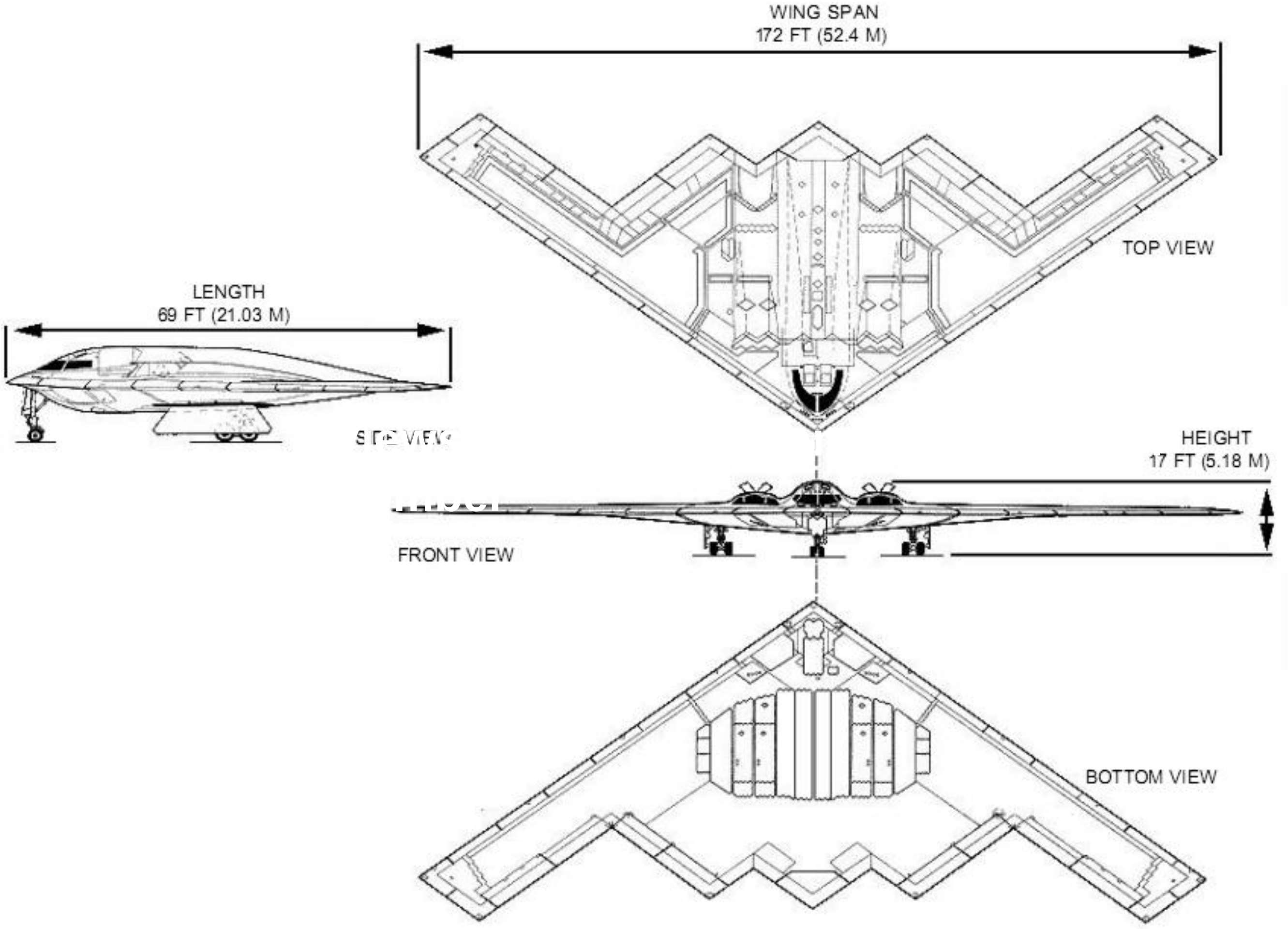
Design

Northrop-Grumman B-2 Stealth Bomber

Overview

- The B-2 Spirit was developed to take over the USAF's vital penetration missions, able to travel deep into enemy territory to deploy ordnance which could include nuclear weapons The B-2 is a flying wing aircraft, meaning that it has no fuselage or tail.
- It has significant advantages over previous bombers due to its blend of low-observable technologies with high aerodynamic efficiency and large payload.

Views Northrop-Grumman B-2 Stealth Bomber



Views Northrop-Grumman B-2 Stealth Bomber

General characteristics

- Crew: 2: pilot (left seat) and mission commander (right seat)
- Length: 69 ft (21 m)
- Wingspan: 172 ft (52 m)
- Height: 17 ft (5.2 m)
- Wing area: 5,140 sq ft (478 m2)
- Empty weight: 158,000 lb (71,668 kg)
- Gross weight: 336,500 lb (152,634 kg)
- Max takeoff weight: 376,000 lb (170,551 kg)
- Fuel capacity: 167,000 pounds (75,750 kg)
- Power plant: 4 × General Electric F118-GE-100 nor afterburning turbofans, 17,300 lbf (77 kN) thrust each

Performance

- Maximum speed: 630 mph (1,014 km/h; 547 kn) at 40,000 ft altitude / Mach 0.95 at sea level[verification needed]
- Maximum speed: Mach 0.95
- Cruise speed: 560 mph (901 km/h; 487 kn) at 40,000 ft altitude
- Range: 6,905 mi; 11,112 km (6,000 nmi) 11,100 km (6,900 mi)
- Service ceiling: 50,000 ft (15,000 m)
- Wing loading: 67.3 lb/sq ft (329 kg/m2)
- Thrust/weight: 0.205

THANK YOU