AVIONICS AND INSTRUMENT SYSTEM

IV B. Tech VIII semester (Autonomous IARE R-16)

BY

Mrs. M. Mary Thraza, Assistant Professor
Assistant Professor

DEPARTMENT OF AERONAUTICAL ENGINEERING
INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
DUNDIGAL, HYDERABAD - 500 043

Course outcome

COs	Course outcome
CO1	Describing aviation technology, bus systems and few basics of aircraft systems
CO2	Differentiating aircraft instrumentation - sensors and displays systems
CO3	Understanding communication systems and navigation aids
CO4	Estimation of military aircraft adaptation mission system interface, navigation and flight management
CO5	Acquiring knowledge on airborne radar, astrionics, avionics for spacecraft

Unit-I

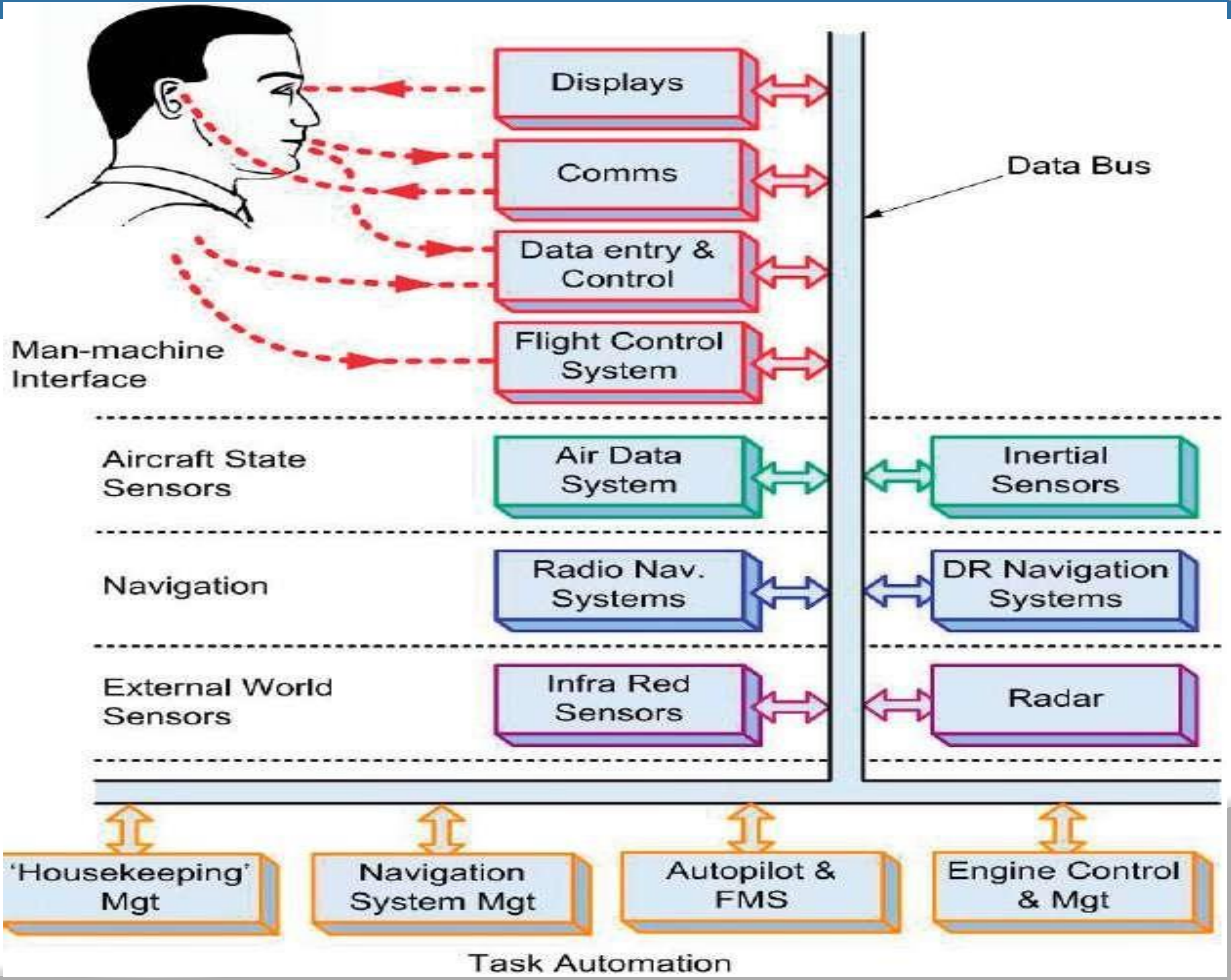
Avionics Technology

Evolution of electronics

The ***Display Systems*** provide the visual interface between the pilot and the air- craft systems and comprise *Display Systems* provide the visual interface between the pilot and the aircraft systems and comprise.

- Head Up Displays (HUDS),
- Helmet Mounted Displays (HMDS)
- Head Down Displays (HDDS).
- Avionics can account for 10% of their total cost.
- It should be noted that unmanned aircraft (UMAs) are totally dependant on the avionic systems.
- These comprise displays, communications, data entry and control and flight control.

Core avionic systems



The nature of microelectronic devices

- Microelectronics is a subfield of electronics.
- As the name suggests, microelectronics relates to the study and manufacture (or microfabrication) of very small electronic designs and components.
- Usually, but not always, this means micrometre-scale or smaller.
- These devices are typically made from semiconductor materials.
- Many components of normal electronic design are available in a microelectronic equivalent.
- These include transistors, capacitors, inductors, resistors, diodes and (naturally) insulators and conductors can all be found in microelectronic devices

Digital **integrated Circuits**(ICs)

- Digital integrated circuit (ICs) consist of billions of transistors, resistors, diodes, and capacitors.
- Analog circuits commonly contain resistors and capacitors as well. Inductors are used in some high frequency analog circuits, but tend to occupy larger chip area due to their lower reactance at low frequencies.
- Gyrators can replace them in many applications.
- As techniques have improved, the scale of microelectronic components has continued to decrease
- At smaller scales, the relative impact of intrinsic circuit properties such as interconnections may become more significant.

Processors, memory devices

The problems of component obsolescence in a standard module can be seen by looking at the very rapid advances in technology that are being made.

Provision must therefore be made in a standard module design, particularly in the software, to allow for component obsolescence and updating with later technology components.

The alternative is living with older technology and procuring sufficient devices in the initial purchase to provide replacement spares for the service life of the equipment.

Introduction to avionics

- Avionics’ is a word derived from the combination of aviation and electronics.
- It was first used in the USA in the early 1950s and has since gained wide scale usage and acceptance although it must be said that it may still be necessary to explain what it means to the lay person on occasions.
- The term ‘avionic system’ or ‘avionic sub-system’ is used in this book to mean any system in the aircraft which is dependent on electronics for its operation, al- though the system may contain electro-mechanical elements.

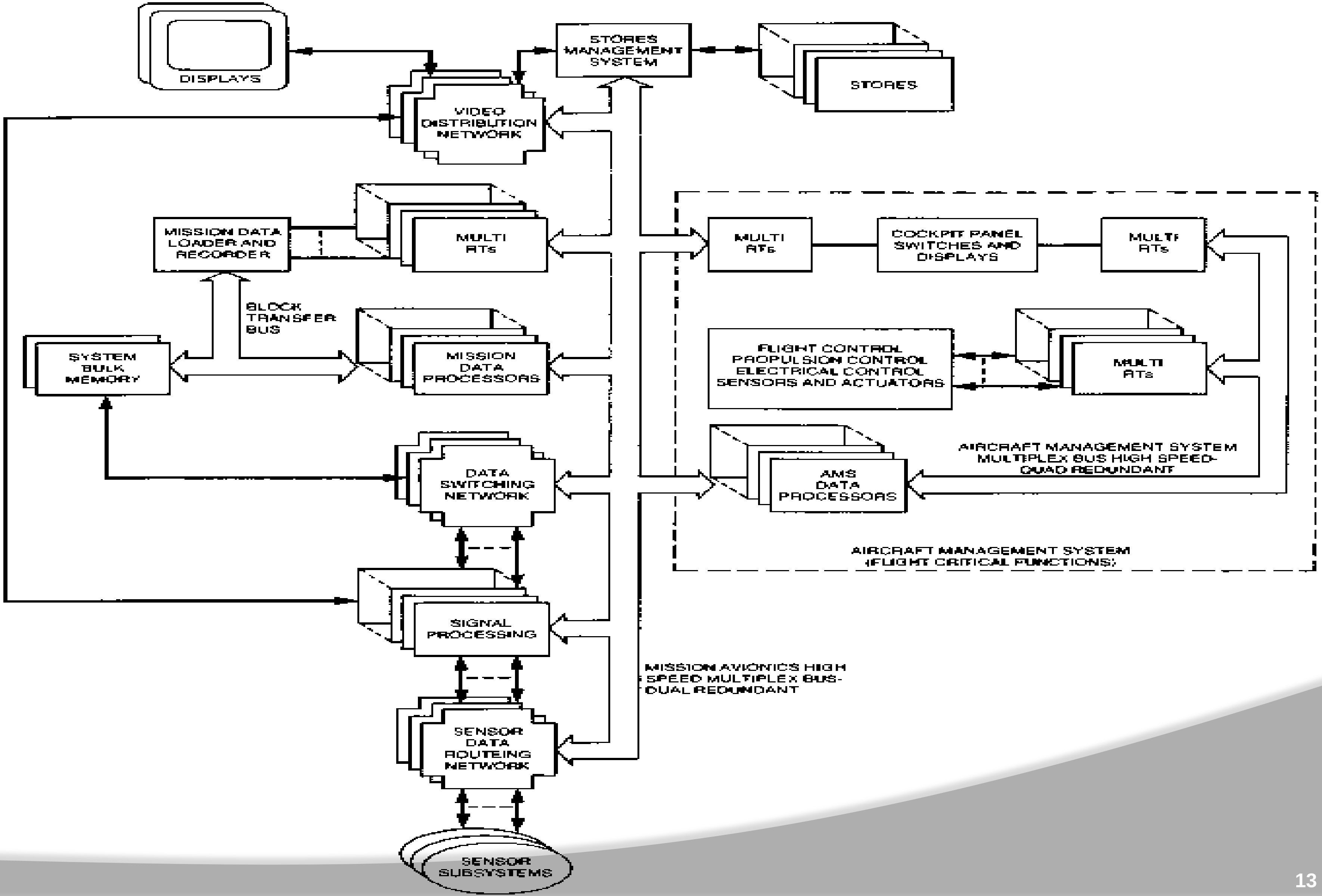
- To date, modular avionics is generally limited to the digital processing and communication areas of the mission systems, and the power supplies necessary to run them.
- Here, the complex functionality is implemented in software, and can be developed largely independent of the actual platform.
- Both the Lockheed F-22 ‘Raptor’ fighter in service with the USAF, and the Lock- heed Martin F-35 ‘Lightning 2’ Joint Strike Fighter, currently under development, exploit modular avionics in their mission avionics systems.
- An overall avionic systems architecture for a military aircraft and designed for implementation using standard avionic modules

- The essential intercommunication system provided by the high speed multiplex data buses can be seen.
- The grouping together of the systems which carry out flight critical functions, such as flight control, propulsion control.
- Electrical power supply con- trol, sensors and actuators, into the ‘aircraft management system’ is a noteworthy feature.

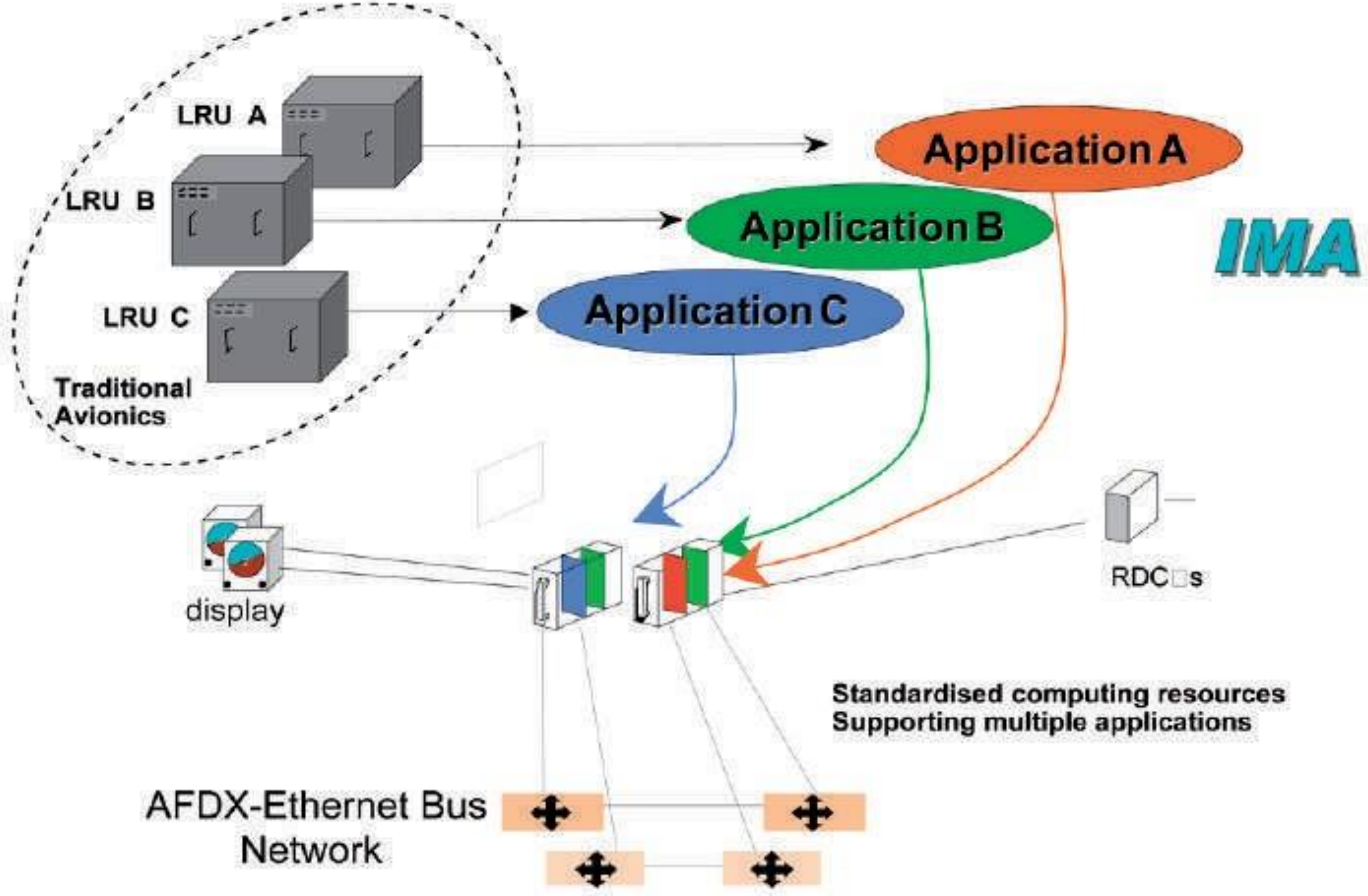
Systems Integration

- As in military systems, the use of new hardware, software and communication technologies has enabled the design of new system architectures based on resource sharing between different systems.
- Current microprocessors are able to provide computing capabilities that exceed the needs of single avionics functions. Specific hardware resources, coupled with the use of Operating Systems with a standardized Application.
- Programming Interface provide the means to host independent applications on the same in a segregated environment.

Integrated Avionic Systems Architecture.

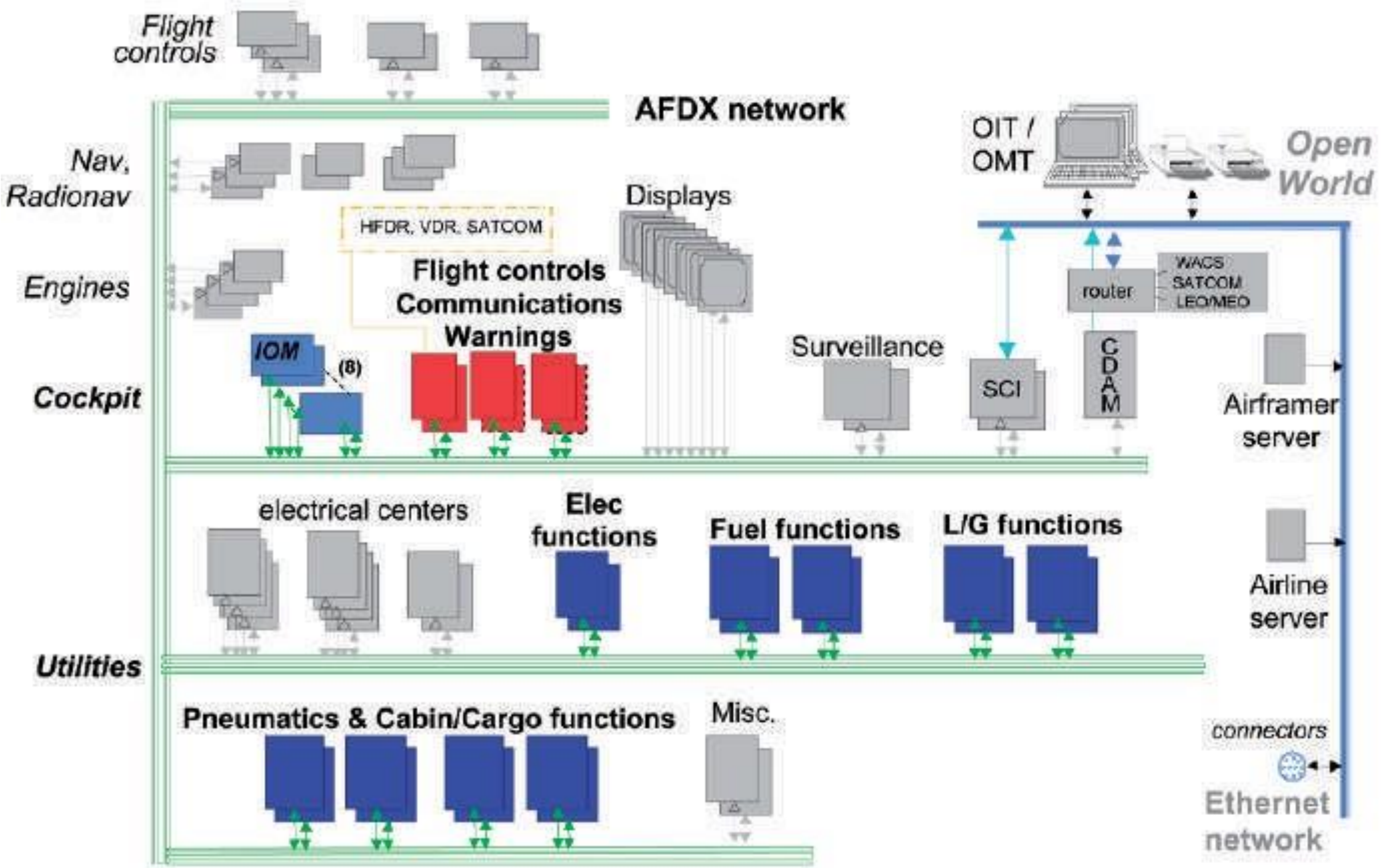


Need - data bus systems



Standardised computing resources
Supporting multiple applications

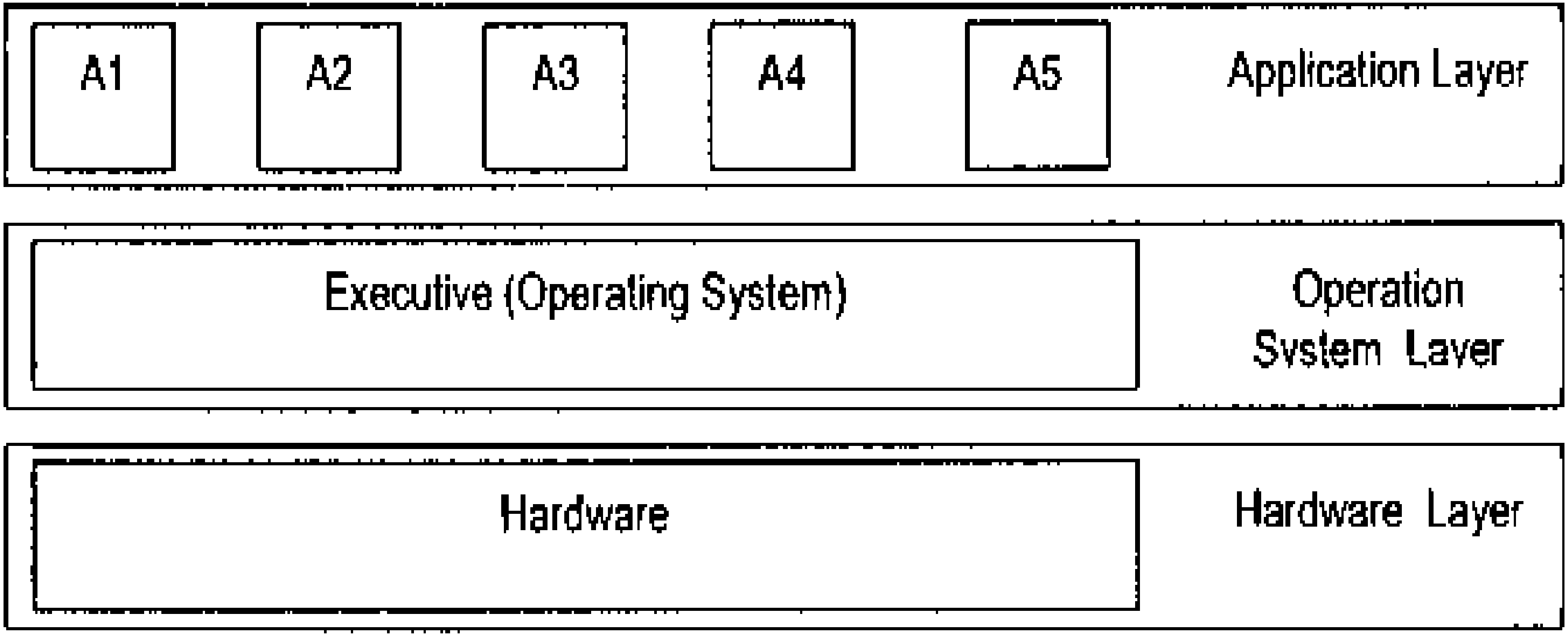
Integrated modular avionic systems on the A380 (by courtesy of Airbus).



Civil Integrated Modular Avionic Systems

- As in military systems, the use of new hardware, software and communication technologies has enabled the design of new system architectures based on resource sharing between different systems.
- Current microprocessors are able to provide computing capabilities that exceed the needs of single avionics functions. Specific hardware resources, coupled with the use of Operating Systems with a standardised Application Programming Interface provide the means to host independent applications on the same computing resource in a segregated environment.
- The AFDX Communication Network provides high data throughput coupled with low latencies to multiple end users across the bus network. The basic concepts are illustrated

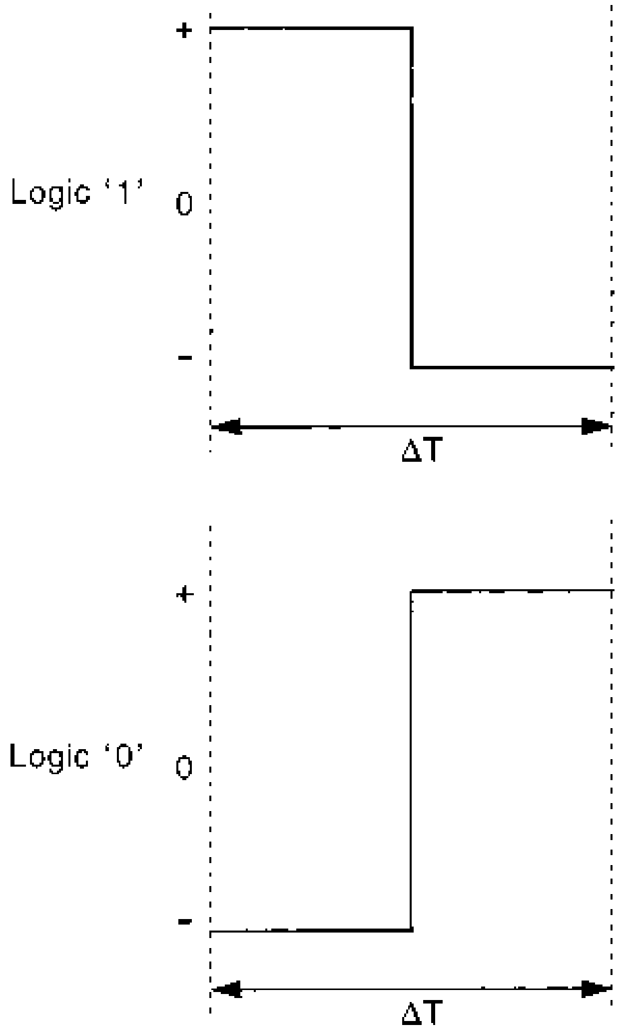
The ‘three layer stack’ modular software concept.



MIL STD 1553 bus system

- MIL STD 1553B is a US military standard which defines a TDM multiple-source– multiple-sink data bus system which is in very wide scale use in military aircraft in many countries.
- It is also used in naval surface ships, submarines, and land vehicles such as main battlefield tanks.
- The system is a half duplex system, that is operation of a data transfer can take place in either direction over a single line, but not in both directions on that line simultaneously.

Logic ‘1’ and logic ‘0’.

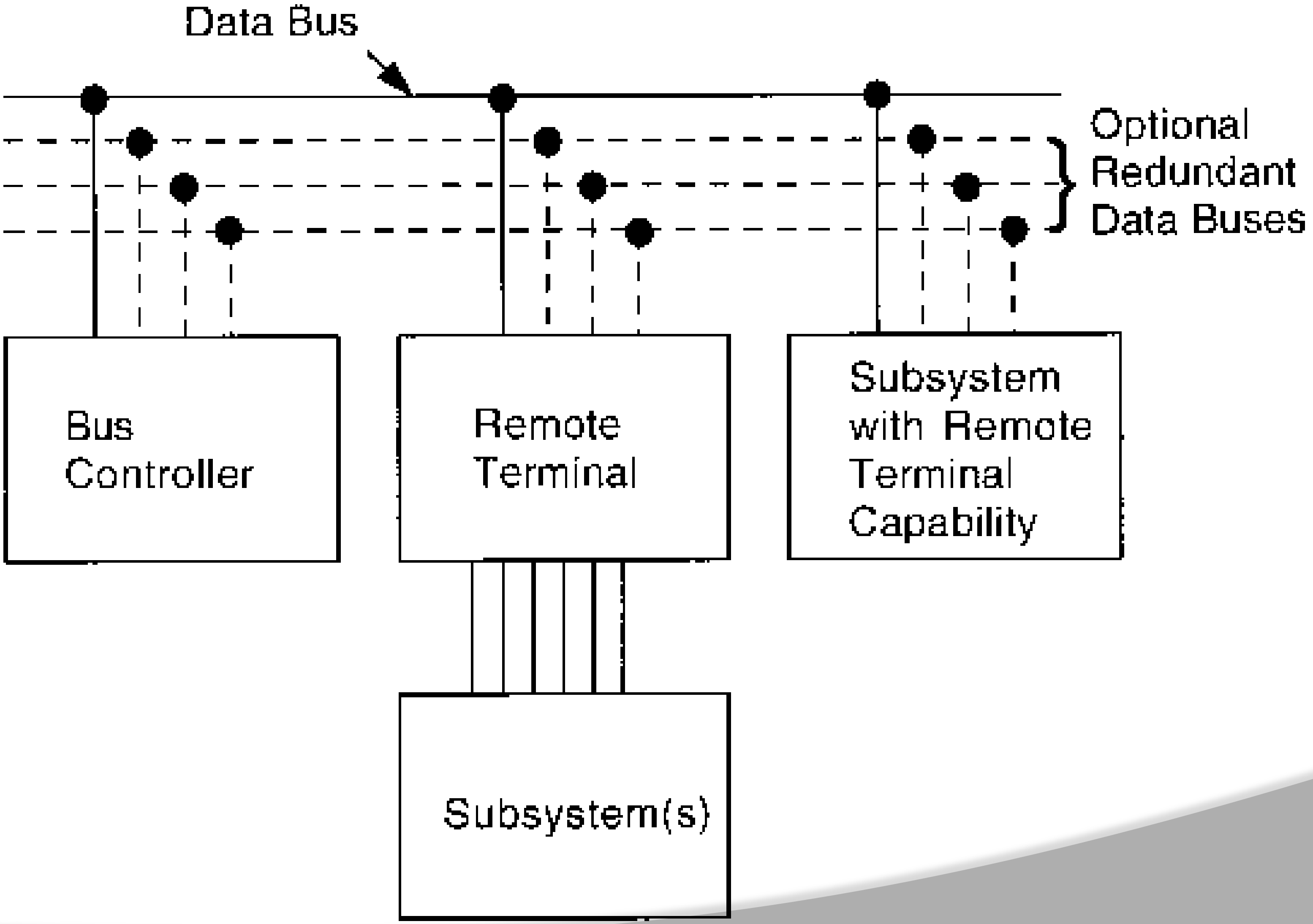


ΔT = 1 Clock Period
= 1 µs

ARINC 429/ARINC 629 bus systems

- Mark33 Digital Information Transfer System (DITS)," is also known as the Aeronautical Radio INC. (ARINC) technical standard for the predominant avionics data bus used on most higher-end commercial and transport aircraft.
- It defines the physical and electrical interfaces of a two-wire data bus and a data protocol to support an aircraft's avionics local area network.
- ARINC 429 is a data transfer standard for aircraft avionics. It uses a self-clocking, self-synchronizing data bus protocol (Tx and Rx are on separate ports).

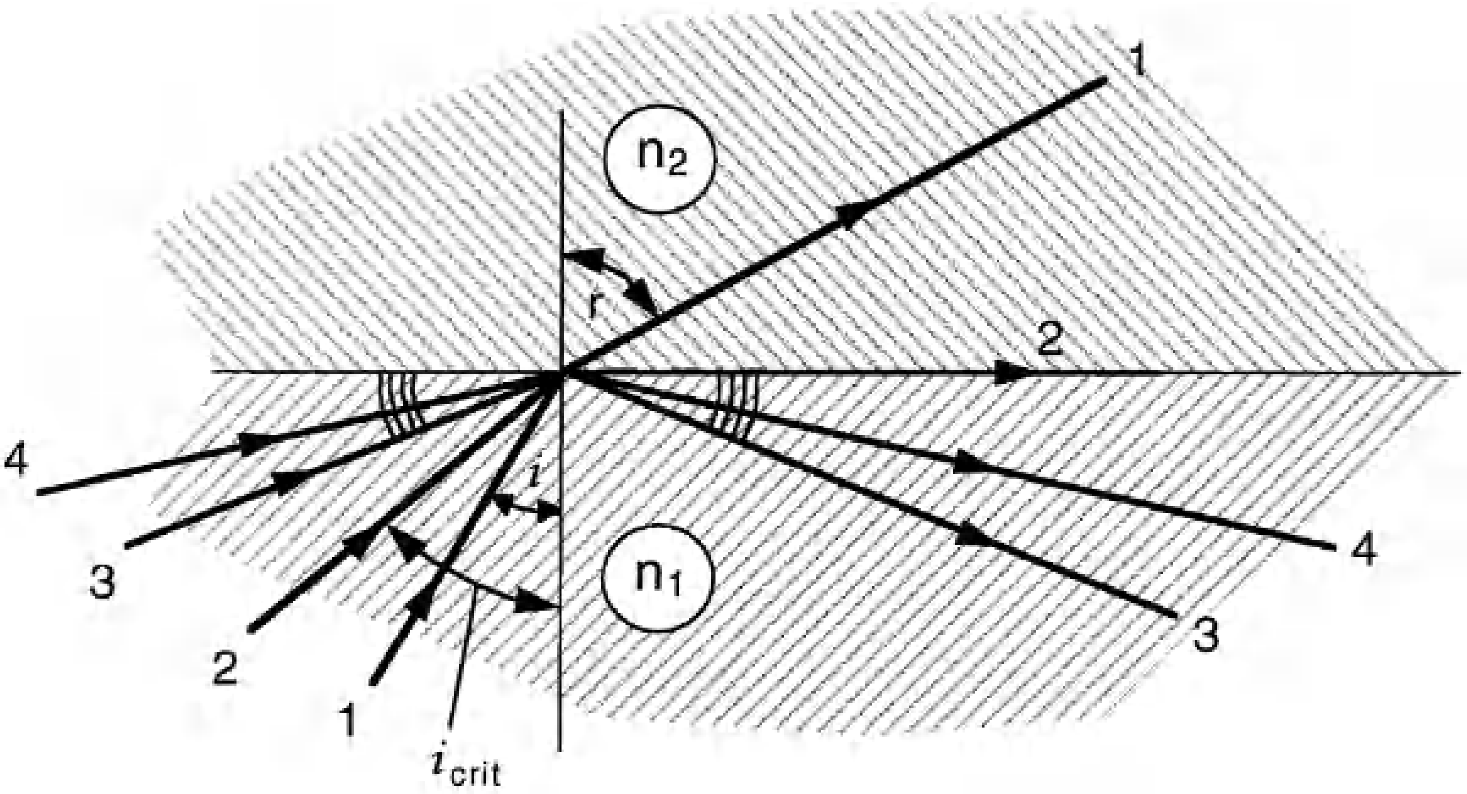
Typical multiplex data bus system architecture.



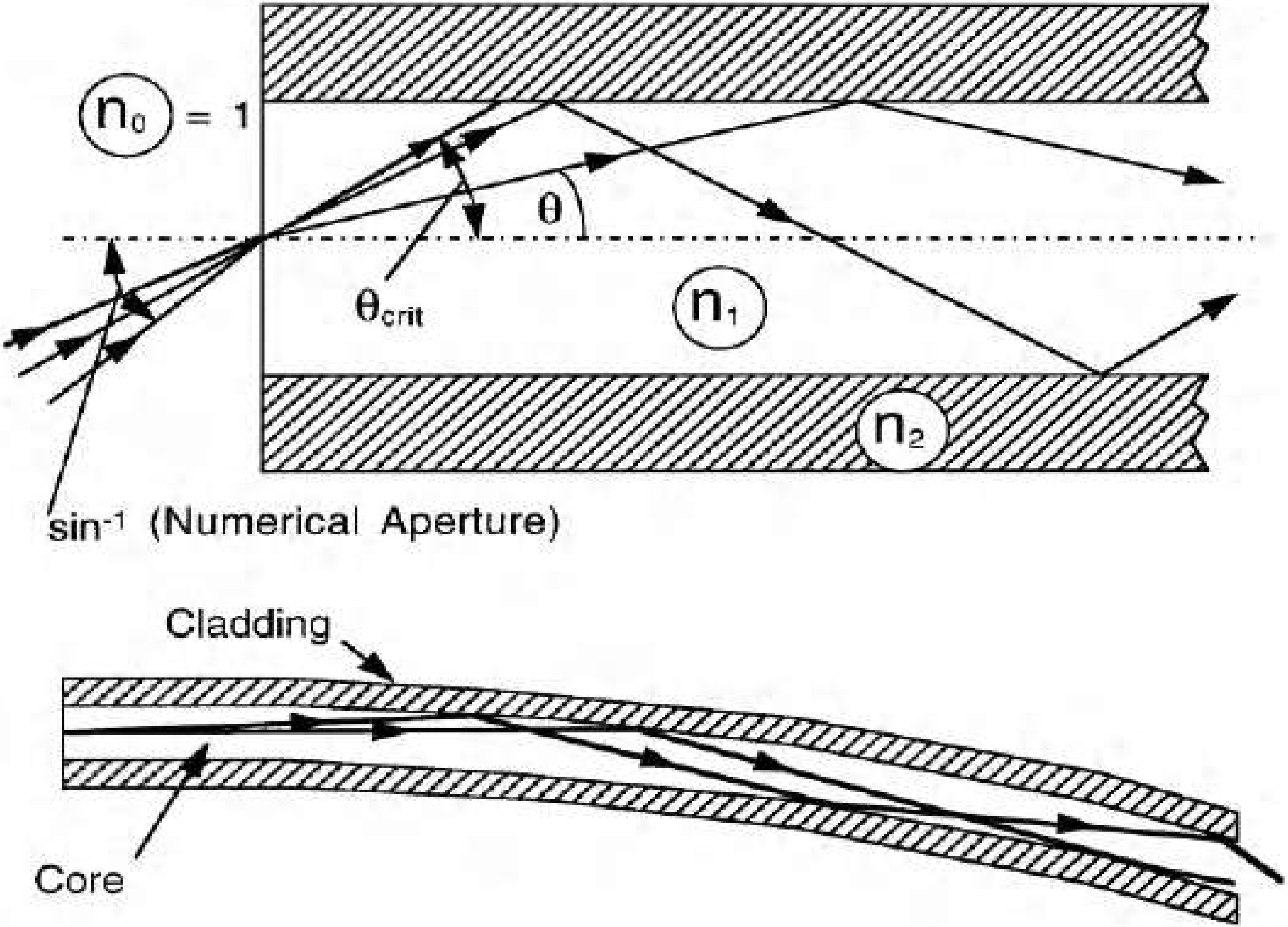
optical data bus systems

- Most readers are probably familiar to some extent with the use of optical fibres to transmit light signals.
- A brief explanation is set out below for those readers who need to refresh themselves on the subject and also to make clear the difference between multi-mode and single mode optical fibres and their respective applications.
- The transmission of light signals along any optical fibre depends on the optical property of total internal reflection.
- Ray 1 is refracted in passing through the second medium, the relationship between the angle the incident ray makes with the normal, *i*, and the angle the refracted ray makes with the normal, *r*, being given by Snell's law:

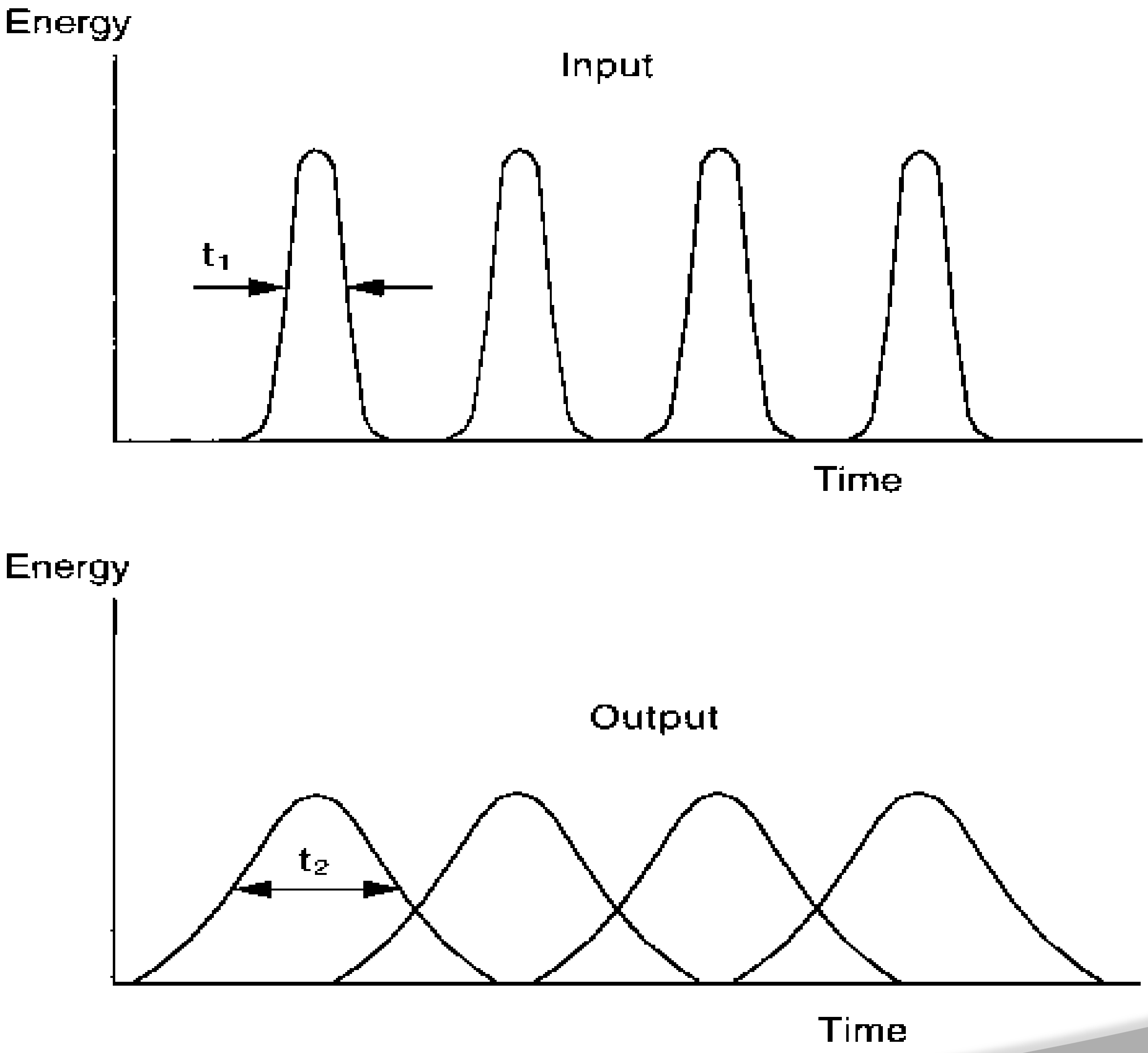
Total internal reflection



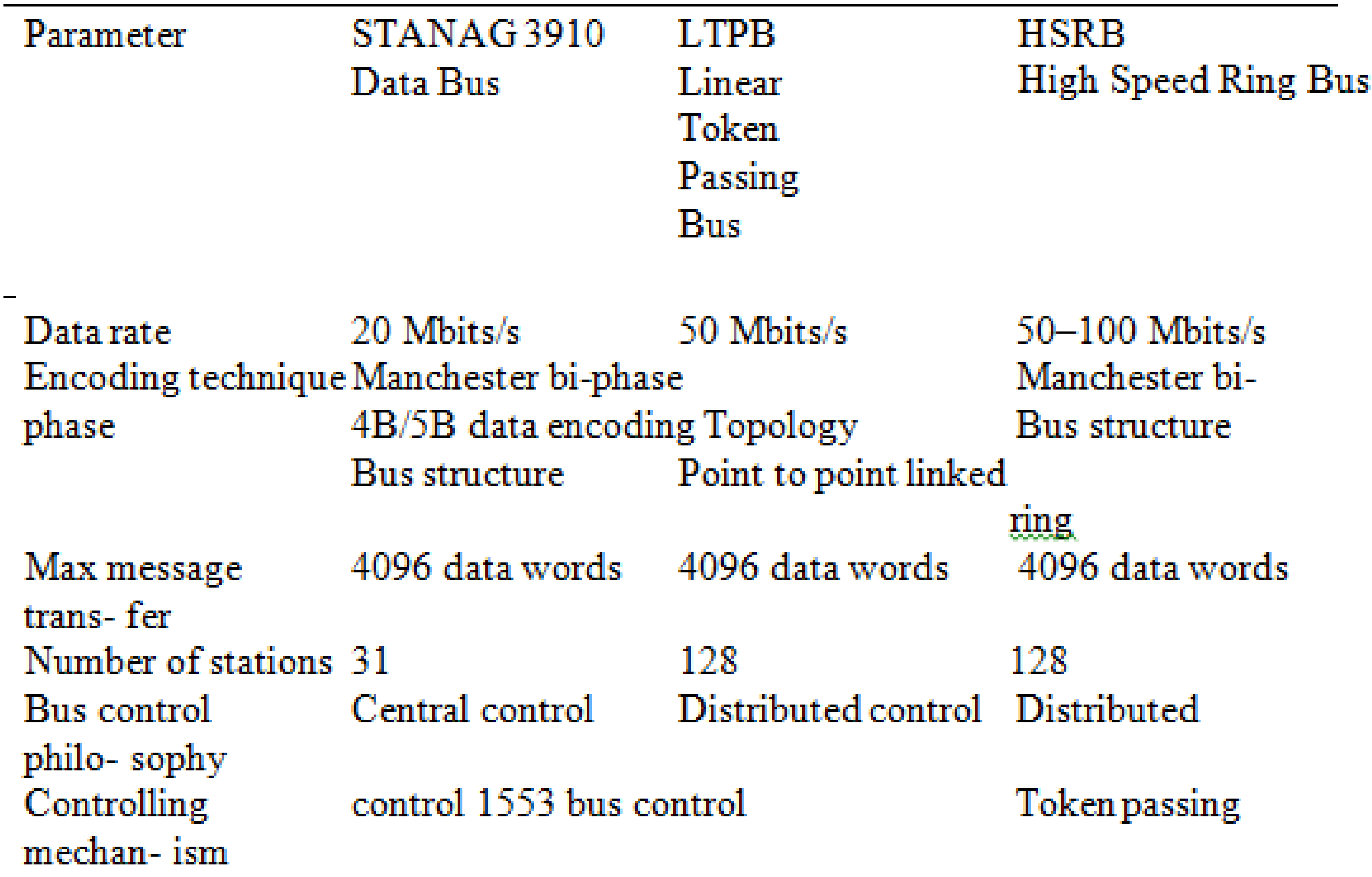
Multi-mode optical fibre.



