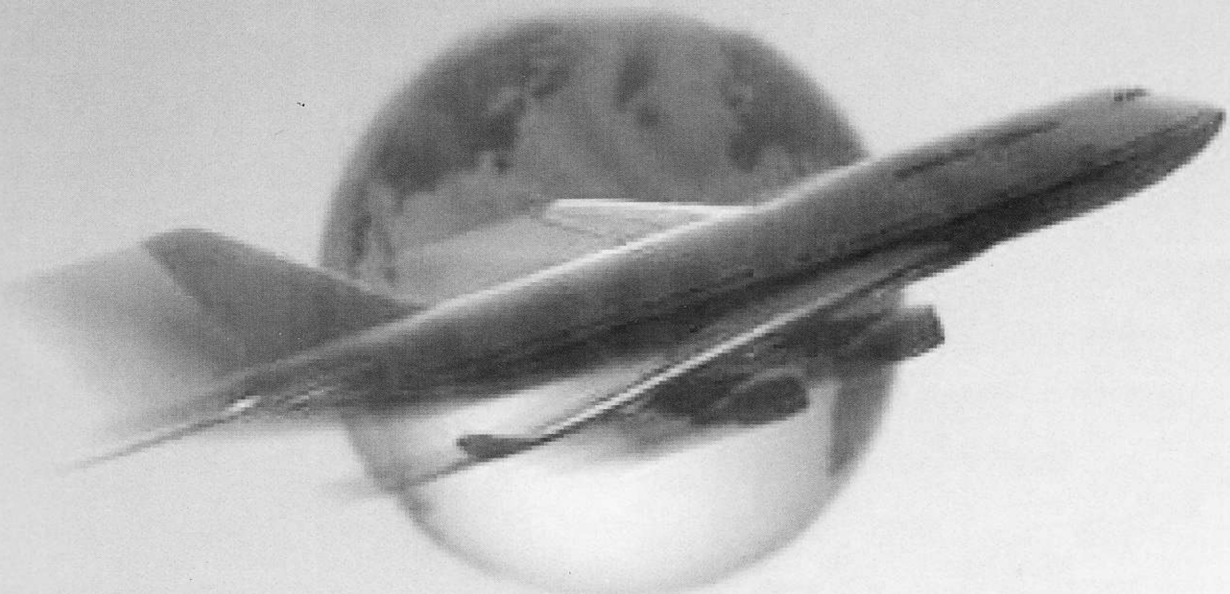
L.Zhuravlova

AVIATION FUNDAMENTALS



THEORY GUIDE

NATIONAL AVIATION UNIVERSITY
INFORMATION TECHNOLOGIES CENTER ITC

L.A. Zhuravlyova

AVIATION FUNDAMENTALS

THEORY GUIDE

KYIV
2012

To my parents
with great gratitude and respect

UDC 629.73(076.8)

LBC 052я7

Z-62

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Z-62 Aviation Fundamentals: Theory Guide / Larysa A. Zhuravlyova.- K.:ITC, 2012.-109 p.

The Theory Guide contains general information about aircraft: the main elements, basic notions and principles of flight. Some general information about aircraft ground handling and maintenance is given. The Theory Guide is intended as an introduction for the students of aviation specialties.

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CONTENTS

INTRODUCTION

Aviation is the design, development, production, operation, and use of aircraft, especially heavier-than-air aircraft. Aviation is derived from "avis" - the Latin word for "bird".

No other mode of transportation has had greater impact on the world than aviation. None has so changed the economic, political, and social traditions of the world in such a short period of time. The phenomenal growth of the aerospace industry, the rapid expansion of commercial air travel, the tremendous influence of aviation on military concepts and international affairs, all have had inescapable and overwhelming effects on day-to-day living.

The youth of today must have an appreciation and awareness of the history, practical effect, and future potential of this transportation giant. Only through an understanding and application of aeronautical principles, by both the present and future generations, will the young people be able to maintain its professional-power position. Many young people have already realized the value of a technical aviation education, including flight and engineering, and are well on the way to participation in the Aerospace Age. Space travel and the space frontier are absorbing and vital problems.

But just as important is an awareness of the advantages and disadvantages, the privileges and restrictions, and the rewards and consequences of expanding aviation in the world of today and tomorrow. The impacts of aviation are economic, social, and political.

Categorically speaking, there are three basic areas in aviation:

1 the aerospace manufacturing industry, both civil and military;

2 the air transport industry;

3 general aviation.

Aerospace Industry Classification

Aerospace Manufacturing Industry:

- Aircraft
- Aircraft Engines
- Aircraft Parts and Accessories
- Missiles
- Spacecraft

Air Transport Industry:

- Domestic Scheduled Airlines.
- Trunk Lines.

- Local Service Lines.
- Helicopter Airlines.
- Supplemental Air Carriers.
- International and Overseas Lines.
- All-cargo Airlines.

General Aviation:

- Business Flying.
- Commercial Flying.
- Instructional Flying.
- Personal Flying.

The aerospace manufacturing industry includes all research, development, fabrication, assembly, and sales operations relating to airplanes, missiles, parts, accessories, and equipment. The industry also includes major overhaul, maintenance, and modification facilities

In contrast, the air transport industry encompasses only scheduled flying activities performed by commercial airlines and air freight carriers. The routes flown, the rates charged for services, and all items pertaining to safety are carefully regulated by the federal aviation authorities.

General aviation consists of all other aviation activities except those of the air transport industry and the military services.

Today aviation exerts considerable influence upon the economic activities of mankind. The aerospace industry provides thousands of job opportimities. It has grown to be a dominant employer in manufacturing.

Further, this industry consumes a sizeable portion of the total defense budget, which is sustained by all taxpayers in some countries.

Commercial aviation is entering a new era, with ever-widening horizons. The commercial jet airliner promises to revolutionize the travel habits of businessmen and families alike. The distances of global travel have been reduced to a few hours of pleasant riding in air-conditioned, living-room comfort.

General aviation is coming into its own with the growing use of aircraft for business travel. Increasing acceptance of the airplane as an economic businessasset will acquaint new thousands with private air travel. As consumer incomes increase, light aircraft ownership costs will fall within the reach of hundreds more. Freedom of movement, now associated with the automobile, may be shifted to the airplane.

Sociological change has followed the development of the airplane. The airplane has increased the living tempo, opened new markets, and affected the distribution of the world's population. Distant and previously inaccessible areas will be opened, new towns will be constructed, and sparsely populated regions lying adjacent to air routes will increase in population.

Formal education will be vitally affected by aviation with all phases of the present educational system directly influenced by aviation activity.

Aircraft are generally characterized by their mean of producing lift.

Powered lift or powered-lift refers to a type of aircraft that can take off and land vertically and functions differently from a rotorcraft in horizontal flight. Powered lift - relies on downward thrust from the engines to stay airborne (*VTOL, STOL, STVOL*). The initialism VTOL (vertical take off and landing) is applied to aircraft that can take off and land vertically. Most are rotorcraft. Others take off and land vertically using powered lift and transfer to aerodynamic lift in steady flight. Similarly, STOL stands for short take off and landing. Some VTOL aircraft often operate in a short take off/vertical landing mode known as STOVL.

A fixed-wing aircraft, typically called an aeroplane, airplane or just plane, is an aircraft capable of flight using forward motion that generates lift as the wing moves through the air. Planes include jet engine and propeller driven vehicles propelled forward by thrust, as well as unpowered aircraft (such as gliders), which use thermals, or warm-air pockets to inherit lift. Fixed-wing aircraft are distinct from ***ornithopters*** and ***rotary-wing aircraft*** in which wings rotate about a fixed mast.

Fixed-wing aircraft are generally characterized by their ***wing configuration***.

Number and position of main-planes. Aircraft can have different numbers of wings:

No wings at all. A lifting body is an aircraft configuration in which the body itself produces lift.

Ornithopter ['ɔːnɪˌθɒptə] a machine designed to achieve flight by means of flapping wings.

A ***rotorcraft or rotary wing aircraft*** is a heavier-than-air flying machine that uses lift generated by wings, called rotor blades that revolve around a mast. Several rotor blades mounted to a single mast are referred to as a ***rotor***.

A flexible wing is a wing made of fabric or thin sheet material, often stretched over a rigid frame.

1. AIRPLANE MAIN PARTS

An aircraft is a vehicle which is able to fly by being supported by the air, or in general, the atmosphere of a planet. An aircraft counters the force of gravity by using either static lift or by using the dynamic lift of an airfoil, or in a few cases the downward thrust from jet engines.

Although airplanes are designed for a variety of purposes, most of them have the same major components. The overall characteristics are largely determined by the original design objectives. Most airplane main parts are: fuselage, wings, an empennage, landing gear, and a powerplant (Figure 1.1).

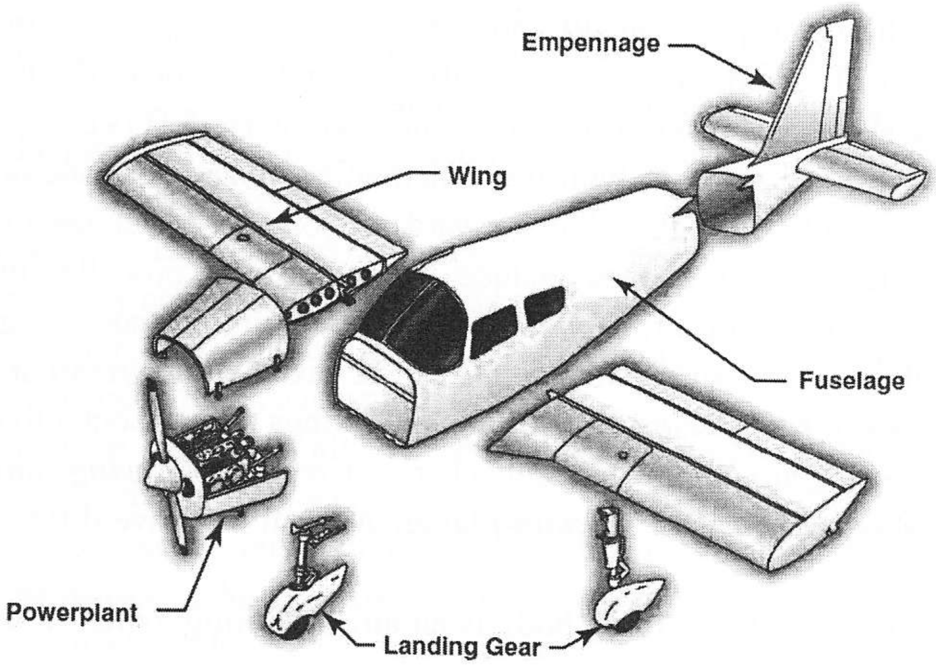


Figure 1.1- Airplane Main Parts

Fuselage

The fuselage (from the French fuselé "spindle-shaped") is an aircraft's main body section that holds crew and passengers or cargo. In single-engine aircraft it will usually contain an engine, although in some amphibious aircraft the single engine is mounted on a pylon attached to the fuselage which in turn is used as a floating hull. The fuselage also serves to position control and stabilization surfaces in specific relationships to lifting surfaces, required for aircraft stability and maneuverability. The fuselage includes the cabin and/or cockpit, which contains seats for the occupants and the controls for the airplane. In addition, the fuselage may also provide room for cargo and attachment points for the other major airplane components.

Some aircraft utilize an open **truss** structure.

Truss is fuselage design made up of supporting structural members that resist deformation by applied loads.The truss-type fuselage is constructed of steel or aluminum tubing. Strength and rigidity is achieved by welding the tubing together into a series of triangular shapes, called trusses.