Pulse broadening.



Features of Transmission Systems

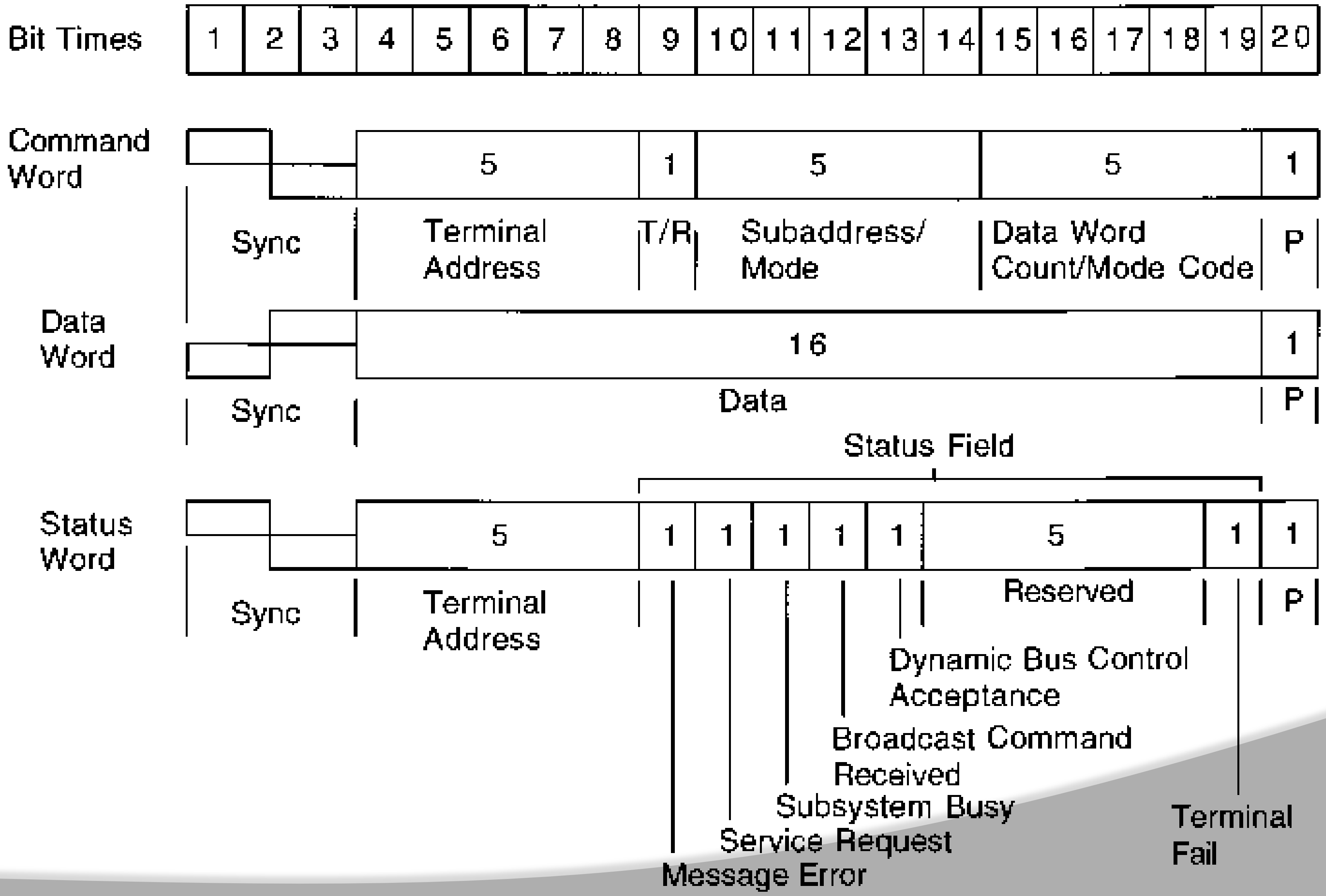


Parameter	STANAG 3910 Data Bus	LTPB Linear Token Passing Bus	HSRB High Speed Ring Bus
Data rate	20 Mbits/s	50 Mbits/s	50–100 Mbits/s
Encoding technique	Manchester bi-phase		Manchester bi-
phase	4B/5B data encoding	Topology	Bus structure
	Bus structure	Point to point linked	
			ring
Max message trans- fer	4096 data words	4096 data words	4096 data words
Number of stations	31	128	128
Bus control philo- sophy	Central control	Distributed control	Distributed
Controlling mechan- ism	control 1553 bus control		Token passing

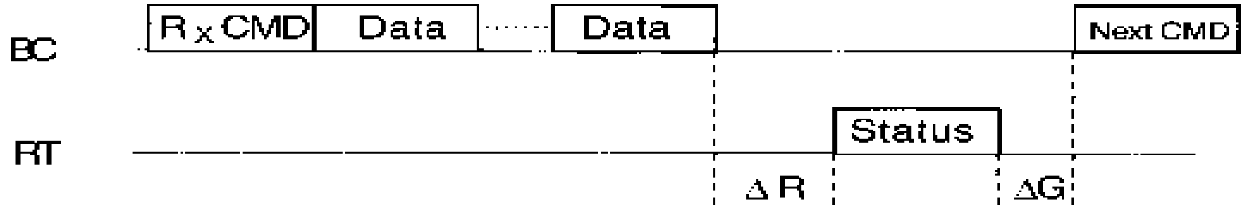
Integrated modular avionics architectures

- The version which has been adapted for airborne applications is known as the ‘Avionics Full Duplex Switched Ethernet’.
- which has been shortened to ‘AFDX Eth- ernet’ network.
- It meets the civil aircraft avionic system requirements.
- In all aspects and its commercially sourced components make it a very competitive system.

Word formats.



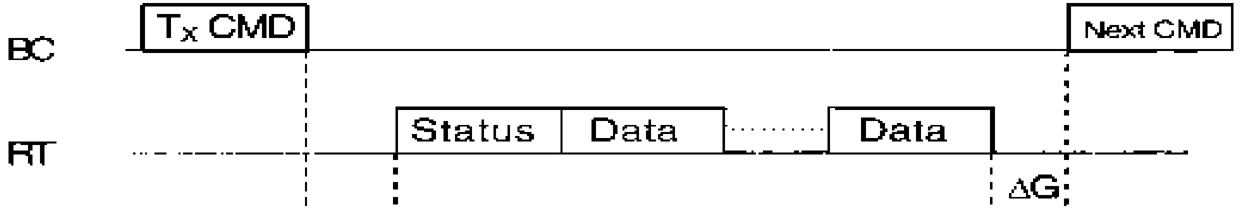
Transfer formats.



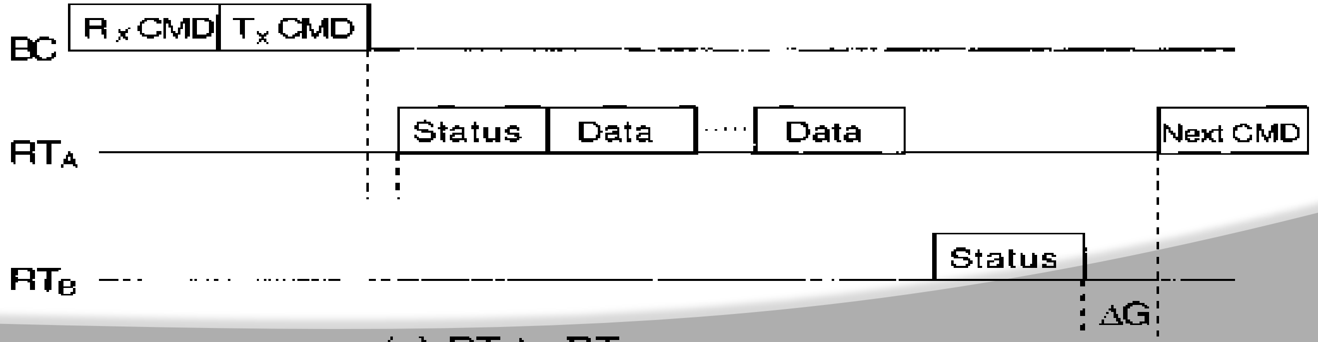
(a) BC to RT

Δ R = Response time of RT once all data has
been received (14µs = Time-out Failure)

Δ G = Inter-message Gap (Typically 2 – 5µs)

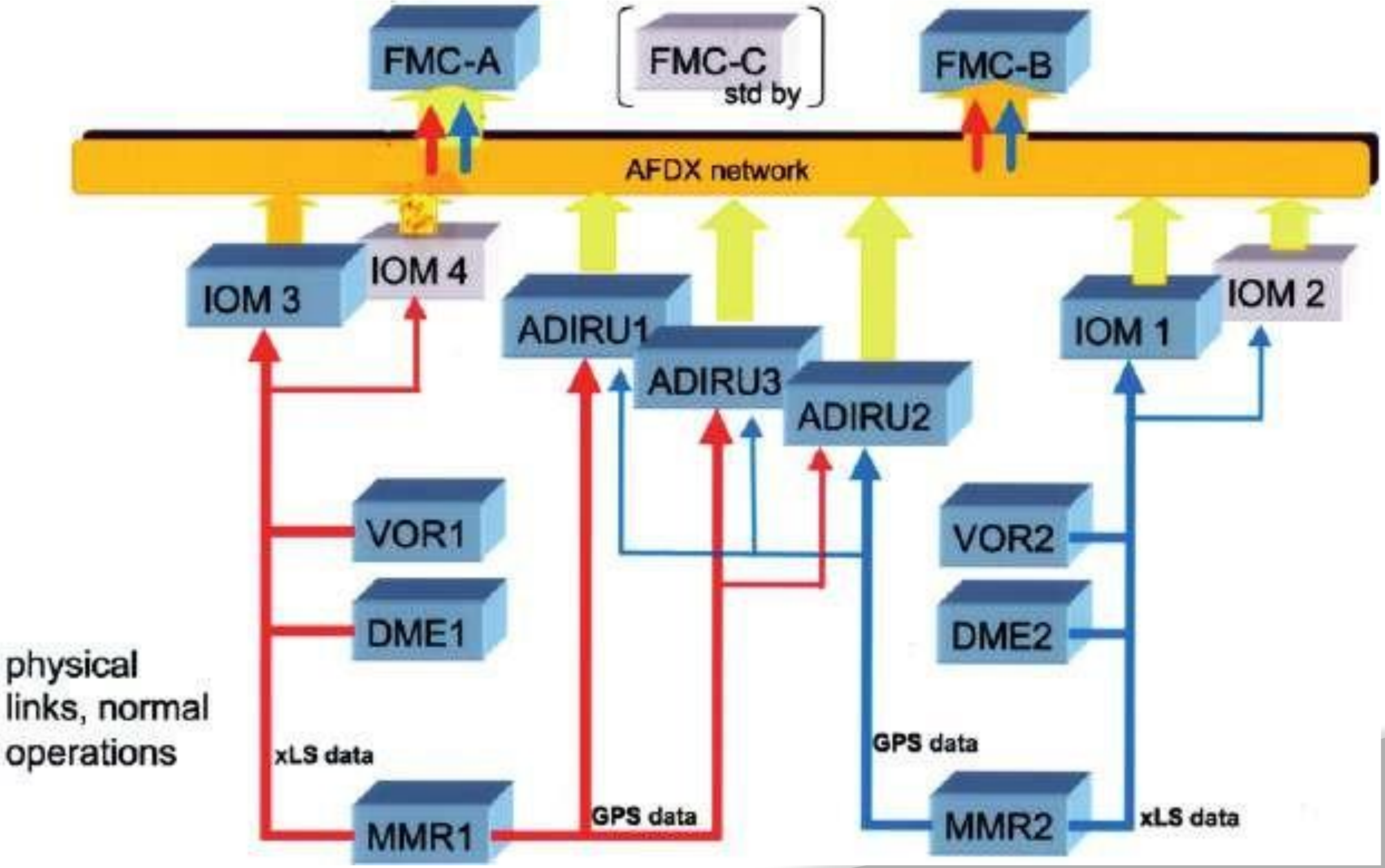


(b) RT to BC

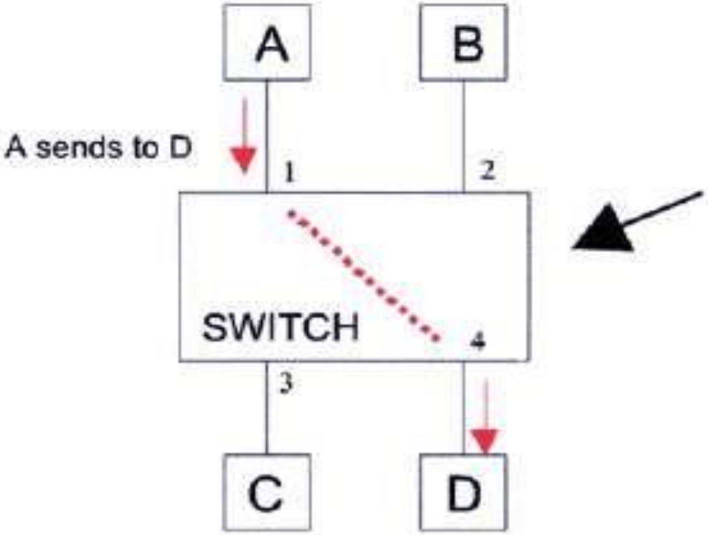


(c) RT to RT

Interconnection of Navigation System units by the AFDX network (by courtesy of Air- bus).



Switched Ethernet principle



Subscriber	Port #
A	1
B	2
C	3
D	4

Addressing example:

- A sends a frame to D

Aircraft State Sensor Systems

These comprise the air data systems and the inertial sensor systems.

Air Data Systems provide accurate information on the air data quantities, that is the altitude, calibrated airspeed, vertical speed, true airspeed, Mach num- ber and airstream incidence angle.
I
nertial Sensor Systems provide the information on aircraft attitude and the direction in which it is heading which is essential information for the pilot in ex- ecuting a manoeuvre or flying in conditions of poor visibility, flying in clouds or at night.

Dead Reckoning Navigation Systems

- The *Dead Reckoning Navigation Systems* derive the vehicle’s present position by estimating the distance travelled from a known position from a knowledge of the speed and direction of motion of the vehicle.
- They have the major advantages of being completely self contained and independent of external systems.

DR navigation systems

The main types of DR navigation systems used in aircraft are:

Inertial navigation systems.

a. The most accurate and widely used systems.

b. Doppler/heading reference systems. These are widely used in helicopters.

c. Air data/heading reference systems

These systems are mainly used as a rever- sionary navigation system being of lower accuracy than (a) or (b).

Commercial off the shelf systems

- Avionic systems equipment is very different in many ways from ground based equipment carrying out similar functions.
- The reasons for these differences are briefly explained in view of their fundamental importance.
- The importance of achieving minimum weight.
- The adverse operating environment particularly in military aircraft in terms of operating temperature range, acceleration, shock, vibration, humidity range and electro-magnetic interference.
- The importance of very high reliability, safety and integrity.

- The over-riding importance of avionic equipment reliability can be appreciated In view of the essential roles of this equipment in the operation of the aircraft
- Every possible care is taken in the design of avionic equipment to achieve maximum reliability.
- A typical RST cycle requires the equipment to operate satisfactorily through the cycle described below.

Avionics packaging.

Putting Intelligence Closer to the Action

- A distributed avionics system creates flexible capabilities in a smaller, lighter package.
- The Mini Modular Rack Principle (MiniMRP), standardized in ARINC 836A, is fast emerging as the leading choice for packaging of distributed systems.
- The Mini MRP provides standardized modules that can be easily deployed through an aircraft, allowing information to be collected and distributed around a fiber optic or copper backbone

Modularity Simplifies Configuration:

- By creating a series of standard modules, the MiniMRP system allows a mix-and-match approach to design and deployment.
- Modules can be used singly or combined as needed to create specific functionality
- Throughout the aircraft. Module upgrades, replacements, or expansions are easily accomplished

Lower Costs through Standardization

- By providing compact, standardized modules, MiniMRP enhances the ability to distribute embedded computing functions throughout the aircraft.
- Standardization of both connectors inserts and modular enclosures sizes provide a commonality of components within an aircraft and across a wide range of different aircraft platforms.

Lower Costs – COTS Components

- Designers of avionic systems can take advantage of commercial off-the-shelf (COTS) components.
- Thereby streamlining the design cycle to enable a faster time to market.
- Additionally, they give designers access to well-established, high-volume products
- That can lower costs through economies of scale. Standardization creates a competitive ecosystem

Unit-II

Aircraft Instrumentation - Sensors And Displays

UNIT-II

CLOS	Course Learning Outcome
CLO 4	Understanding the concept of sensing system in aircraft instrumentation system.
CLO 5	Development of different types of indication systems.
CLO 6	Constructing different display systems in instrumentation system.
CLO 7	Developing the concept of different communication system.

Air data sensors

The military pilot has also a wide array of additional information to view, such as:

- Infrared imaging sensors,
- Radar,
- Tactical mission data
- Weapon aiming,
- Threat warnings.

Air data

Air data is a measurement of the air mass surrounding an airplane. The two physical characteristics measured are pressure and temperature. Air data is acquired through various sensors on the aircraft and is used to calculate altitude, speed, rate of climb or decent, and angle-of-attack or angle-of-sideslip.

Static Pressure (Ps) is the absolute pressure of still air surrounding the aircraft. This is the barometric pressure at the altitude where the aircraft is traveling and is independent of any pressure disturbances caused by the motion of the aircraft.

Total Pressure (Pt) is the sum of the local atmospheric pressure (Ps) and the impact pressure (Qc) caused by the aircraft's motion through the air.

Impact Pressure (Qc) is the pressure a moving stream of air produces against a surface that brings part of the moving stream to rest. It is the difference between the total pressure (Pt) and the static pressure (Ps).

Introduction

The cockpit display systems provide a visual presentation of the information and data from the aircraft sensors and systems to the pilot (and crew) to enable the pilot to fly the aircraft safely and carry out the mission. They are thus vital to the operation of any aircraft as they provide the pilot, whether civil or military, with:

- Primary flight information,
- Navigation information,
- Engine data,
- Airframe data,
- Warning information.

Magnetic Sensing

- Magnetic sensors detect moving ferrous metal. The simplest magnetic sensor consists of a wire coiled around a permanent magnet.
- A ferrous object approaching the sensor changes magnetic flux through the coil, generating a voltage at the coil terminals.
- They have high resolution, generating many pulses/in. of target travel and can sense very small ferrous objects.
- For example, one sensor responds to 96-pitch gears, while Hall-effect sensors can only register 16-pitch gear teeth. In these applications, magnetic transducers can be accurate to hundredths of a mechanical degree.
- For sensing rotating shaft speed, on the other hand, output-pulse frequency is converted to rpm at an accuracy of 0.1%.

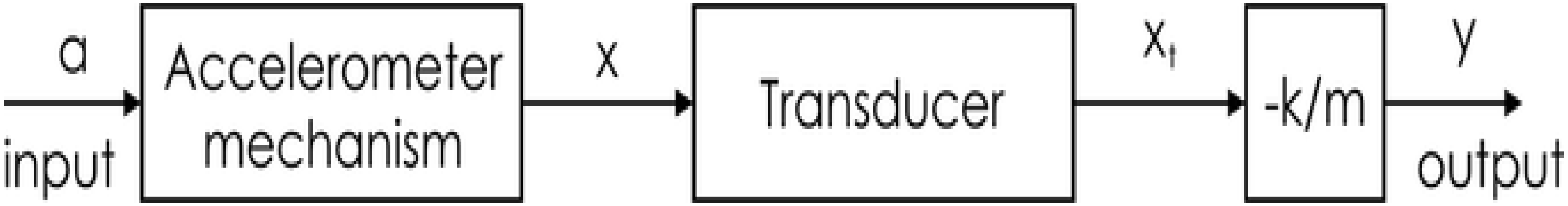
- Eddy Currents: Eddy-current sensors detect ferrous and nonferrous metals. A high-frequency magnetic field induces eddy currents in metal targets.
- The eddy currents generally change the sensor's oscillation amplitude, which is sensed by a coil to create an output signal.
- For measuring speed, these sensors register metallic discontinuities in a moving target at a rate of about 5 kHz, but some models respond up to about 20 kHz.
- Maximum response speed is determined by the method used to sense oscillator amplitude.
- Devices that sense amplitude changes with conventional demodulator/integrator circuits are slower than those that convert oscillator amplitude into a string of pulses whose widths vary with frequency.

Inertial Sensing

- Inertial sensors are sensors based on inertia and relevant measuring principles.
- These range from Micro Electro Mechanical Systems (MEMS) inertial sensors, measuring only few mm, up to ring laser gyroscopes that are high-precision devices with a size of up to 50cm.
- Within this note, we will briefly summarize these cases of inertial sensors that are most important to the autonomous navigation of unmanned aircraft.
- Inertial sensors for aerial robotics typically come in the form of an Inertial Measurement Unit (IMU) which consists of accelerometers, gyroscopes and sometimes also magnetometers.
- Subsequently, we will briefly summarize the main principles of accelerometers and gyroscopes widely used in unmanned aviation

Accelerometers

Accelerometers are devices that measure proper acceleration ("g-force"). Proper acceleration is not the same as coordinate acceleration (rate of change of velocity).



$$\omega_n = \sqrt{\frac{k}{m}}, \quad \zeta = \frac{c}{2\sqrt{km}}$$

Sizing With Fixed Engine And With Rubber Engine

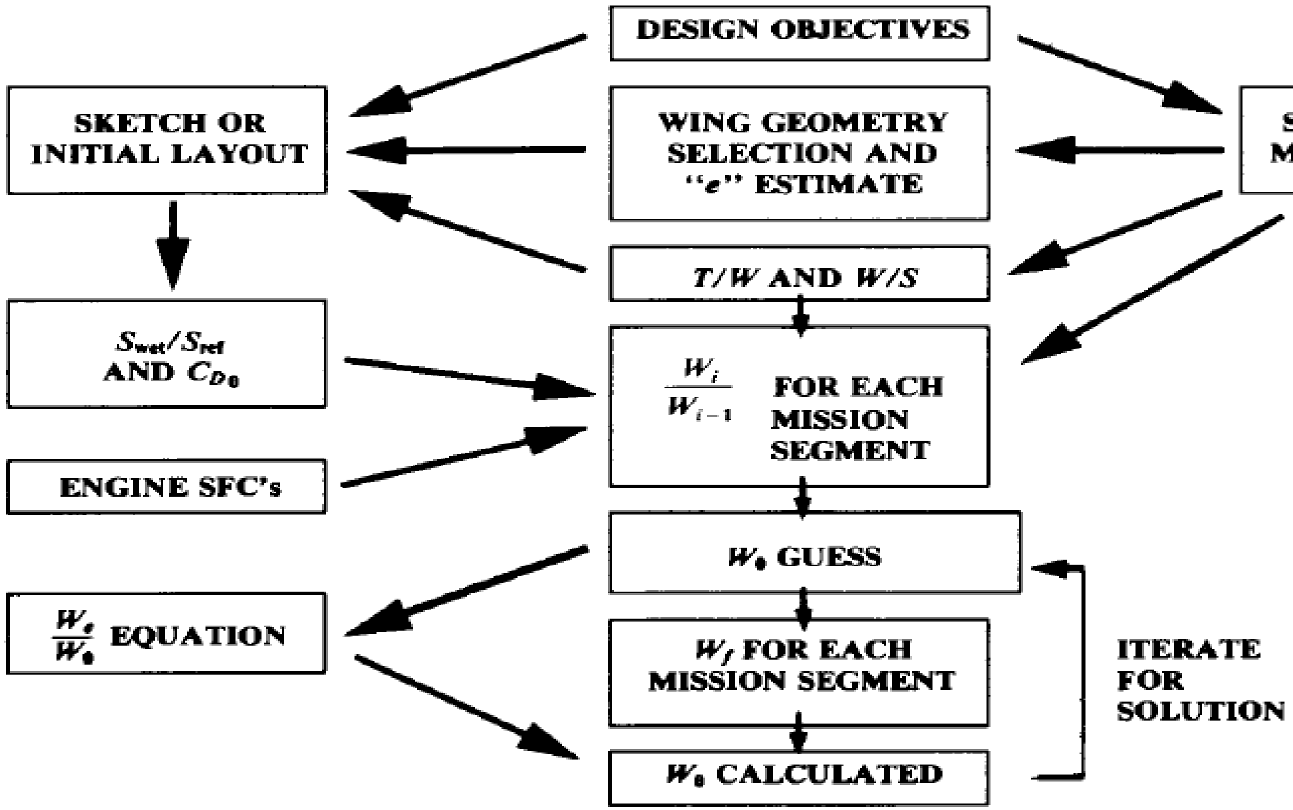
- This information a crude estimate of the maximum L/D was obtained. Using approximations of the specific fuel consumption, the changes in weight due to the fuel burned during cruise and loiter mission segments were estimated, expressed as the mission-segment weight fraction.
- Using these fractions 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



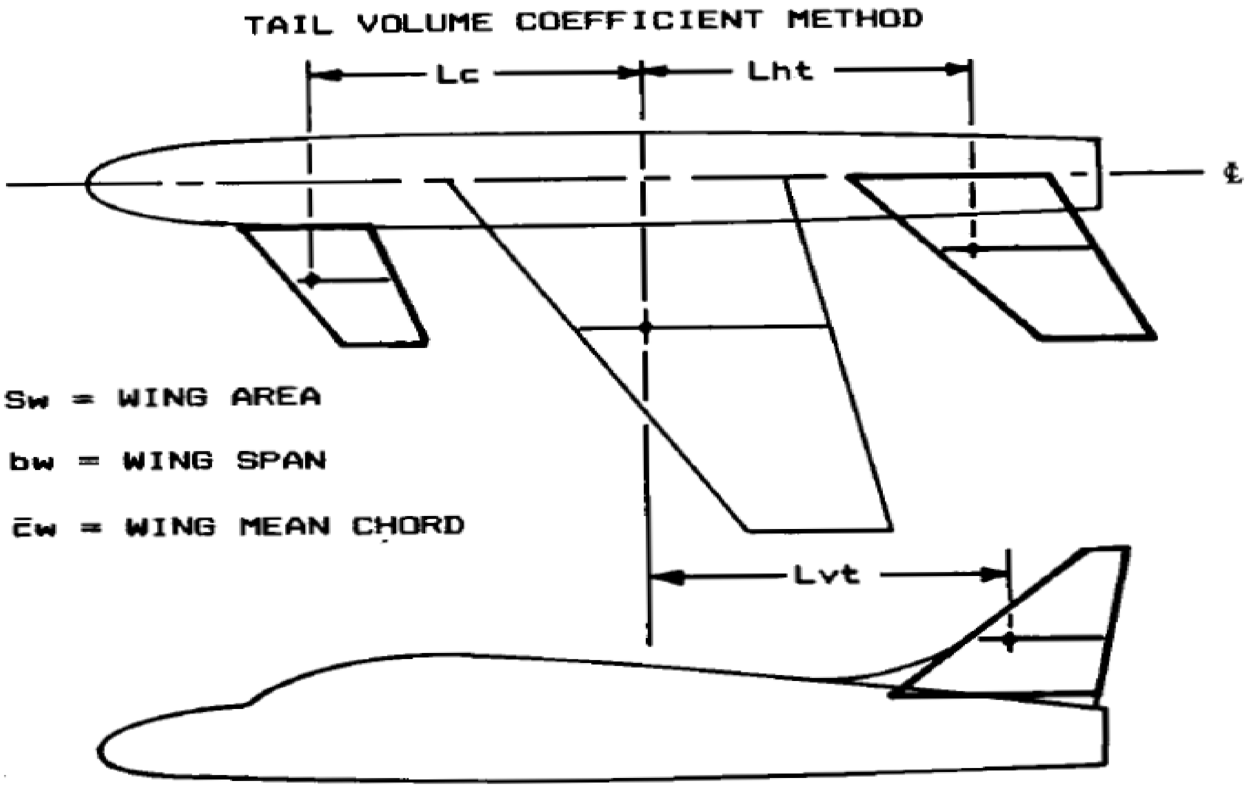
Geometry Sizing

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

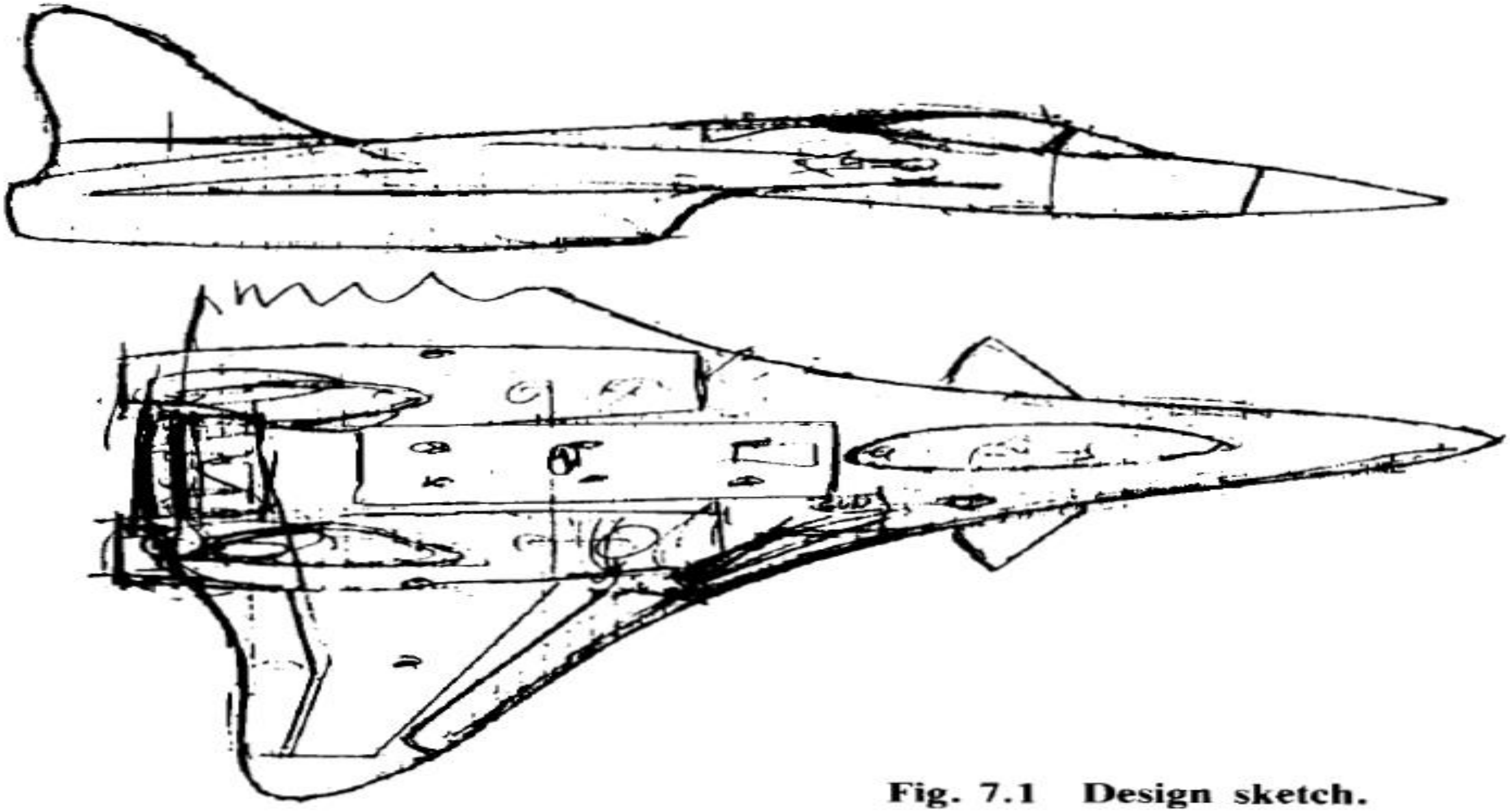
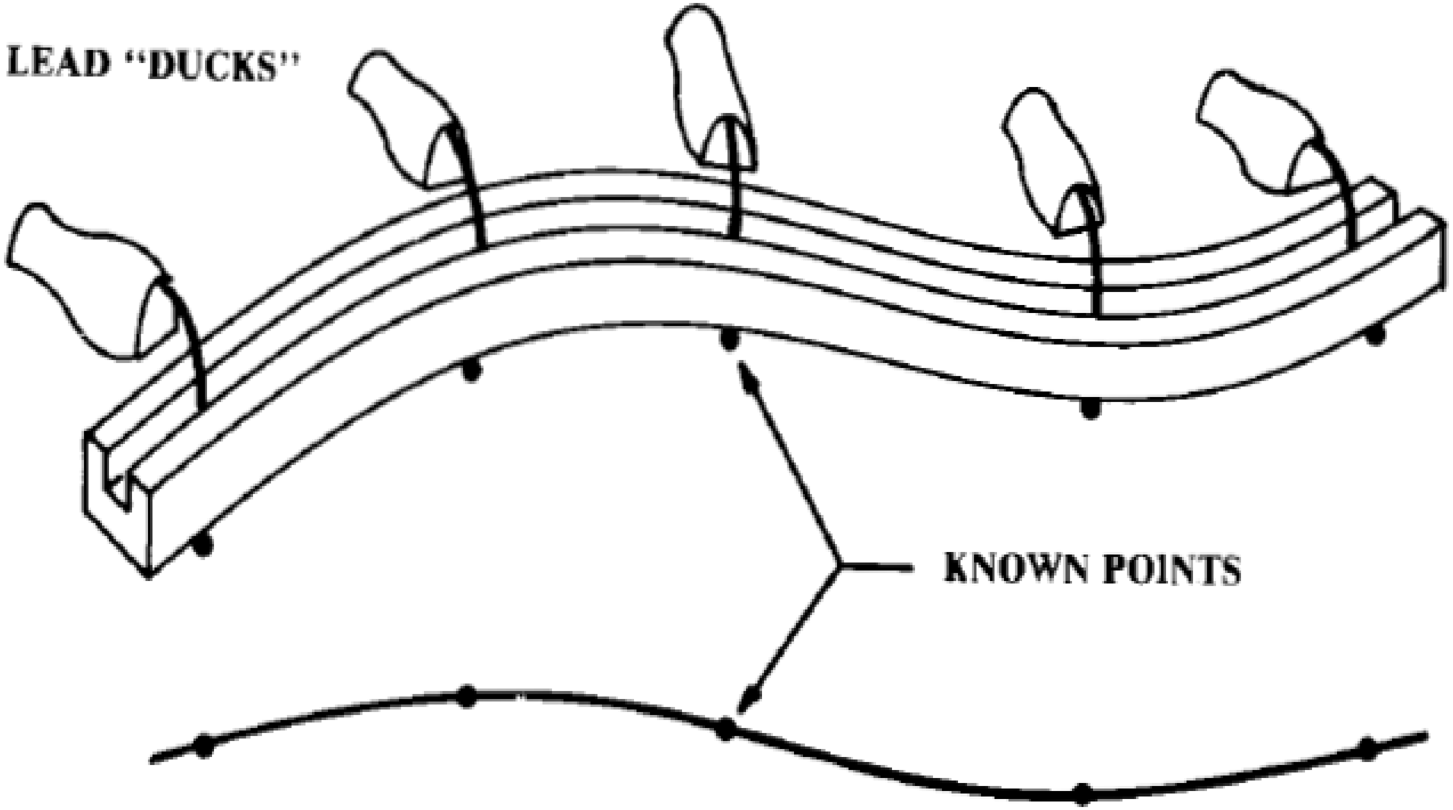


Fig. 7.1 Design sketch.

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.

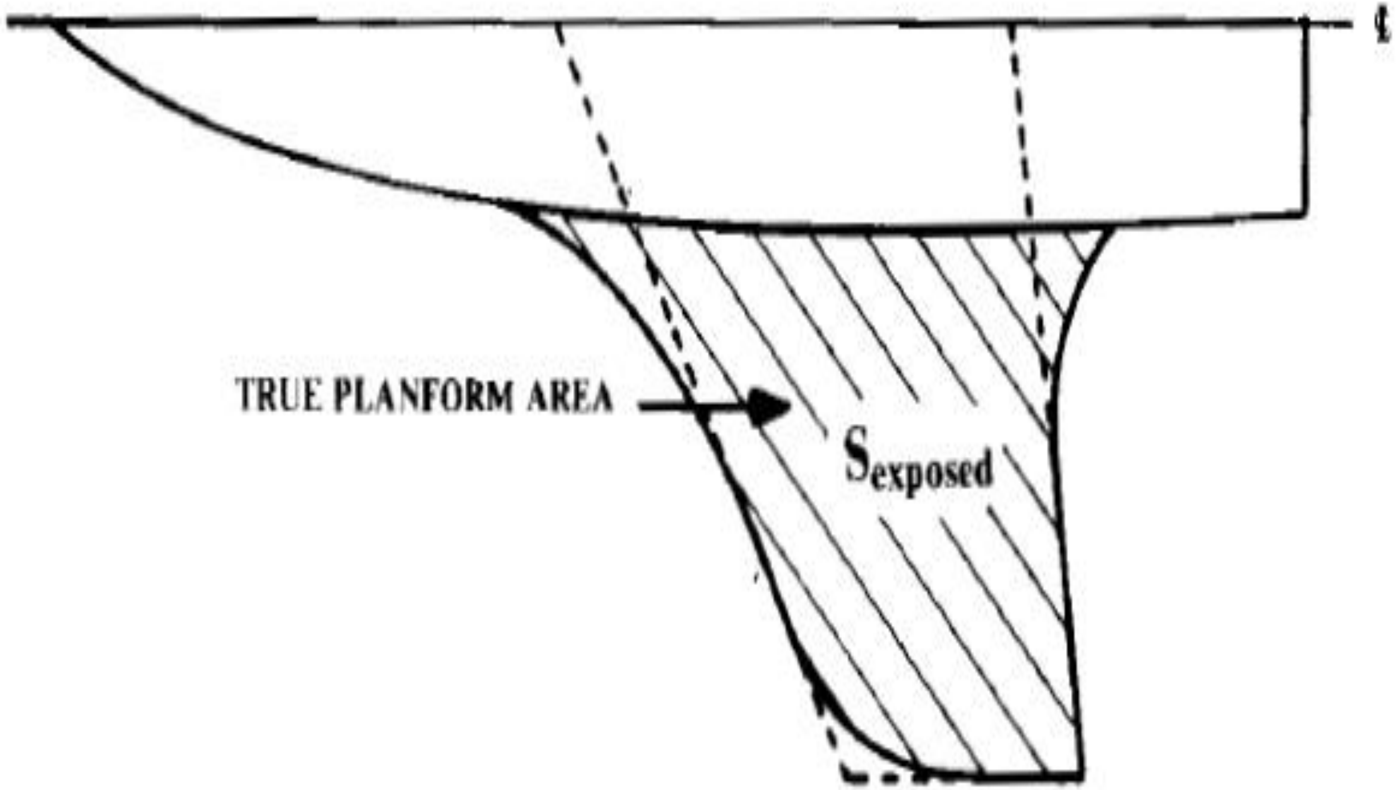
Spline Lofting



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)



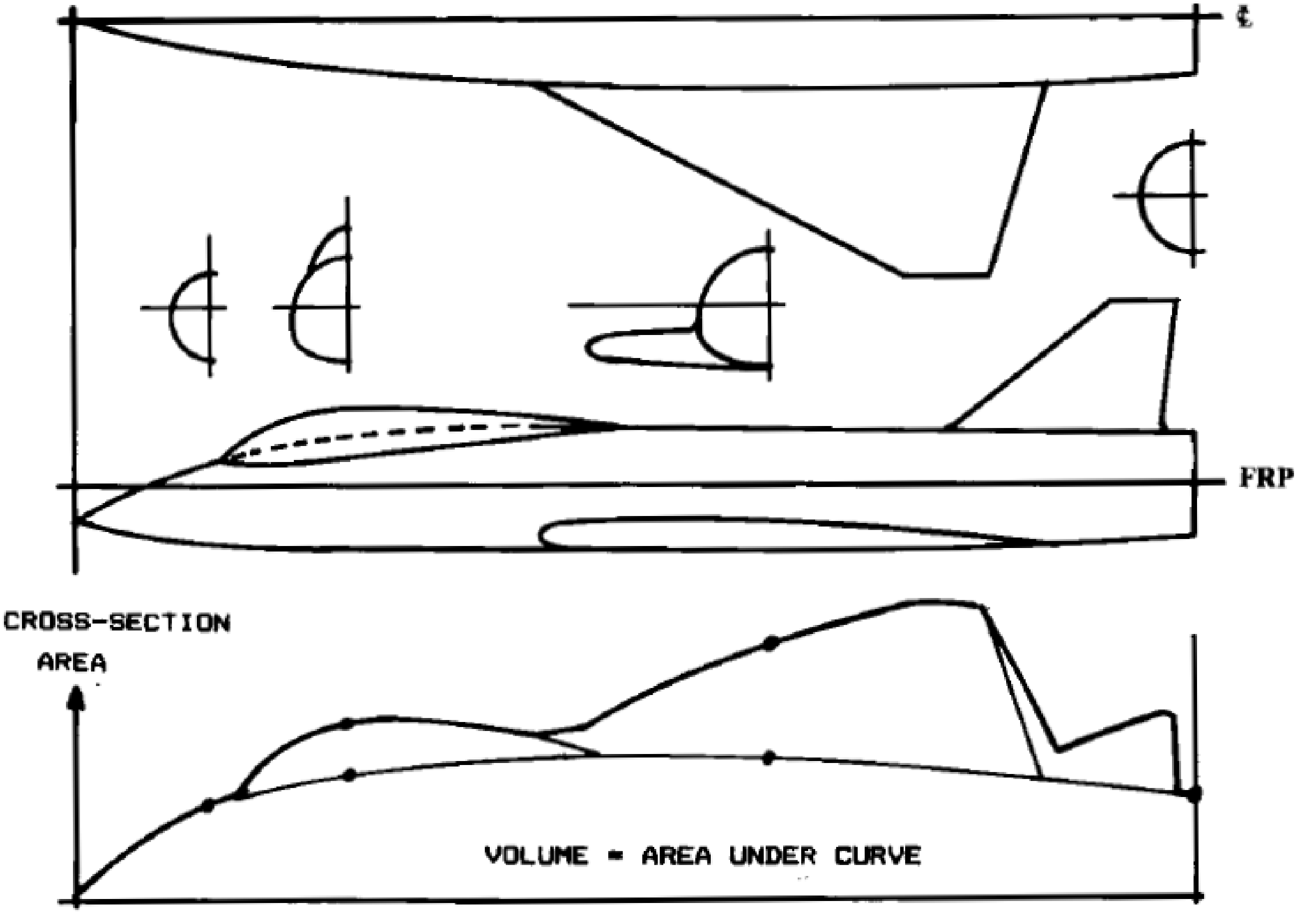
Estimation Of Wetted Area(wing/ Tail Wetted Area)

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



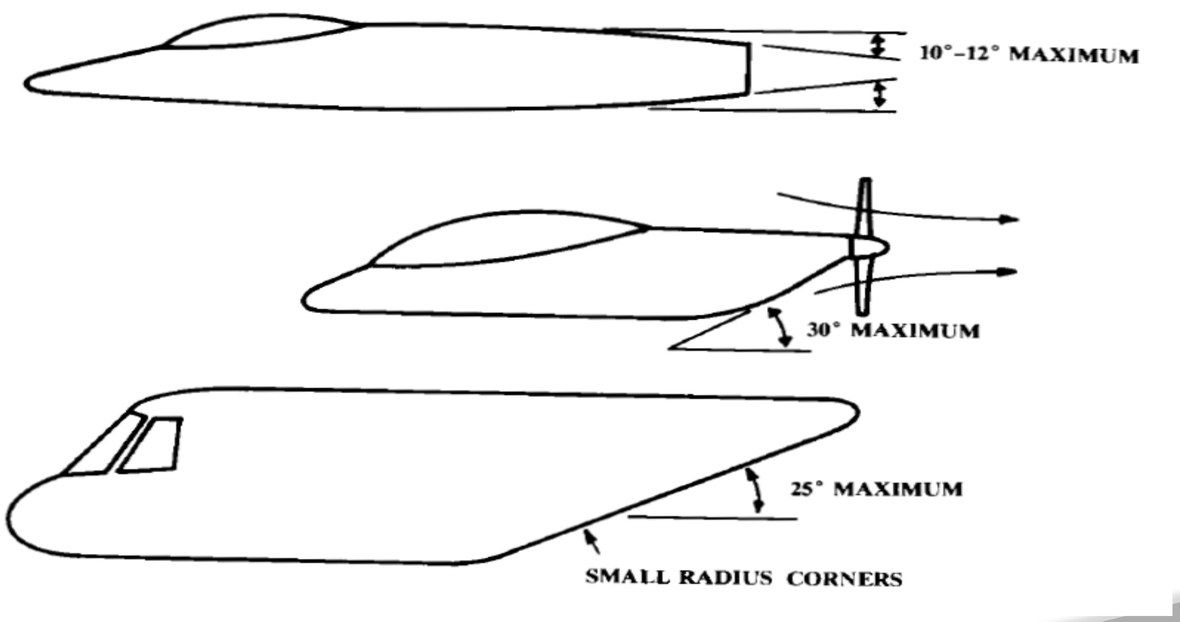
Aircraft Volume Plot

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

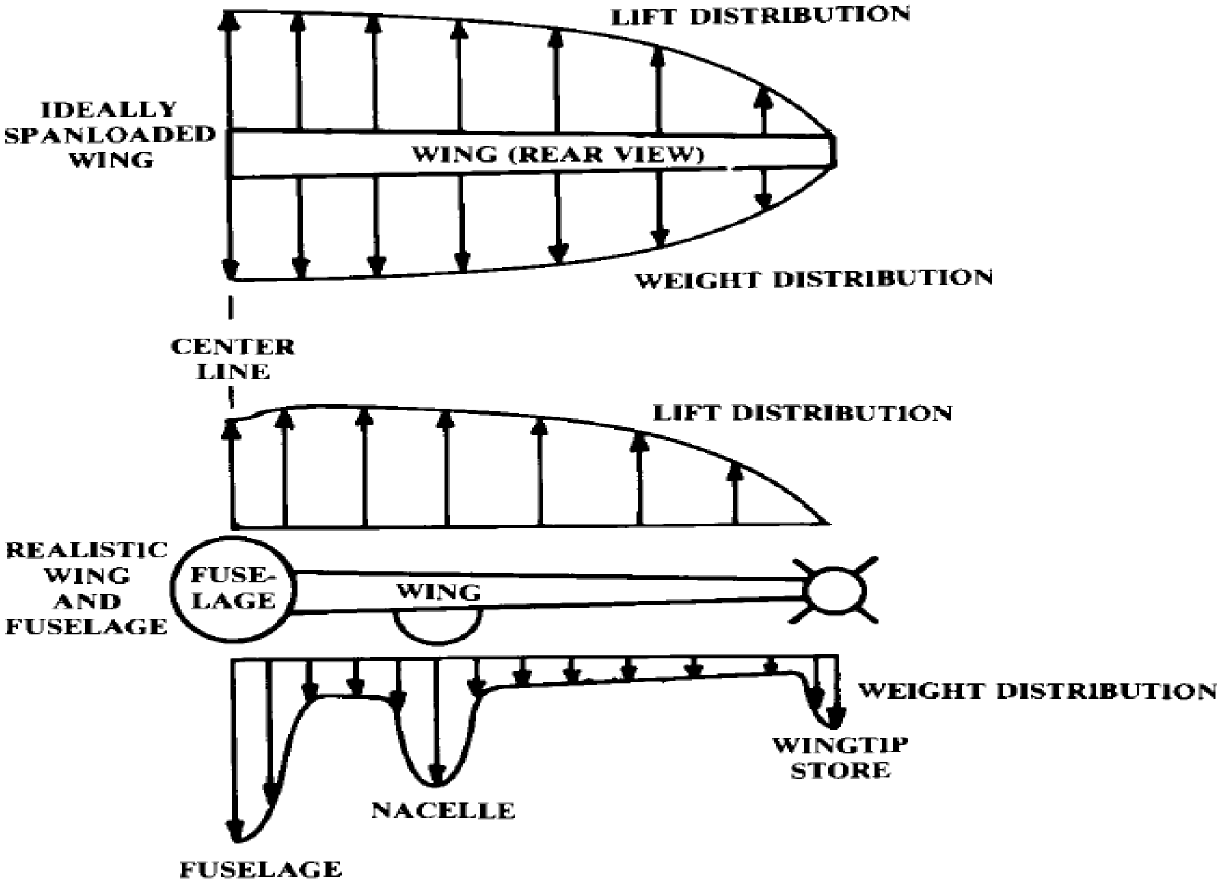
- The overall arrangement and smoothness of the fuselage can have a major effect upon aerodynamic efficiency. A poorly designed aircraft can have excessive flow separation, transonic drag rise, and supersonic wave drag



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

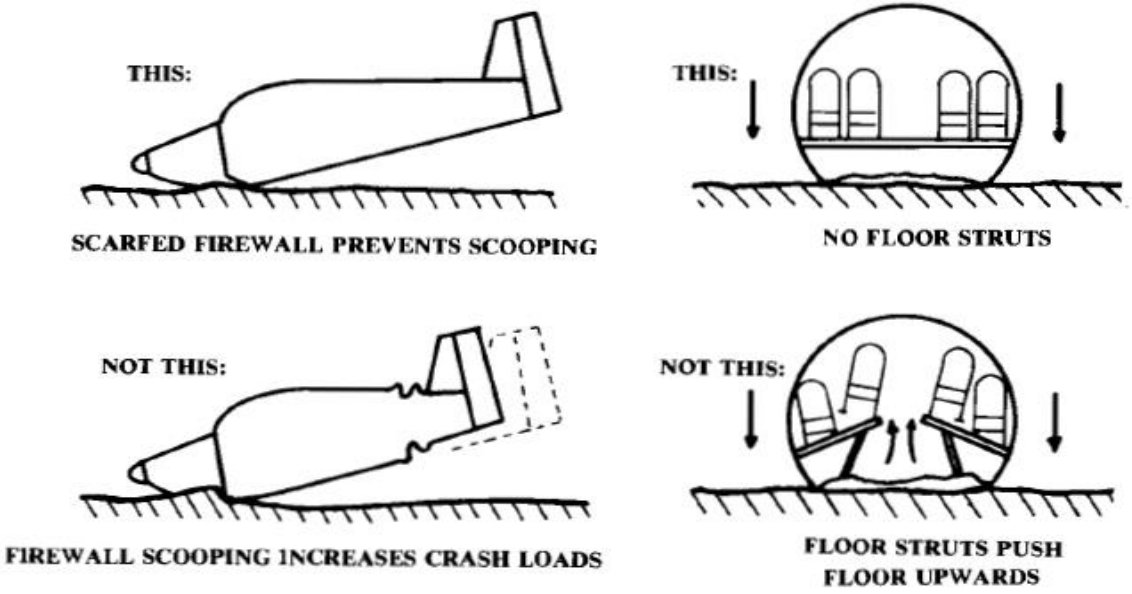
- Aural signature (noise) is important for civilian as well as military aircraft. Commercial airports frequently have an ordinances that restrict some aircraft. Aircraft noise is largely caused by airflow shear layers, primarily due to the engine exhaust.
- A small-diameter, high-velocity jet exhaust 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:

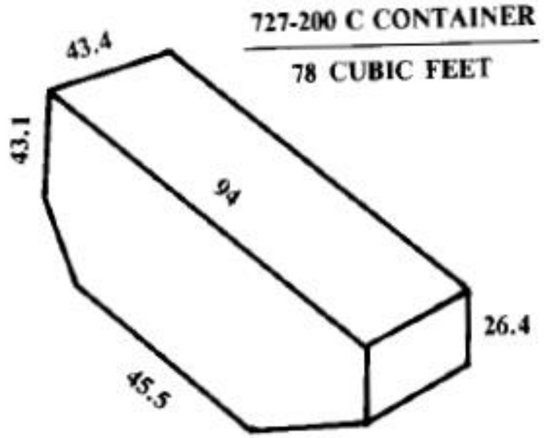
- General-aviation cockpits are designed to whatever range of pilot sizes the marketing department feels is needed for customer appeal, but typically are comfortable only for those under about 72 in.
- Commercial-airliner cockpits are designed to accommodate pilot sizes similar to those of military Aircraft.

Passenger Compartment

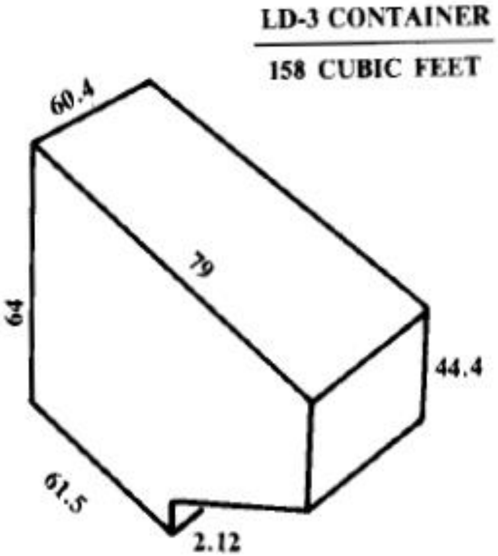
- The actual cabin arrangement for a commercial aircraft is determined more by marketing than by regulations.
- Defines the dimensions of interest. of the seats is defined as the distance from the back of one seat to the back of the next. Pitch includes fore and aft seat length as well as leg room.
- 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

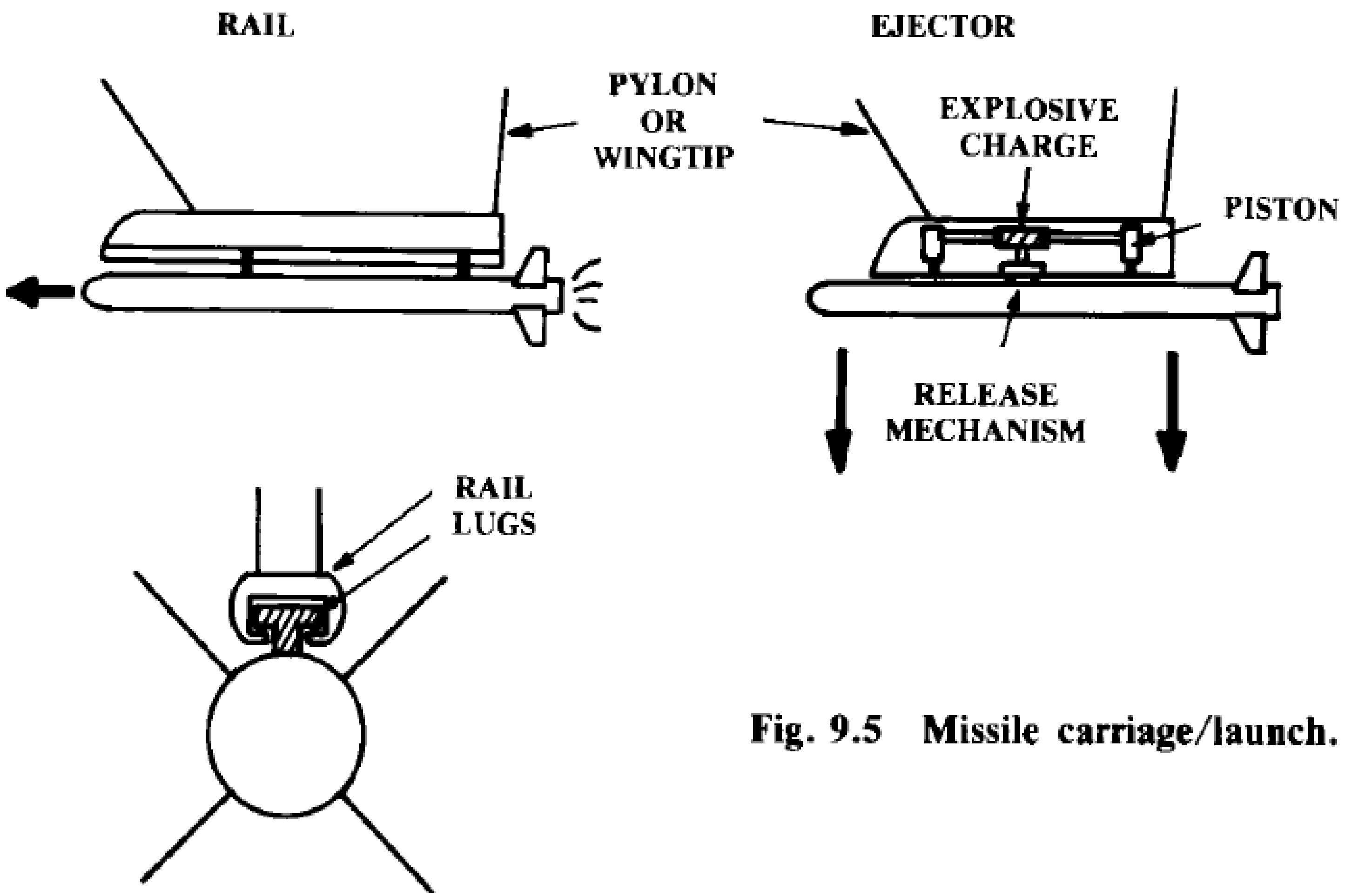
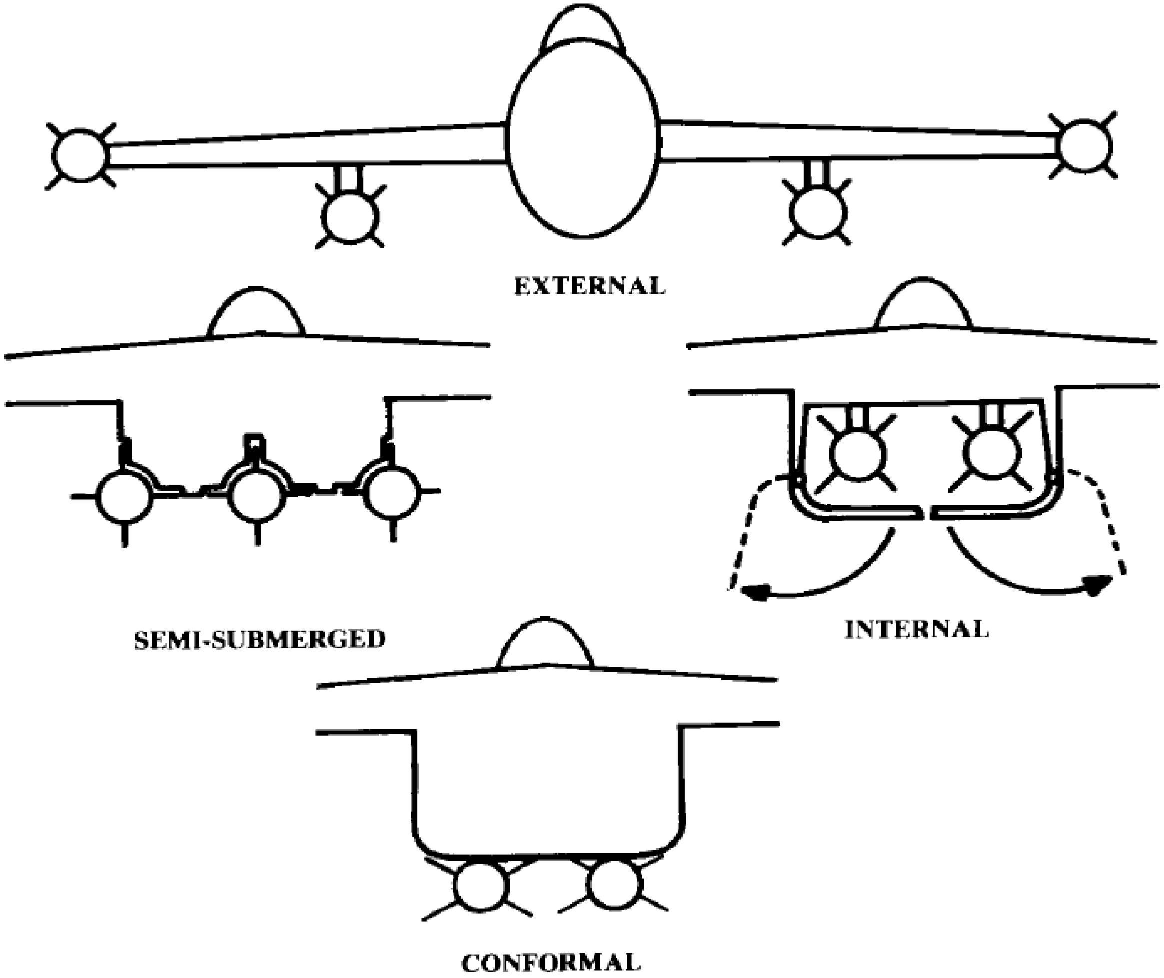


Fig. 9.5 Missile carriage/launch.

Weapon Carriage Options



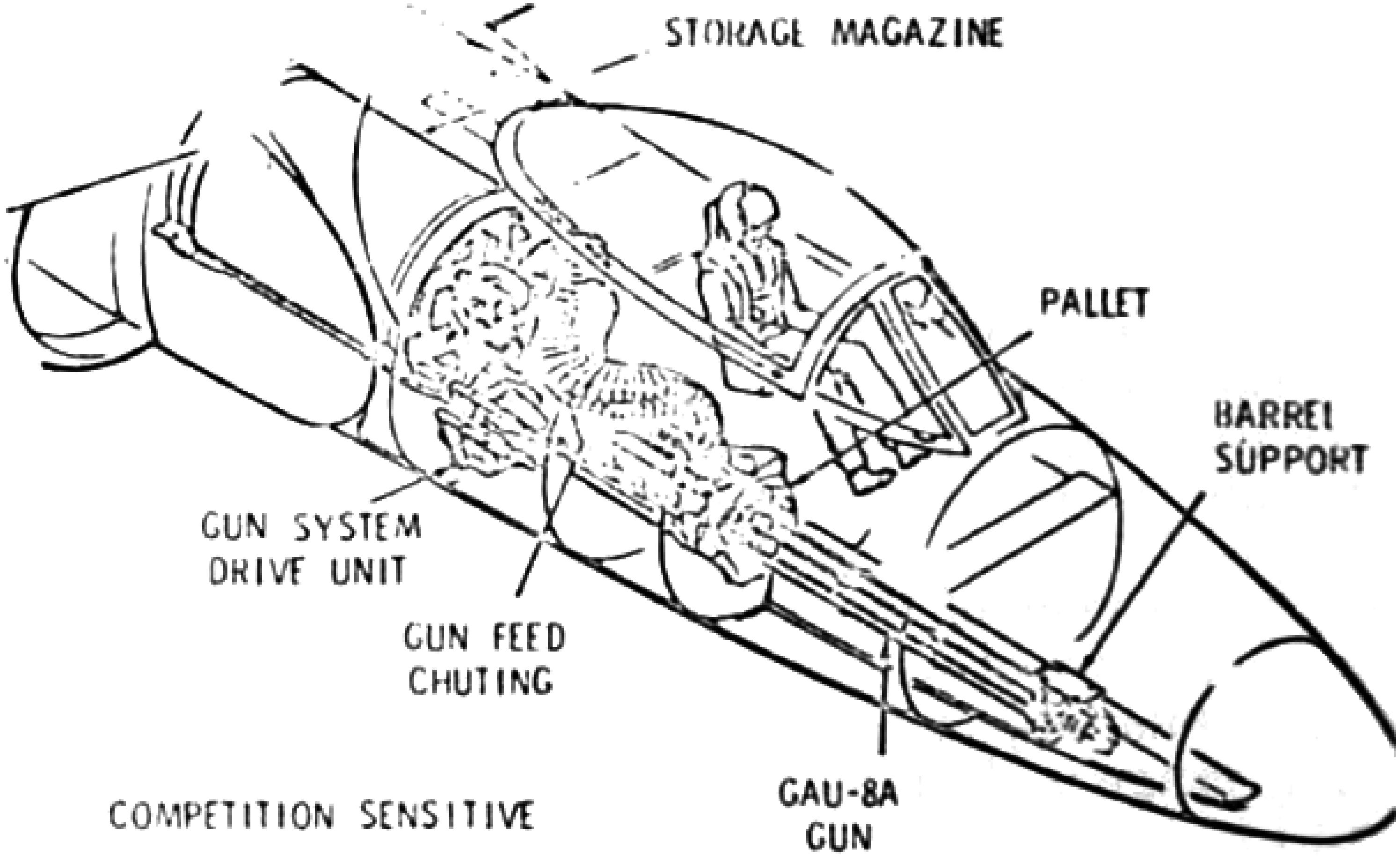
Weapon Carriage Options

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

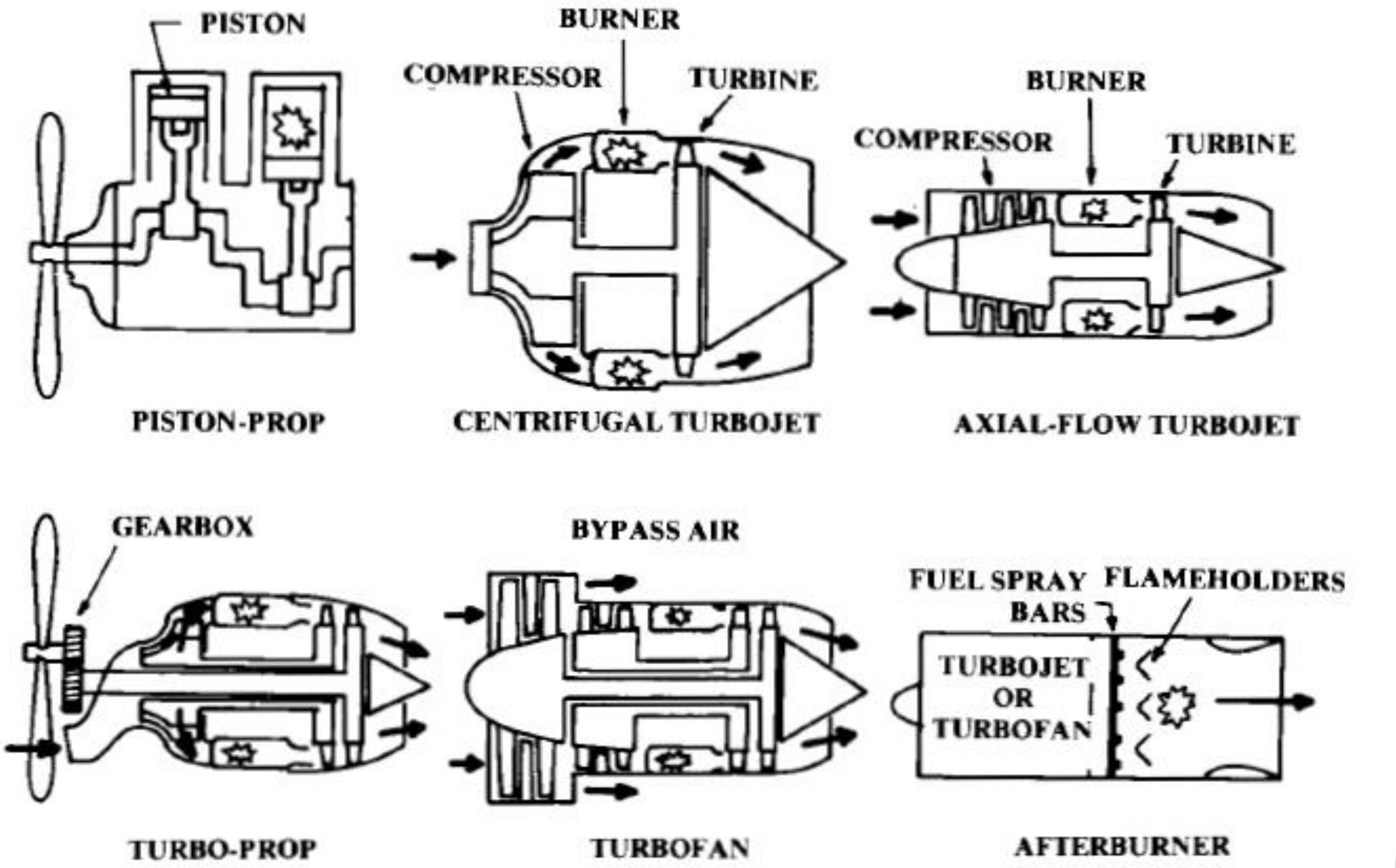
COMMUNICATION AND NAVIGATION AIDS

UNIT-III

CLOS	COURSE LEARNING OUTCOMES
CLO 8	Understanding different navigation systems, global and local area augmentation
CLO 9	Understanding different navigation systems, global and local area augmentation
CLO 10	Measuring of avionic and mission system interface, navigation and flight management

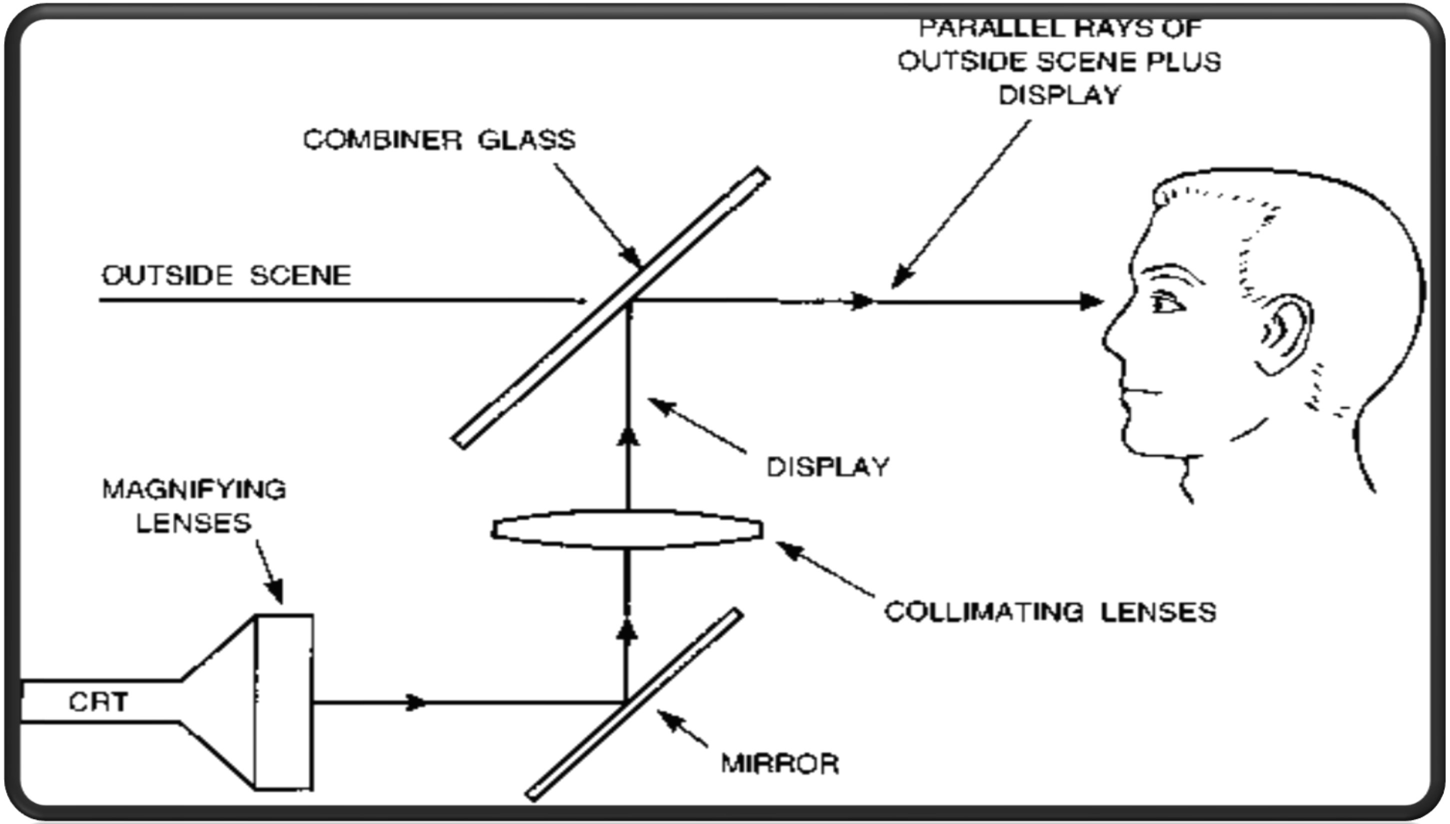
Radio frequency spectrum

- 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.

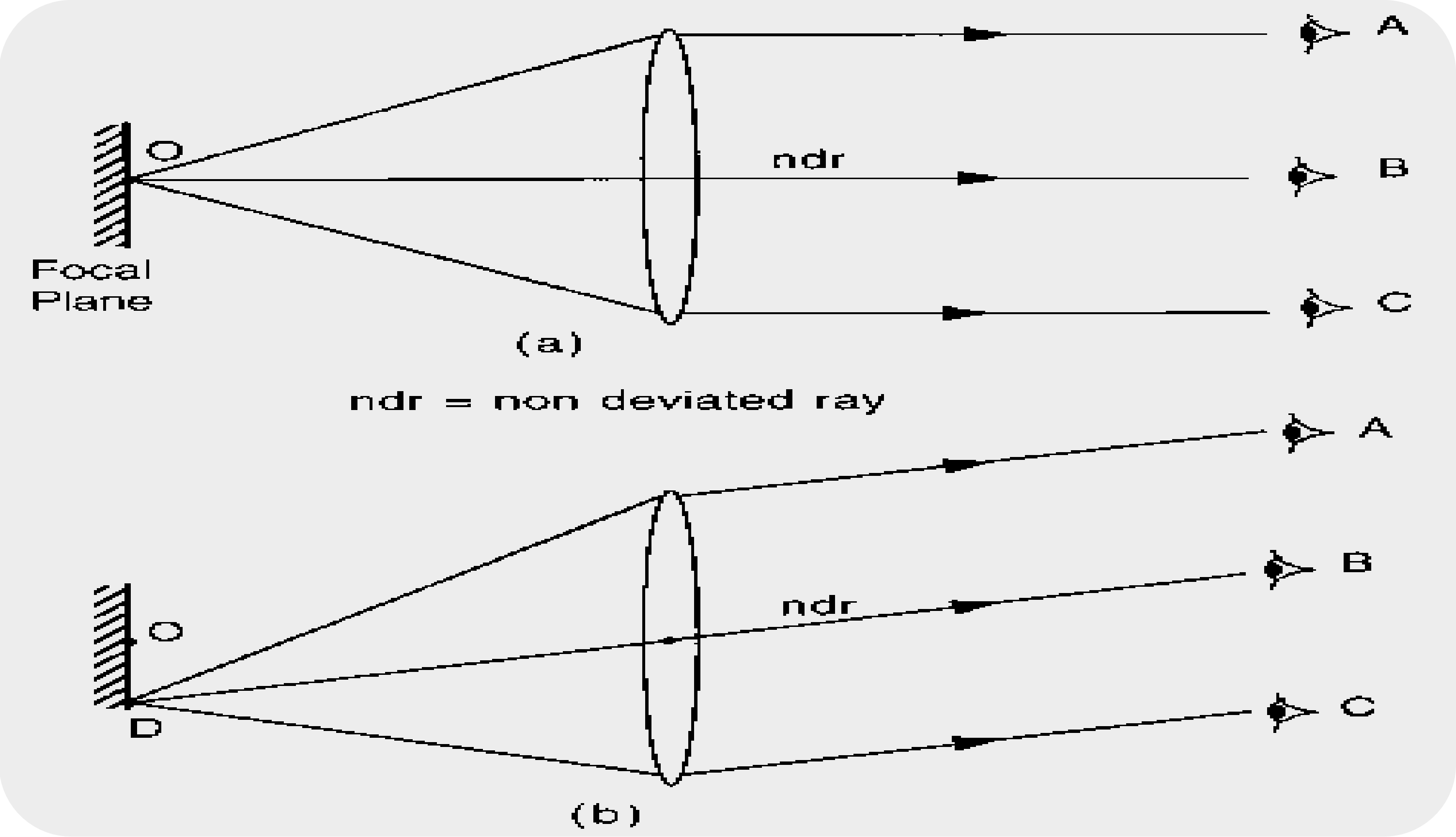


Propulsion System Options

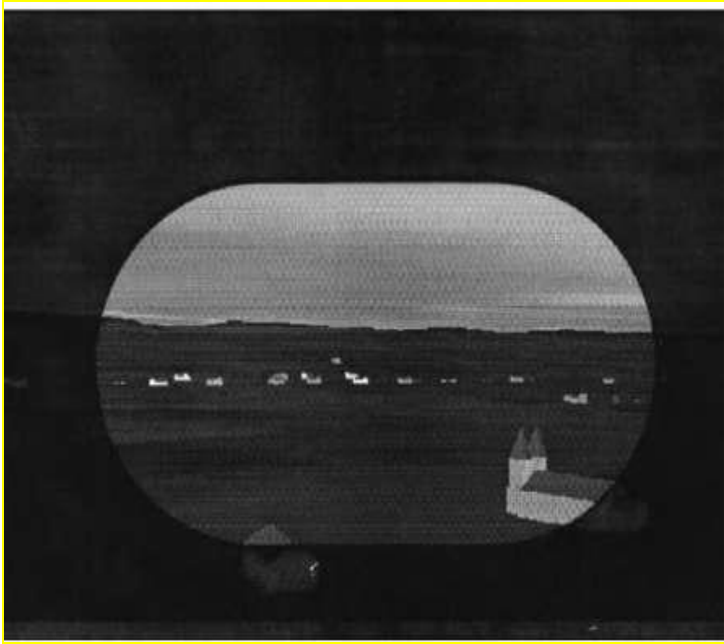
Basic Principles of HUD Technology



Simple Optical Collimator

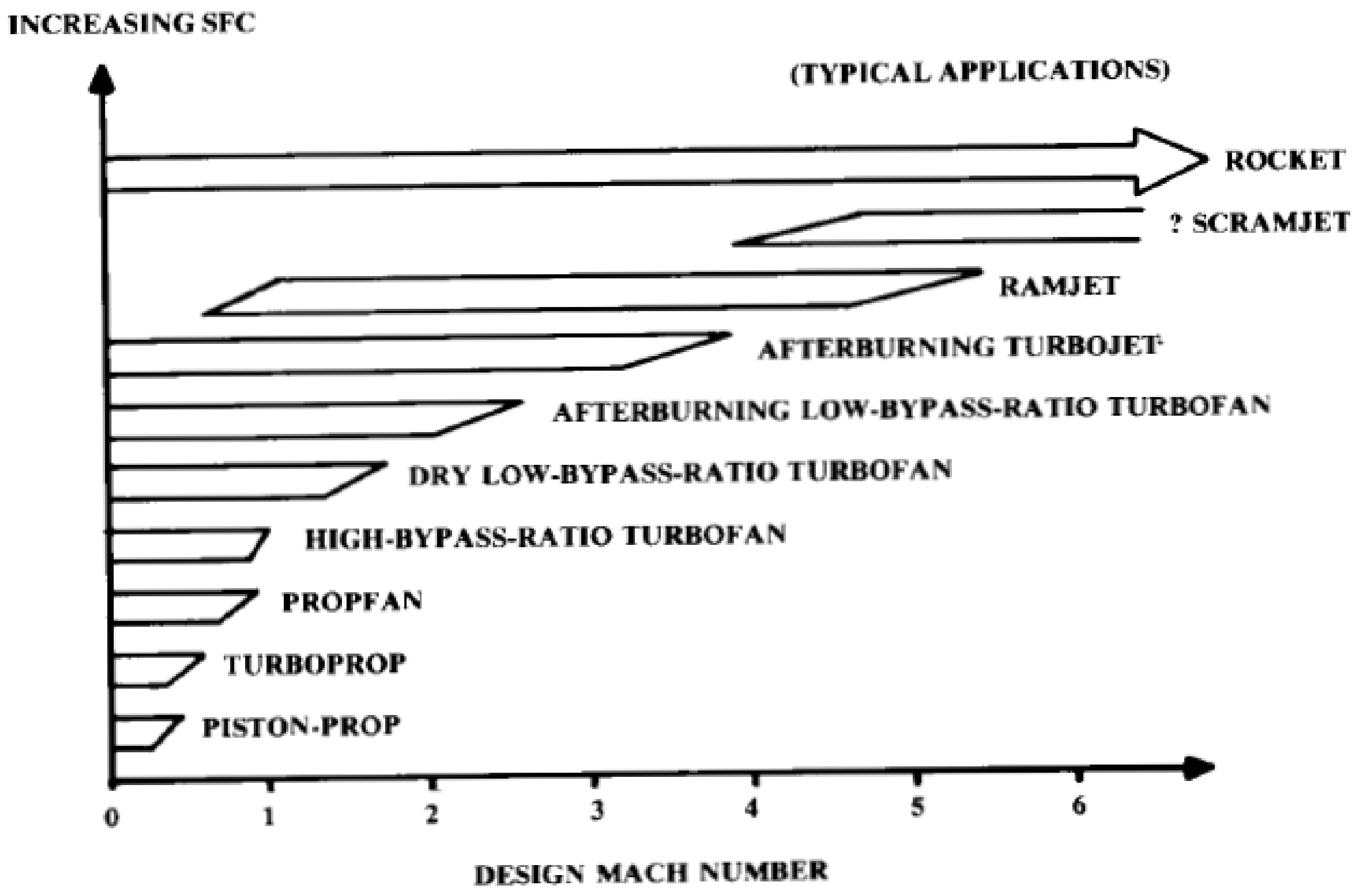


Instantaneous FOV of conventional HUD.