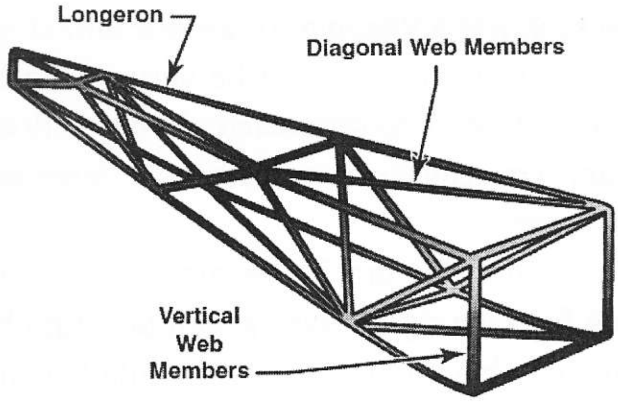


Figure 1.2- The Warren Truss

Main parts of truss structure are shown on Figure 1.2.

In aircraft construction, a longeron or stringer or stiffener is a thin strip of material, to which the skin of the aircraft is fastened. In the fuselage, longerons are attached to formers (also called frames) and run the longitudinal direction of the aircraft. In the wing or horizontal stabilizer, longerons run spanwise and attach to ribs.

A strut is a structural component designed to resist longitudinal compression. Struts provide outwards-facing support in their lengthwise direction, which can be used to keep two other components separate, performing the opposite function of a tie. They are commonly used in architecture and engineering, for instance as components of an automobile chassis, where they can be passive braces to reinforce the chassis and/or body, or active components of the suspension. In piping, struts restrain movement of a component in one direction while allowing movement or contraction in another direction.

In some cases, the outside skin can support all or a major portion of the flight loads. Most modern aircraft use a form of this stressed skin structure known as monocoque or semimonocoque construction.

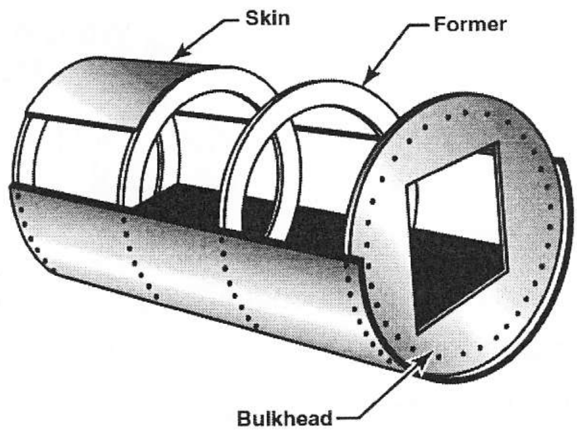


Figure 1.3- Monocoque Fuselage Design

The **monocoque** design (Figure 1.3) uses stressed skin to support almost all imposed loads.

Monocoque is a shell-like fuselage design in which the stressed outer skin is used to support the majority of imposed stresses. Monocoque fuselage design may include bulkheads but not stringers. The bulkhead is a component of an aircraft fuselage, which purpose is to seal the fuselage and thus maintain cabin pressure, and as such it is a vital part of the aircraft.

This structure can be very strong but cannot tolerate dents or deformation of the surface. This characteristic is easily demonstrated by a thin aluminum beverage can. You can exert considerable force to the ends of the can without causing any damage.

Since no bracing members are present, the skin must be strong enough to keep the fuselage rigid. Thus, a significant problem involved in monocoque construction is maintaining enough strength while keeping the weight within allowable limits. Due to the limitations of the monocoque design, a semi-monocoque structure is used on many of today's aircraft.

The **semi-monocoque** (Figure 1.4) system uses a substructure to which the airplane's skin is attached.

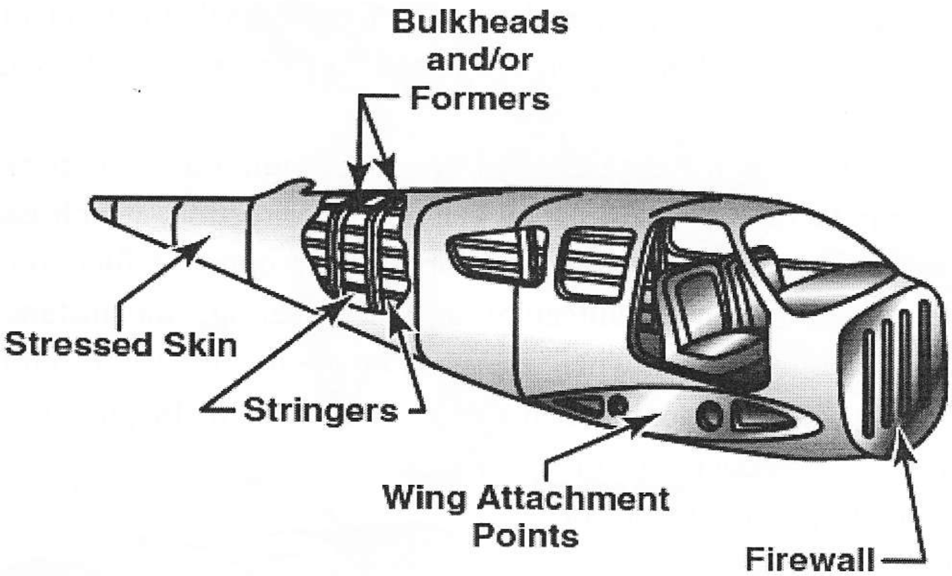


Figure 1.4- Semi-Monocoque Construction

Semi-Monocoqueis a fuselage design that includes a substructure of bulkheads and/or formers, along with stringers, to support flight loads and stresses imposed on the fuselage.

A former is a structural member of an aircraft fuselage, of which a typical fuselage has a series from the nose to the empennage, typically perpendicular to the longitudinal axis of the aircraft. The primary purpose of formers is to establish the shape of the fuselage and reduce the column length of stringers to prevent instability. Formers are typically attached to longerons, which support the skin of the aircraft.

The substructure, which consists of bulkheads and/or formers of various sizes and stringers, reinforces the stressed skin by taking some of the bending stress from the fuselage.

The main section of the fuselage also includes wing attachment points and a firewall. Different types of fuselage are shown in Appendix A.

Cross-Section Shape

Most fuselage cross-sections are relatively circular in shape. This is done for two reasons

1. By eliminating corners, the flow will not separate at moderate angles of attack or sideslip
2. When the fuselage is pressurized, a circular fuselage can resist the loads with tension stresses, rather than the more severe bending loads that arise on non-circular shapes.

Many fuselages are not circular, however. Aircraft with unpressurized cabins often incorporate non-circular, even rectangular cabins in some cases, as dictated by cost constraints or volumetric efficiency (Figure 1.5).

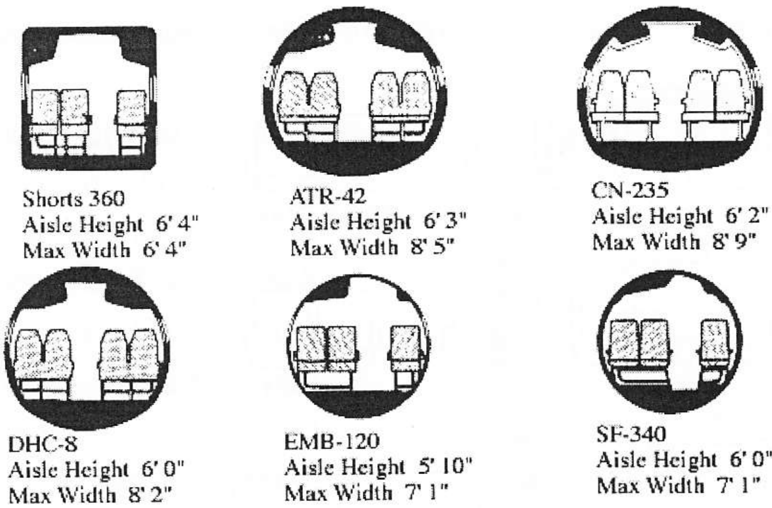


Figure 1.5.- Cross-Section Shapes of Fuselage

Sometimes substantial amounts of space would be wasted with a circular fuselage when specific arrangements of passenger seats and cargo containers must be accommodated. In such cases, elliptical or double-bubble arrangements can used. The double-bubble geometry uses intersecting circles, tied together by the fuselage floor, to achieve an efficient structure with less wasted space (Figure 1.6).

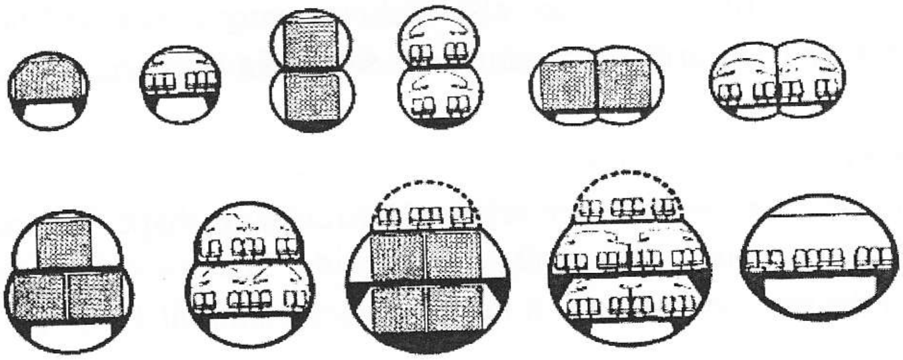


Figure 1.6.- Arrangements of Fuselages

Fuselage Diameter

The dimensions are set so that passengers and standard cargo containers may be accommodated.

Typical dimensions for passenger aircraft seats are shown by way of the several examples on Figures 1.7-1.8.

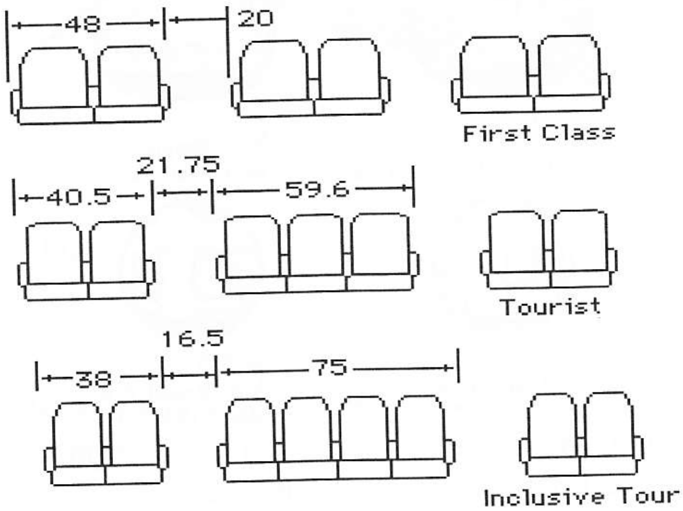


Figure 1.7.- Typical Dimensions for Passenger Aircraft Seats

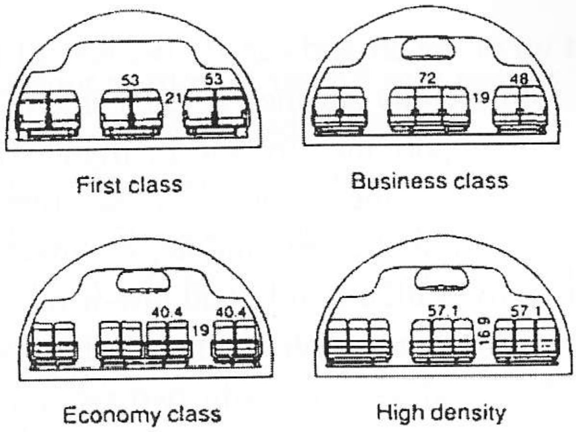


Figure 1.8.- Dimensions for different Passenger Classes

In addition, space must be available for cargo: either revenue cargo or lugggage. Typical cargo weighs 10 lb/ft^3 while luggage averages 12.5 lb/ft^3 (Torenbeek). Passengers are generally allotted 35 to 40 lbs for bags. This means about 4 ft^3 per passenger for baggage. Most large airplanes have much more room than this, thus allowing space for revenue cargo. 767/ MD-11 / 747 values are more like 12 ft^3 per person, although this is not a requirement. A 757 provides about 10 ft^3 per passenger of bulk cargo volume. Since substantial income is generated by revenue cargo, it is often desirable to allow room for extra cargo. The preferred approach is to accommodate standard size containers, some of which are shown below.

One must provide for a sidewall clearance of about 3/4" to account for shell deflection, seat width tolerances, and seat track location tolerances. Finally, the fuselage frame, stringers, and insulation thickness must be added to determine the fuselage outer diameter. Typically, the outer diameter is about 8% larger than the cabin diameter (Figure1.9).

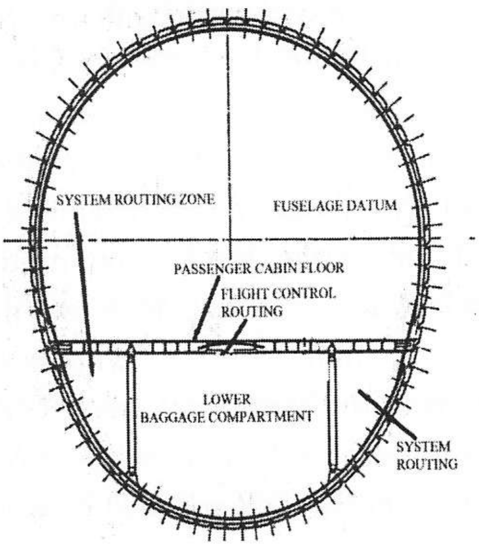


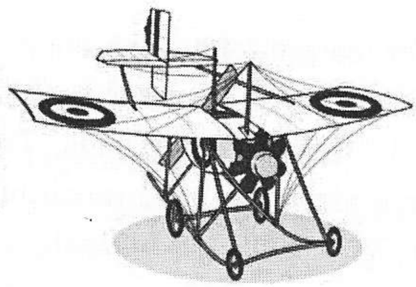
Figure 1.9.- Typical Internal Space of Fuselage

Recent interest in very large aircraft suggests that additional creative possibilities exist for the aircraft interior.

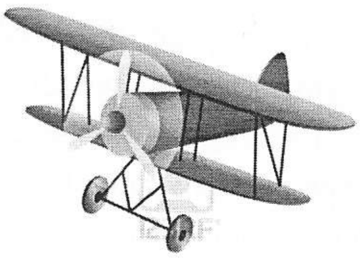
Wing

Aircraft are kept up in the air and can fly because of lift produced by **wing or mainplane**. The wings are **airfoils** attached to each side of the fuselage and are the main lifting surfaces that support the airplane in flight. There are numerous wing designs, sizes, and shapes used by the various manufacturers.

Wings may be attached at the top, middle, or lower portion of the fuselage. These designs are referred to as high-, mid-, and low-wing, respectively. The number of wings can also vary. Airplanes with a single set of wings are referred to as **monoplanes** (Figure 1.10,a), while those with two sets are called **biplanes** (Figure 1.10,b).



a



b

Figure 1.10- Monoplane and Biplane

Monoplane is an airplane that has only one main lifting surface or wing, usually divided into two parts by the fuselage.

Biplane is an airplane that has two main airfoil surfaces or wings on each side of the fuselage, one placed above the other.

The number of wings higher than three is not practical.

Nowadays, modern aircraft almost all have monoplane. Currently, there are a few aircraft that employ biplane, but no modern aircraft is found to have three wings. In the past, the major reason to select more than one wing was the manufacturing technology limitations. A single wing usually has a longer wing span compared with two wings (with the same total area). Old manufacturing technology was not able to structurally support a long wing to stay level and rigid. With the advance in the manufacturing technology and also new aerospace strong materials; such as advanced light aluminum, and composite materials; this reason is not valid anymore. Another reason was the limitations on the aircraft wing span. Hence a way to reduce the wing span is to increase the number of wings.

Thus, a single wing (that includes both left and right sections) is almost the only practical option in conventional modern aircraft. However, a few other design considerations may still force the modern wing designer to lean toward more than one wing.

Wings develop the major portion of the lift of a heavier-than-air aircraft.Wing structures carry some of the heavier loads found in the aircraft structure. The particular design of a wing depends on many factors, such as the size, weight, speed, rate of climb, and use of the aircraft. The wing must be constructed so that it holds its aerodynamics shape under the extreme stresses of combat maneuvers or wing loading.

Wing construction is similar in most modern aircraft. In its simplest form, the wing is a framework made up of spars and ribs and covered with metal. The construction of an aircraft wing is shown in Figure 1.11.

Spars are the main structural members of the wing. They extend from the fuselage to the tip of the wing. All the load carried by the wing is taken up by the spars. The spars are designed to have great bending strength.

In a fixed-wing aircraft, the spar is often the main structural member of the wing, running spanwise at right angles (or thereabouts depending on wing sweep) to the fuselage. The spar carries flight loads and the weight of the wings while on the ground. Other structural and forming members such as ribs may be attached to the spar or spars, with stressed skin construction also sharing the loads where it is used. There may be more than one spar in a wing or none at all. However, where a single spar carries the majority of the forces on it, it is known as the main spar.

Spars are also used in other aircraft aerofoil surfaces such as the tailplane and fin and serve a similar function, although the loads transmitted may be different to those of a wing spar.

Ribs give the wing section its shape, and they transmit the air load from the wing covering to the spars. Ribs extend from the leading edge to the trailing edge of the wing.

In an aircraft, ribs are forming elements of the structure of a wing, especially in traditional construction.

By analogy with the anatomical definition of "rib", the ribs attach to the main spar, and by being repeated at frequent intervals, form a skeletal shape for the wing. Usually ribs incorporate the airfoil shape of the wing, and the skin adopts this shape when stretched over the ribs.

In most modern airplanes, the fuel tanks either are an integral part of the wing's structure, or consist of flexible containers mounted inside of the wing a (Appendix B).

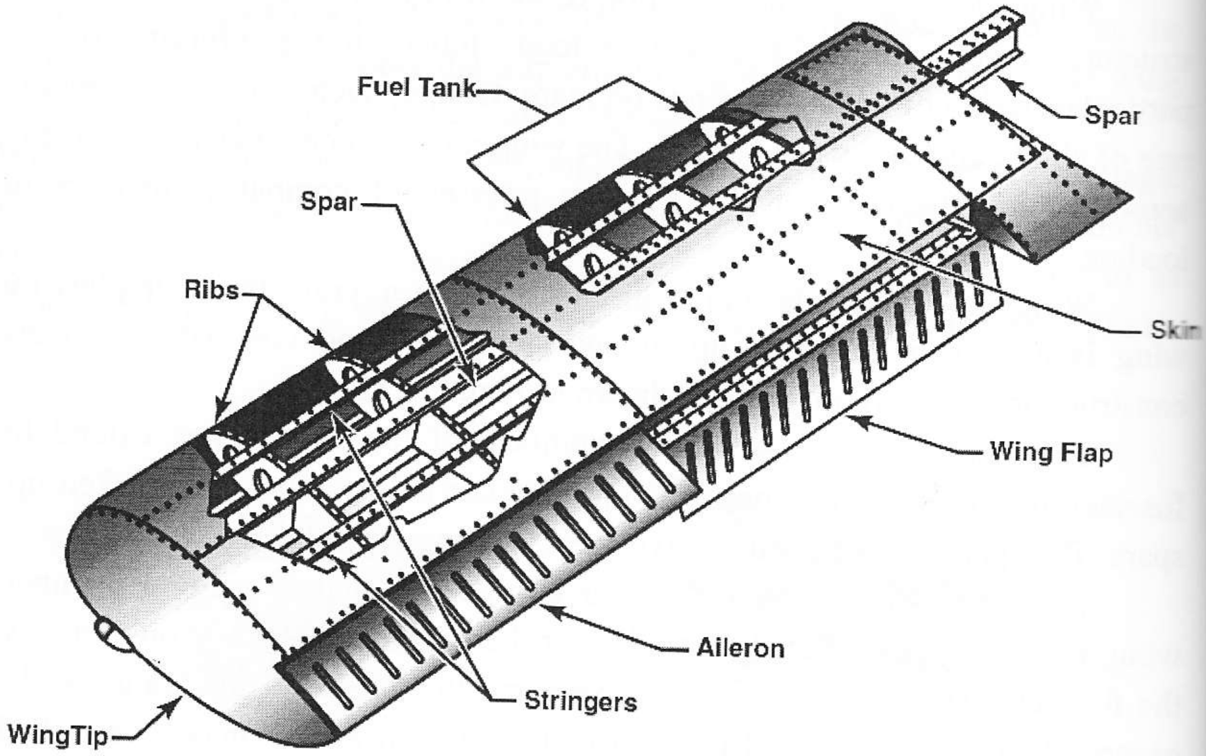


Figure 1.11- Wing Components

A wing tip is the part of the wing that is most distant from the fuselage of a fixed-wing aircraft.

Wing may have different shape in plane, and location on the fuselage.

Number and position of main-planes

Monoplane

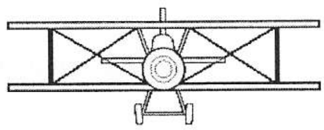
A monoplane is an aircraft with one main set of wing surfaces, in contrast to a biplane or triplane. Since the late 1930s it has been the most common form for a fixed wing aircraft.

Low wing - mounted on the lower fuselage (Figure 1.12, a).
Mid wing - mounted approximately half way up the fuselage (Figure 1.12, b).
High wing- mounted on the upper fuselage. (Figure 1.12, c).
Parasol wing - mounted on "cabane" struts above the fuselage (Figure 1.12, d).

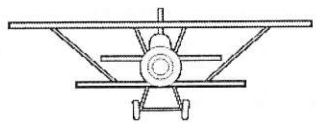
a *b* *c* *d*

Figure 1.12.- Positions of Mainplane

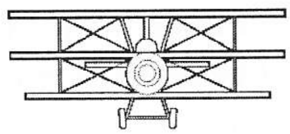
A fixed wing aircraft may have more than one wing plane, stacked one above another:



Biplane - two planes of approximately equal size, stacked one above the other. The most common type until the 1930s, when the cantilever monoplane took over.

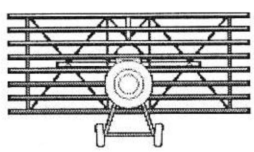


Sesquiplane - literally "one-and-a-half planes" is a variant on the biplane in which the lower wing is significantly smaller than the upper wing.



Triplane - three planes stacked one above another. Triplanes such as the Fokker Dr.I enjoyed a brief period of popularity during the First World War due to their small size and high manoeuvrability as fighters, but were soon replaced by improved biplanes.

Quadruplane - four planes stacked one above another. A small number of the Armstrong Whitworth F.K.10 were built in the First World War but it never saw operational military service.



Multiplane - many planes, sometimes used to mean more than one or more than some arbitrary number. The term is occasionally applied to arrangements stacked in tandem as well as vertically. No example with more than four wings has ever flown successfully: the nine-wing Caproni Ca.60 flying boat was only airborne briefly before crashing.

A Tandem wing design (Figure 1.13) has two similar-sized wings, one behind the other.

A ***staggered design*** (stagger ['stægə]) has the upper wing slightly forward of the lower. This helps give stability to stacked wings, and is usual on successful designs (Figure 1.14).

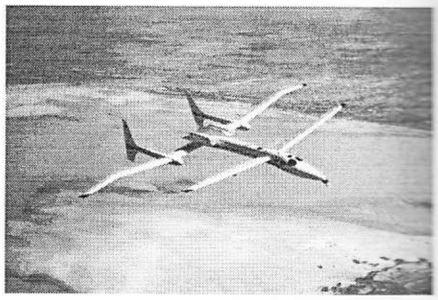


Figure 1.13.-Tandem Wing

Wing support

Forwards stagger

Backwards stagger

Figure 1.14.- Staggered Wing Design

To support itself a wing has to be rigid and strong and consequently may be heavy. By adding external *bracing*, the weight can be greatly reduced. Originally such bracing was always present, but it causes a large amount of drag at higher speeds and has not been used for faster designs since the early 1930s.