Instantaneous FOV of holographic HUD

Propulsion System Speed Limits

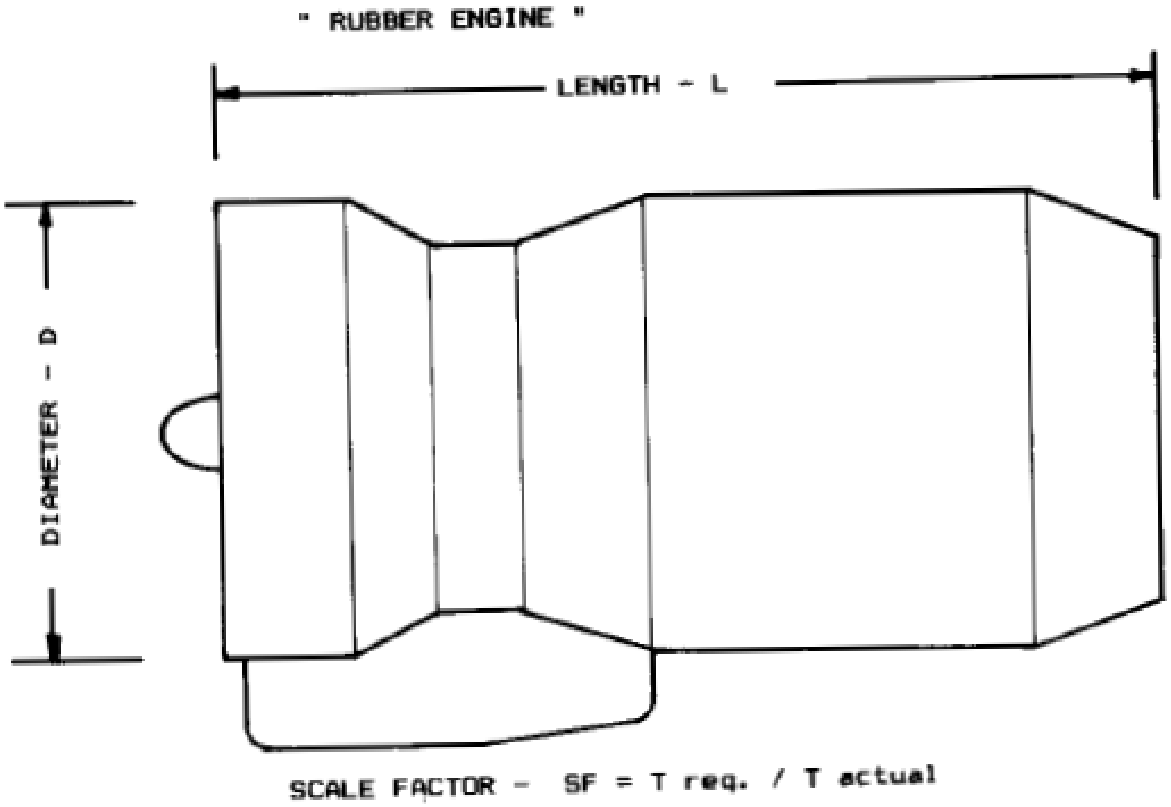


Propulsion System Speed Limits

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

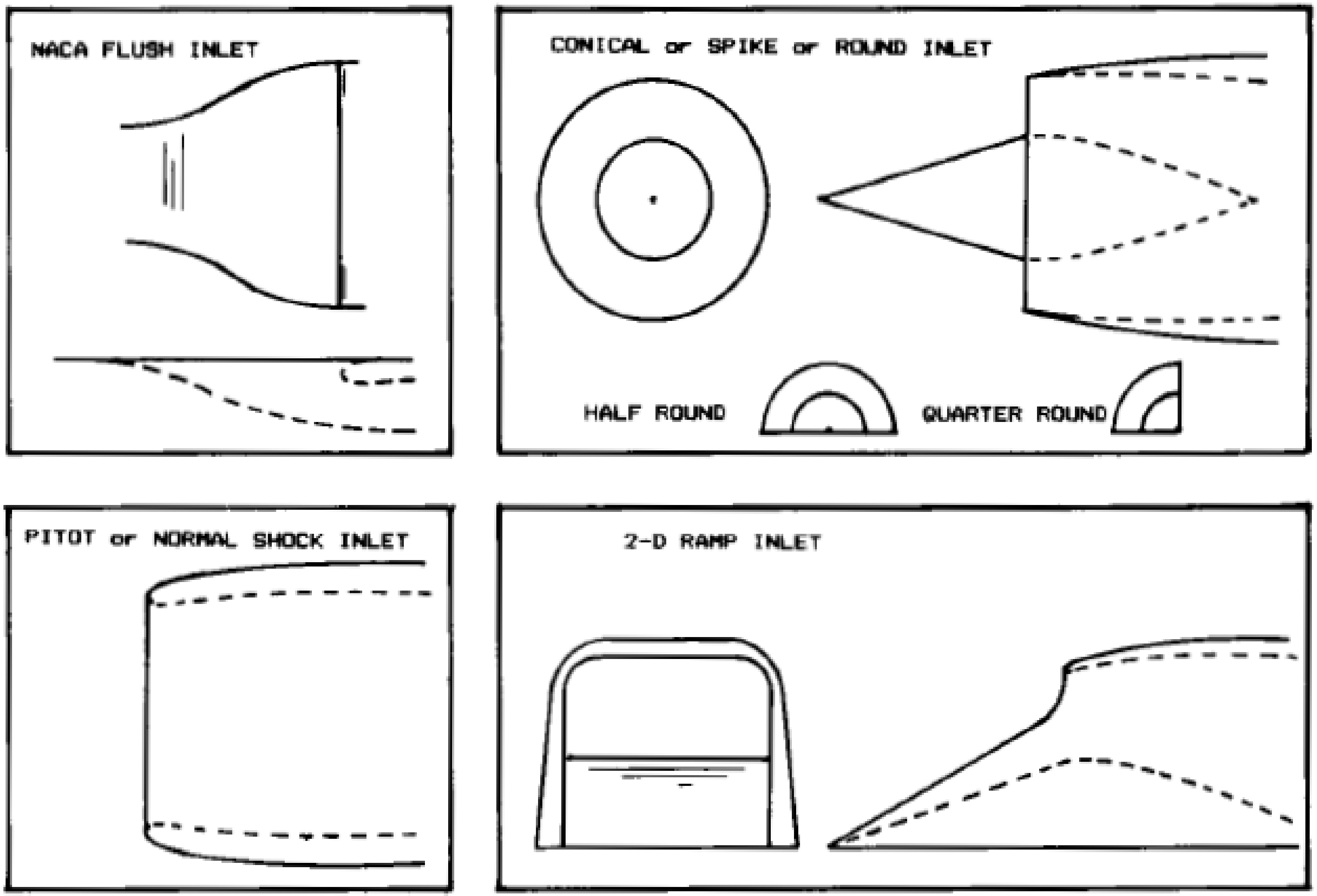


Engine Scaling

Inlet Geometry

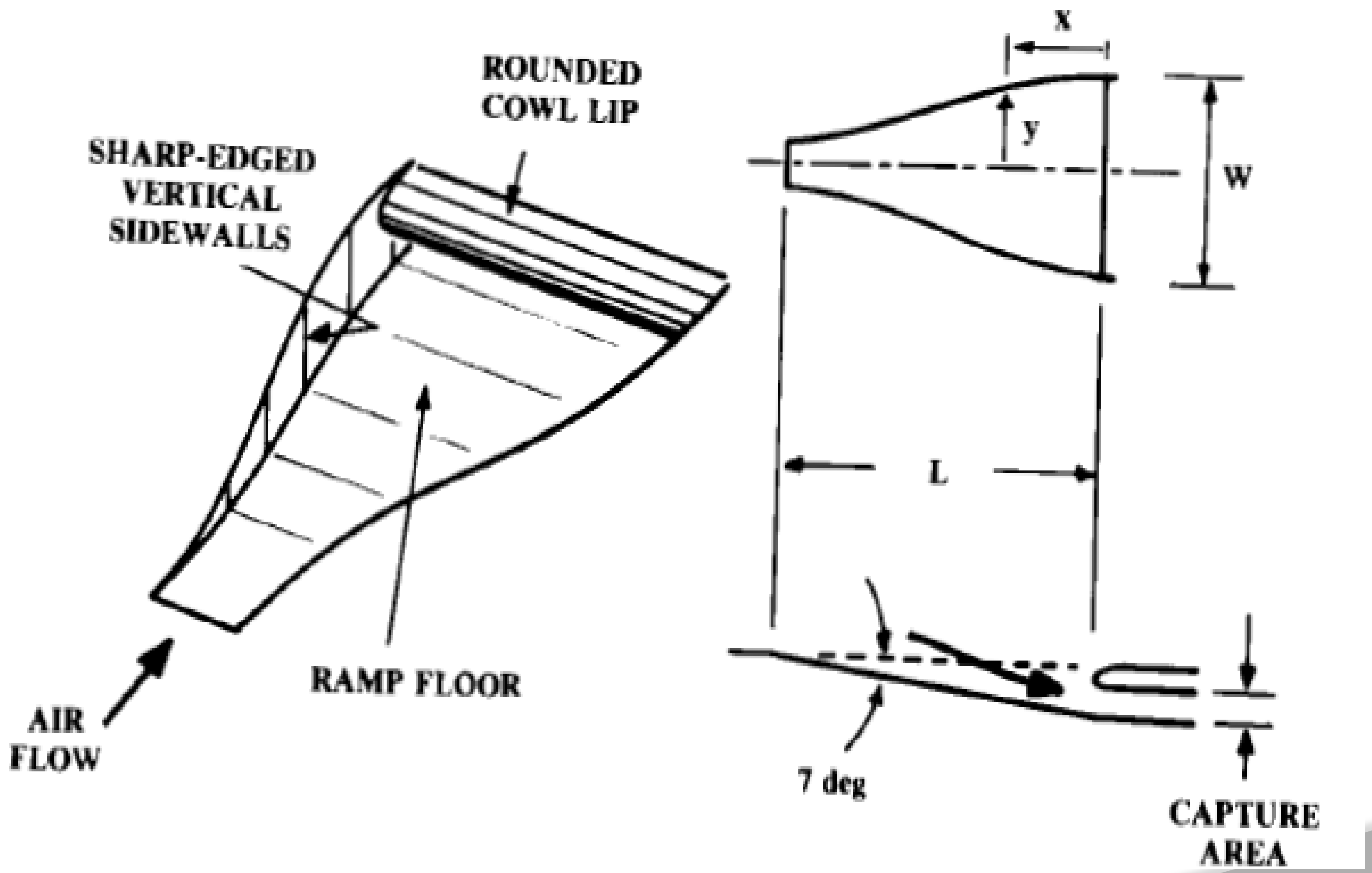
- Turbojet and turbofan engines are incapable of efficient operation unless the air entering them is slowed to a speed of about Mach 0.4-0.5.
- This is to keep the tip speed of the compressor blades below sonic speed relative to the incoming air.
- Slowing down the incoming air is the primary purpose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

Inlet Types



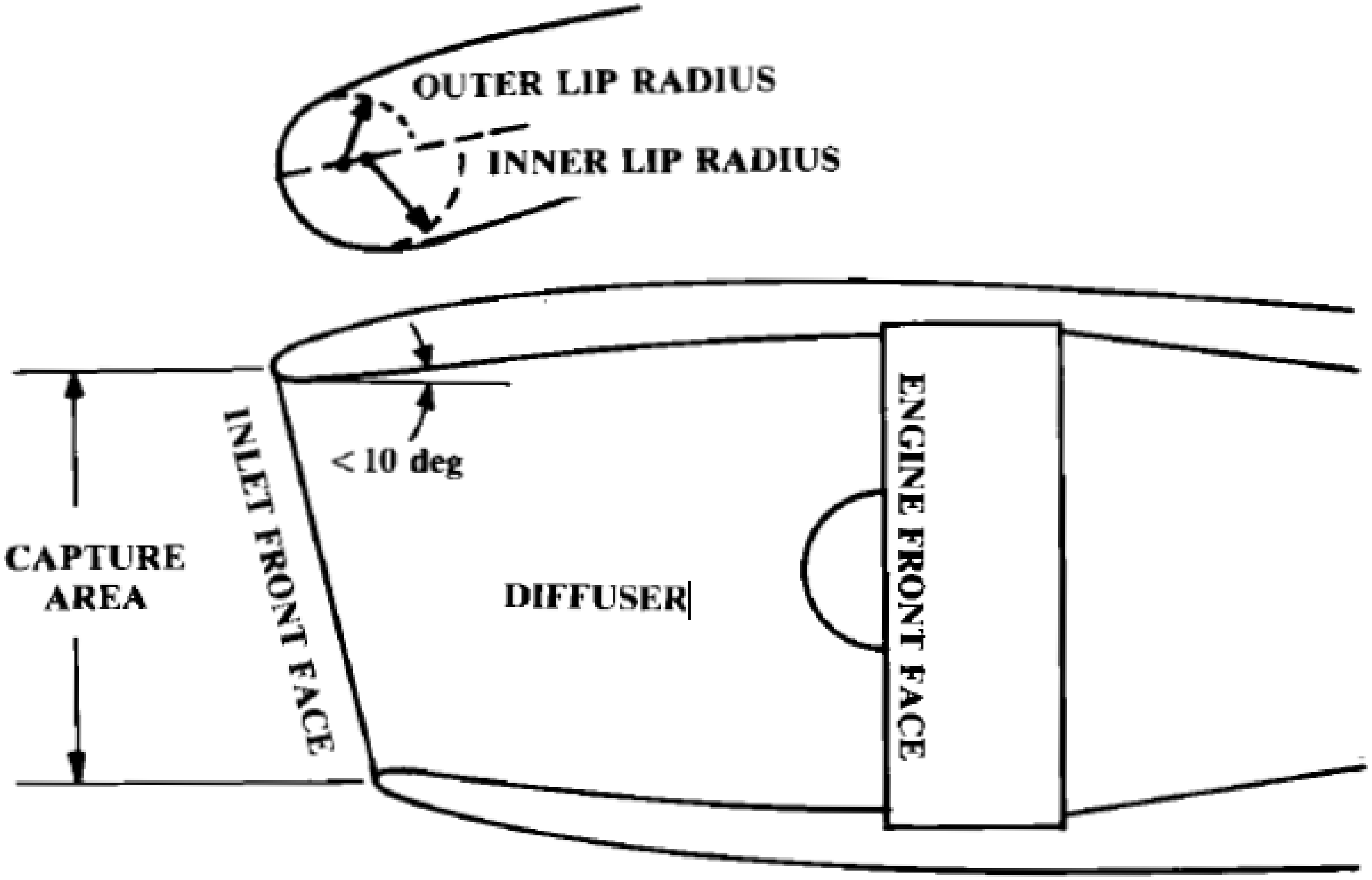
Inlet Types

Flush Inlet Geometry



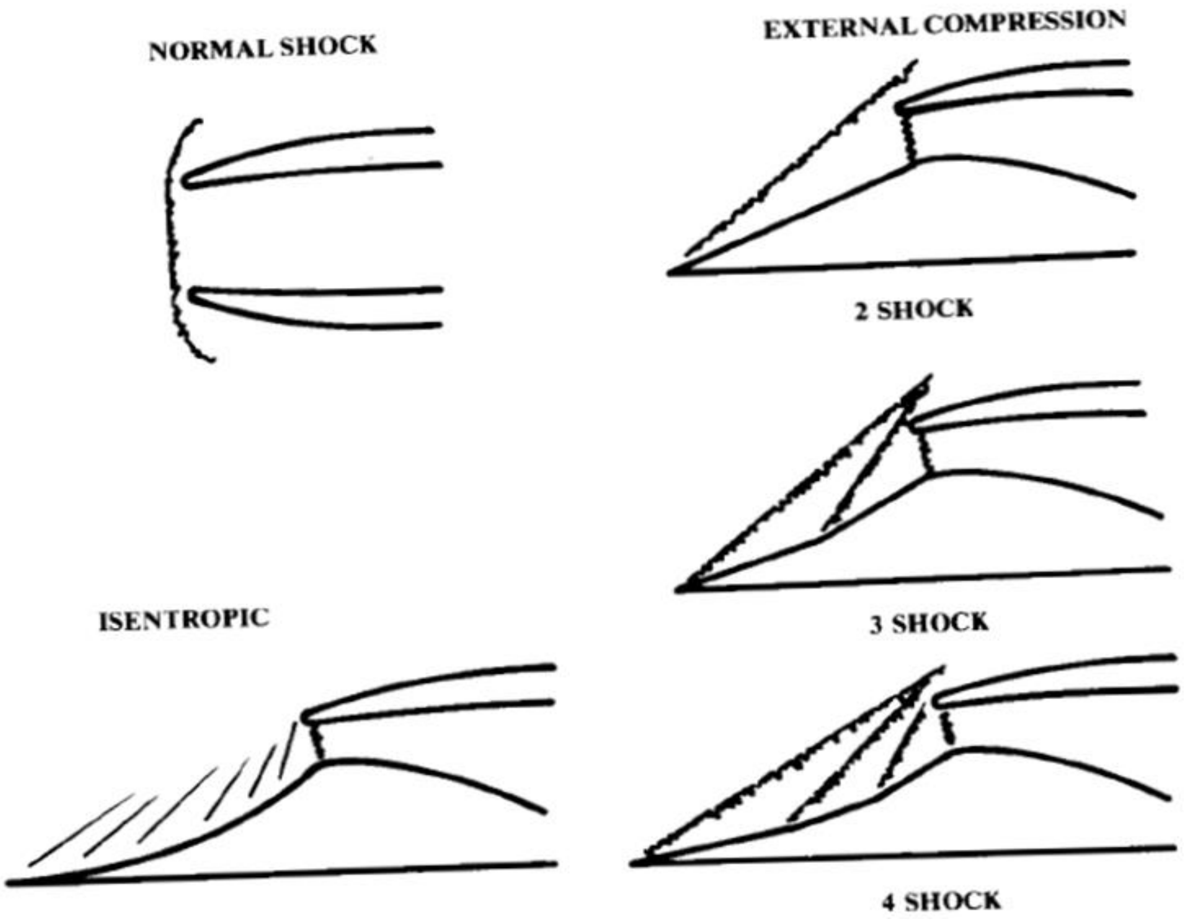
Flush Inlet Geometry

pilot (normal shock) inlet layout



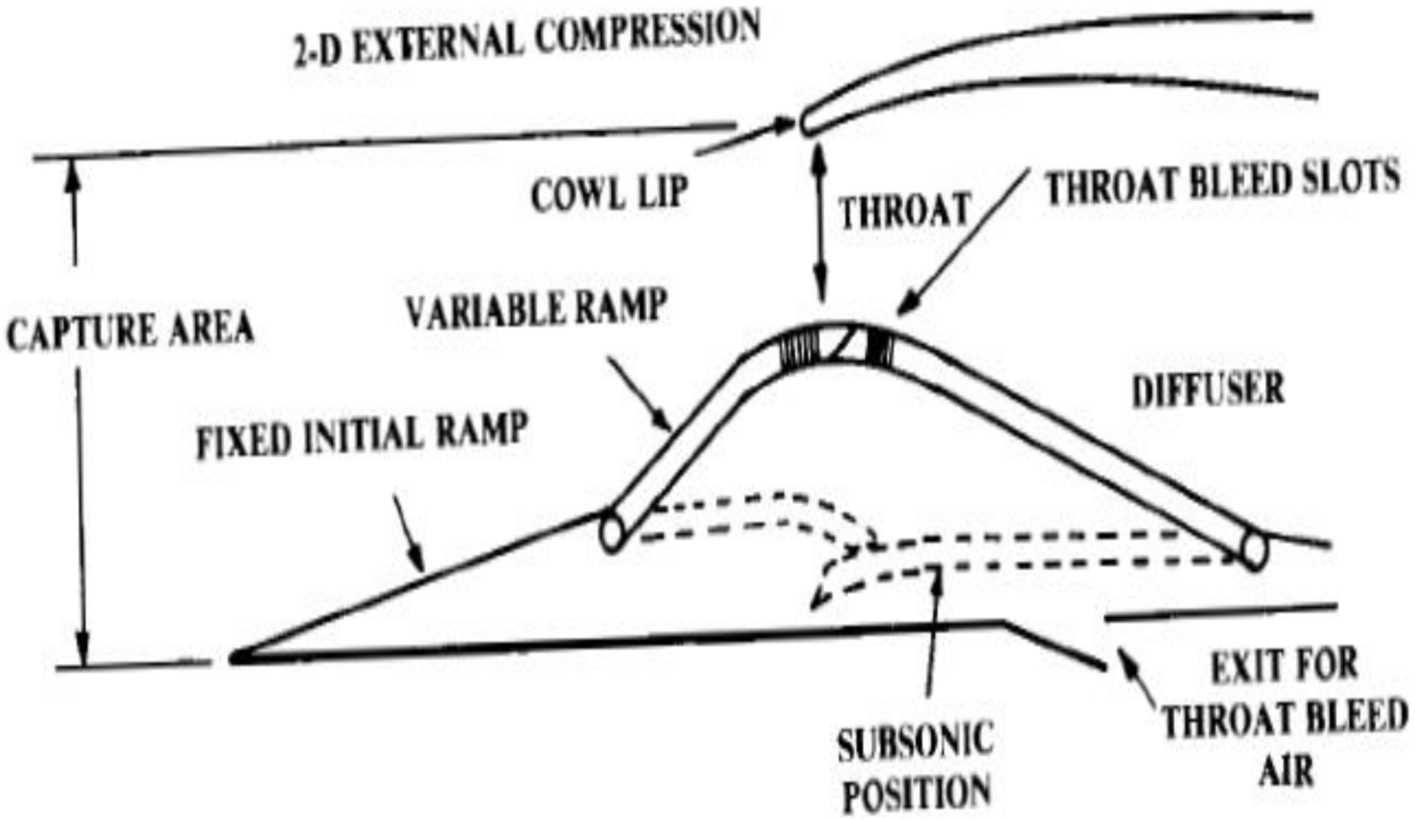
Pilot (normal shock) inlet layout

Supersonic Inlets-external Shocks



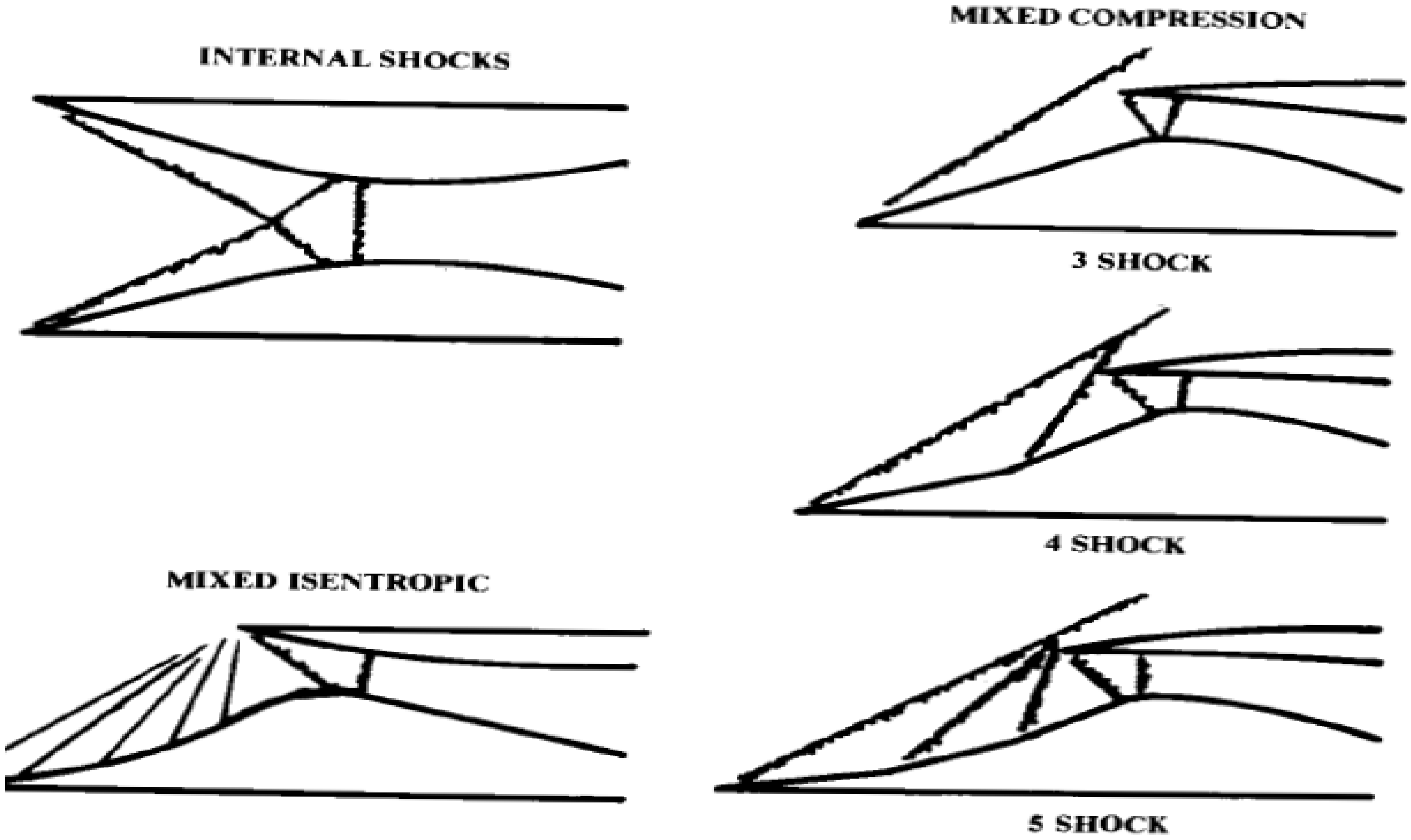
Supersonic Inlets-external Shocks

Variable Inlet Geometry



Variable Inlet Geometry

Supersonic Inlets-internal And Mixed

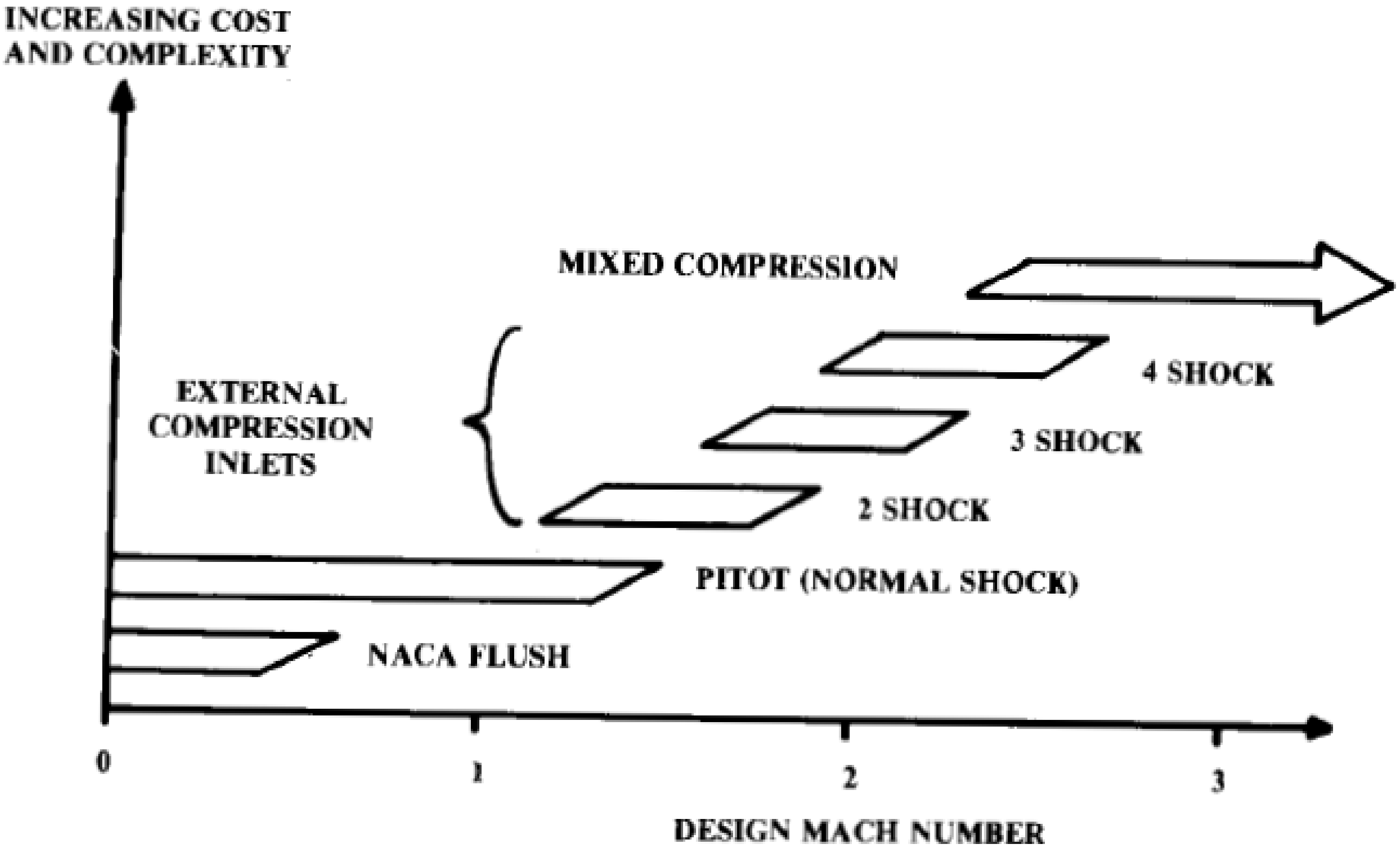


Supersonic Inlets-internal And Mixed

Inlet Location

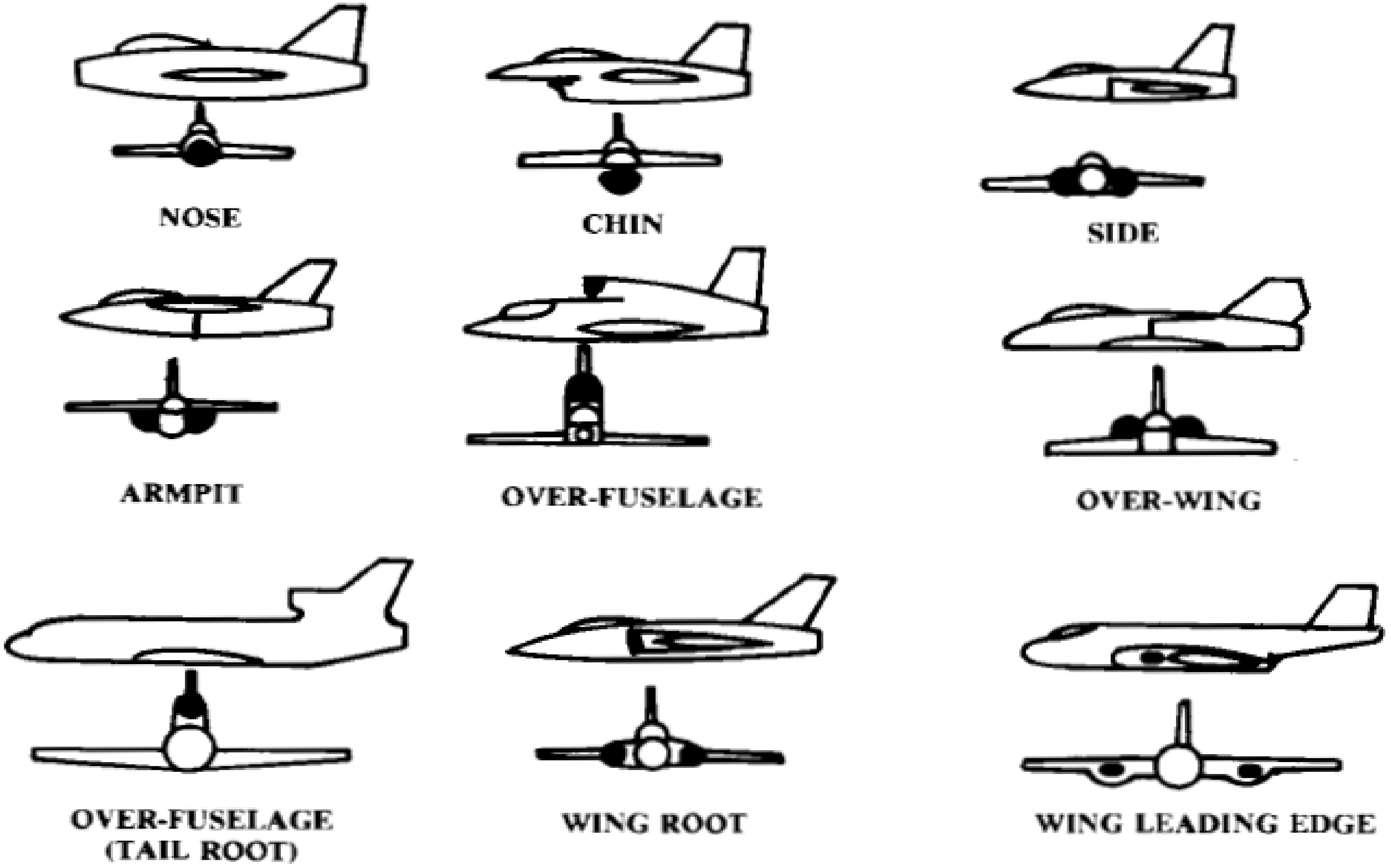
- The inlet location can have almost as great an effect on engine performance as the inlet geometry. If the inlet is located where it can ingest vortex off the fuselage or a separated wake from a wing, the resulting
- An over-fuselage inlet is much Tike an inverted chin inlet, and has a short duct length 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



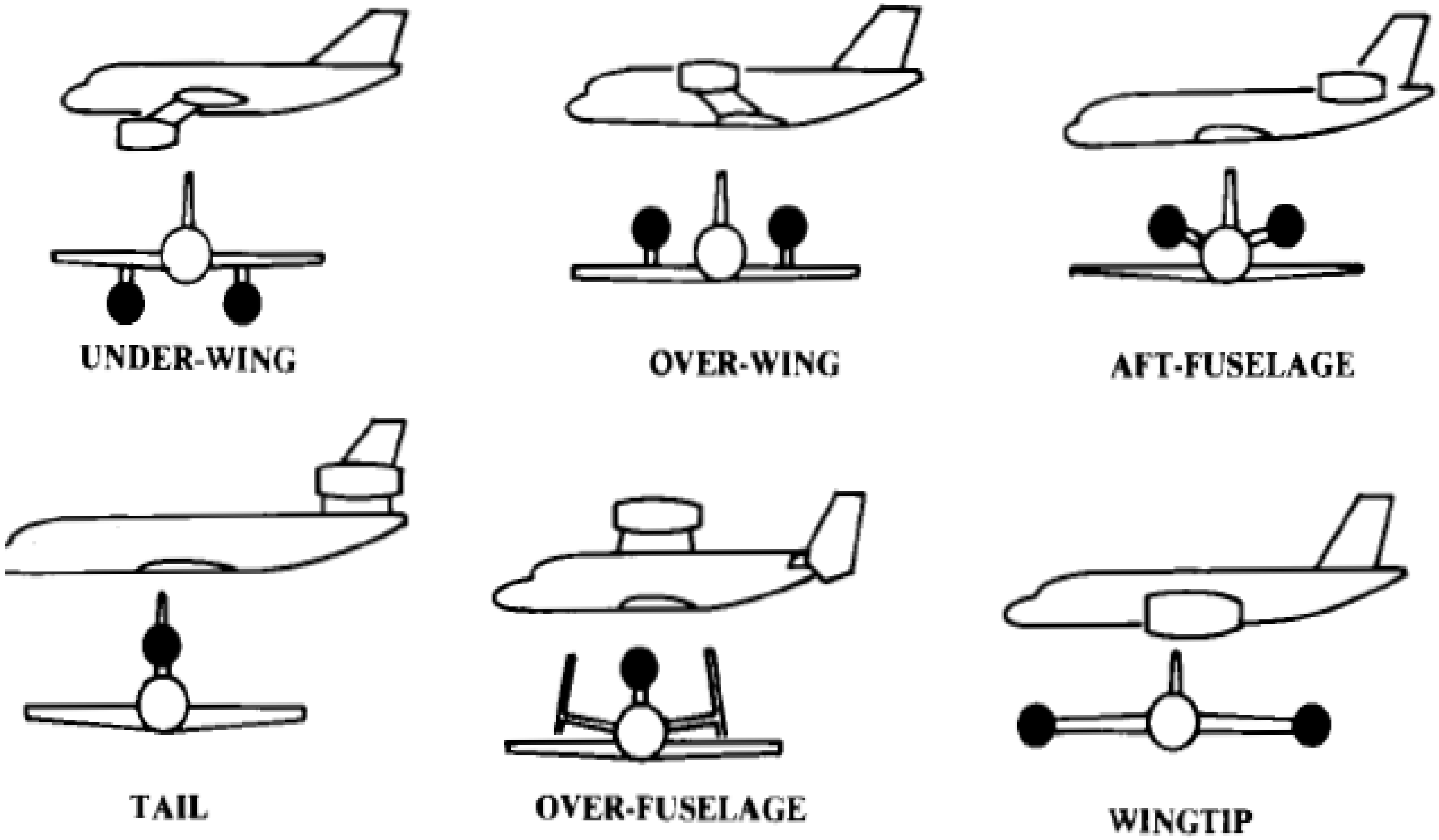
Inlet Applicability

Inlet Locations-buried Engines



Inlet Locations-buried Engines

Inlet Location-podded Engines

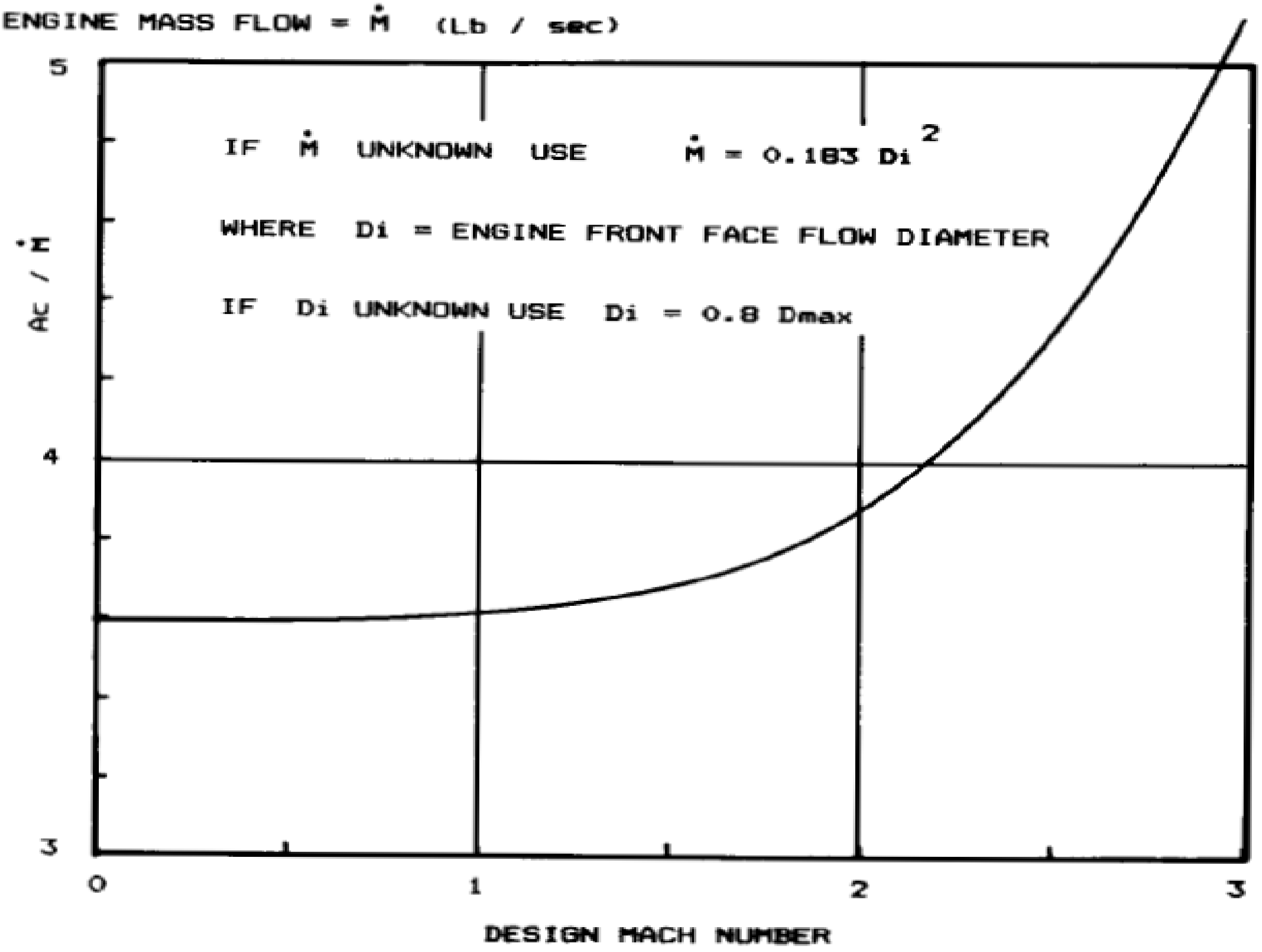


Inlet Location-podded Engines

Capture Area Calculation

INLET CAPTURE AREA = Ac (square inches)