The types are:

Cantilevered – (cantilever ['kæntɪli:və]) self-supporting wing (Figure 1.15). All the structure is buried under the aerodynamic skin, giving a clean appearance with low drag.

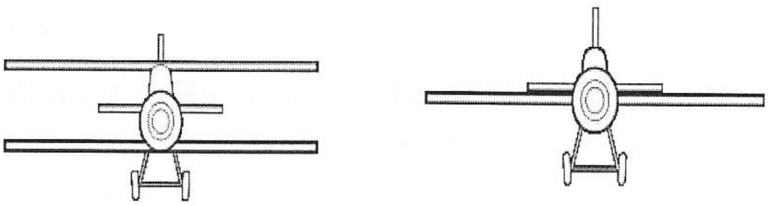


Figure 1.15.- Self-Supporting (Cantilever) Wing

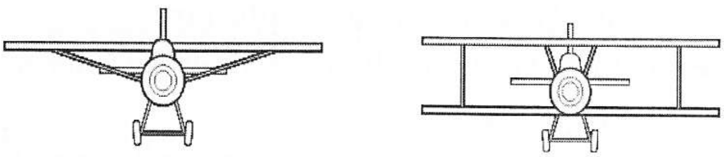


Figure 1.16.- Strut-Braced Wing

Braced: the wings are supported by external structural members. Nearly all multi-plane designs are braced. Some monoplanes, especially early designs such as the Fokker Eindecker, are also braced to save weight. Braced wings are of two types:

Strut braced –one or more stiff struts help to support the wing (Figure 1.16). A strut may act in compression or tension at different points in the flight regime.

Wire braced - alone, or in addition to struts, tension wires also help to support the wing (Figure 1.17) . Unlike a strut, a wire can act only in tension.

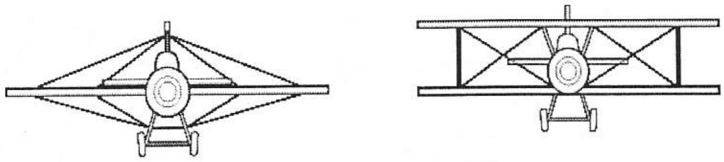


Figure 1.17.- Cross-Section Shapes of Fuselage

A braced multiplane may have one or more ***"bays"***, which are the compartments created by adding interplane struts; the number of bays refers to one side of the aircraft's wing panels only. For example, the de Havilland Tiger Moth is a single-bay biplane where the Bristol F.2 Fighter is a two-bay biplane.

Combined or closed wing - two wings are joined structurally at or near the tips in some way (Figure 1.18). This stiffens the structure, and can reduce aerodynamic losses at the tips. Variants include:

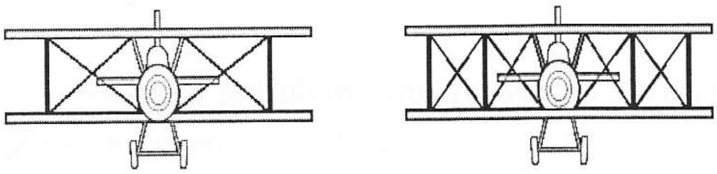


Figure 1.18.- Combined Wing

Box wing - upper and lower planes are joined by a vertical fin between their tips Figure 1.19).

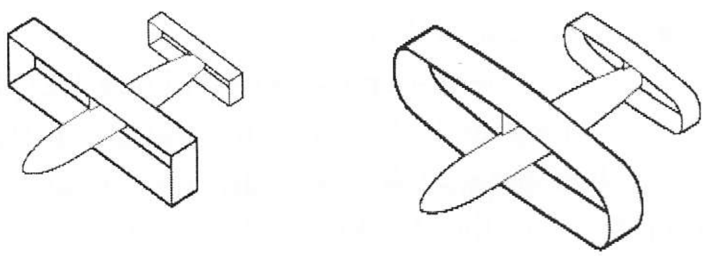


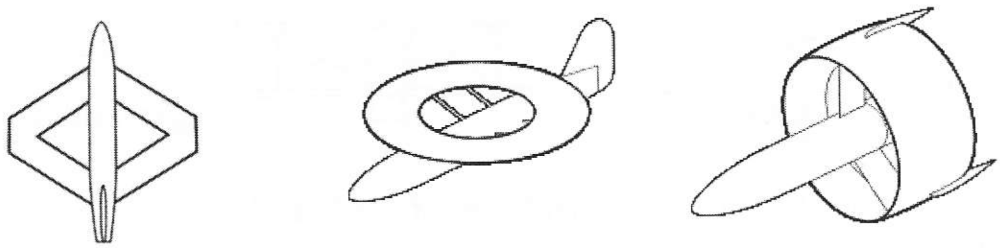
Figure 1.19.- Box Wing

Rhomboidal wing - a tandem layout in which the front wing sweeps back and the rear wing sweeps forwards such that they join at or near the tips to form a continuous surface in a hollow diamond shape (Figure 1.20,a).

Annular or ring wing –may refer to various types:

Flat - the wing is shaped like a circular disc with a hole in it (Figure 1.20, b). A Lee-Richards type was one of the first stable aircraft to fly, shortly before the First World War.

Cylindrical - the wing is shaped like a cylinder (Figure 1.20,c).



a *b* *c*

Figure 1.20.- Rhomboidal, Flat and Cylindrical Wing

Wings can also be characterized as: ***rigid*** - stiff enough to maintain the aerofoil profile in varying conditions of airflow and ***flexible*** - usually a thin membrane.

Wing planform

The wing planform is the silhouette of the wing when viewed from above or below.

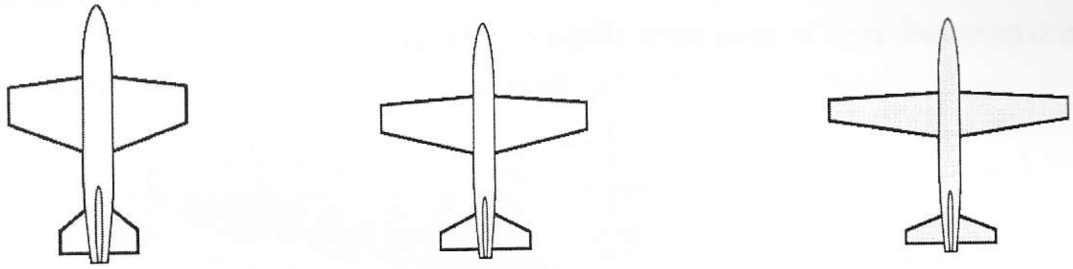
Variable geometry types vary the wing planform during flight.

Aspect ratio. The aspect ratio is the span divided by the mean or average chord. It is a measure of how long and slender (узкий) the wing appears when seen from above or below.

Low aspect ratio - short and stubby wing (Figure 1.21, a). More efficient structurally, more maneuverable and with less drag at high speeds. They tend to be used by fighter aircraft, such as the Lockheed F-104 Starfighter, and by very high-speed aircraft (e.g. North American X-15).

Moderate aspect ratio - general-purpose wing (Figure 1.21, b).

High aspect ratio - long and slender wing (Figure 1.21,c). More efficient aerodynamically, having less drag, at low speeds. They tend to be used by high-altitude subsonic aircraft (e.g. the Lockheed U-2), subsonic airliners (e.g. the Bombardier Dash 8) and by high-performance sailplanes (e.g. Glaser-Dirks DG-500).



a b c

Figure 1.21.- Wing Aspect Ratio

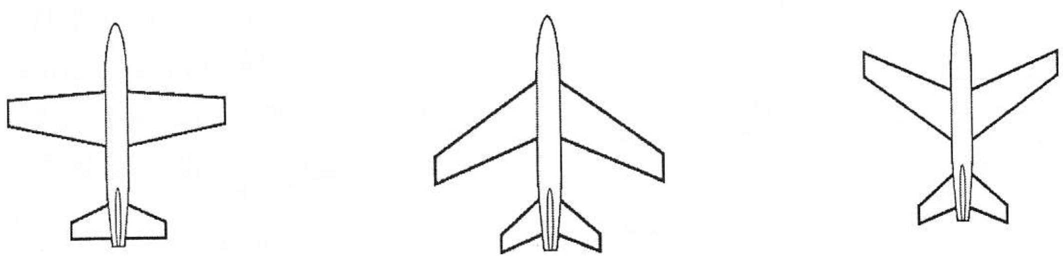
Wing sweep

Wings may be swept forwards or back for a variety of reasons. A small degree of sweep is sometimes used to adjust the centre of lift when the wing cannot be attached in the ideal position for some reason. Other uses are described below.

Straight wing- extends at right angles to the line of flight (Figure 1.22, a). The most efficient structurally, and common for low-speed designs.

Swept back - (references to "swept" often assume swept back). From the root, the wing angles backwards towards the tip (Figure 1.22,b).

Forward swept - the wing angles forwards from the root (Figure 1.22,c).



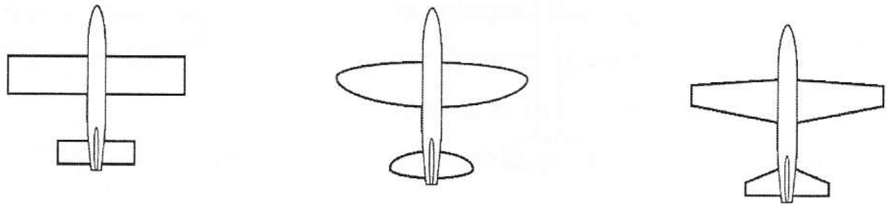
a b c

Figure 1.22.- Wing Sweep

Planform variation along span

The wing chord may be varied along the span of the wing, for both structural and aerodynamic reasons.

Constant chord - leading and trailing edges are parallel. Simple to make, and common where low cost is important (Figure 1.23,a).



a *b* *c*

Figure 1.23.- Constant chord, Elliptical and Tapered wing

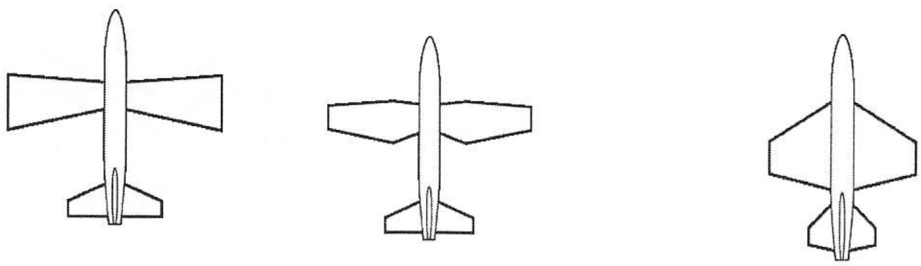
Elliptical wing- wing edges are parallel at the root, and curve smoothly inwards to a rounded tip, with no division between the edges and the tip (Figure 1.23,b) . Aerodynamically the most efficient, but difficult to make.

Tapered wing- wing narrows towards the tip, with straight edges (Figure 1.23,c). Structurally and aerodynamically more efficient than a constant chord wing, and easier to make than the elliptical type.

Reverse tapered wing- wing widens towards the tip (Figure 1.24,a).

Compound tapered wing- taper reverses towards the root, to increase visibility for the pilot (Figure 1.24,b). Typically needs to be braced to maintain stiffness.

Trapezoidal wing- a low aspect ratio tapered wing, having little or no sweep such that the leading edge sweeps back and the trailing edge sweeps forwards (Figure 1.24,c).



a *b* *c*

Figure 1.24.- Reverse Tapered, Compound Tapered and Trapezoidal Wing

Bird like - a curved shape appearing similar to a bird's outstretched wing (Figure 1.25). Popular during the pioneer years.

Circular - approximately circular planform (Figure 1.26,a).

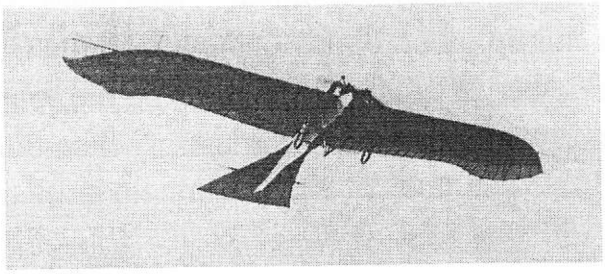
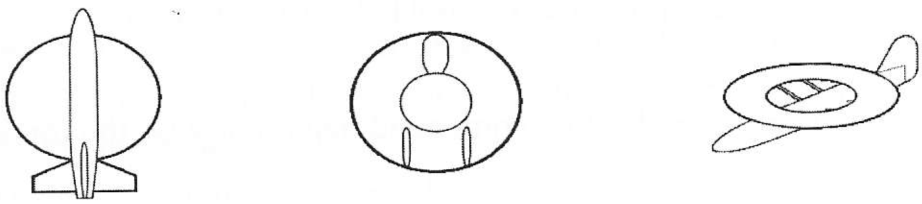


Figure 1.25.- Birdlike Wing

Flying saucer - tailless circular flying wing (Figure 1.26,b).

Flat annular wing - the circle has a hole in, forming a closed wing (Figure 1.26,c).



a *b* *c*

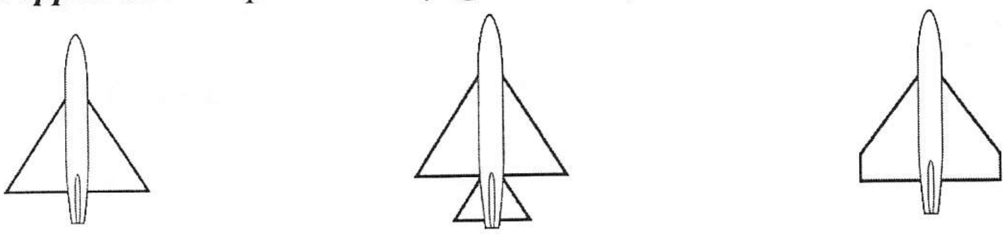
Figure 1.26.- Circular Wing, Flying Saucer and Flat Annual Wing

Delta - triangular planform with swept leading edge and straight trailing edge. Offers the advantages of a swept wing, with good structural efficiency. Variants are:

Tailless delta - a classic high-speed design (Figure 1.27,a).

Tailed delta - adds a conventional tailplane, to improve handling (Figure 1.27,b).

Cropped delta - tip is cut off (Figure 1.26,c).



a *b* *c*

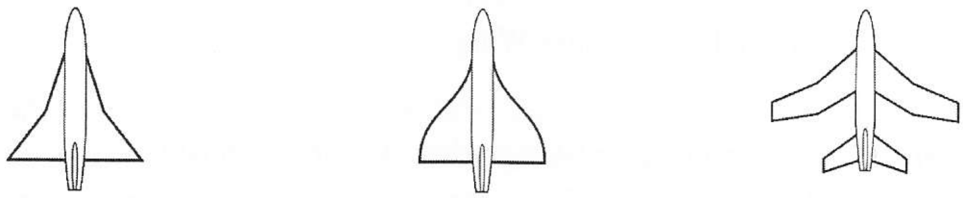
Figure 1.26.- Delta Wings

Compound delta or double delta wing - inner section has a (usually) steeper leading edge sweep (Figure 1.27,a).

Ogival delta wing - a smoothly blended "wineglass" double-curve encompassing the leading edges and tip of a cropped compound delta (Figure 1.27,b).

The angle of sweep may also be varied, or cranked, along the span:

Crescent wing - wing outer section is swept less sharply than the inner section (Figure 1.27,c).



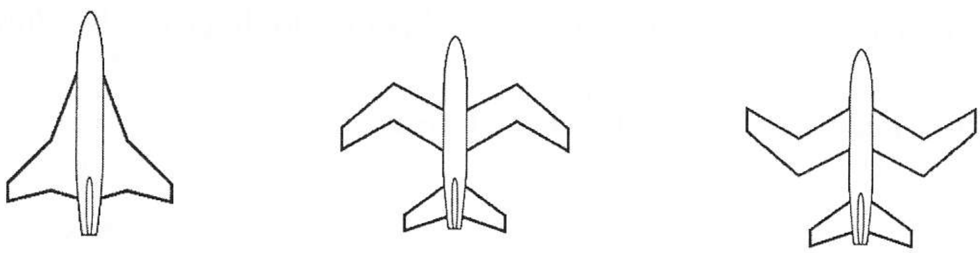
a *b* *c*

Figure 1.27.- Compound Delta, Ogival Delta and Crescent Wing

Cranked arrow wing - similar to a compound delta, but with the trailing edge also kinked inwards (Figure 1.28,a).

M-wing - the inner wing section sweeps forward, and the outer section sweeps backwards (Figure 1.28,b).

W-wing - the inner wing section sweeps back, and the outer section sweeps forwards Figure 1.28,c). The reverse of the M-wing.



a *b* *c*

Figure 1.28.- Cranked Arrow, M- and W- Wing

Dihedral and anhedral

Angling the wings up or down spanwise from root to tip can help to resolve various design issues, such as stability and control in flight.

Dihedral - the tips are higher than the root, giving a shallow 'V' shape when seen from the front. Adds lateral stability (Figure 1.29,a).

Anhedral - the tips are lower than the root, the opposite of dihedral (Figure 1.29.b). Used to reduce stability where some other feature results in too much stability thus making manoeuvering difficult.

a *b*

Figure 1.29.-Dihedral and Anhedral

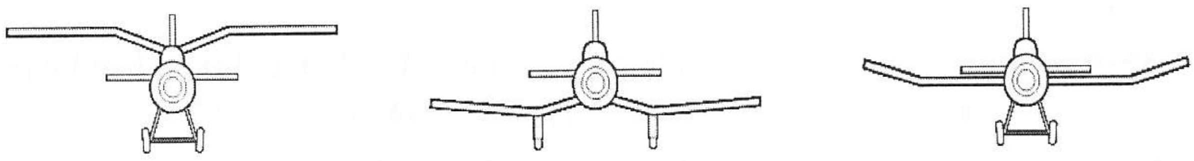
Some biplanes had different angles of dihedral/anhedral on different wings; e.g. the first Short Sporting Type, known as the Shrimp, had a flat upper wing and a slight dihedral on the lower wing.

The dihedral angle may vary along the span.

Gull wing - sharp dihedral on the wing root section, little or none on the main section. Typically done to raise wing-mounted engines higher above the ground or water.

Inverted gull wing - anhedral on the root section, dihedral on the main section. The opposite of a gull wing. Typically done to reduce the length and weight of wing-mounted undercarriage legs.

Cranked wing- tip section dihedral differs from the main section. (Note that the term "cranked" varies in usage. Here, it is used to help clarify the relationship between changes of dihedral nearer the wing tip vs. nearer the wing root.)



a *b* *c*

Figure 1.30.- Dihedral variation

The ***channel wing*** is an unusual variation where the frontal profile follows the arc of a propeller down, around and back up, before continuing outwards in a conventional manner (Figure 1.31).

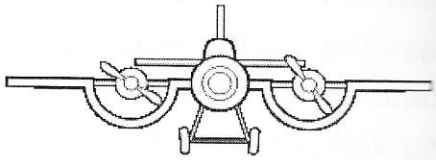


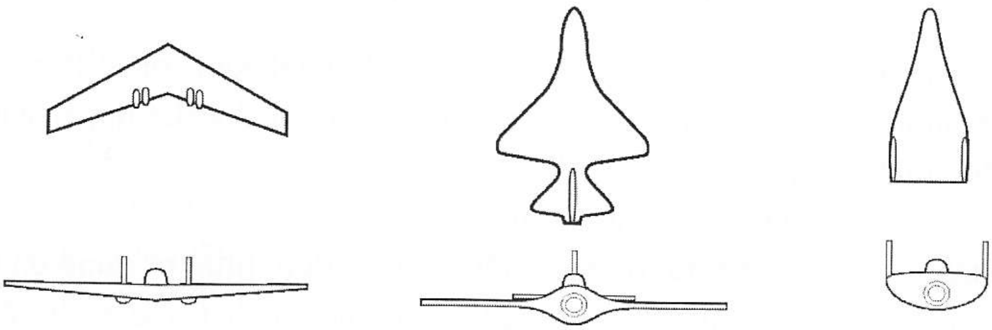
Figure 1.31.-Channel Wing

Some designs have no clear join between wing and fuselage, or body. This may be because one or other of these is missing, or because they merge into each other:

Flying wing - the aircraft has no distinct fuselage or tail empennage (although fins and small pods, blisters, etc. may be present) (Figure 1.32,a).

Blended body or blended wing-body - smooth transition between wing and fuselage, with no hard dividing line (Figure 1.32,b).

Lifting body - the aircraft has no significant wings, and relies on the fuselage to provide aerodynamic lift (Figure 1.32,c).



a *b* *c*

Figure 1.32.- Flying Wing, Blended Body and Lifting Body

Variable geometry

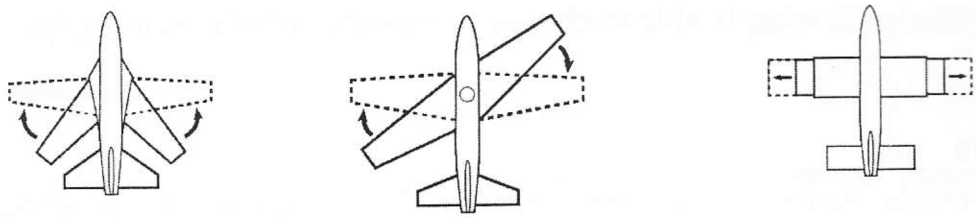
A variable geometry aircraft is able to change its physical configuration during flight.

Variable planform

Swing-wing - also called "variable sweep wing". The left and right hand wings vary their sweep together, usually backwards (Figure 1.33,a).

Oblique wing- a single full-span wing pivots about its mid point, so that one side sweeps back and the other side sweeps forward (Figure 1.33,b).

Telescopic wing - the outer section of wing telescopes over the inner section of wing, varying span, aspect ratio and wing area (Figure 1.33,c).



a *b* *c*

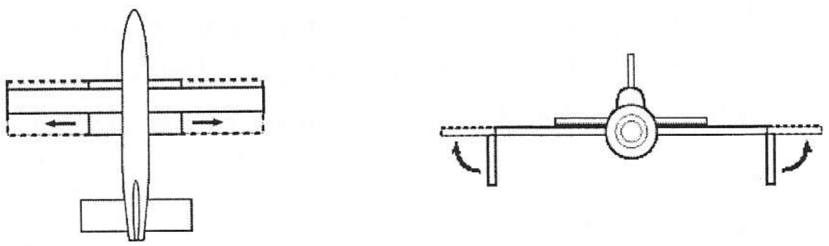
Figure 1.33.- Swin-Wing, Oblique and Telescopic Wings

Extending wing - part of the wing retracts into the main aircraft structure to reduce drag and low-altitude buffet for high-speed flight, and is extended only for takeoff, low-speed cruise and landing (Figure 1.34,a).

Folding wing - part of the wing extends for takeoff and landing, and folds away for high-speed flight (Figure 1.34,b). Many aircraft have folding wings that can only be folded for storage on the ground.

Variable chord

Variable incidence - the wing plane can tilt upwards or downwards relative to the fuselage (Figure 1.35,a).



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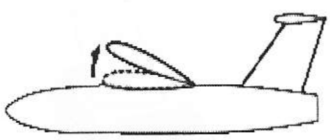
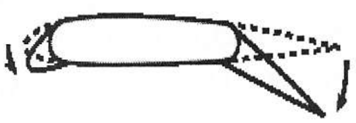


- Extending a



a *b*

Fifure 1.35.- Variable Incidence and Variable Camber Wings

Variable camber - the leading and trailing edge sections of the wing pivot and/or extend to increase the effective camber and/or area of the wing. This increases lift at low angles of attack, delays stalling at high angles of attack, and enhances maneuverability (Figure 1.35,b).