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

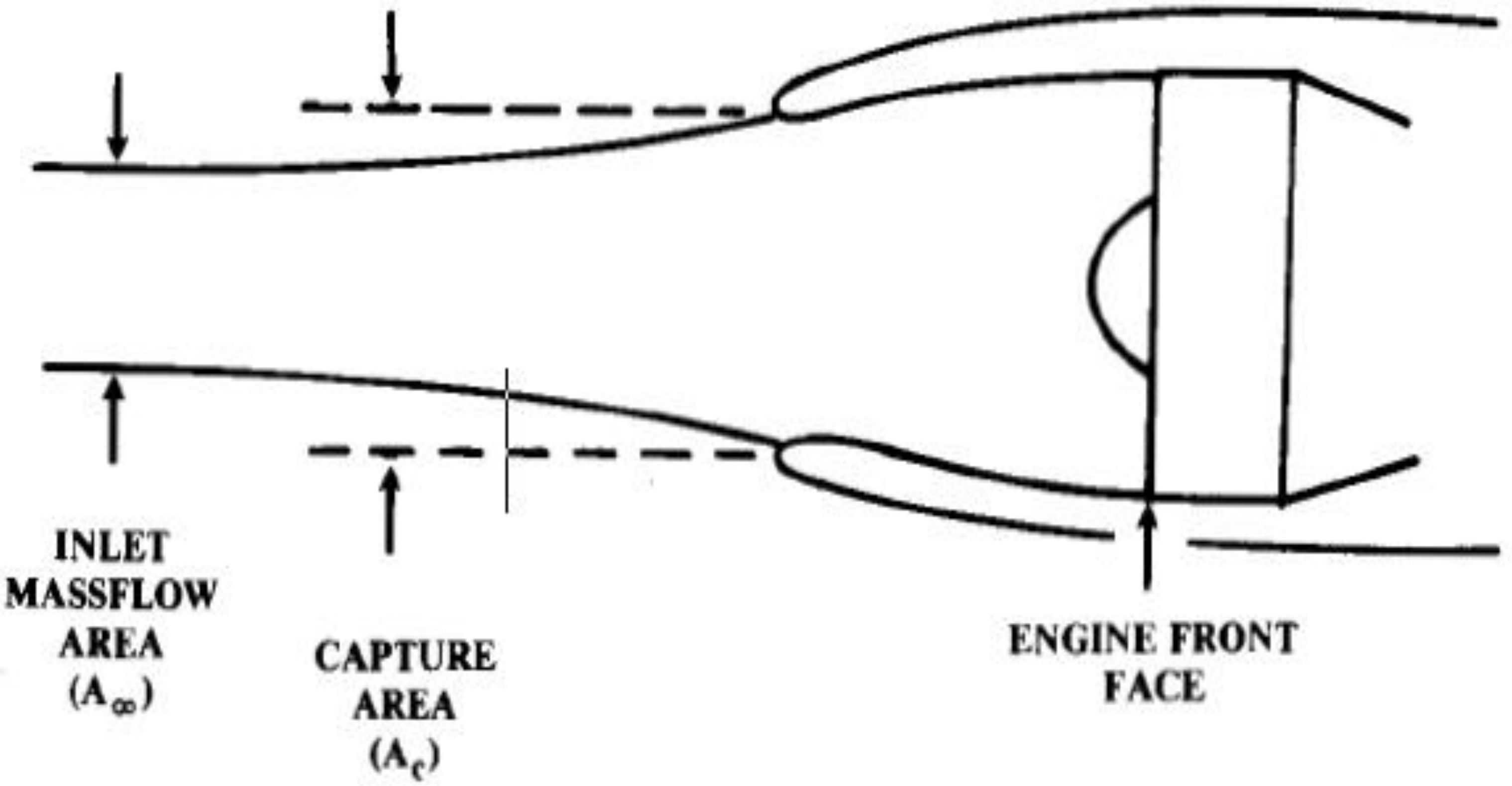


IF $\dot{M}$ UNKNOWN USE $\dot{M} = 0.183\ Di^2$

WHERE Di = ENGINE FRONT FACE FLOW DIAMETER

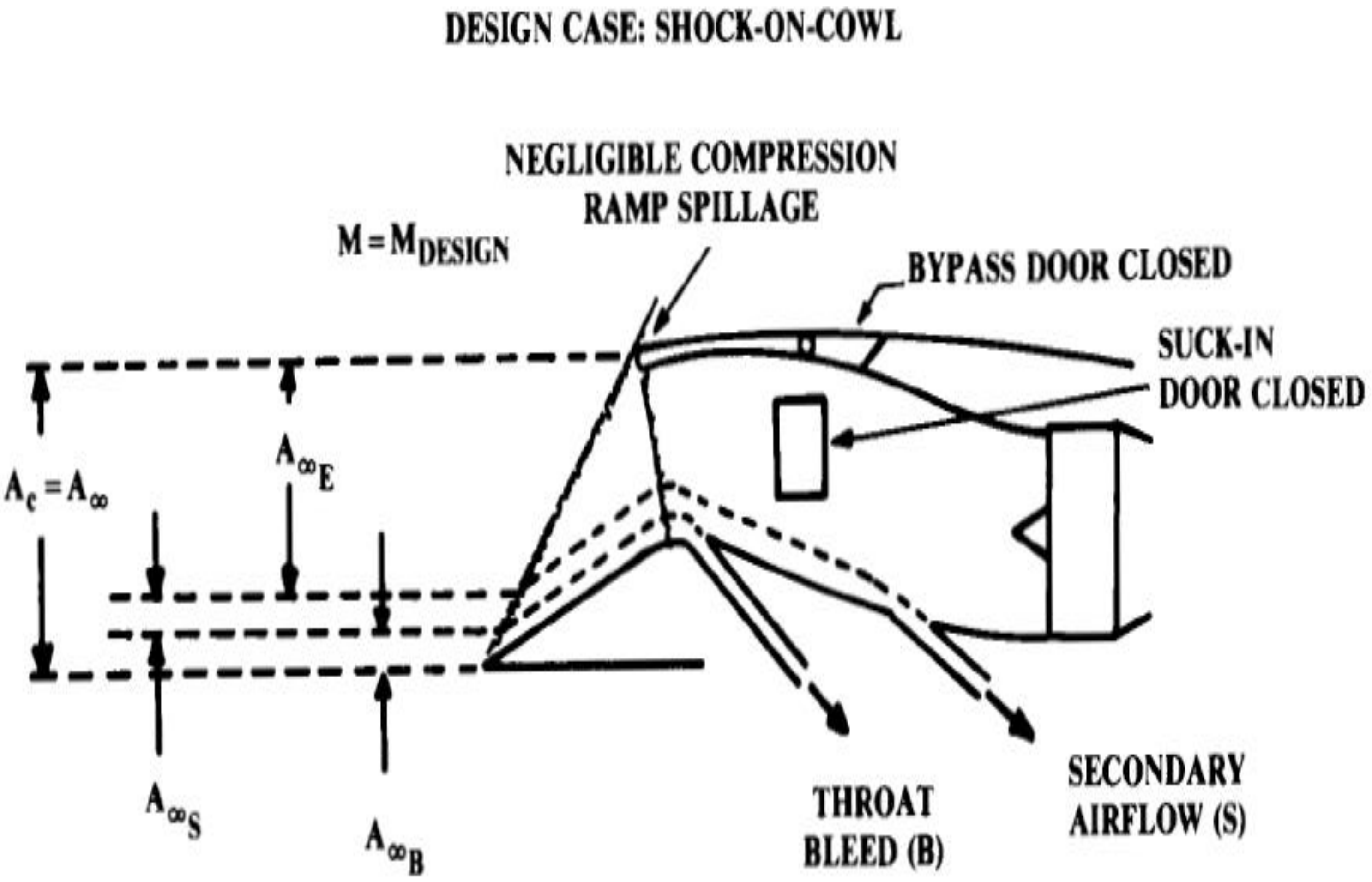
IF Di UNKNOWN USE Di = 0.8 Dmax

Subsonic Inlet Capture Area



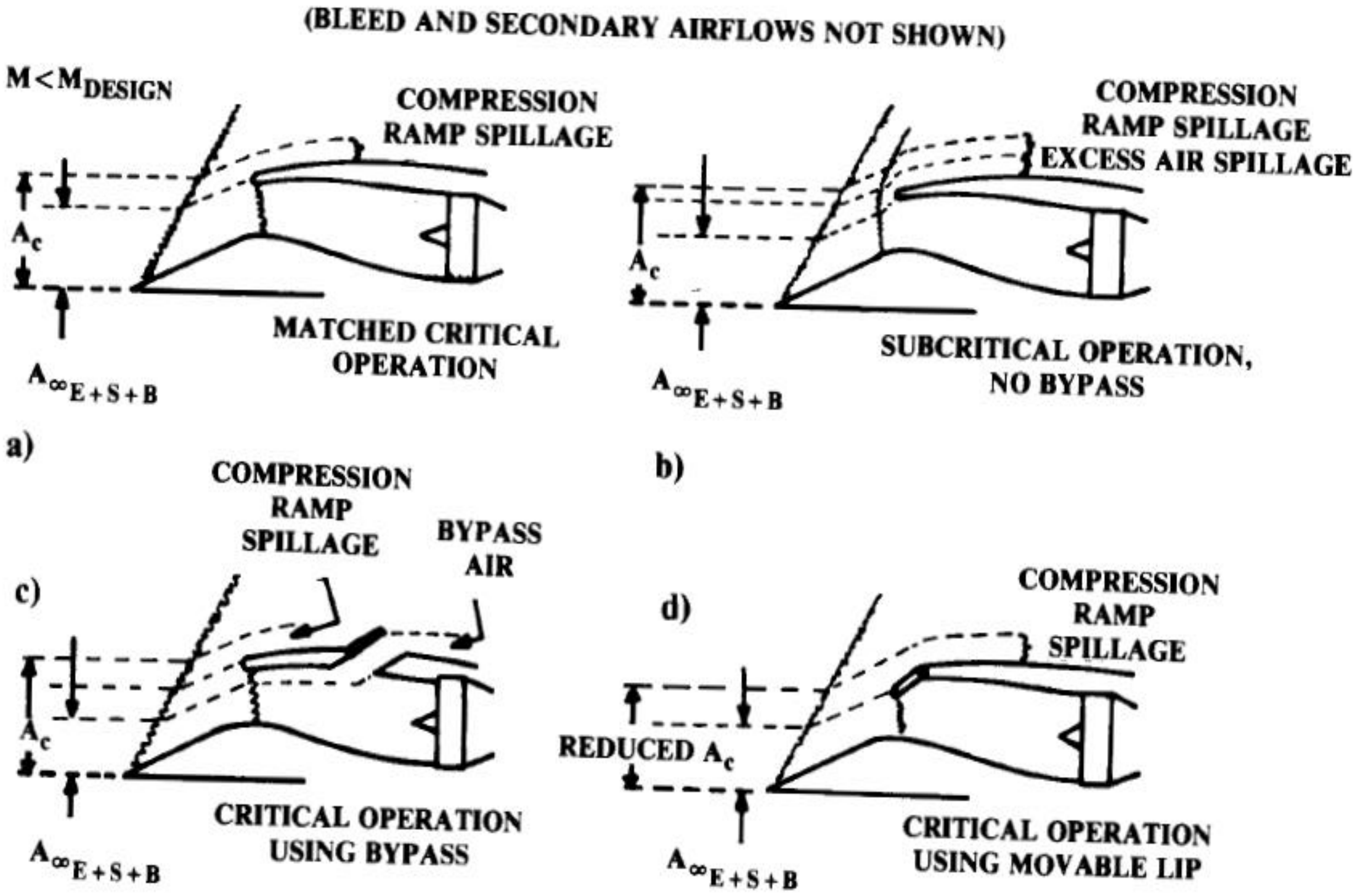
Subsonic Inlet Capture Area

Supersonic Inlet Capture Area-on Design



Supersonic Inlet Capture Area-on Design

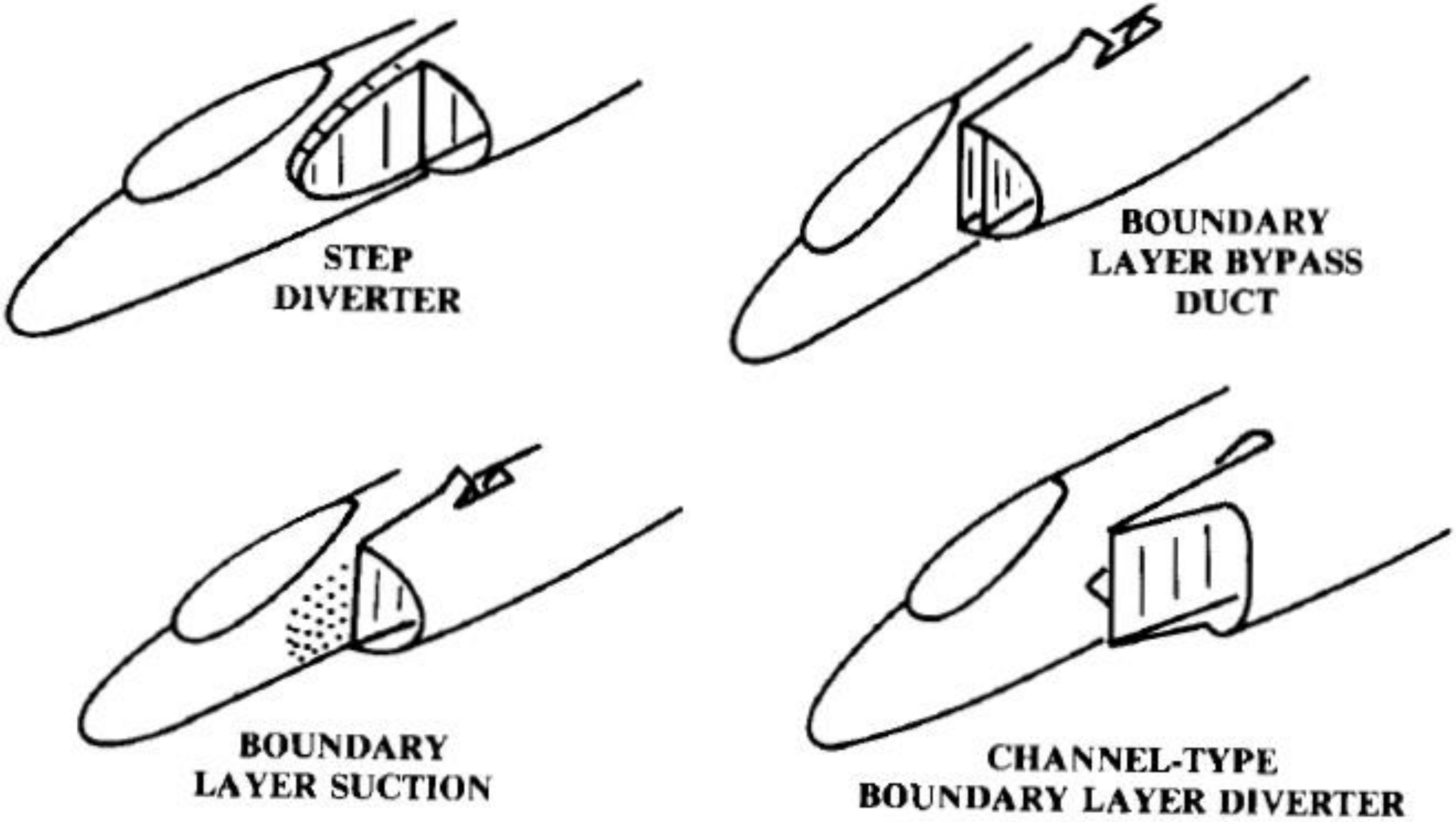
Off-design inlet operations



BOUNDARY LAYER DIVERTERS

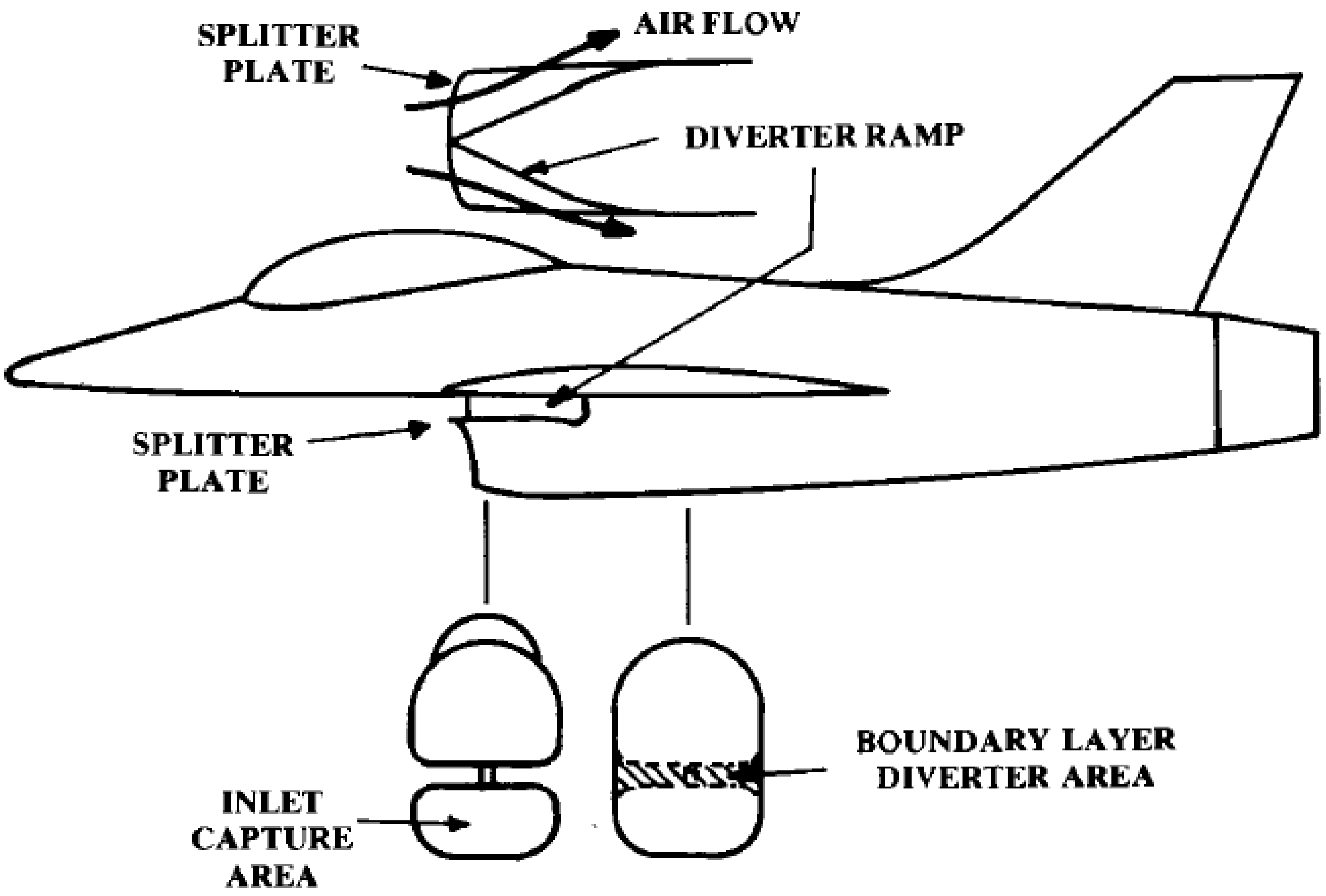
- Any object moving through air will build up a boundary layer on its surface. In the last section, boundary-layer bleed was included in the capture area calculation.
- This boundary-layer bleed was used to remove the low-energy boundary layer air from the compression ramps, to prevent shock-induced 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



Boundary Layer Removal

Boundary Layer Diverter

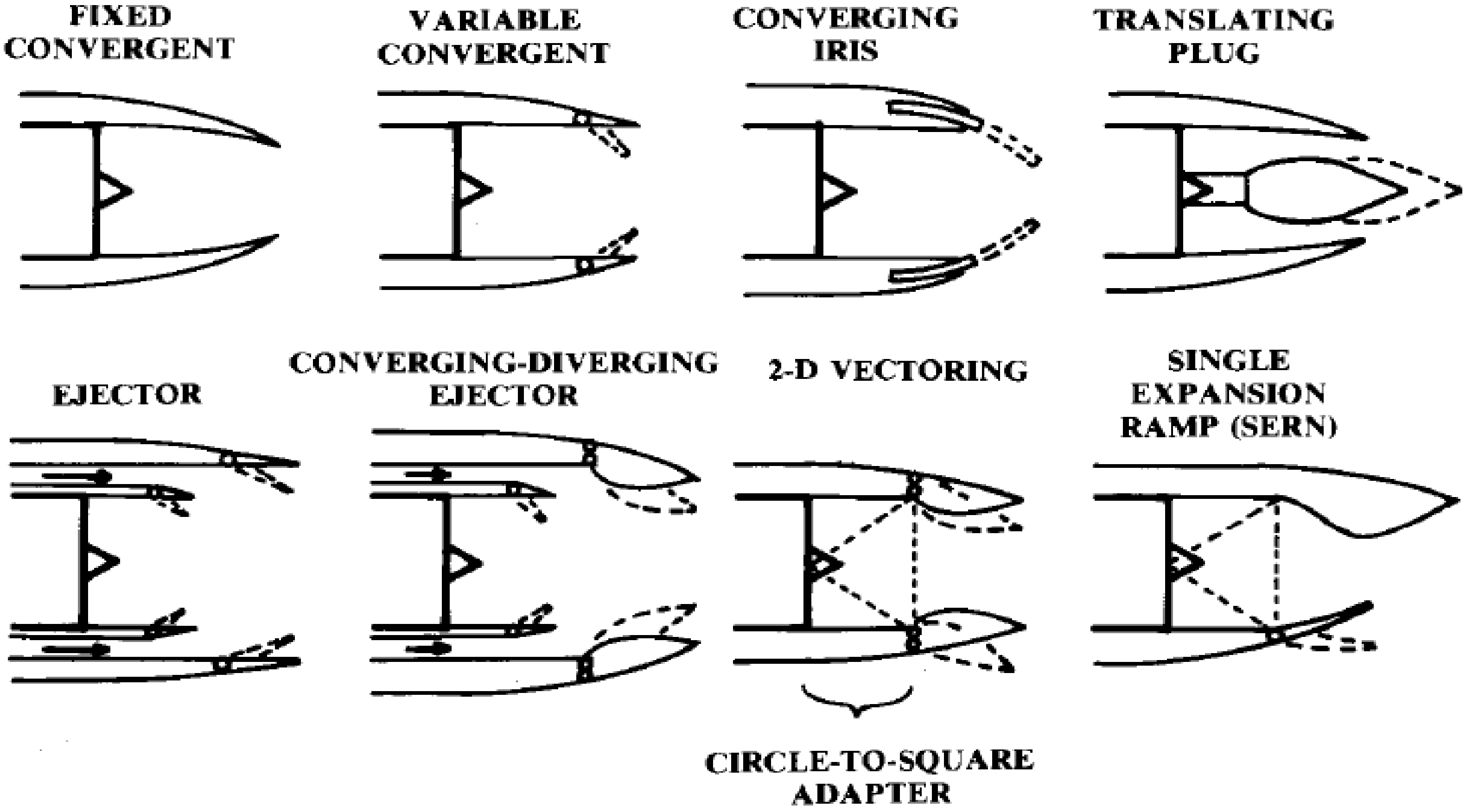


Boundary Layer Diverter

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

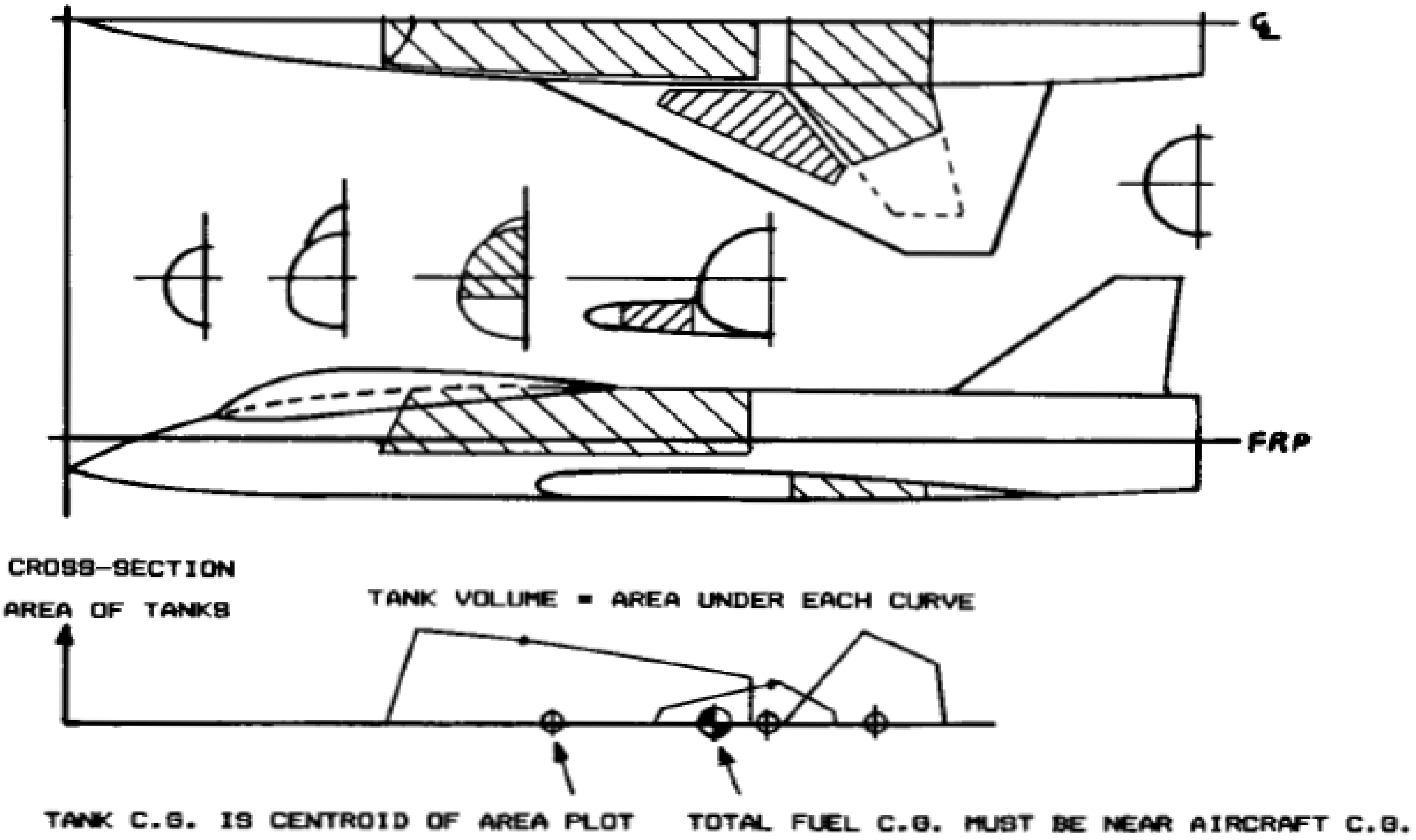
Engine Size Estimation

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

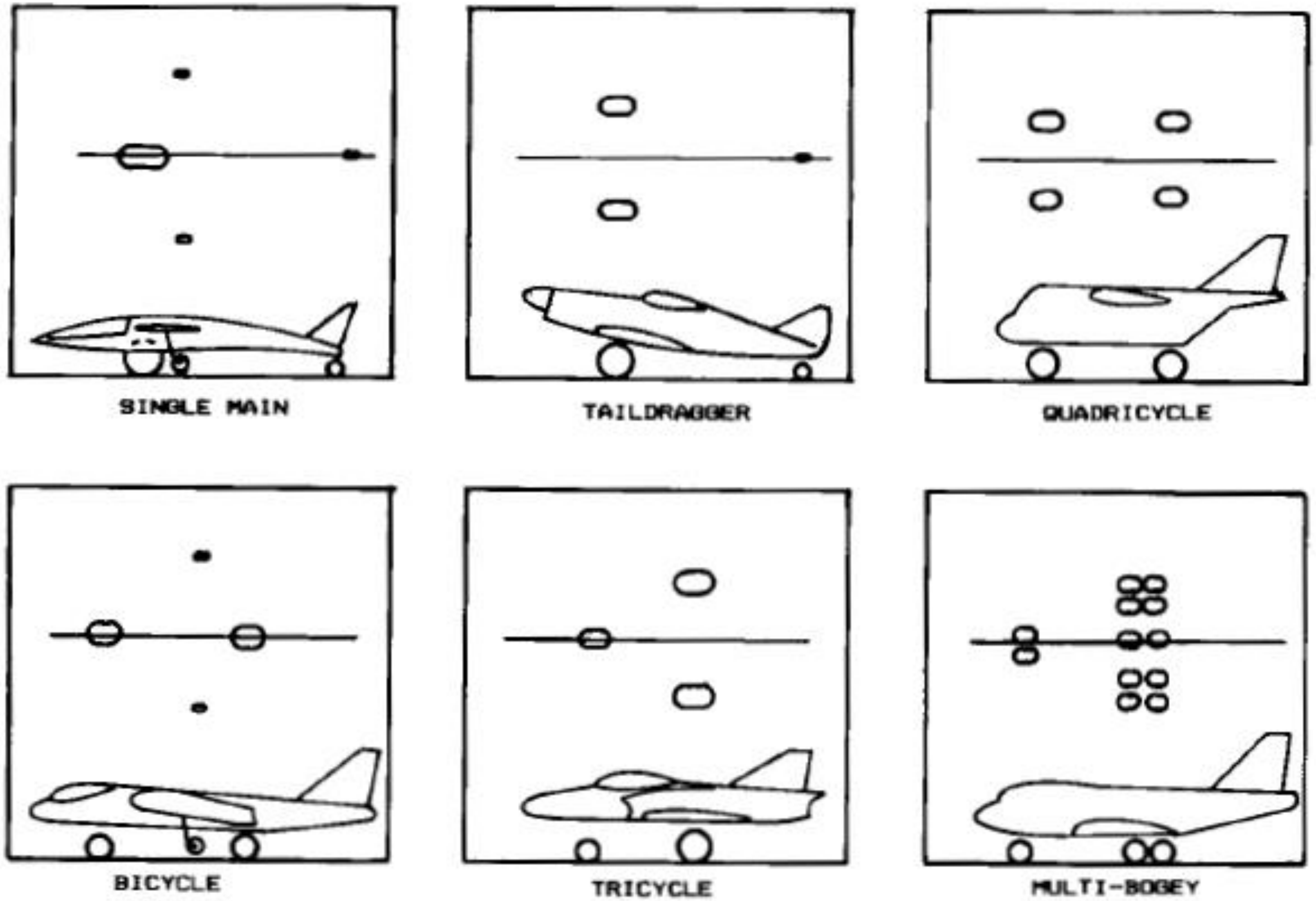
An aircraft fuel system includes the fuel tanks, fuel lines, fuel pumps, vents, and fuel-management controls. Usually the tanks themselves are the only components that impact the overall aircraft layout, although the winglets on the round-the-world Rutan Voyager were added solely to raise the fuel vents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