A polymorphic wing is able to change the number of planes in flight.

Empennage

The correct name for the tail section of an airplane is empennage. The **empennage** includes the entire tail group, consisting of fixed surfaces such as the vertical stabilizer and the horizontal stabilizer. The movable surfaces include the rudder, the elevator, and one or more trim tabs (Figure 1.36).

Trim tabs are small, movable portions of the trailing edge of the control surface. These movable trim tabs, which are controlled from the cockpit, reduce control pressures. Trim tabs may be installed on the ailerons, the rudder, and/or the elevator.

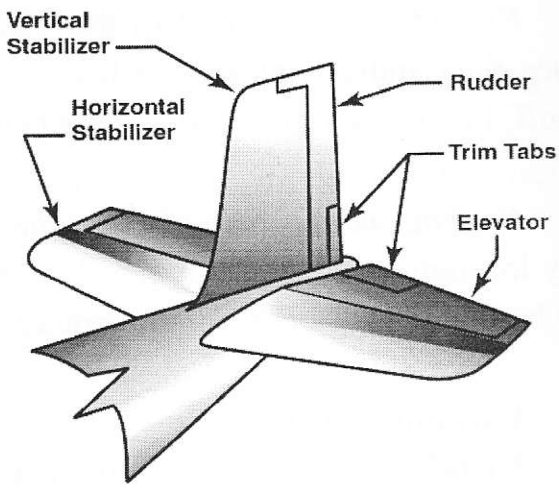


Figure 1.36.- Empennage Components

A second type of empennage design does not require an elevator. Instead, it incorporates a one-piece horizontal stabilizer that pivots from a central hinge point. This type of design is called a stabilator, and is moved using the control wheel, just as you would the elevator. For example, when you pull back on the control wheel, the stabilator pivots so the trailing edge moves up. This increases the aerodynamic tail load and causes the nose of the airplane to move up. (Figure 1.37).

The rudder is attached to the back of the vertical stabilizer. During flight, it is used to move the airplane's nose left and right. The rudder is used in combination with the ailerons for turns during flight. The elevator, which is attached to the back of the horizontal stabilizer, is used to move the nose of the airplane up and down during flight.

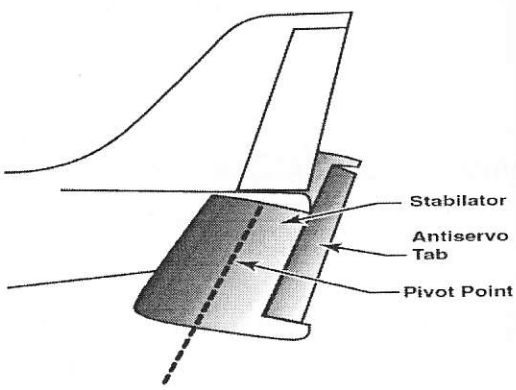
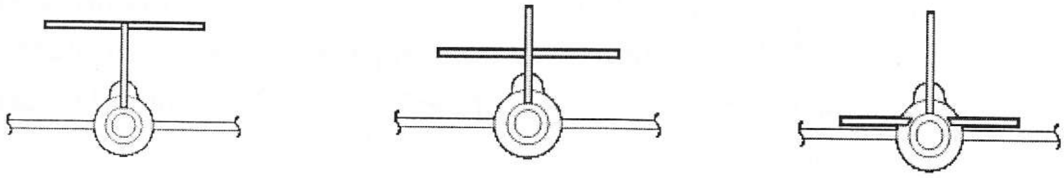


Figure 1.37- Stabilator

The tailplane besides its planform, is characterised by location.

Location of tailplane - mounted high, mid or low on the fuselage, fin or tail booms (Figure 1.38).



a *b* *c*

Figure 1.38.- High (*a*), Mid (*b*) and Low (*c*) Mounted Tailplane

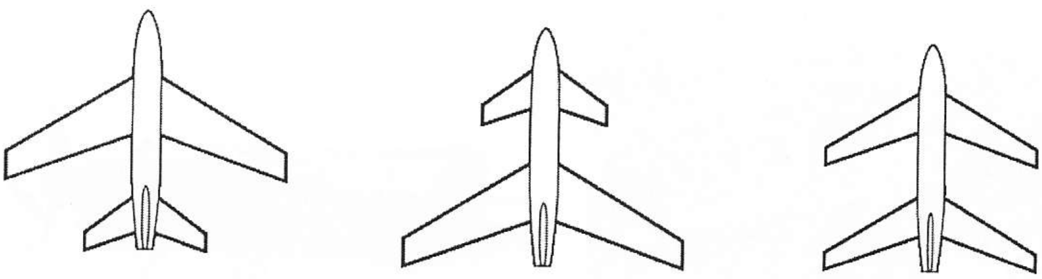
Horizontal stabilizer

The classic aerofoil section wing is unstable in pitch, and requires some form of horizontal stabilizing surface. Also it cannot provide any significant pitch control, requiring a separate control surface (elevator) elsewhere. The elevator may be hinged to a fixed horizontal stabilizer, or the whole stabilizer may pivot to double as the elevator.

Conventional -tailplane - "tailplane" stabilizer at the rear of the aircraft, forming part of the tail or empennage (Figure 1.39,a).

Canard tailplane- "foreplane" stabiliser at the front of the aircraft. A fairly common feature of the 4.5th generation jet fighters (Figure 1.39,b).

Tandem tailplane - - two main wings, one behind the other. The two act together to provide stability and both provide lift (Figure 1.39,c).



a *b* *c*

Figure 1.39.- Conventional, Canard and Tandem Horizontal Stabilizers

Tandem triple or triplet - having both conventional and canard stabilizer surfaces (Figure 1.40,a).

Tailless - no separate stabilizing surface, at front or rear. Either the lifting and horizontal stabilizing surfaces are combined in a single plane, or the aerofoil profile is modified to provide inherent stability (Figure 1.40,b).

a *b*

Figure 1.40.- Tandem Triple Tailplane and Tailless

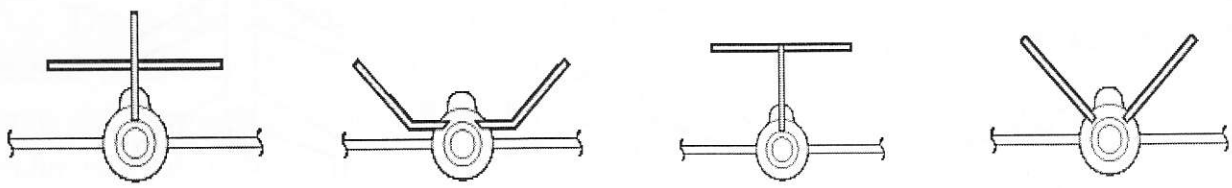
Position of horizontal stabilizers

Cruciform tail - The horizontal stabilizers are placed midway up the vertical stabilizer, giving the appearance of a cross when viewed from the front, hence the name. Cruciform tails are often used to keep the horizontal stabilizers out of the engine wake, while avoiding many of the disadvantages of a T-tail (Figure 1.41,a).

Pelikan tail - uses two control surfaces (Figure 1.41,b).

T-tail - This design incorporates the horizontal stabilizers on top of the vertical stabilizers, creating a "T" design when viewed from the front, hence the name. T-tails keep the stabilizers out of the engine wake (Figure 1.41,c).

V-tail - V-tails are named after their shape from the front, appearing as a large "V". V-tails are lighter than conventional tails, and produce less drag (Figure 1.41,d).



a *b* *c*

Figure 1.41.- Cruciform Tail, Pelican Tail, T- Tail and V-Tail

Vertical stabilizers

Twin boom .A twin boom has two fuselages or booms, with a vertical stabilizer on each, and a horizontal stabilizer between them (Figure 1.42,a).

Twin tail. A twin tail, also called an H-tail, consists of two small vertical stabilizers on either side of the horizontal stabilizer (Figure 1.42,b).

Multiple tails are similar to a twin tail, but with more than two vertical stabilizers (Figure 1.42,c).

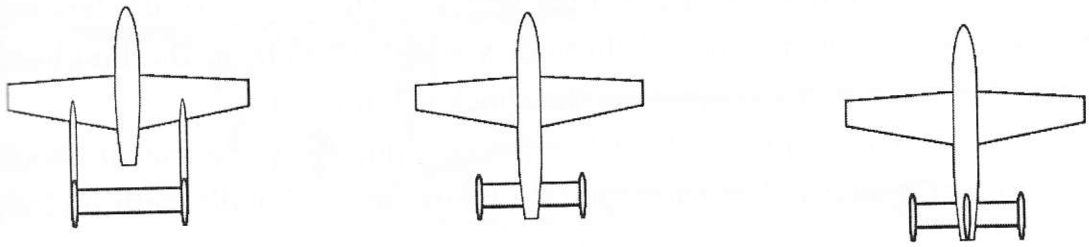


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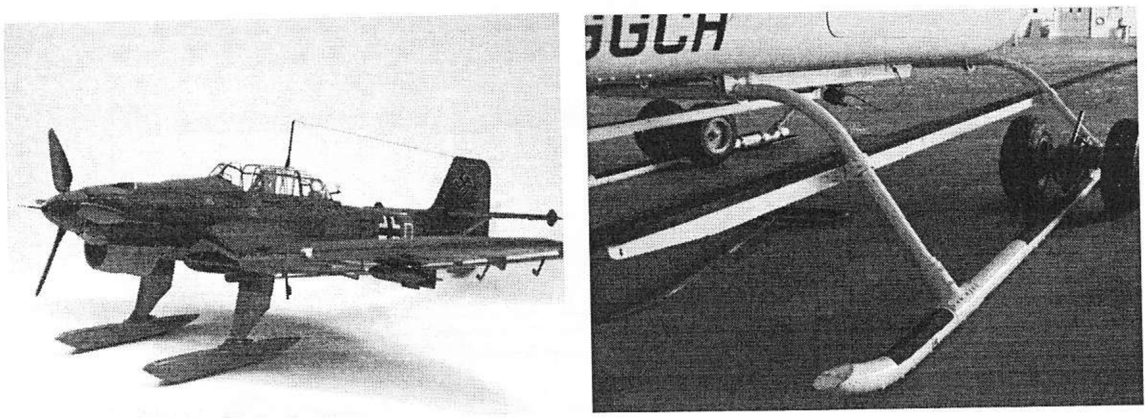
Figure 1.42.- Twin Boom, Twin Tail and Multiple Tails

Landing gear

Undercarriage or landing gear is the structure (usually wheels) that supports an aircraft and allows it to move across the surface of the Earth when it is not flying: when parked, taxiing, taking off, or when landing.