Fuel Tank Volume Plotting



Fuel Tank Volume Plotting

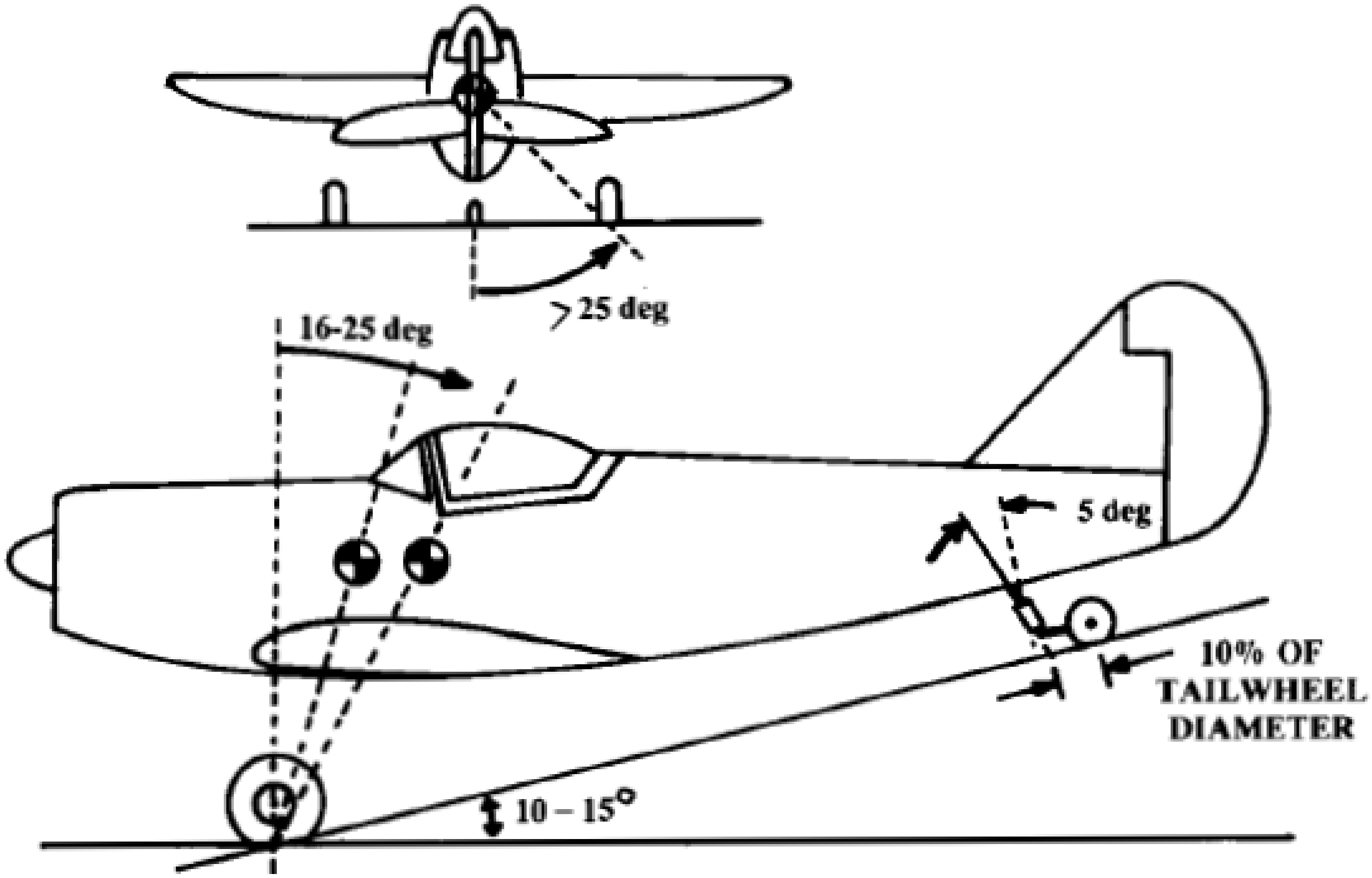
Landing Gear Arrangements



SINGLE MAIN
TAILDRAGGER
QUADRICYCLE
BICYCLE
TRICYCLE
MULTI-BOGEY

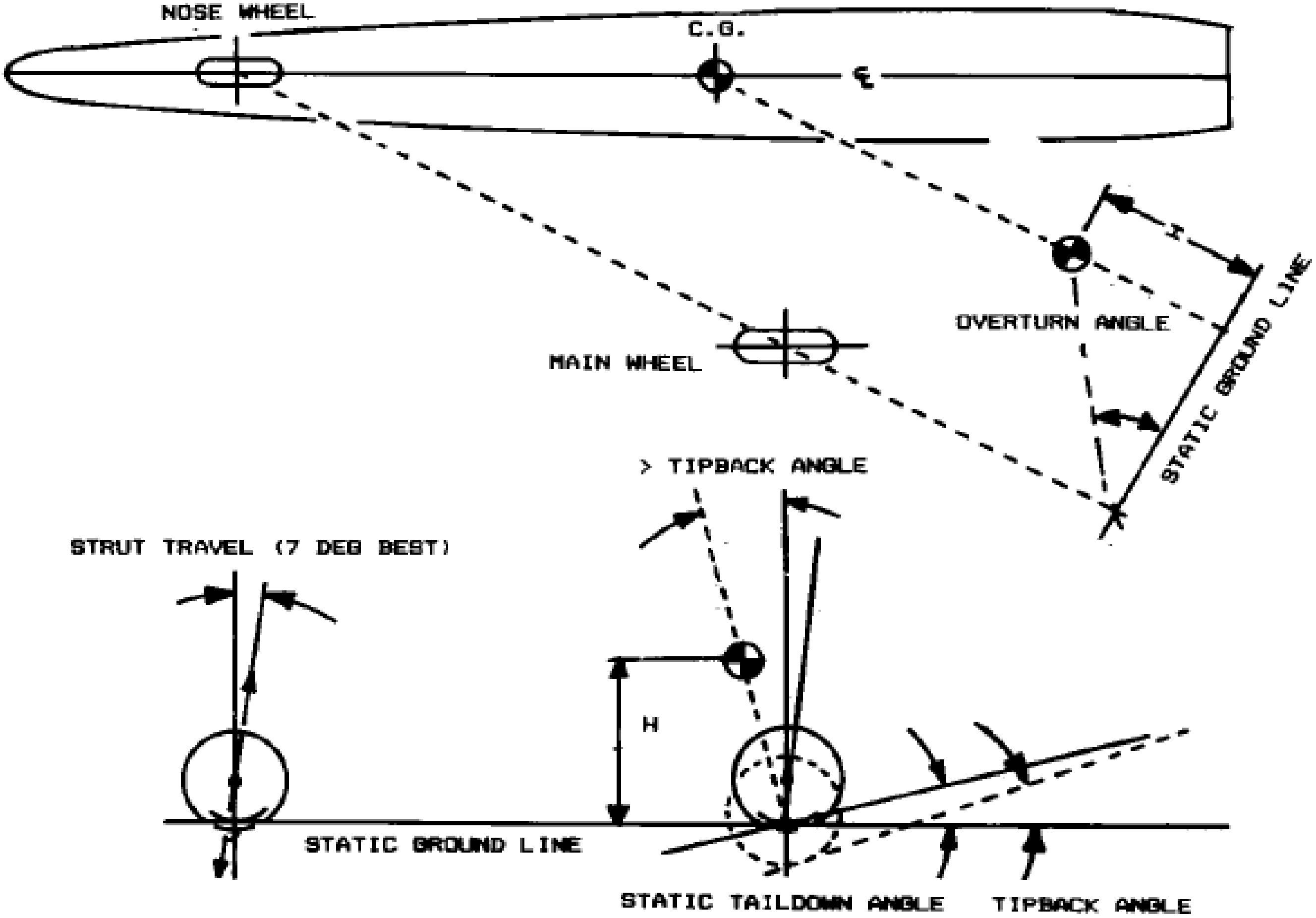
Landing Gear Arrangements

Tail dragger landing gear



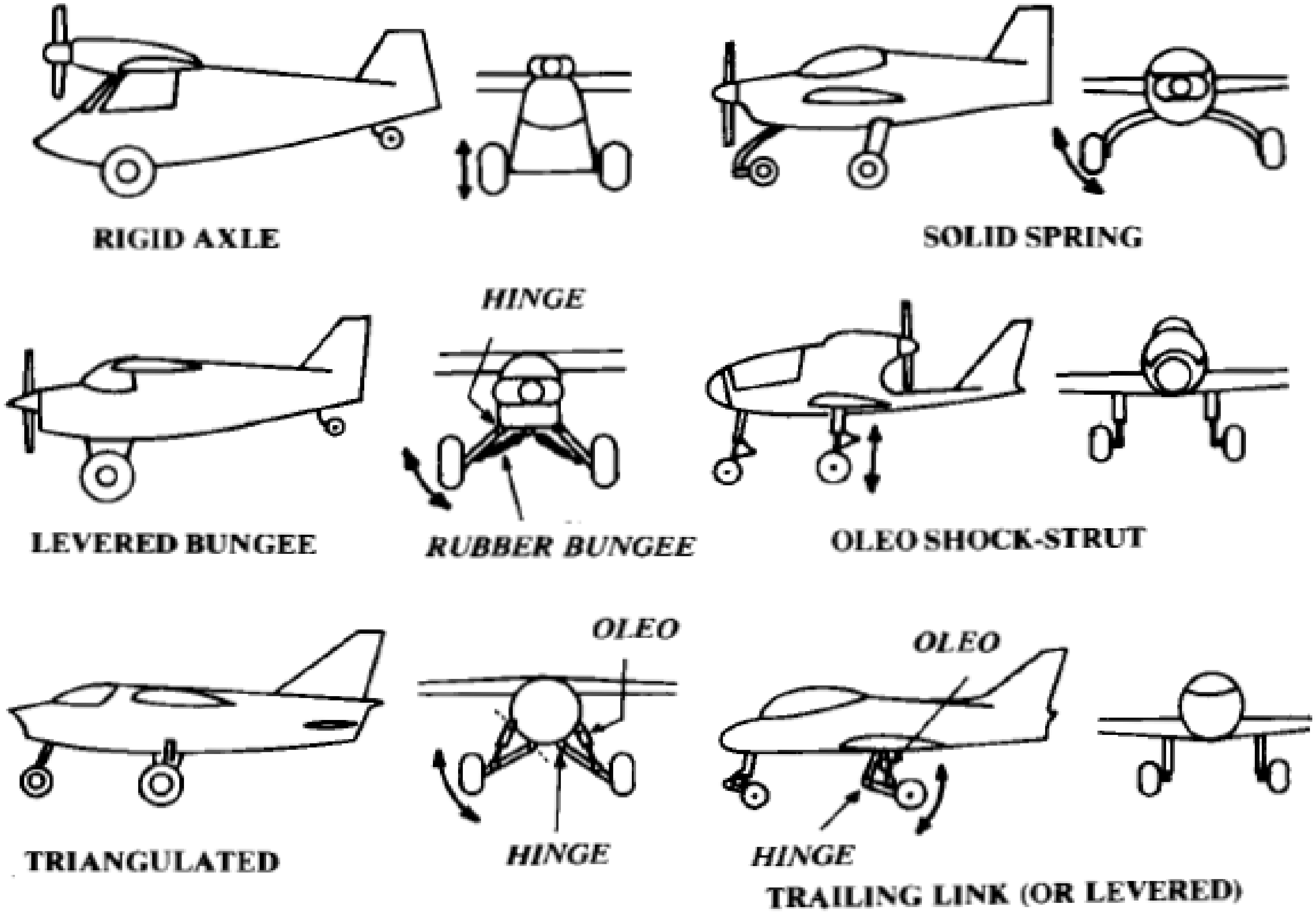
Tail dragger landing gear

Tricycle Landing Gear Geometry

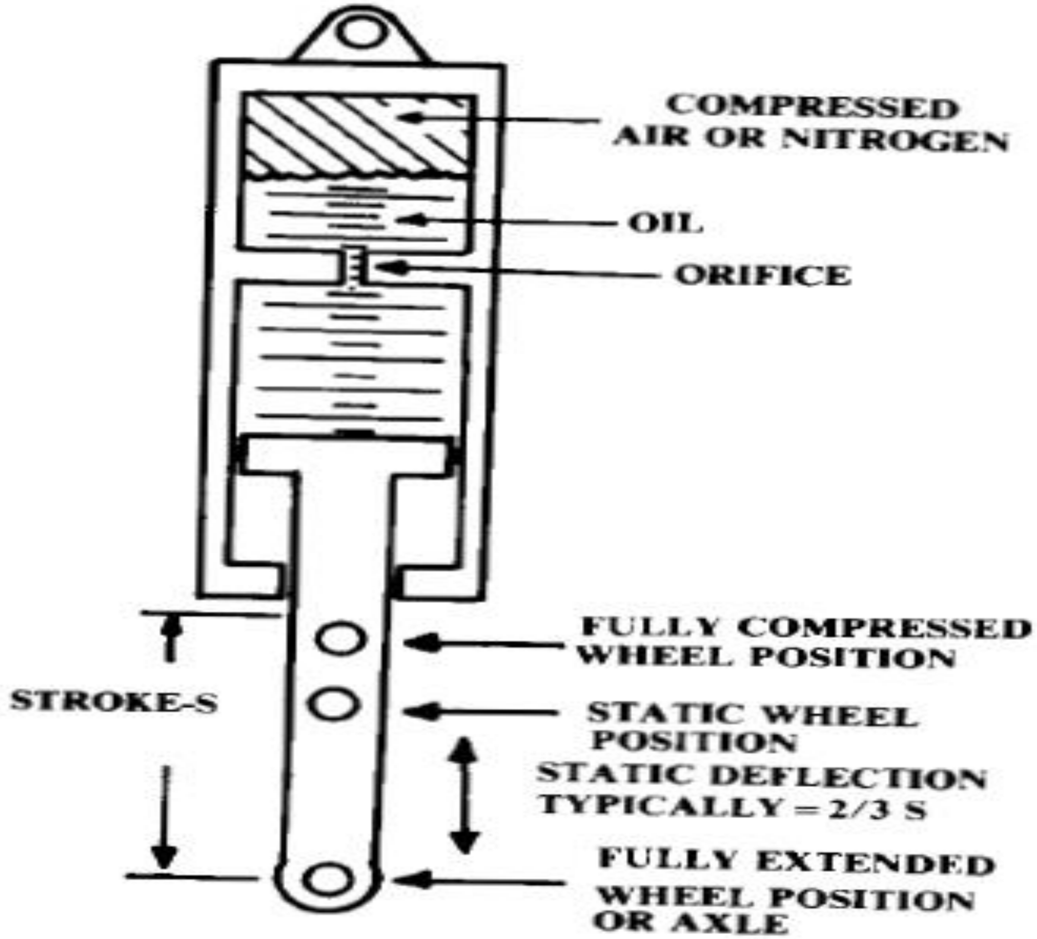


Tricycle Landing Gear Geometry

Gear/Shock Arrangements



Oleo Shock Absorber



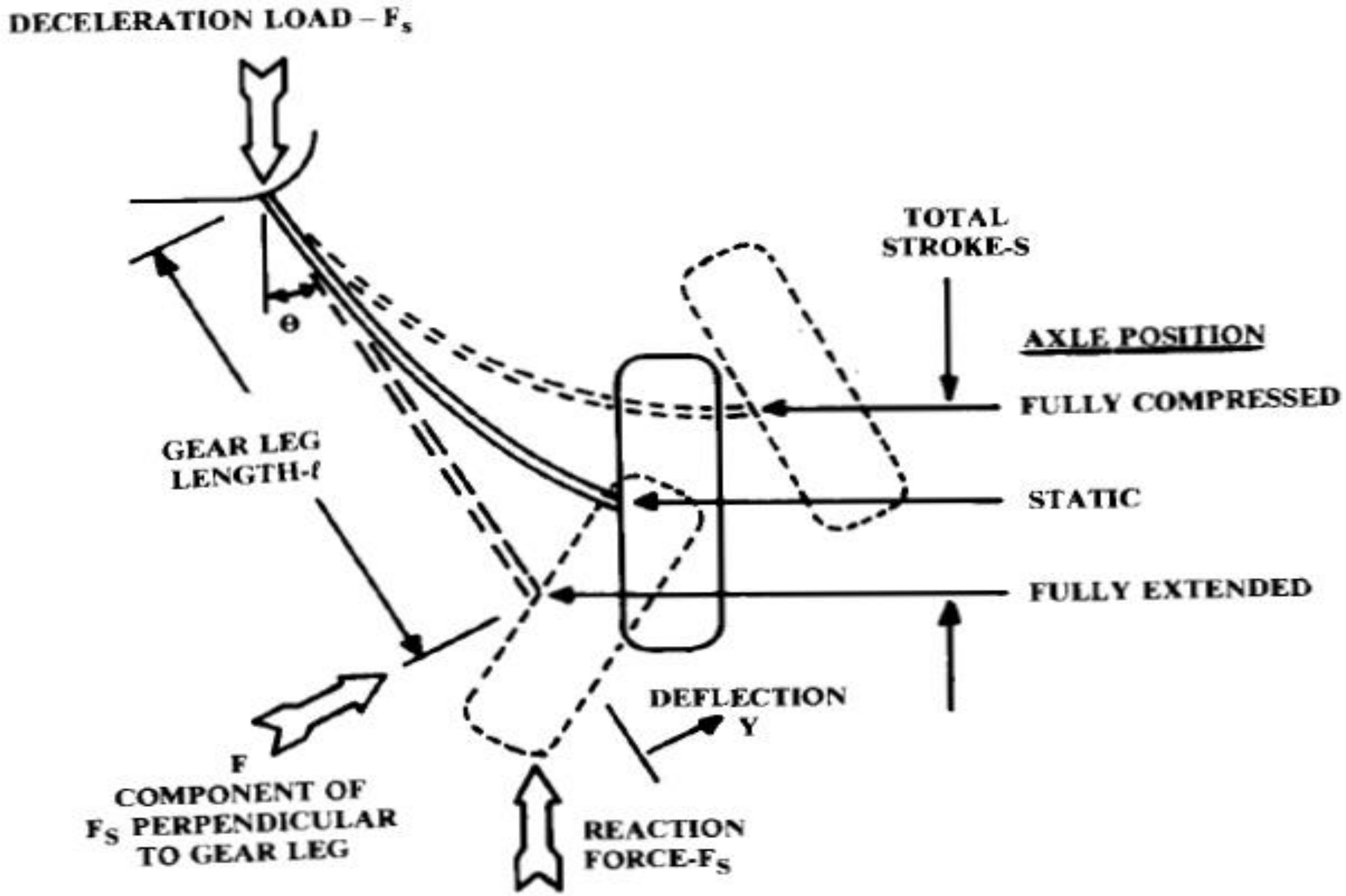
Oleo Shock Absorber

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).

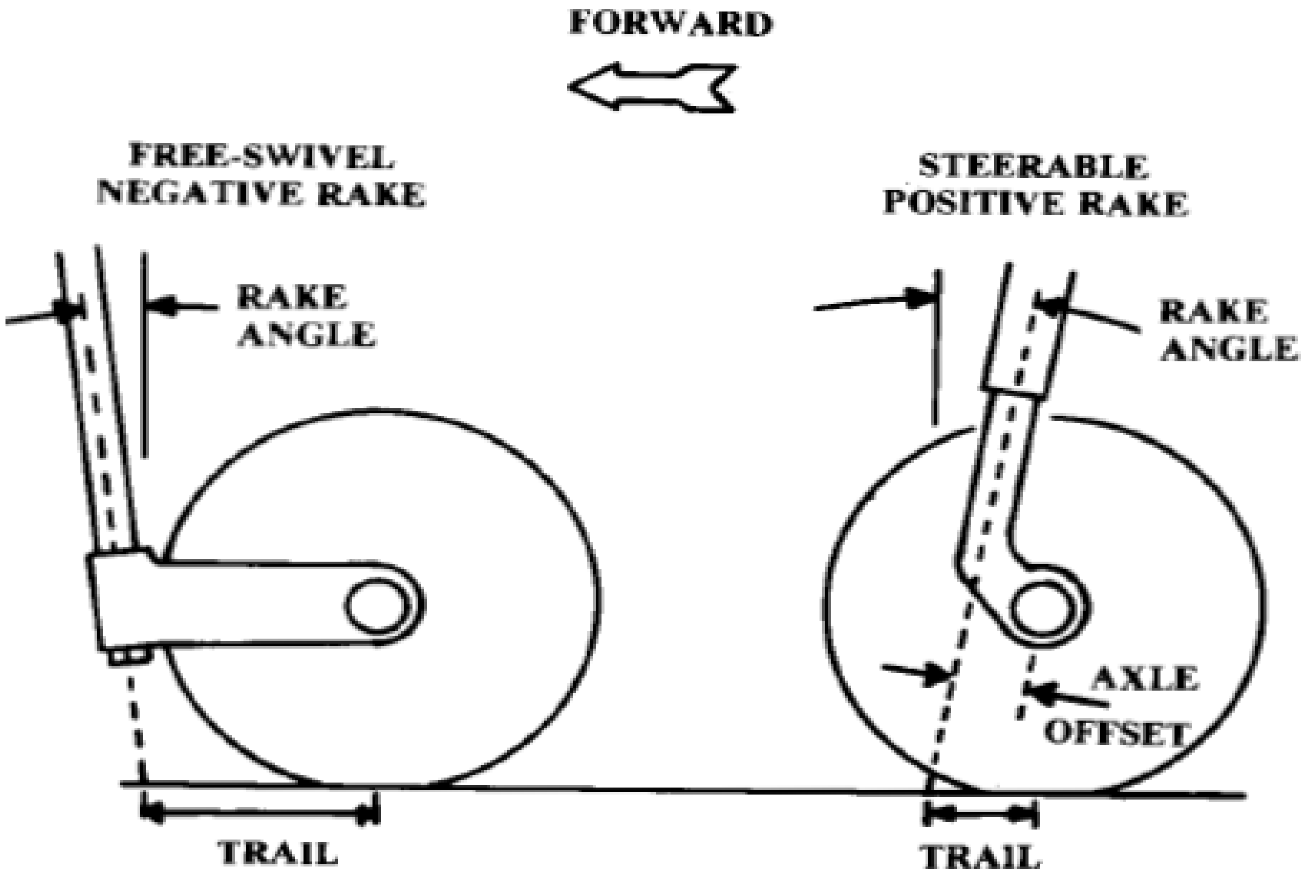
$$KE_{\text{vertical}} = \left(\frac{1}{2}\right)\left(\frac{W_{\text{landing}}}{g}\right)V_{\text{vertical}}^2$$

SOLID-SPRING GEAR SIZING



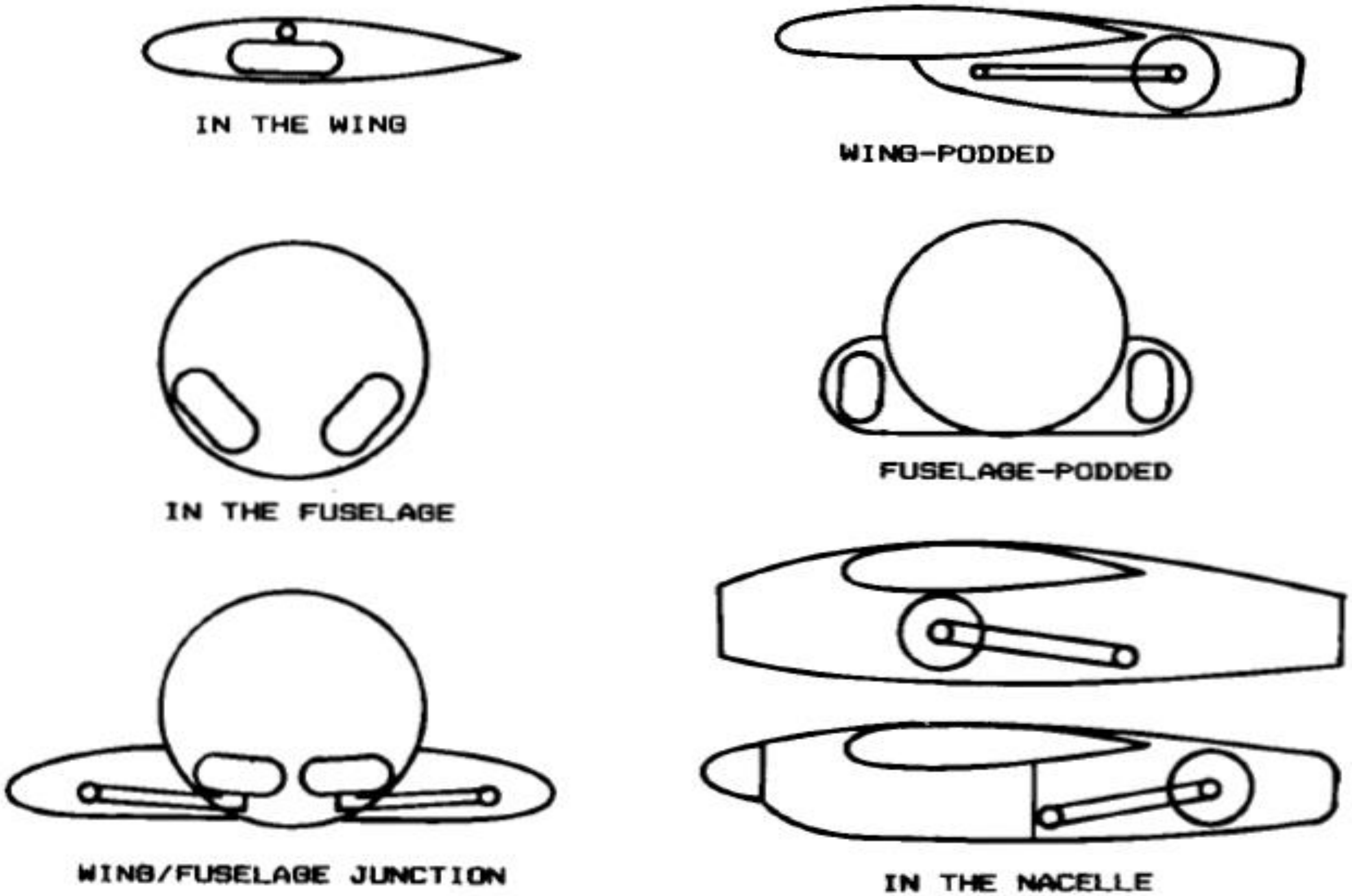
Solid-spring Gear Sizing

STROKE DETERMINATION, GEAR LOAD FACTORS



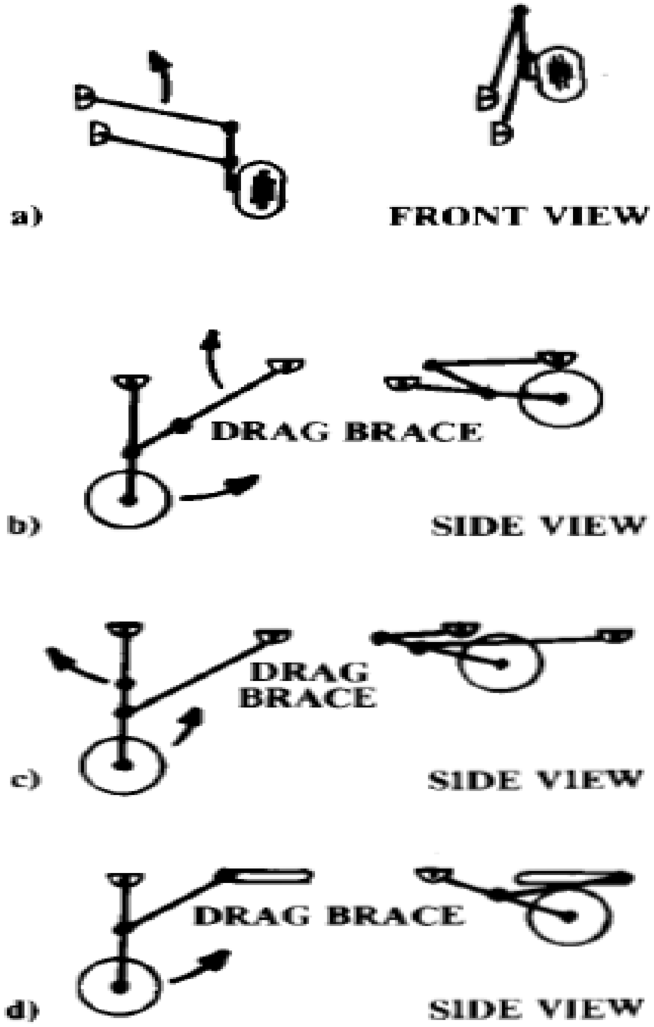
Stroke Determination, Gear Load Factors

Gear Retraction Geometry



Gear Retraction Geometry

Landing Gear Retraction

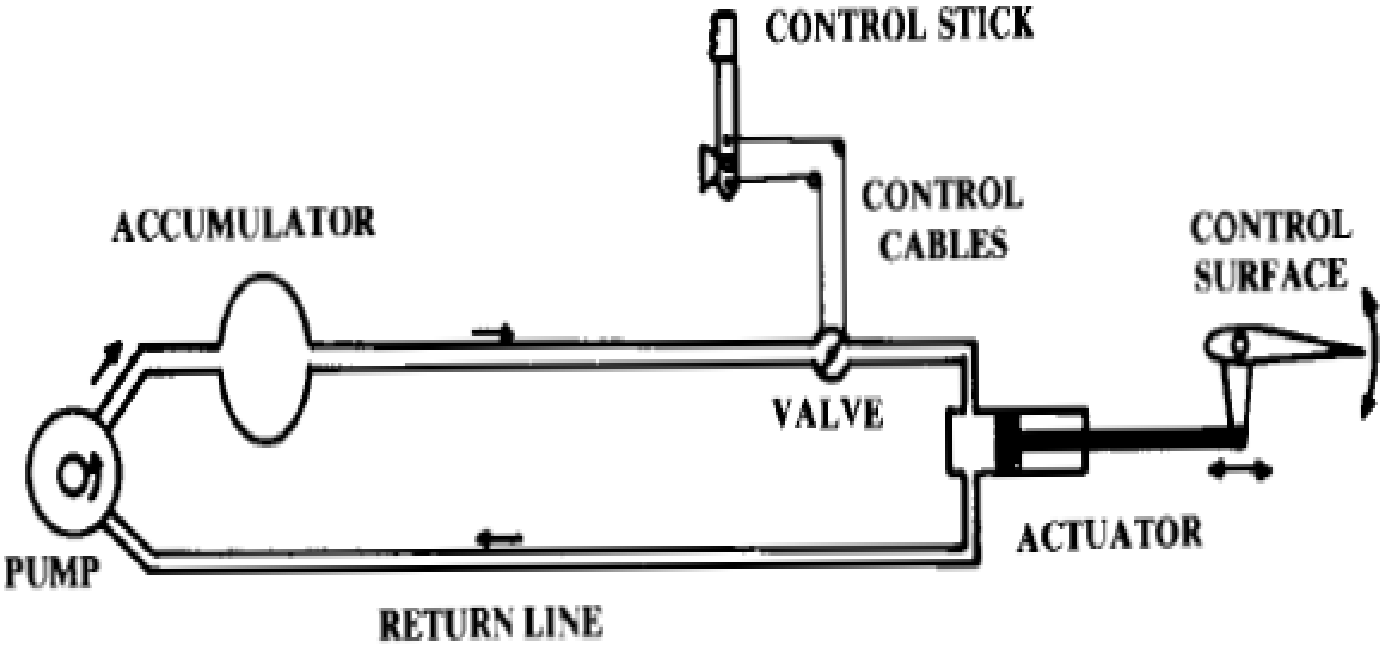


Landing Gear Retraction

AIRCRAFT SUBSYSTEMS

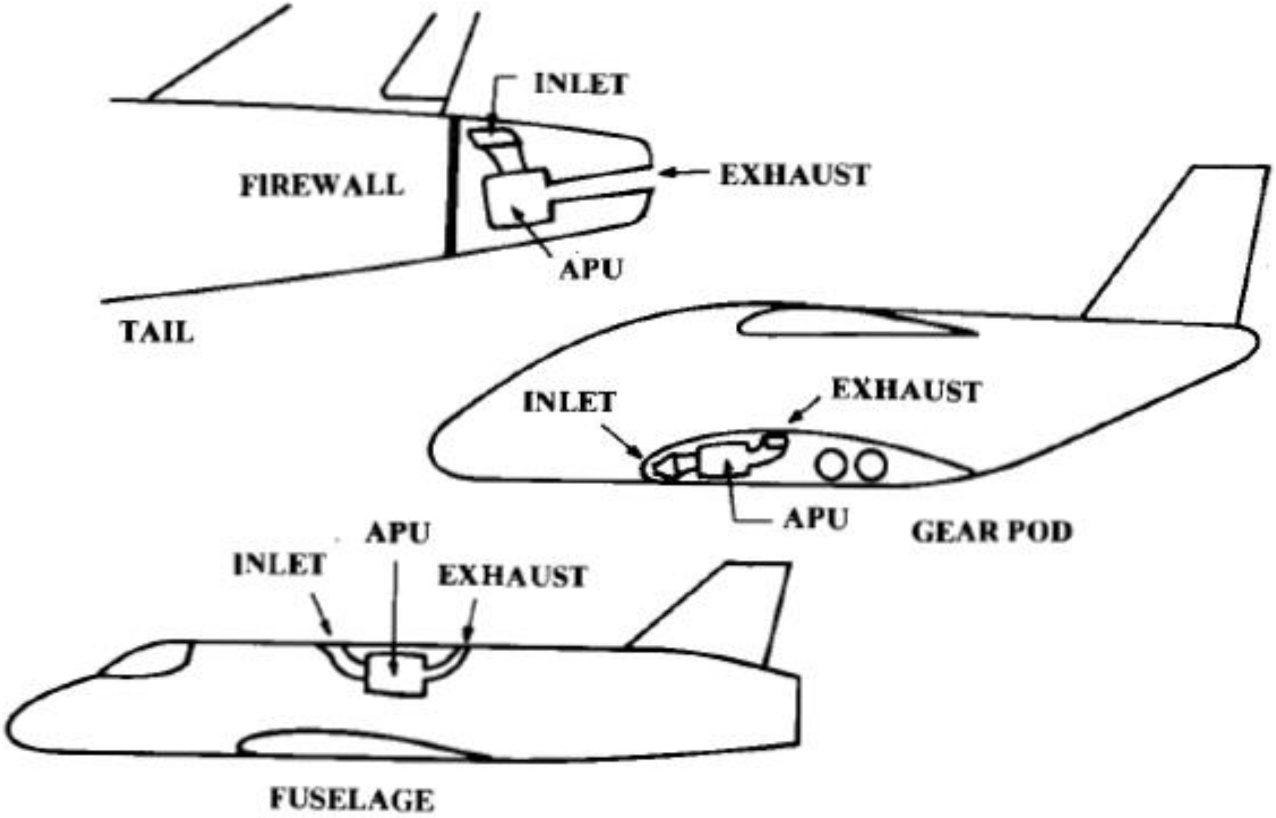
- Aircraft subsystems include the hydraulic, electrical, pneumatic, and auxiliary emergency power systems. Also, the avionics can be considered a subsystem (although to the avionics engineers, the airframe is merely the "mobility subsystem" of their avionics package)
- In general, the subsystems do not 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

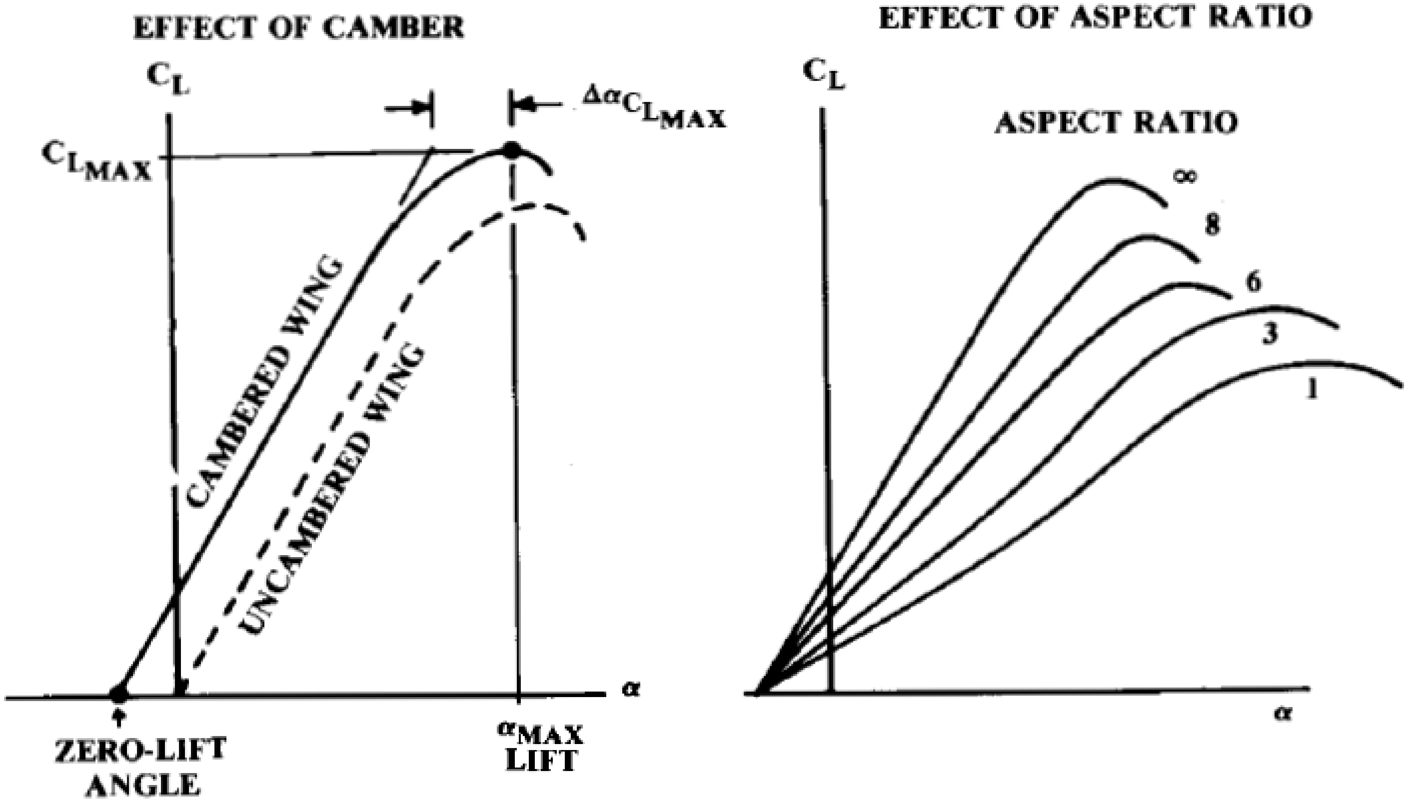
- Avionics (a contraction of "aviation electronics") includes radios, flight instruments, navigational aids, flight control computers, radar, and other aircraft sensors such as infrared detectors.
- For initial layout, it is necessary to provide sufficient volume in the avionics bays. Also, the nose 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

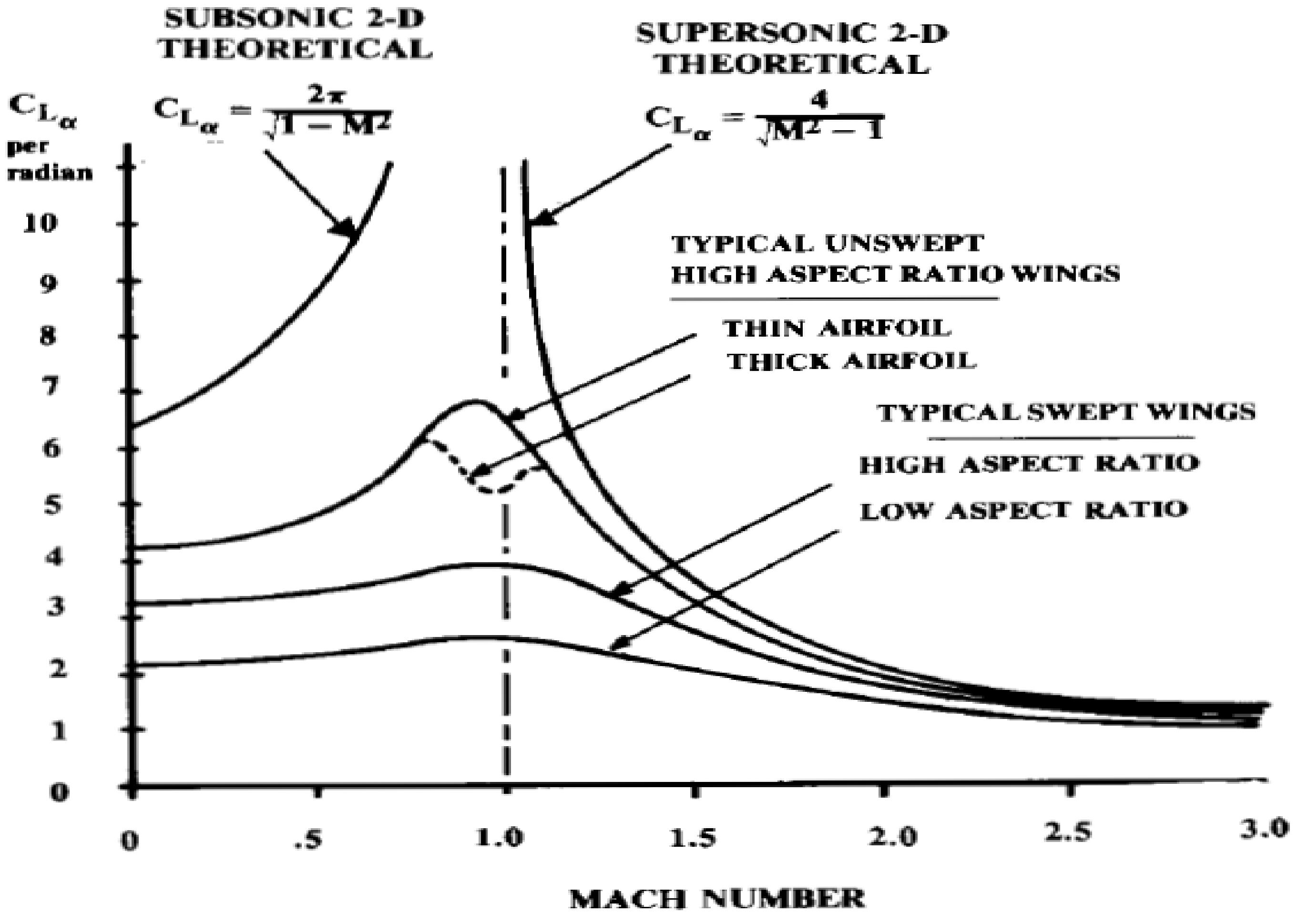
- Viscous separation is largely responsible for the drag of irregular bodies such as landing gear and boundary-layer diverters. It also produces base drag, the pressure drag created by a "cut-off" aft fuselage.
- The subsonic drag of a streamlined, nonlifting body consists solely of skin friction and 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

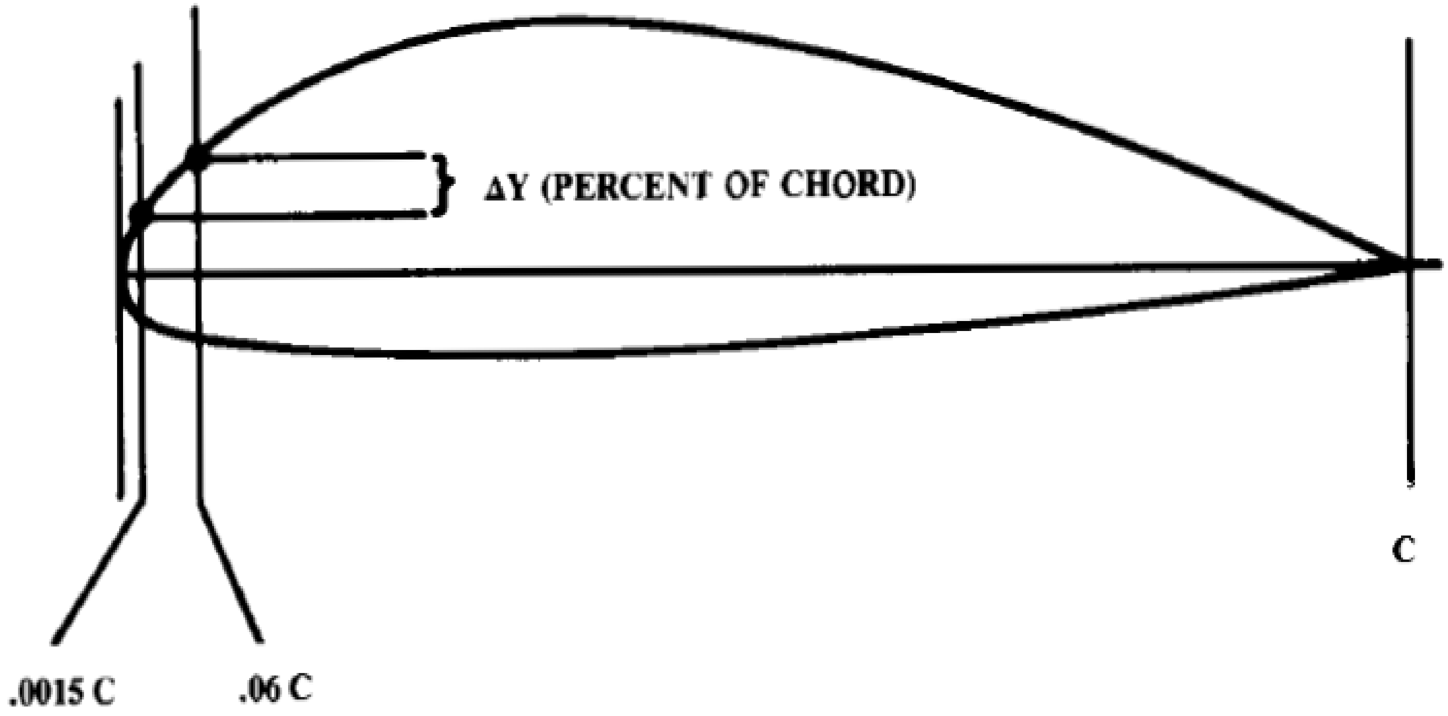


Subsonic Lift-curve Slope

MAXIMUM LIFT COEFFICIENT

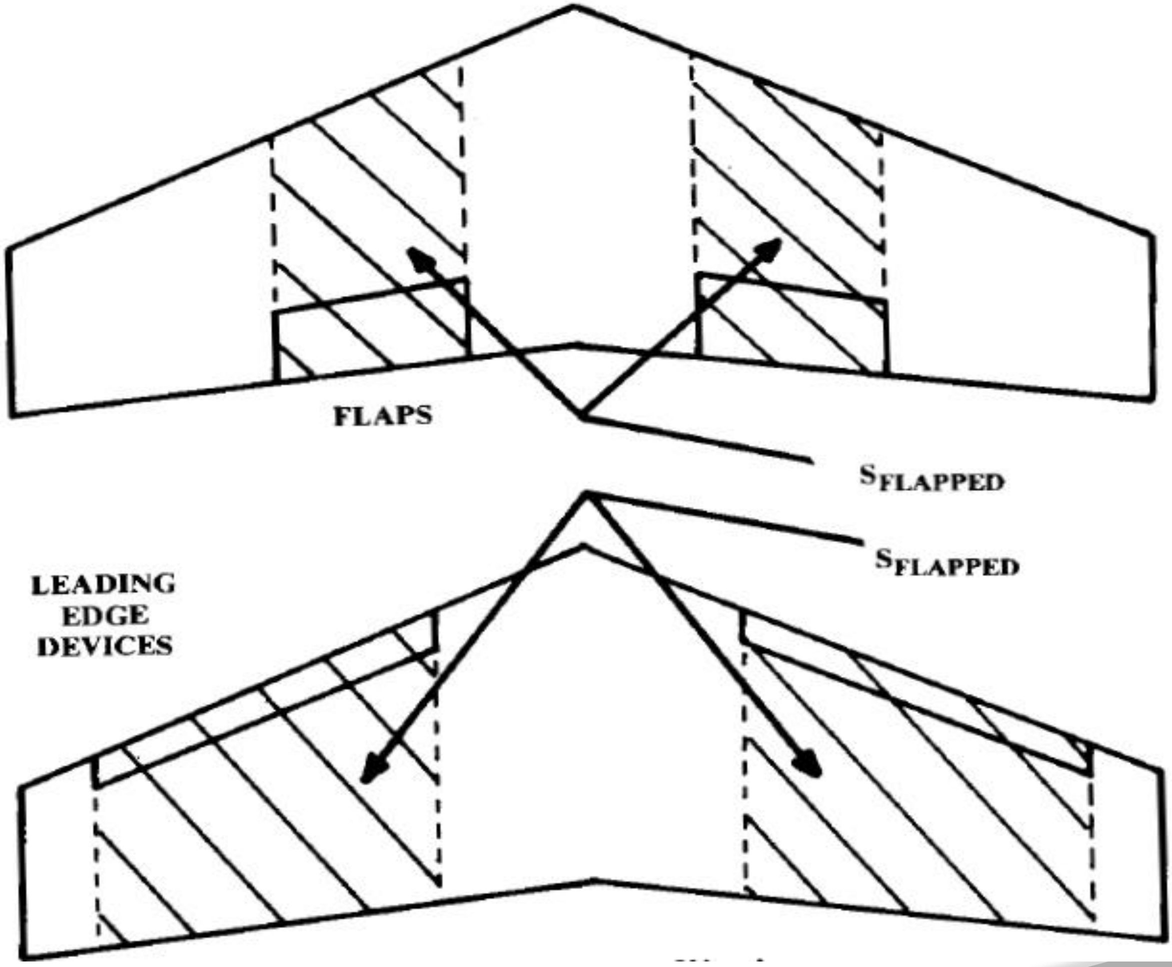
- The maximum lift coefficient of the wing will usually determine the wing area.
- This in turn will have a great influence upon the cruise drag.
- This strongly affects the aircraft takeoff weight to perform the design mission.
- Thus, the maximum lift coefficient is critical in determining the aircraft 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