Airplanes can also be equipped with floats for water operations (Figure 1.43,a), or skis for landing on snow (Figure 1.43,b)



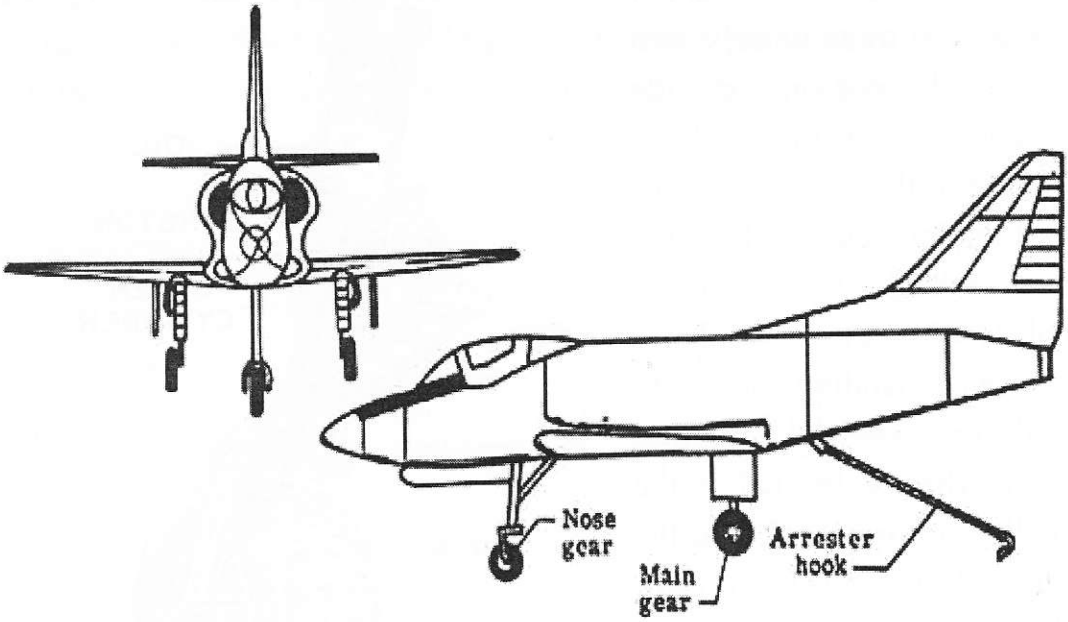
a *b*

Figure 1.43.- Floats and Skids

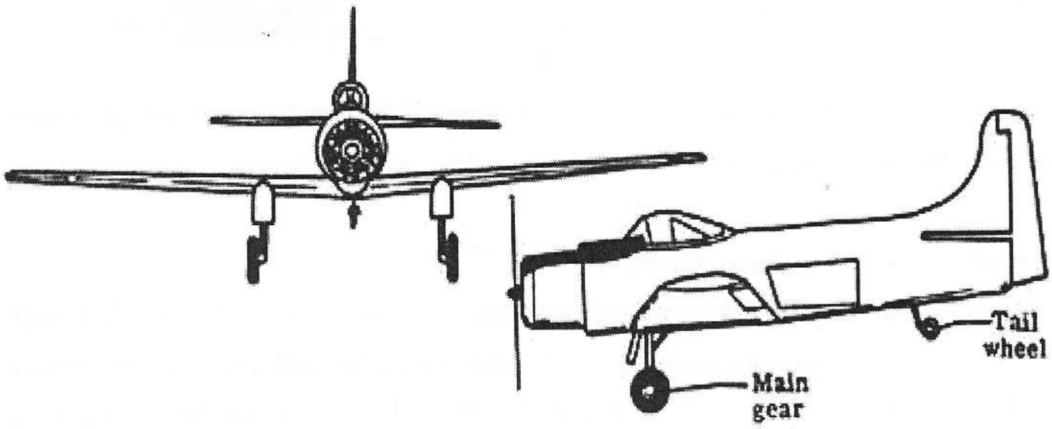
An airplane's landing gear may be the conventional type, with two main wheels and a tail wheel, or it may be the tricycle type, with two main wheels and a nose wheel (Figure 1.44).

To take up the impact of the landing, the wheels of most airplanes are attached to oleo struts, which are shock-absorbing devices that use oil to cushion the blow. This type of shock absorber is located in the landing gear struts to which the wheels are attached, and is composed of an outer cylinder fitted over a piston. The piston is on the end of a short strut attached to the wheel axle. Between the piston and a wall or bulkhead in the outer cyhnder is a space filled with oil. The impact of the landing pushes the piston upward, forcing the oil through a small opening in the bulkhead into the chamber above it, thereby cushioning the shock (Figure 1.45).

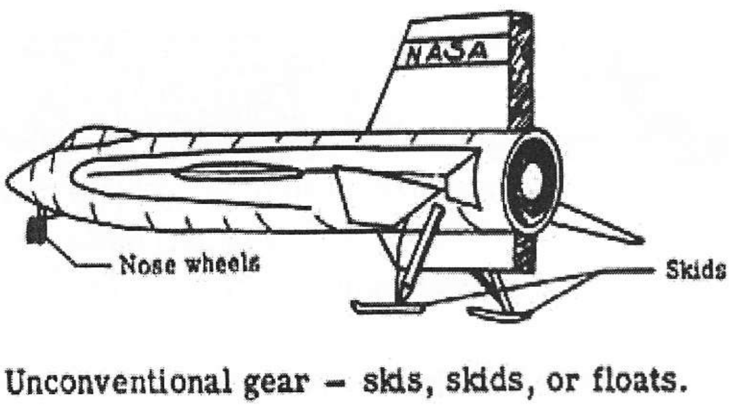
On some light airplanes tlie shock of landing is reduced by the use of sltock cords. These consist of many rubber bands tightly bound into a bundle with a cloth covering.



(a) Tricycle gear – nose wheel, two main wheels.



(b) Conventional gear – tail wheel, two main wheels.



(c) Unconventional gear – skis, skids, or floats.

Figure 1.44- Landing Gea Typesr

The landing gear on small airplanes consists of three wheels: two main wheels, one located on each side of the fuselage, and a third wheel, positioned either at the front or rear of the airplane. Landing gear employing a rear-mounted wheel is called a conventional landing gear. Airplanes with conventional landing gear are often referred to as tailwheel airplanes. When the third wheel is located on the nose, it is called a nosewheel, and the design is referred to as a tricycle gear. A steerable nosewheel or tailwheel permits the airplane to be controlled throughout all operations while on the ground.

Different types and layouts of landing gear are shown in Appendix C.

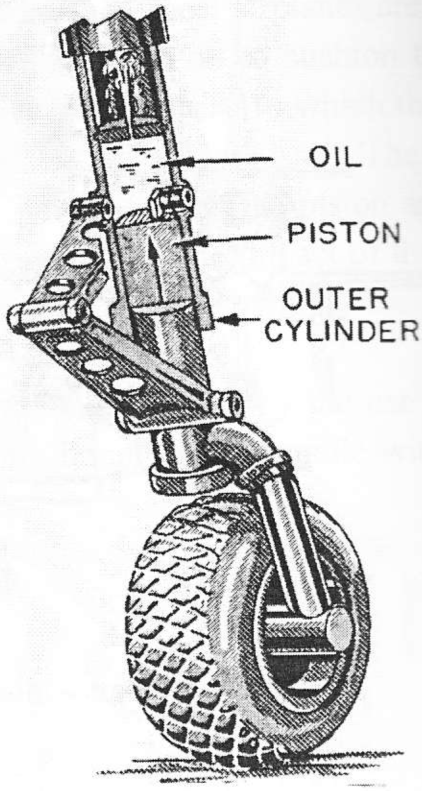
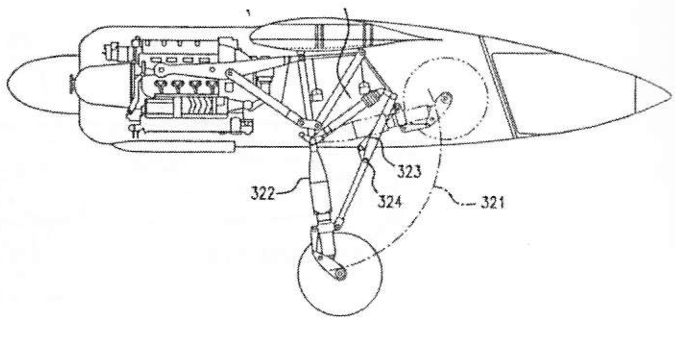


Figure 1.45.- The Principle of Oleo Strut Operation

Fixed and retractable landing gear

Landing gear can also be classified as either fixed or retractable. A fixed gear (Figure 1.46, a) always remains extended and has the advantage of simplicity combined with low maintenance. A retractable gear (Figure 1.46, b). is designed to streamline the airplane by allowing the landing gear to be stowed inside the structure during cruising flight.

a



b

Figure 1.46- Fixed and Retrectable Landing Gear

Landing gear primary parameters

Figure 1.47 illustrates landing gear primary parameters. The descriptions of primary parameters are as follows. Landing gear height is the distance between the

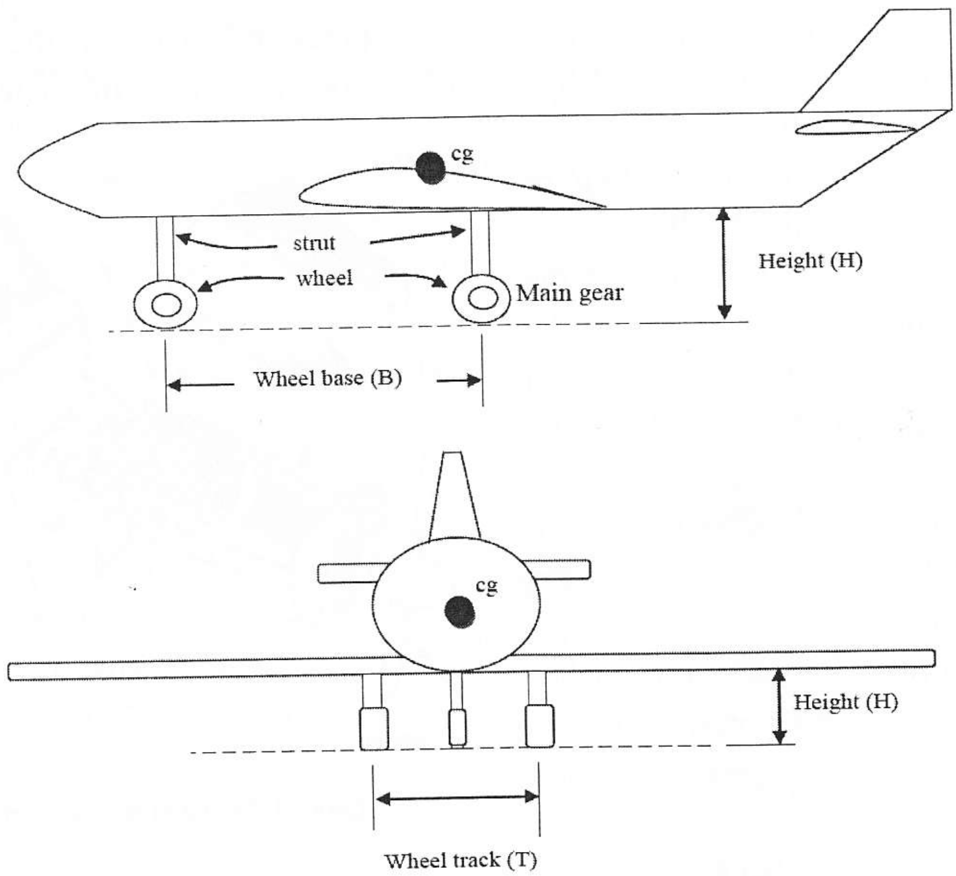


Figure 1.47.- Landing Gear Primary Parameters

lowest point of the landing gear (i.e. bottom of the tire) and the attachment point to the aircraft. Since, landing gear may be attached to the fuselage or to the wing; the term height has different meaning. Furthermore, the landing gear height is a function of shock absorber and the landing gear deflection. The height is usually measured when the aircraft is on the ground; it has maximum take-off weight; and landing gear has the maximum deflection (i.e. lowest height).

Aircraft landing gear wheelbase is the distance between the centers of the front and rear wheels.

Aircraft landing gear wheel track is the distance between the centreline of two roadwheels on the same axle, each on the other side of an aircraft.

Powerplant

The powerplant usually includes both the engine and the propeller. The primary function of the engine is to provide the power to turn the propeller. It also generates electrical power, provides a vacuum source for some flight instruments, and in most single-engine airplanes, provides a source of heat for the pilot and passengers. The engine is covered by a cowling, or in the case of some airplanes, surrounded by a **nacelle**.

The purpose of the cowling or nacelle is to streamline the flow of air around the engine and to help cool the engine by ducting air around the cylinders. The propeller, mounted on the front of the engine, translates the rotating force of the engine into a forward acting force called thrust that helps move the airplane through the air (Figure 1.48).]