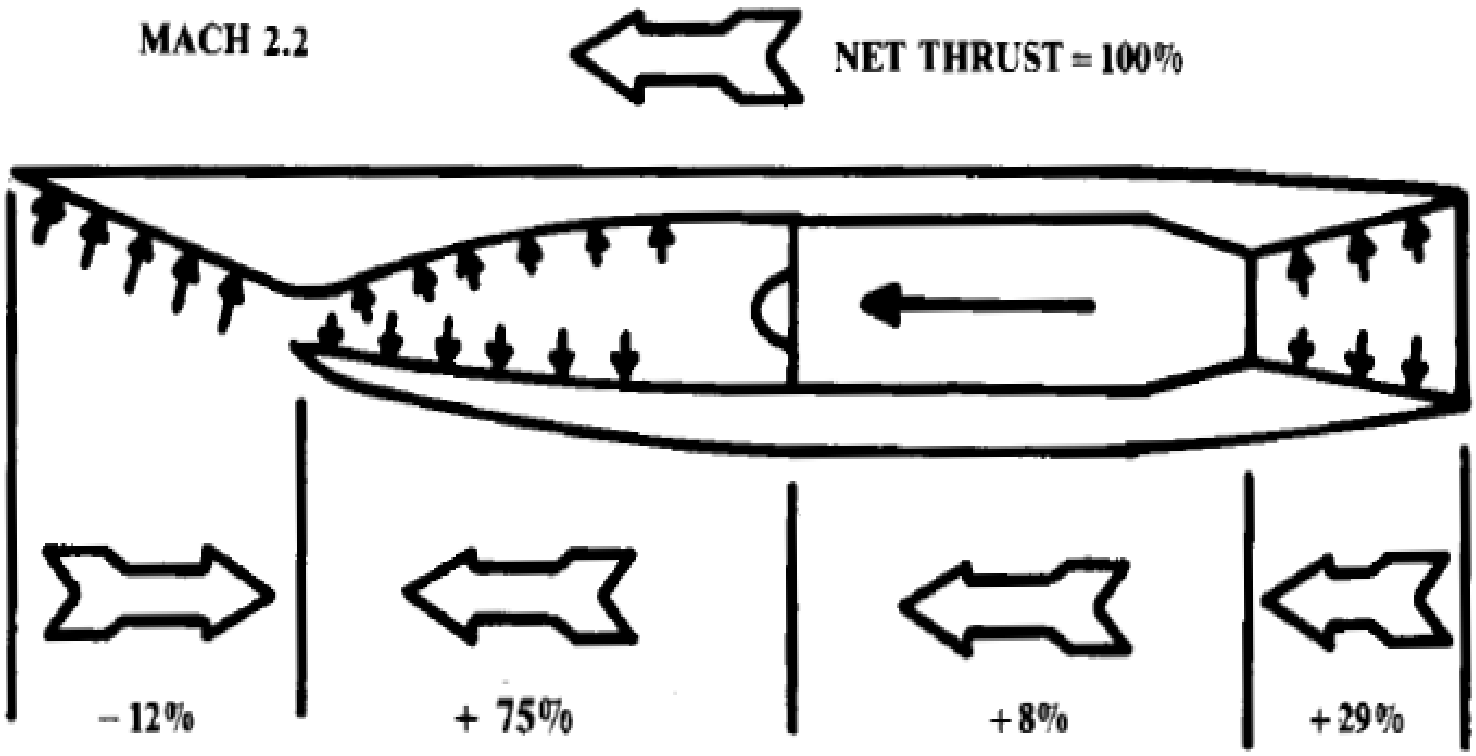


Flapped Wing Area

Installed Performance Of An Engine And Installation

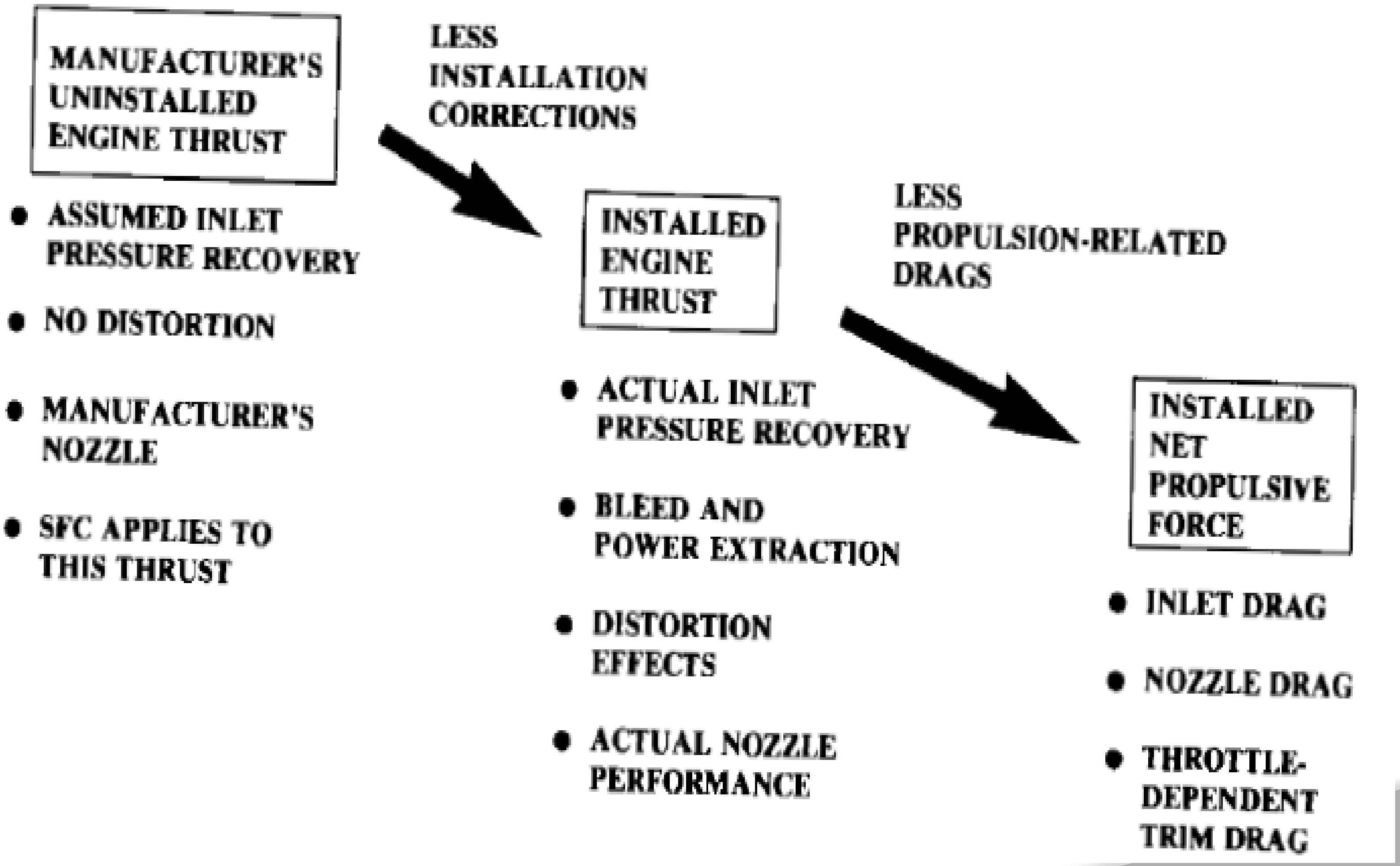
- Aircraft propulsion develop thrust by pushing air (or hot gases) backward. In a simplified case the force obtained can be determined using Newton's equation (F =ma) by summing all the accelerations imparted to the air.
- The analysis above is too simplistic for actual thrust calculation. It falsely 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

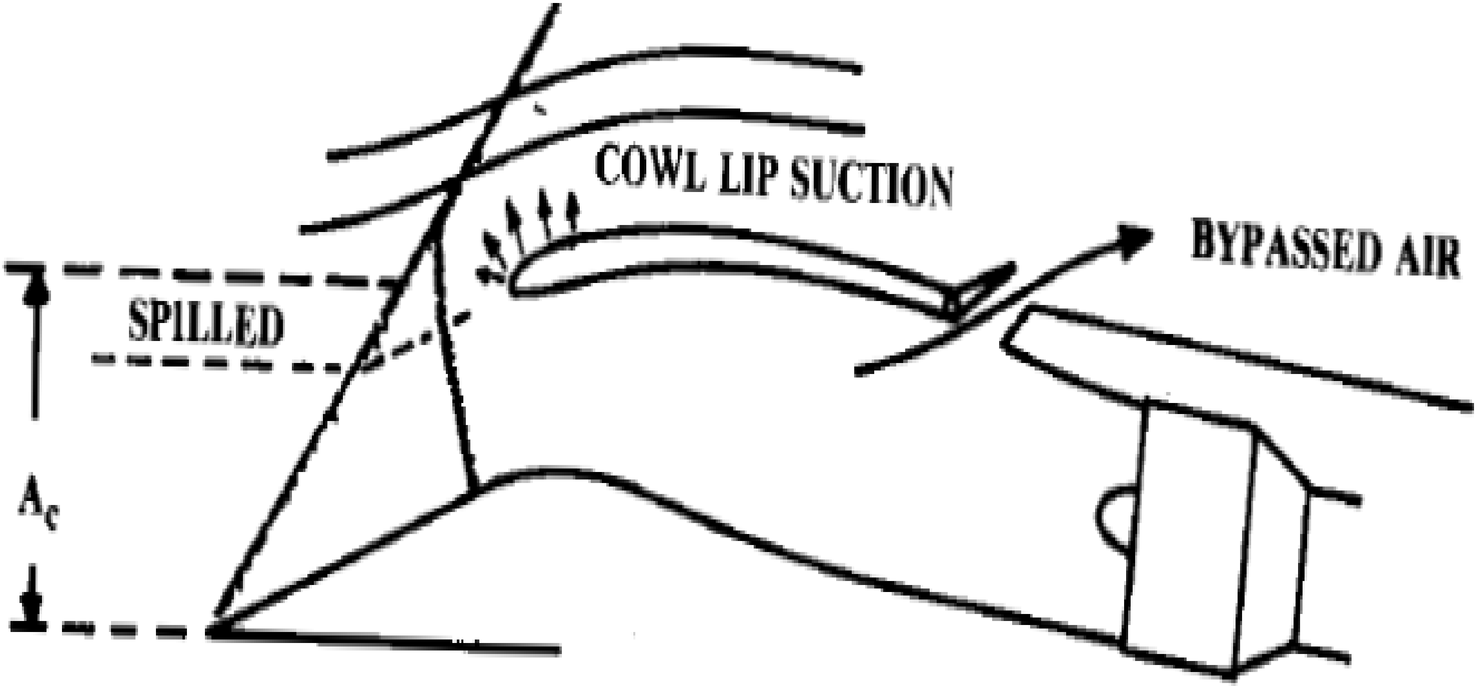
- ACTUAL INLET PRESSURE RECOVERY
- BLEED AND POWER EXTRACTION
- DISTORTION EFFECTS
- ACTUAL NOZZLE PERFORMANCE

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

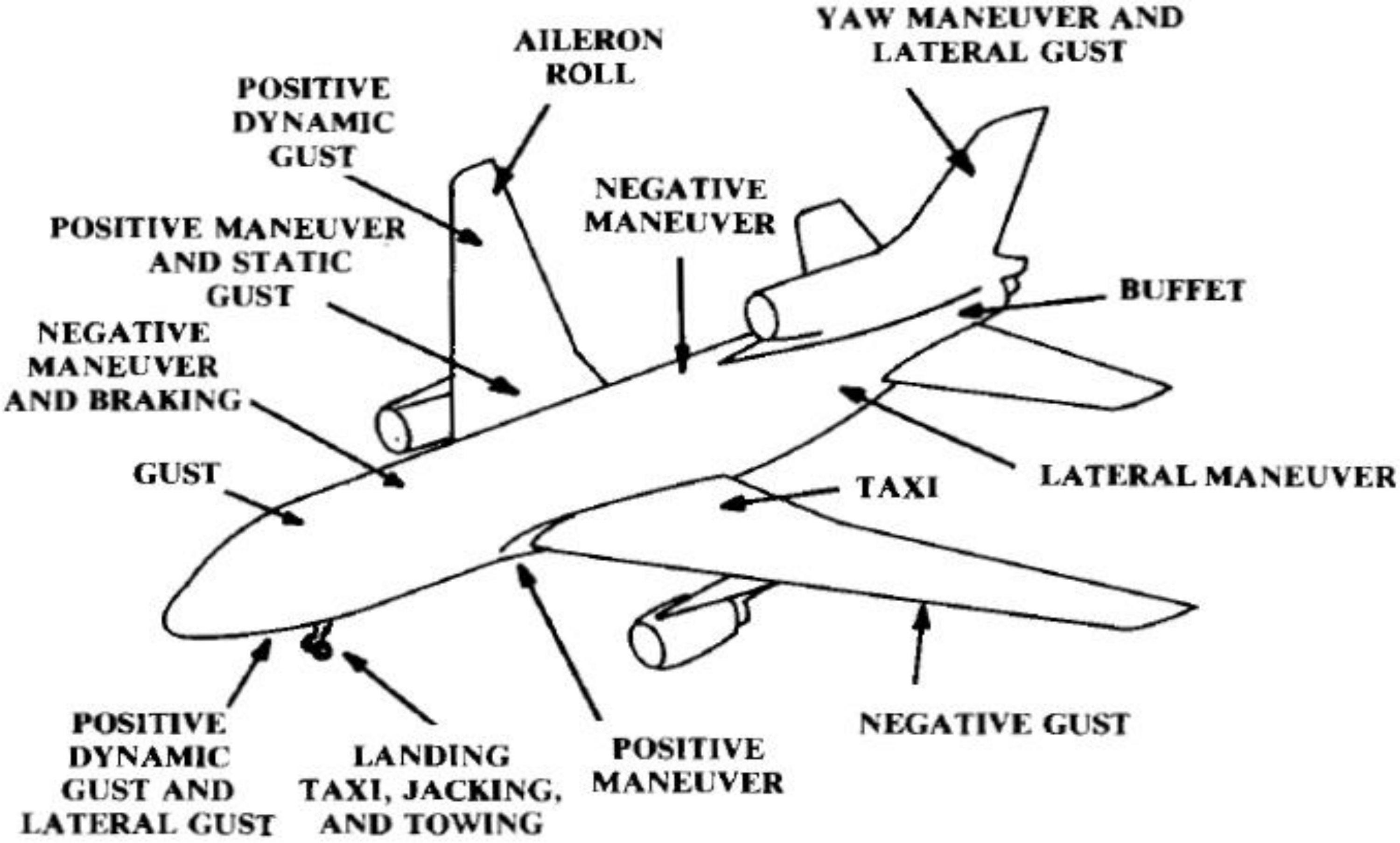


Additive Drag, Cowl Lip Suction And Bypass Subcritical Operation

Maneuver Loads

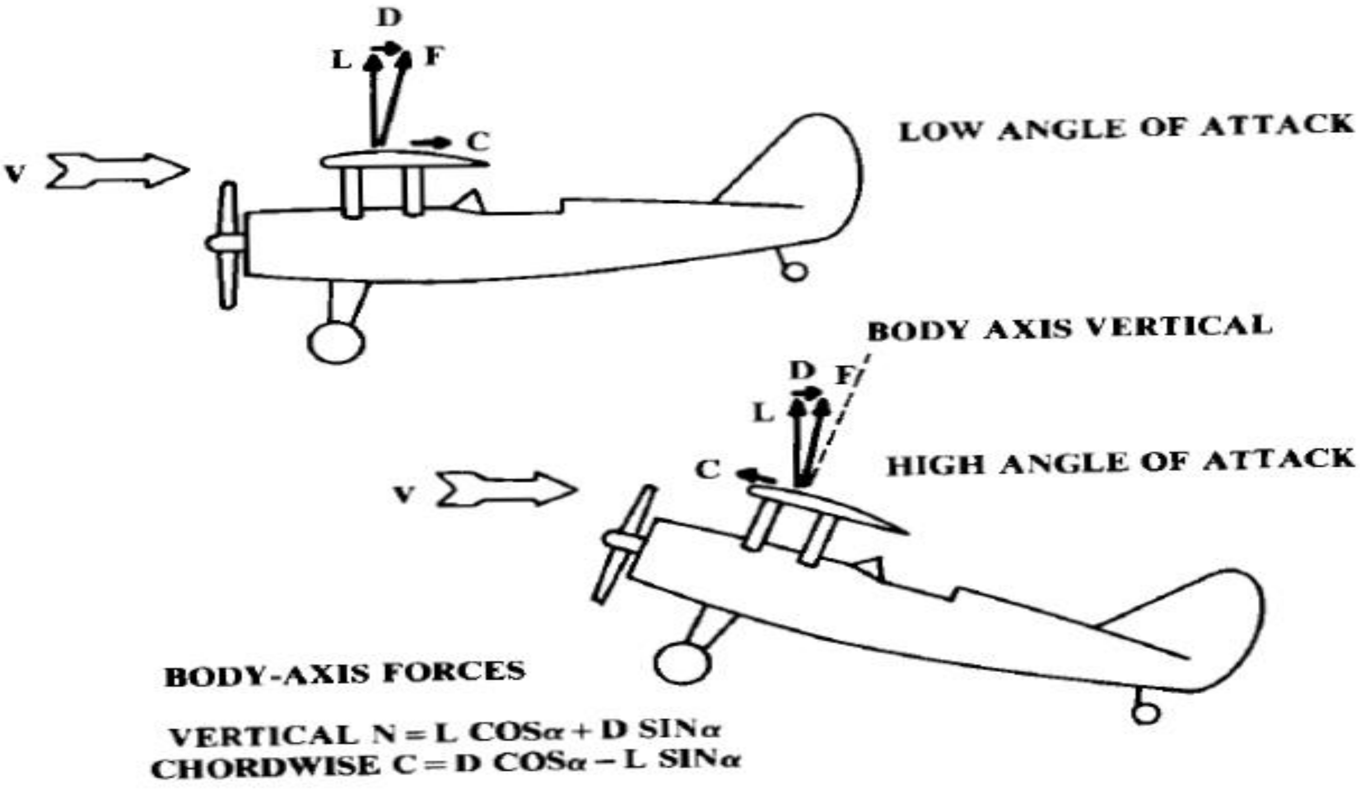
- The greatest air loads on an aircraft usually come from the generation of lift during high-g maneuvers.
- Even the fuselage is almost always structurally sized by the lift of the wing rather than by the air pressures produced directly on the fuselage.
- Aircraft load factor (n) expresses the maneuvering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

L1011 Critical loads



Critical loads

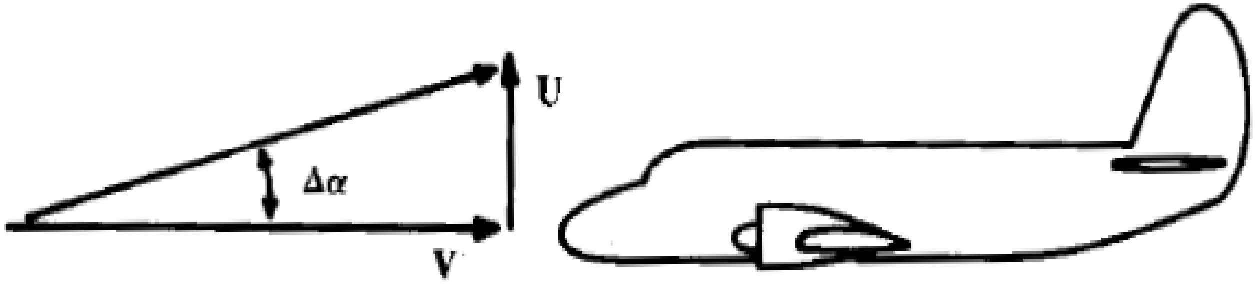
Wing Load Direction At Angle Of Attack



Wing Load Direction At Angle Of Attack

GUST LOADS

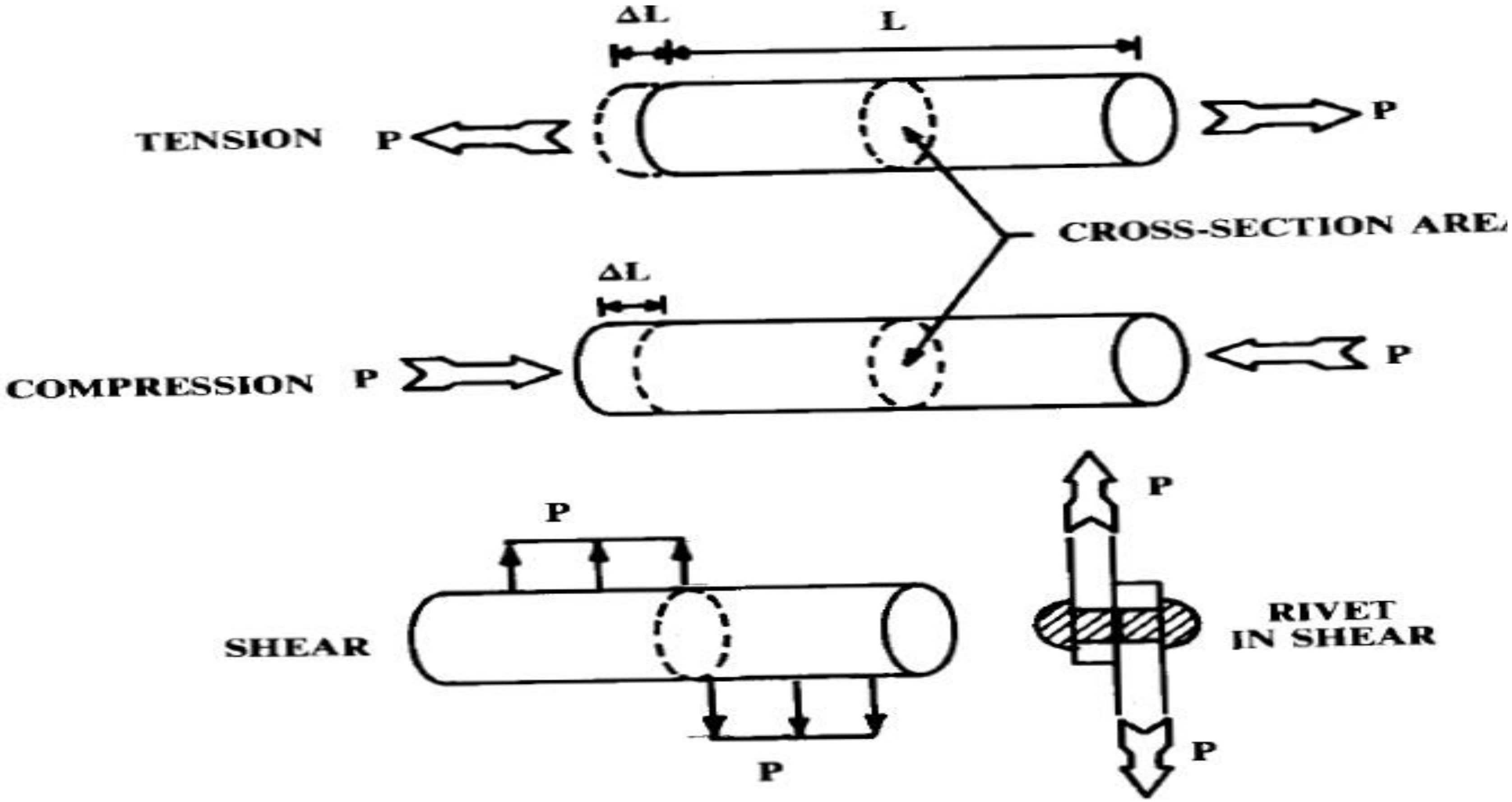
The loads experienced when the aircraft encounters a strong gust can exceed the maneuver loads in some cases. For a transport aircraft flying near thunderstorms or encountering high-altitude "clear air turbulence," it is not unheard of to experience load factors due to gusts ranging from a negative 1.5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

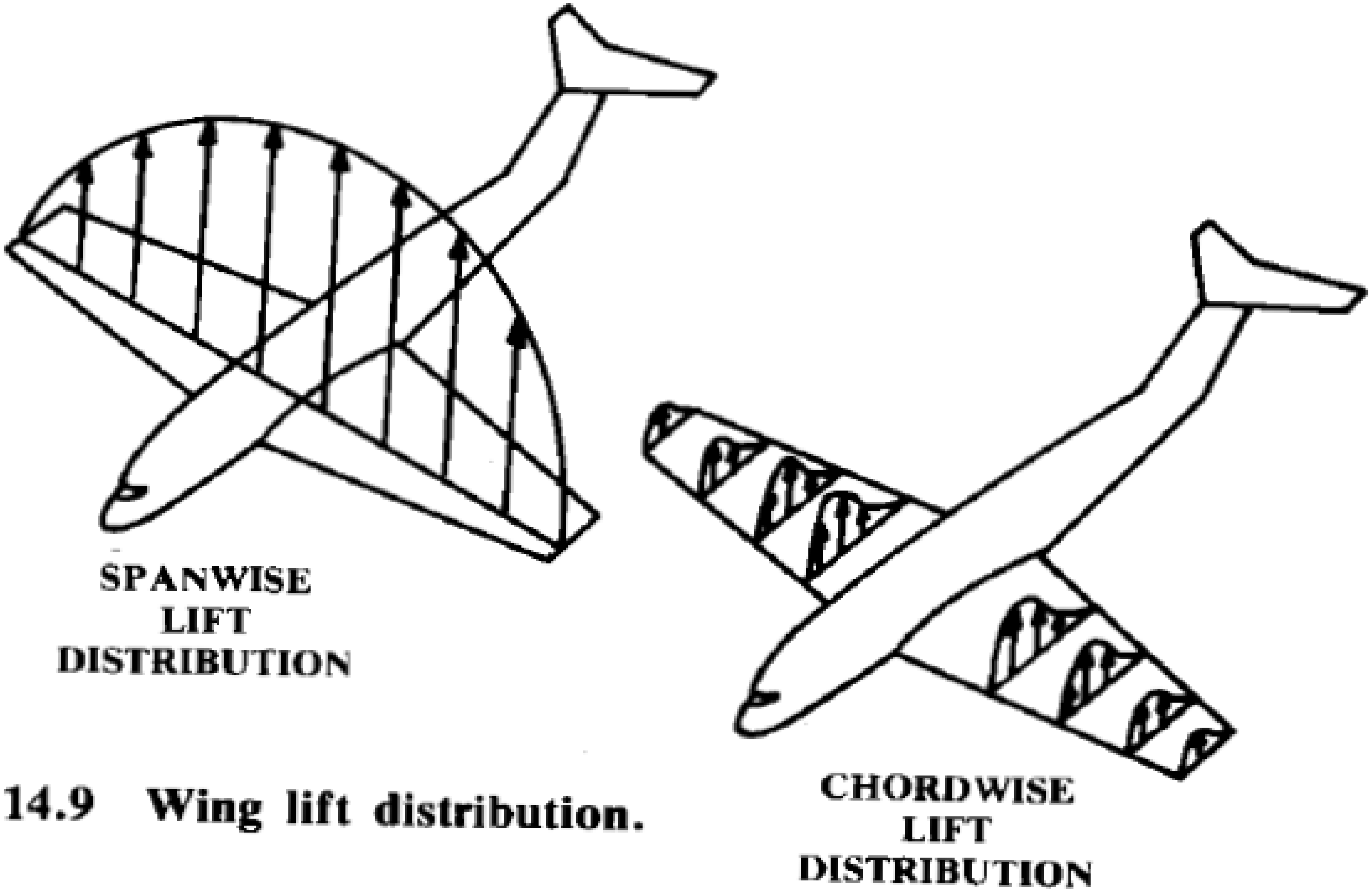
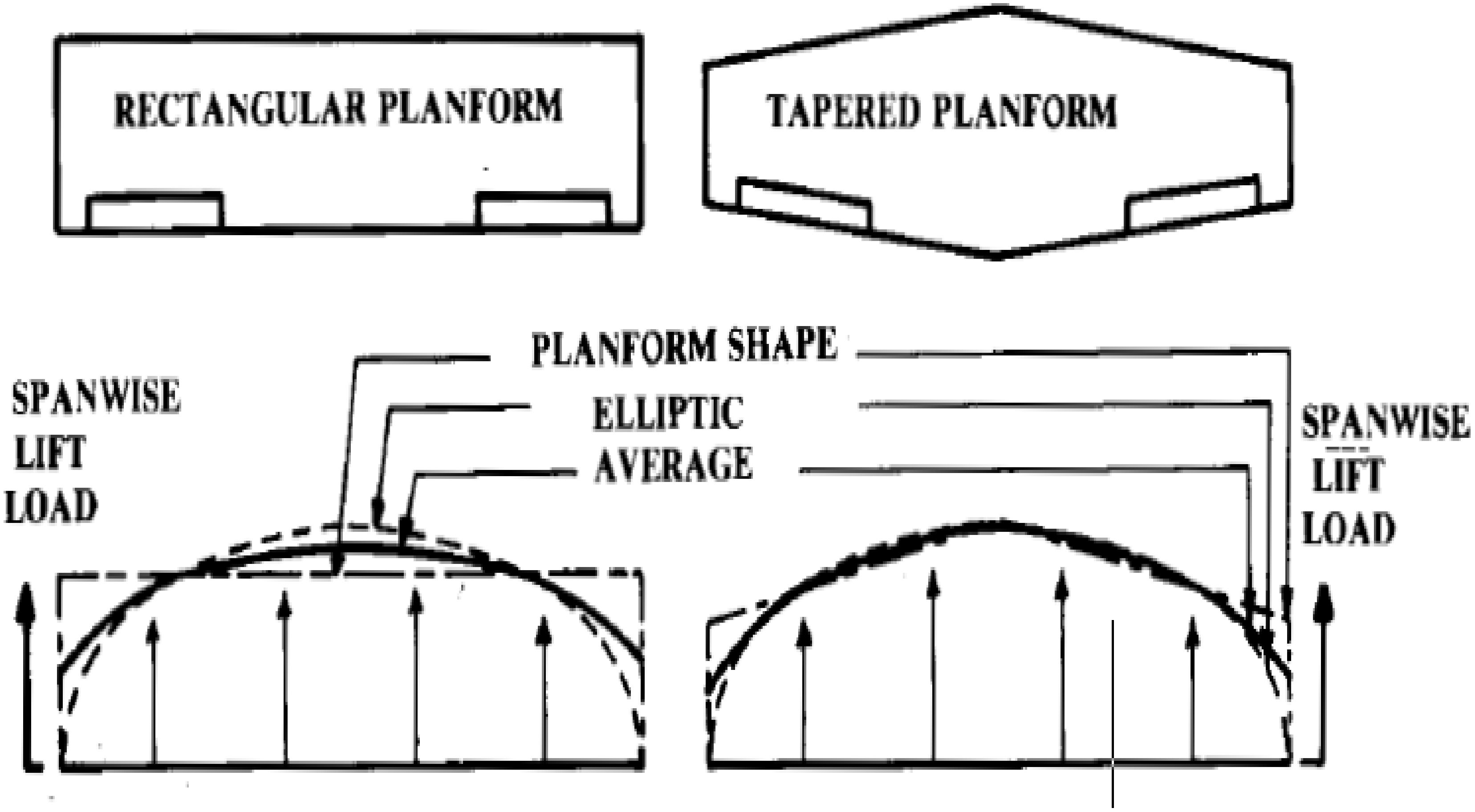


Fig. 14.9 Wing lift distribution.

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.

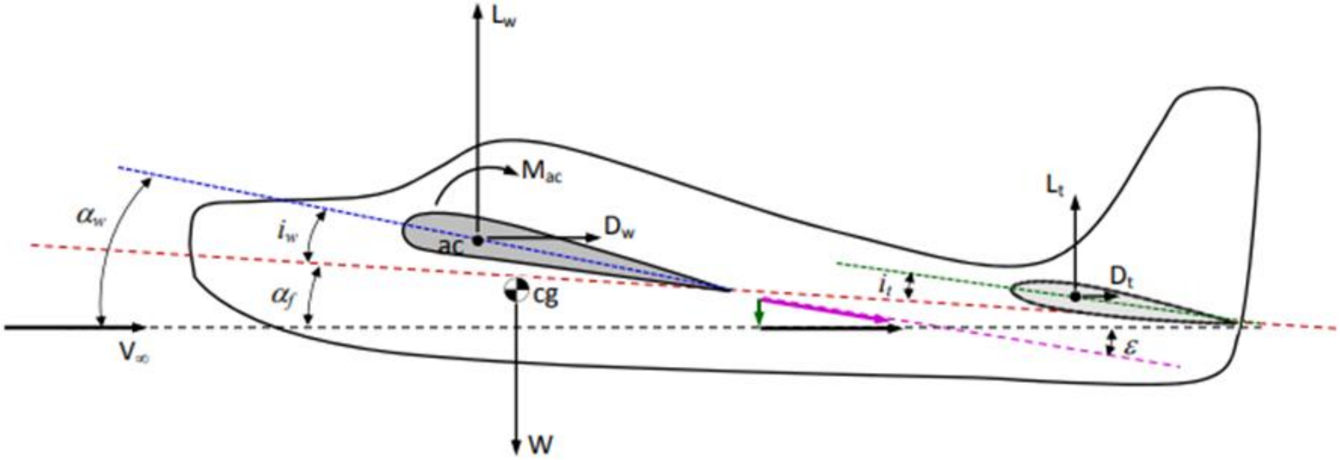
UNIT-IV

MILITARY AIRCRAFT ADAPTATION

UNIT-IV

CLOs	Course Learning Outcome
CLO11	Arranging airborne early warning, ground surveillance
CLO12	Labeling electro-optics and the infra-red optics
CLO13	Characterizing of types of radar- pulse Doppler

Avionic and mission system interface



Longitudinal (pitch) stability requires a moment

HUDs are now being installed in civil aircraft for reasons as:

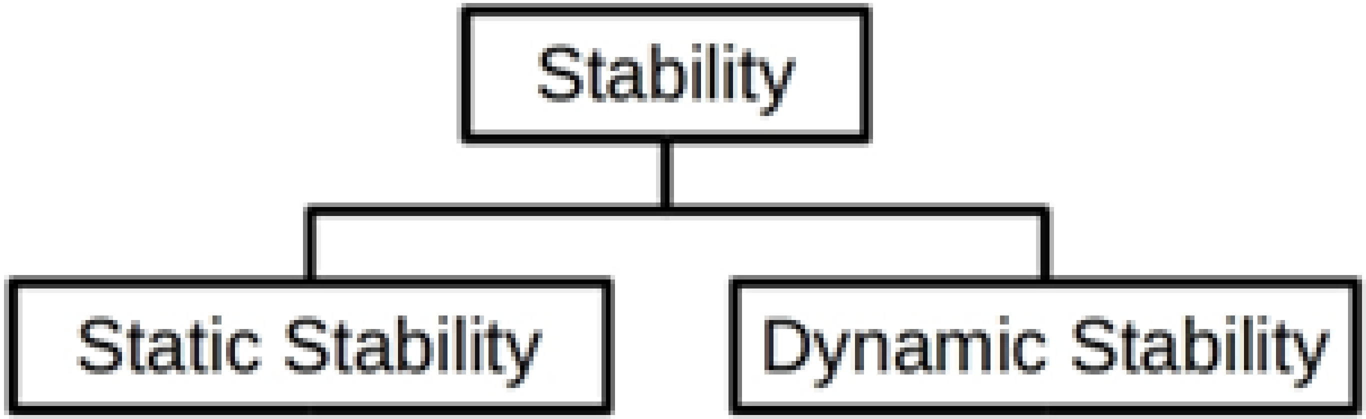
Static Pitch Stability

- 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., $\alpha e = 0$)

Aircraft Systems



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

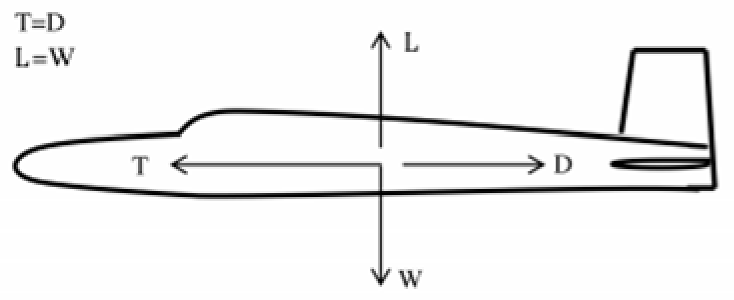
- Not only initial tendency, but also the amplitudes of the response due to disturbance decay in finite time to attain the equilibrium state.
- Static equilibrium also requires that the side force acting on the airplane is also zero.
- Additionally, the summation of moments about the center of gravity (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)

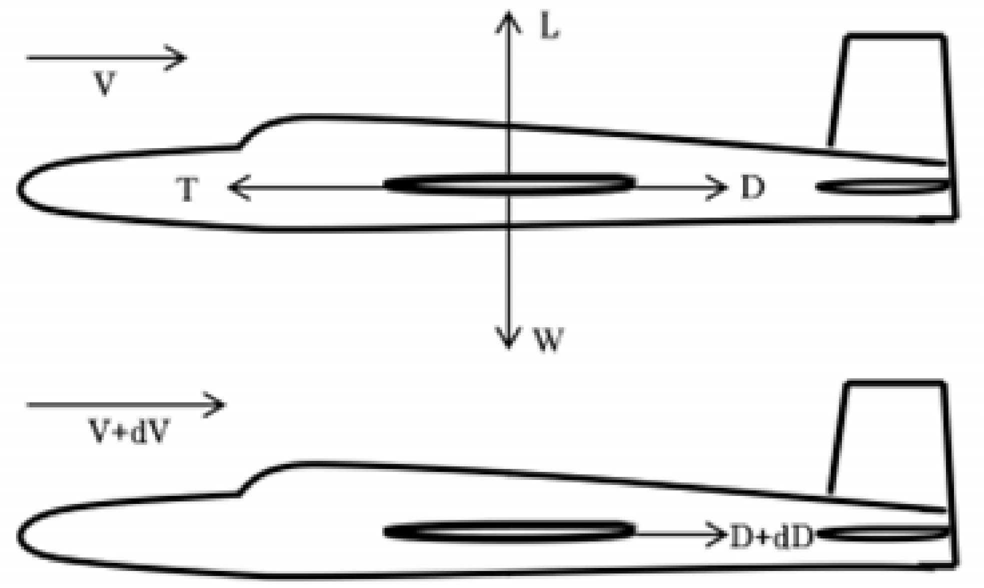
Pitch stability

- 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.

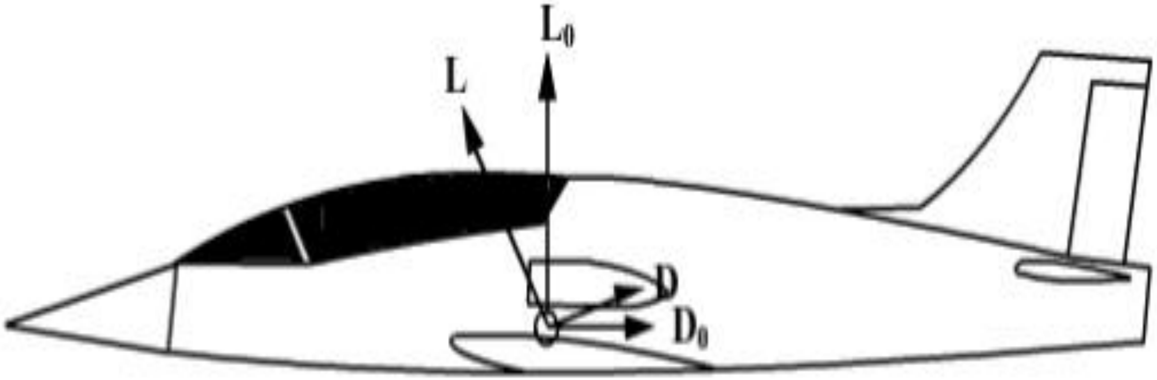
Estimation of Stability and Control Derivatives

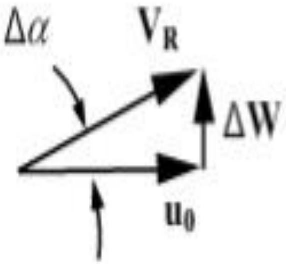
The solution of small perturbation equations for longitudinal motion would be taken up in chapter 8 and for the lateral motion in However, to solve these equations the stability derivatives are required. The following subsections deal with their estimation

∂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.

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

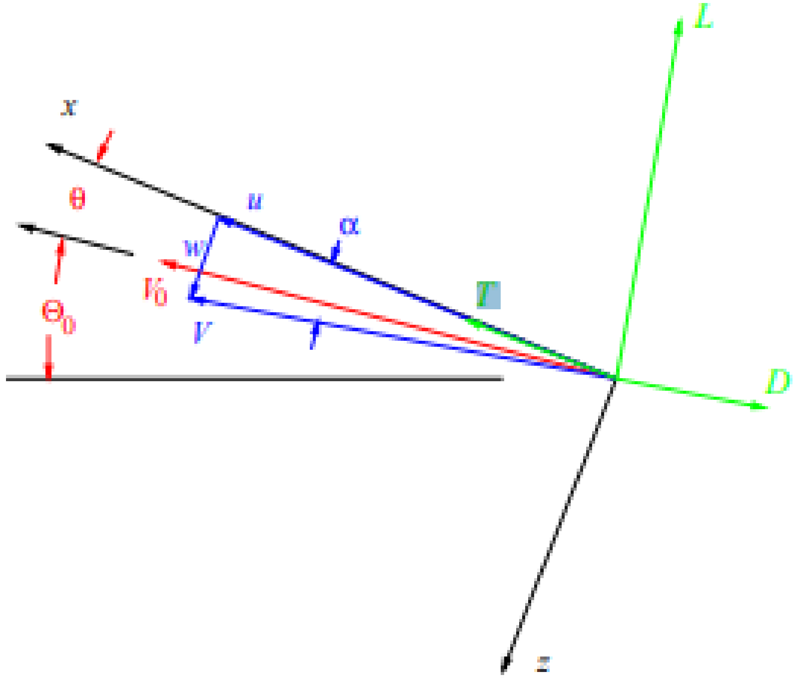
Speed Derivatives

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

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

- 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.

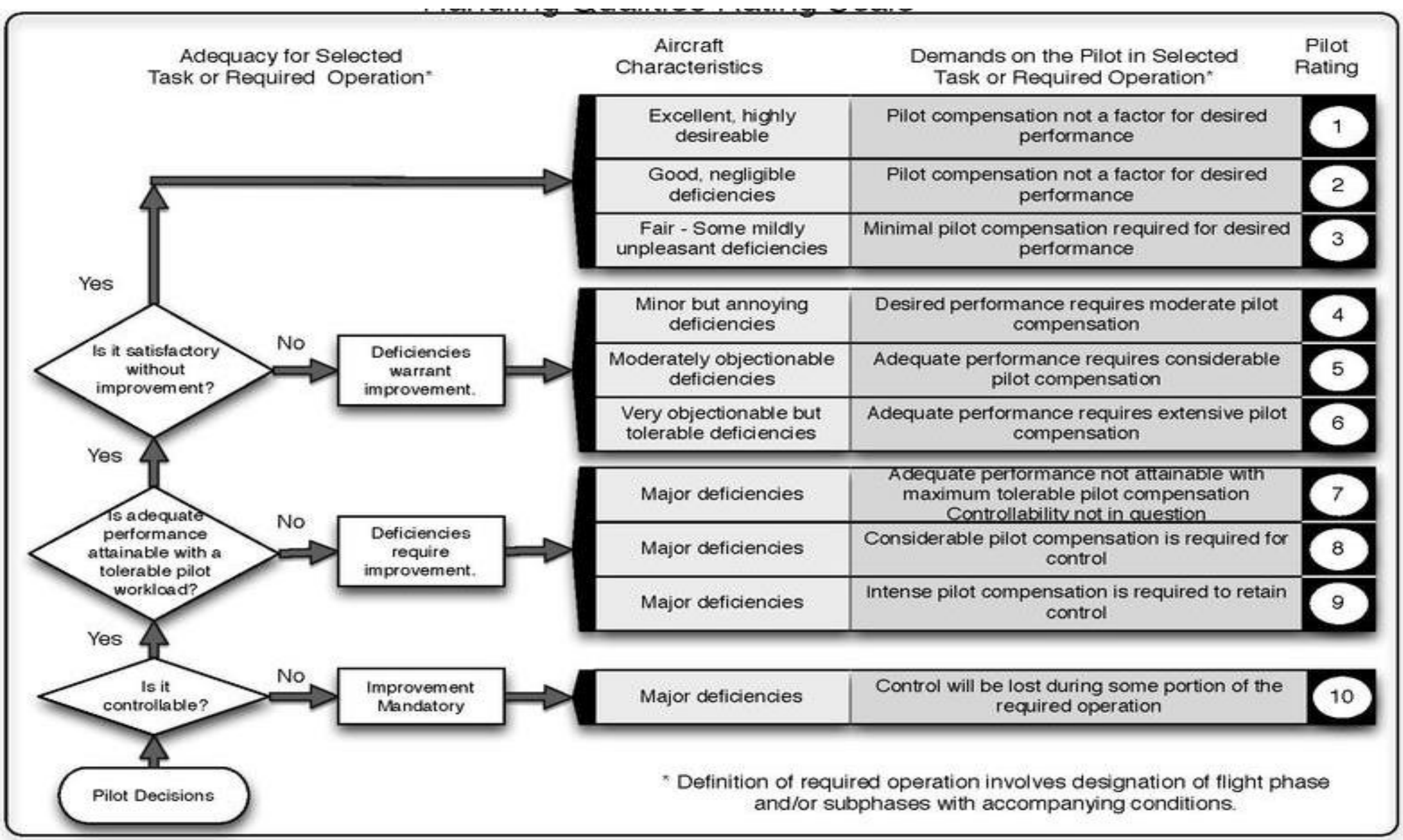
Handling Qualities

- 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

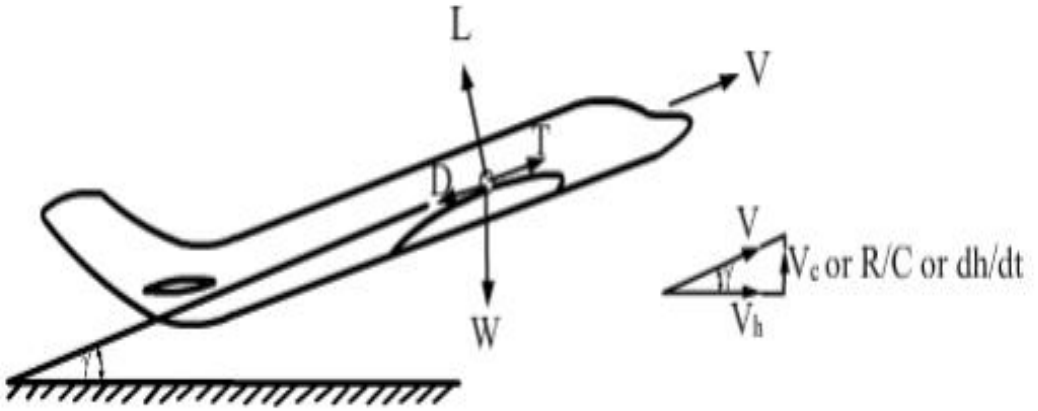


Aircraft Characteristics	Demands on the Pilot in Selected Task or Required Operation*	Pilot Rating
Excellent, highly desireable	Pilot compensation not a factor for desired performance	1
Good, negligible deficiencies	Pilot compensation not a factor for desired performance	2
Fair - Some mildly unpleasant 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

AIRBORNE RADAR, ASTRIONICS - AVIONICS FOR SPACECRAFT

CLOs	Course Learning Outcome
CLO 14	Determination Attitude and control of spacecraft, magnetometers
CLO 15	Construction of command and telemetry in aviation technology

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

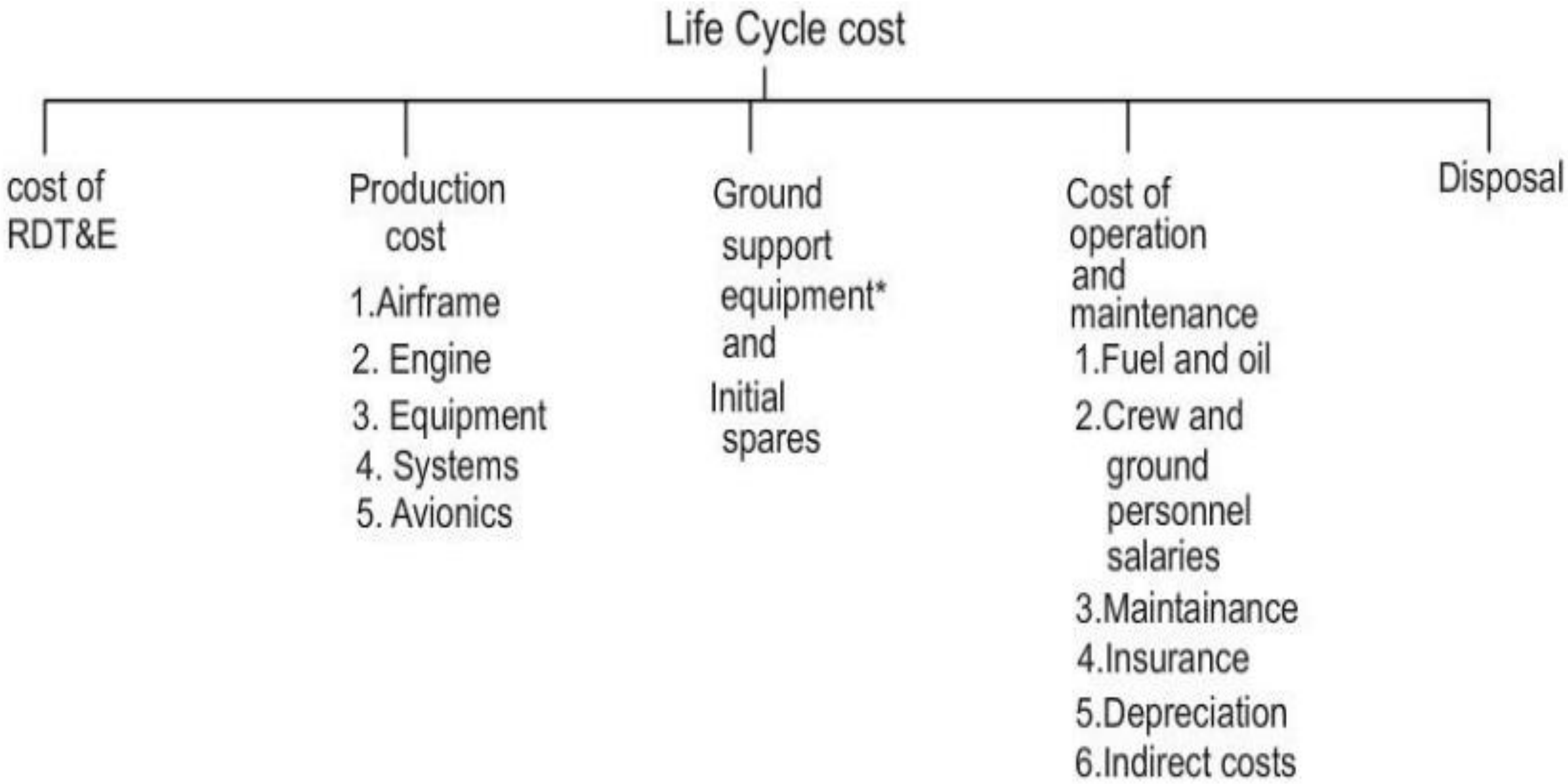
- RDT & E represent the cost towards research, development, test and evaluation of the airplane. It includes the cost of technology development and research, design engineering.
- The purchase cost of the civil airplane (civil purchase price) is arrived at based on expenses towards
    - RDT & E,
  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

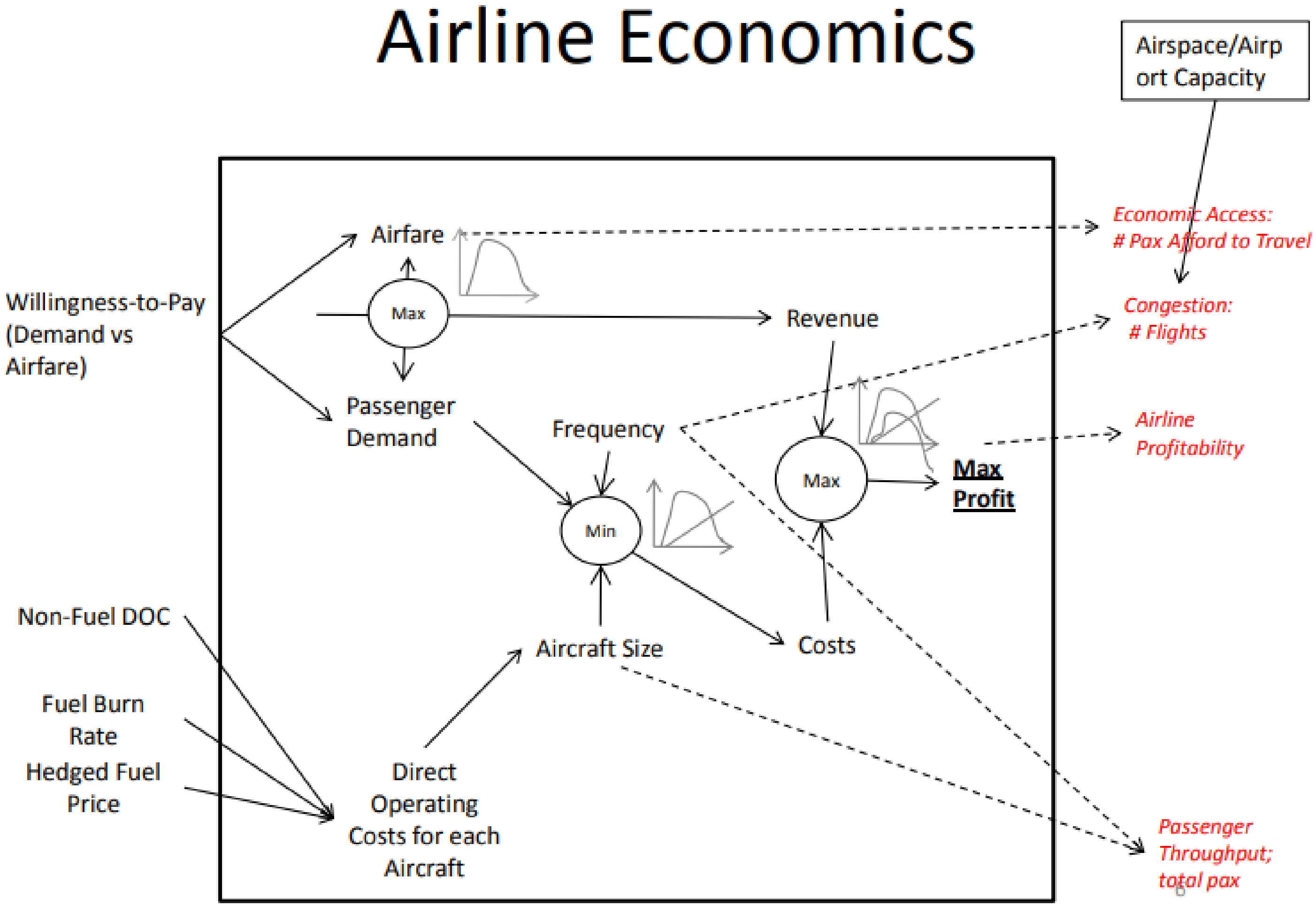
The operations and the maintenance costs include

- 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

Willingness-to-Pay (Demand vs Airfare)

Airfare

Max

Revenue

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

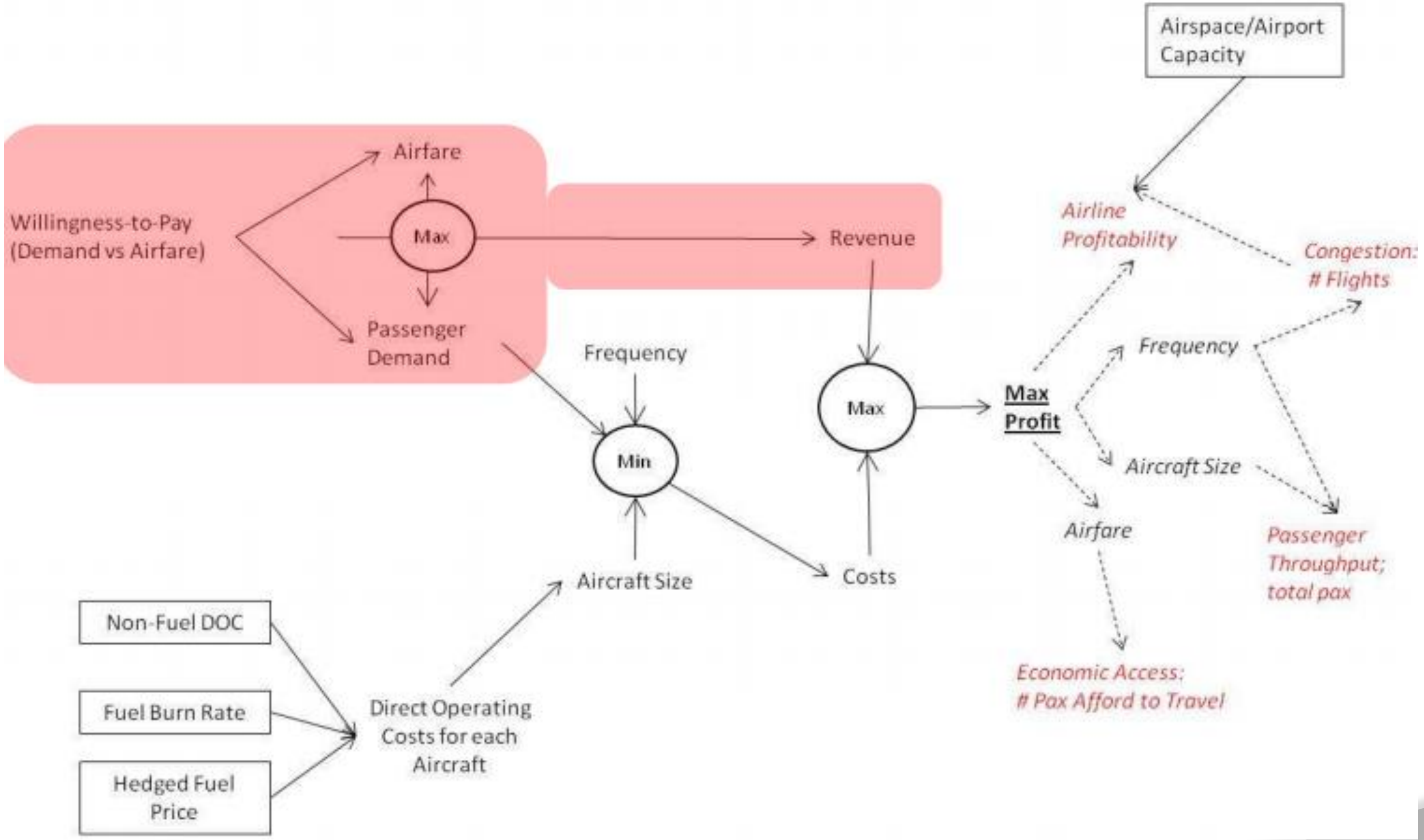
Airline Profitability

Passenger Throughput; total pax

6

Revenue of airline economics

Revenue

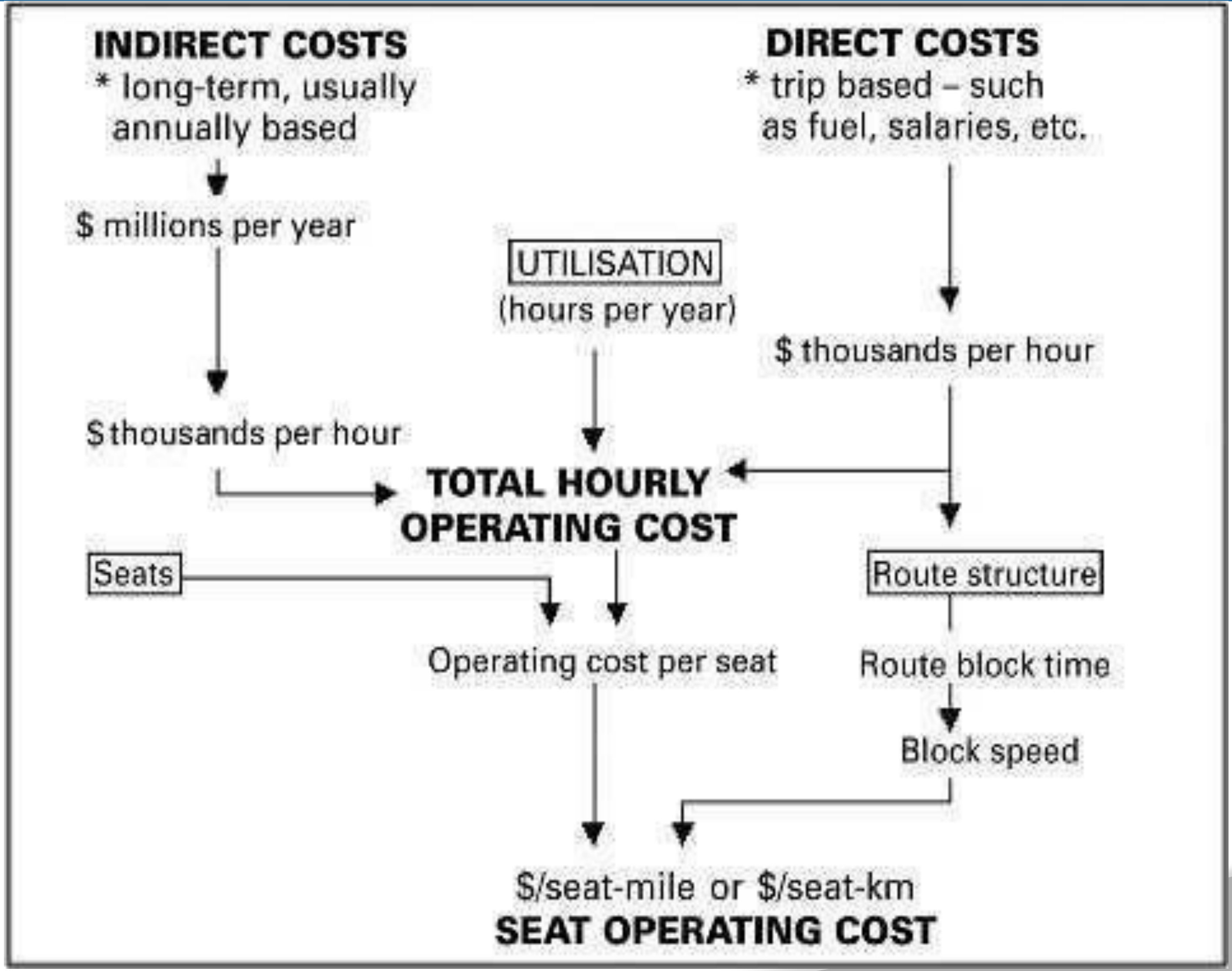


DOC And IOC, Airline Revenue, Breakeven Analysis, Investment Cost Analysis

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.

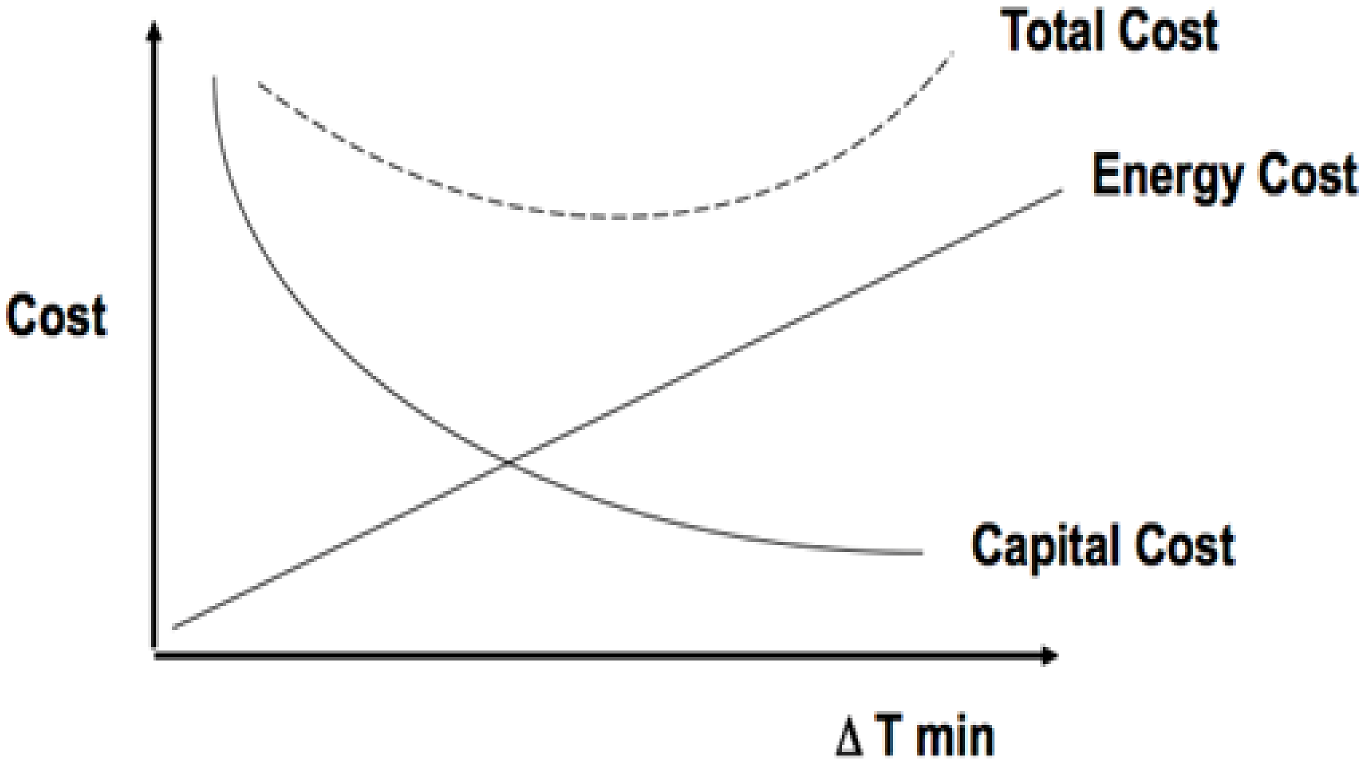
Improved Conceptual Sizing Methods

- 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.

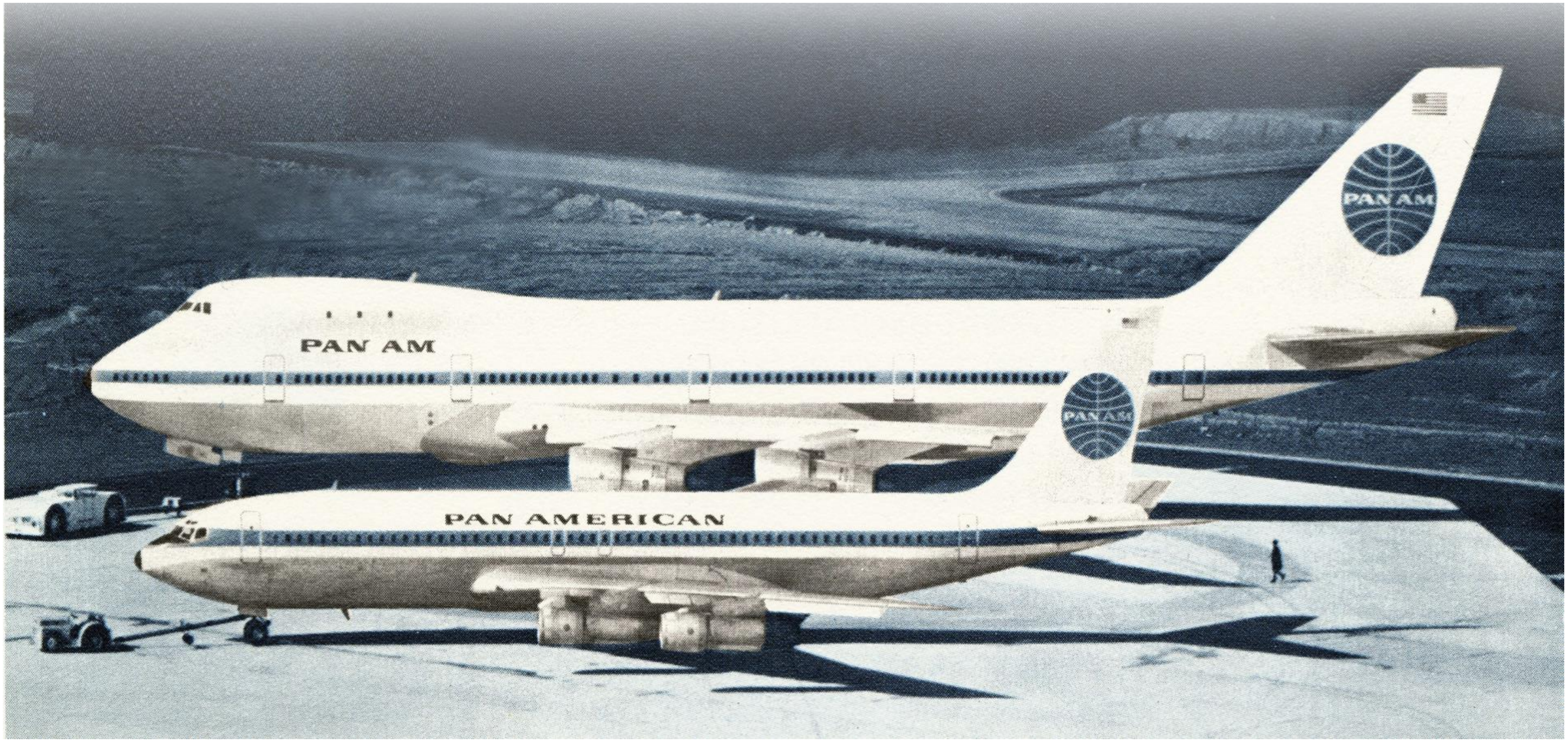
Conclusion

- 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;



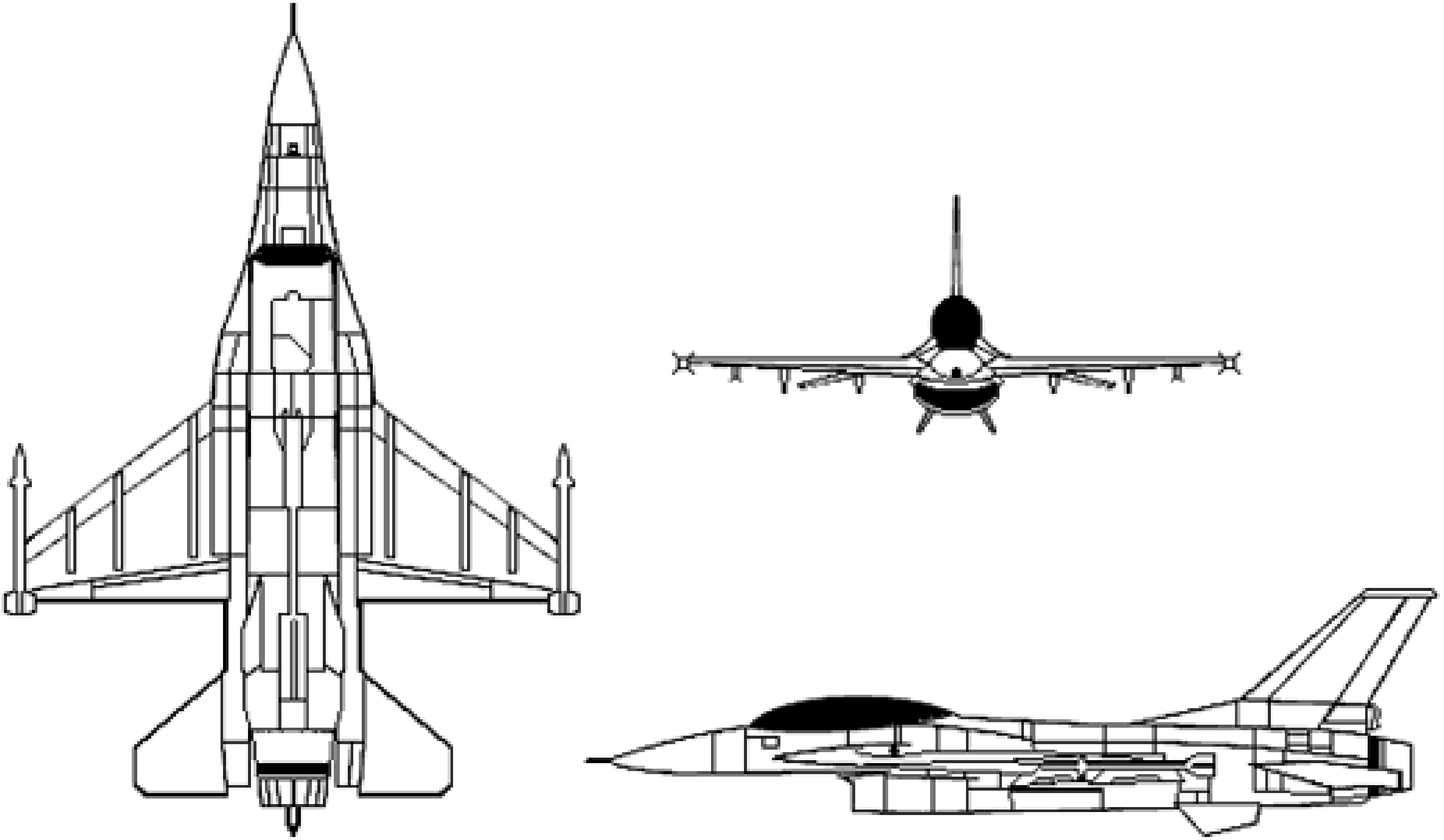
BOEING B-707&747;

- 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.

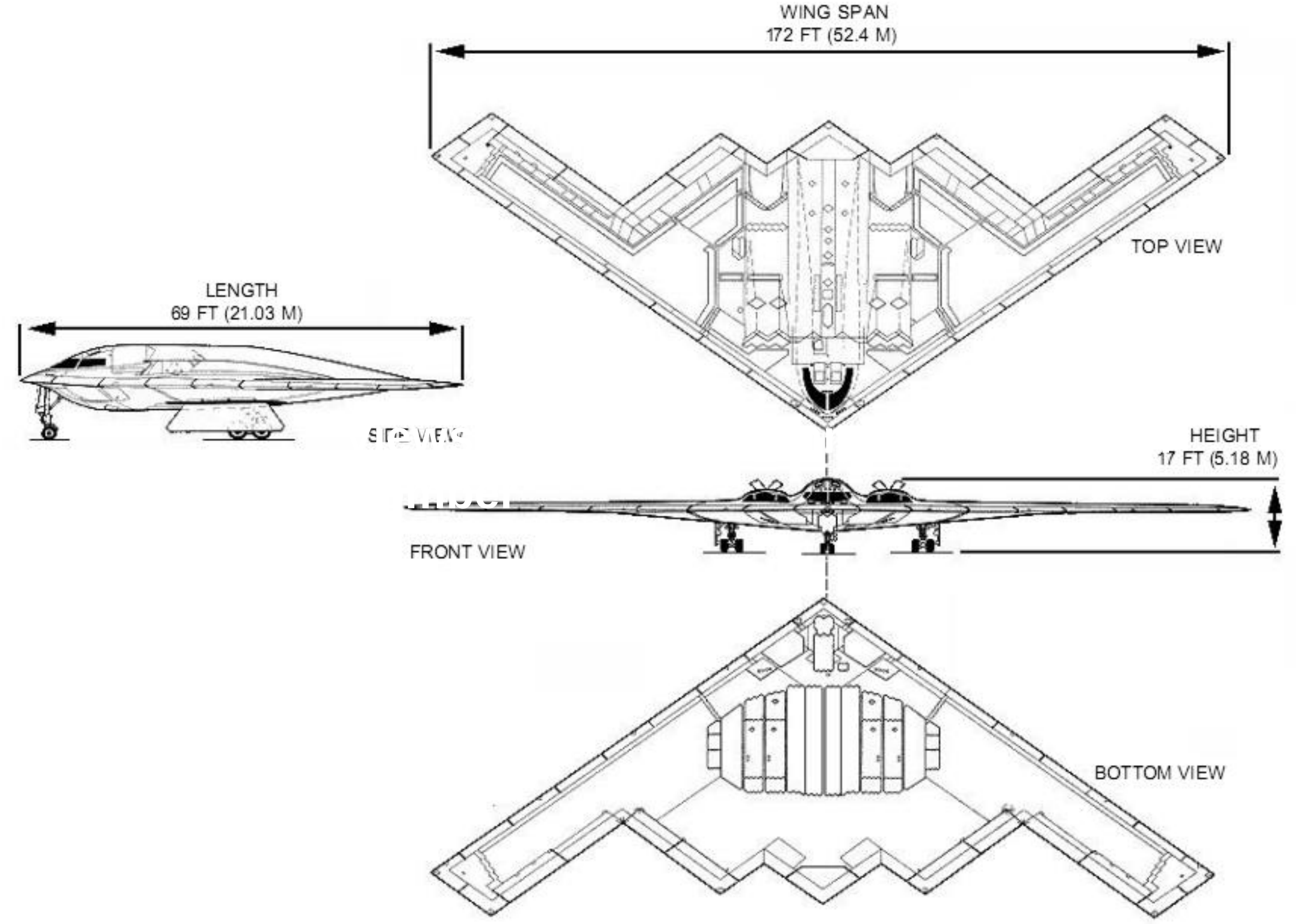
Design

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

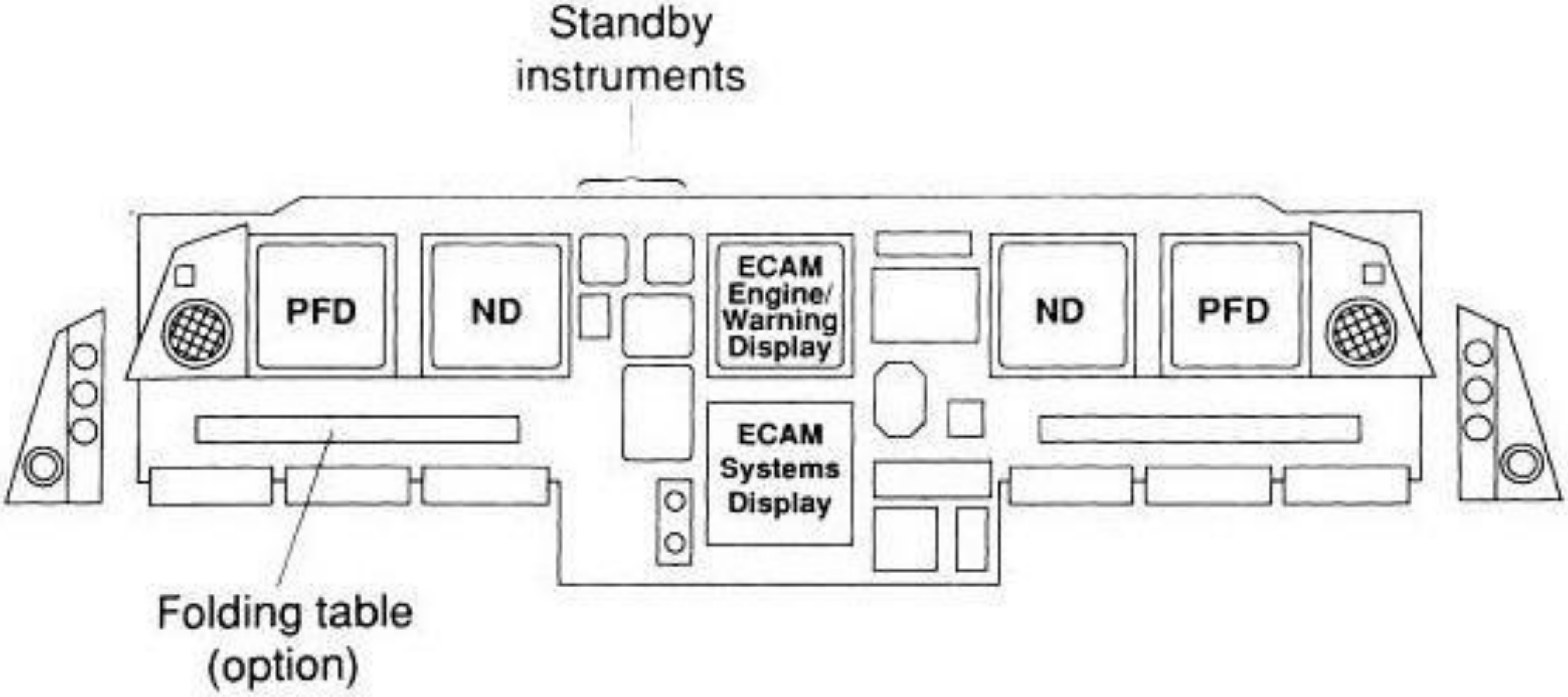
General characteristics

- 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 no 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

Radar sensors



Airbus A340 flight deck – main panel (by courtesy of Airbus Industrie).

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