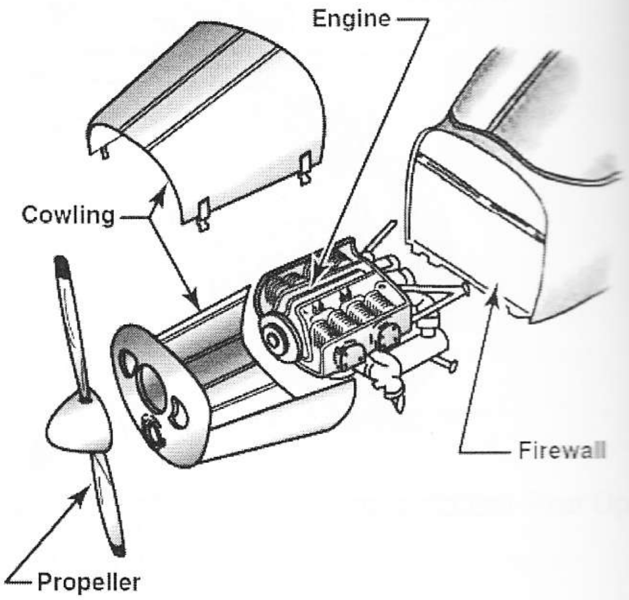


Figure 1.48- Engine Compartment

The airplane engine and propeller work in combination to produce thrust. The powerplant propels the airplane and drives the various systems that support the operation of an airplane.

Reciprocating engines

Most small airplanes are designed with reciprocating engines. The name is derived from the back-and-forth, or reciprocating, movement of the pistons. It is this motion that produces the mechanical energy needed to accomplish work. Two common means of classifying reciprocating engines are:

1. by cylinder arrangement with respect to the crankshaft—radial, in-line, v-type or opposed, or

2. by the method of cooling—liquid or air-cooled.

Radial engines were widely used during World War II, and many are still in service today. With these engines, a row or rows of cylinders are arranged in a circular pattern around the crankcase. The main advantage of a radial engine is the favorable power-to-weight ratio.

In-line engines have a comparatively small frontal area, but their power-to-weight ratios are relatively low. In addition, the rearmost cylinders of an air-cooled, in-line engine receive very little cooling air, so these engines are normally limited to four or six cylinders.

V-type engines provide more horsepower than in-line engines and still retain a small frontal area. Further improvements in engine design led to the development of the horizontally-opposed engine.

Opposed-type engines are the most popular reciprocating engines used on small airplanes. These engines always have an even number of cylinders, since a cylinder on one side of the crankcase “opposes” a cylinder on the other side.

The majority of these engines are air cooled and usually are mounted in a horizontal position when installed on fixed-wing airplanes. Opposed-type engines have high power-to weight ratios because they have a comparatively small, lightweight crankcase. In addition, the compact cylinder arrangement reduces the engine’s frontal area and allows a streamlined installation that minimizes aerodynamic drag.

The main parts of a reciprocating engine include the cylinders, crankcase, and accessory housing. The intake/exhaust valves, spark plugs, and pistons are located in the cylinders. The crankshaft and connecting rods are located in the crankcase (Figure 1.49). The magnetos are normally located on the engine accessory housing.

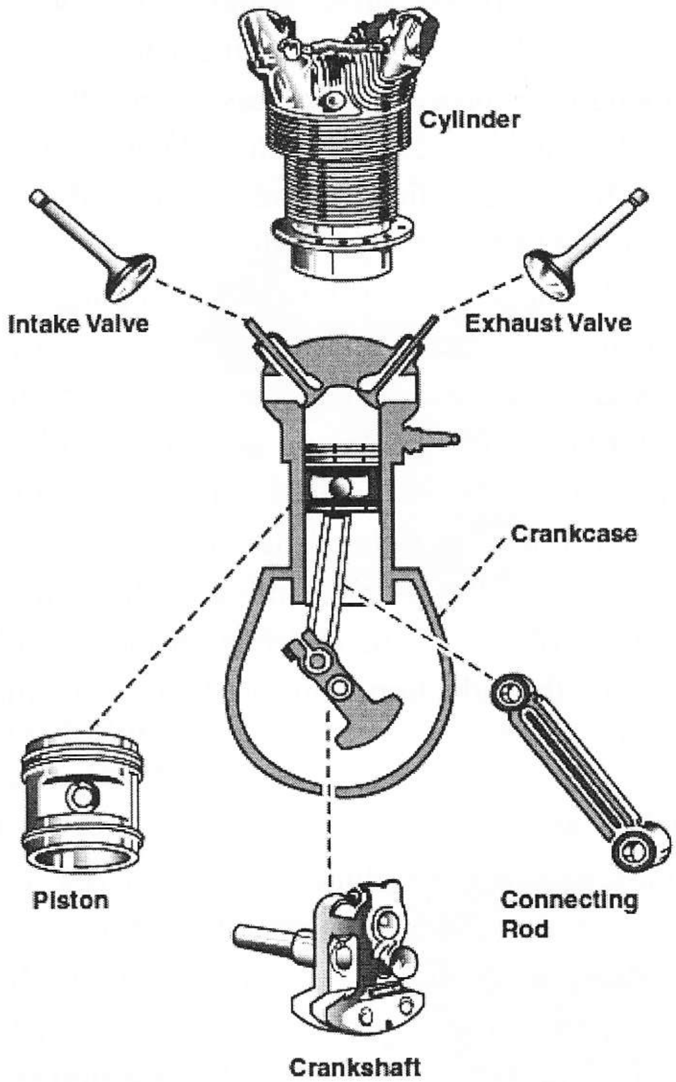


Figure 1.49- Main Components of Reciprocating Engine

The basic principle for reciprocating engines involves the conversion of chemical energy, in the form of fuel, into mechanical energy. This occurs within the cylinders of the engine through a process known as the four-stroke operating cycle. These strokes are called intake, compression, power, and exhaust (Figure 1.50).

1. The intake stroke begins as the piston starts its downward travel. When this happens, the intake valve opens and the fuel/air mixture is drawn into the cylinder.

2. The compression stroke begins when the intake valve closes and the piston starts moving back to the top of the cylinder. This phase of the cycle is used to obtain a much greater power output from the fuel/air mixture once it is ignited.

3. The power stroke begins when the fuel/air mixture is ignited. This causes a tremendous pressure increase in the cylinder, and forces the piston downward away from the cylinder head, creating the power that turns the crankshaft.

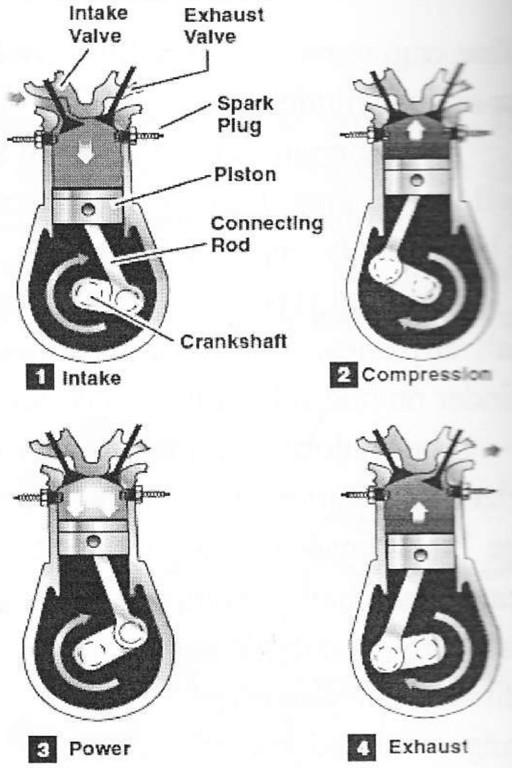


Figure 1.50- Stroke Cycle

4. The exhaust stroke is used to purge the cylinder of burned gases. It begins when the exhaust valve opens and the piston starts to move toward the cylinder head once again.

Even when the engine is operated at a fairly low speed, the four-stroke cycle takes place several hundred times each minute. In a four-cylinder engine, each cylinder operates on a different stroke. Continuous rotation of a crankshaft is maintained by the precise timing of the power strokes in each cylinder. Continuous operation of the engine depends on the simultaneous function of auxiliary systems, including the induction, ignition, fuel, oil, cooling, and exhaust systems.

Turbine engines

Basically, a gas turbine engine consists of five major sections: an inlet duct, a compressor, a combustion chamber (or chambers), a turbine wheel (or wheels), and an exhaust duct (Figure 1.51). In addition to the five major sections, each gas turbine is equipped with an accessory section, a fuel system, a starting system, a cooling system, a lubrication system, and an ignition system.

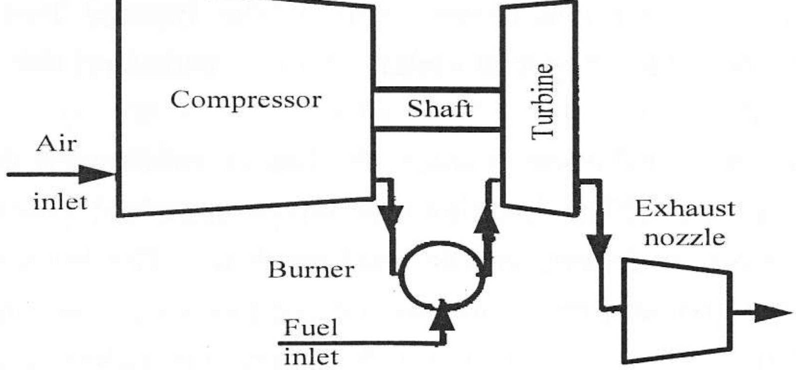


Fig.1.51.- Structural schema of a gas turbine engine

Typical jet engine categories are turbojet, turbofan, and turbopropeller (Appendix D). These types of engines have some parts in common. For example, all of these engines have an *inlet* at the front. At the exit of the inlet is the *compressor*. The compressor is connected by a shaft to the *turbine*. The compressor and the turbine are composed of one or many rows of small airfoil shaped blades. The combination of the shaft, compressor, and turbine is called the *turbomachinery* (Figure 1.52). Between the compressor and the turbine flow path is the *combustor*. This is where the fuel and the air are mixed and burned. The hot exhaust then passes through the turbine and out the *nozzle*. The nozzle is shaped to accelerate the flow, which, in turn, produces thrust.

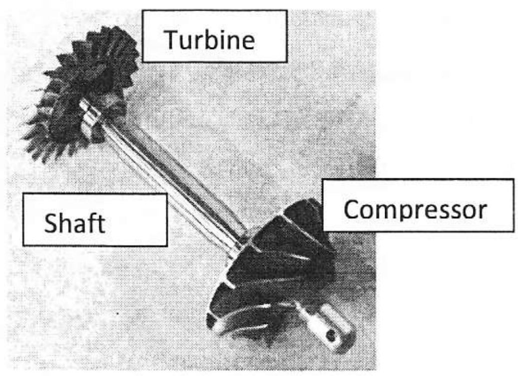
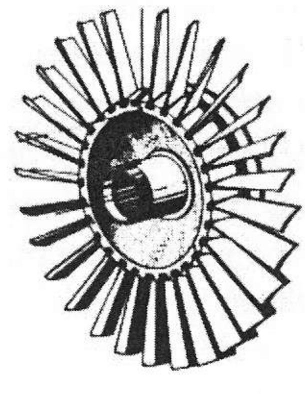


Figure 1.52.- Turbomachinery

The *inlet* brings free stream (outside) air into the engine.

The *compressor* increases the static pressure of the incoming air before it enters the combustor (Figure 1.53). Mechanical work is done on the air by the compressor. At the exit of the compressor, the air is at a much higher pressure than at free stream.



Fiure 1.53.- Compressor rotor

The *power turbine*, located downstream of the burner, extracts energy to turn the compressor, which is linked to the turbine by the central shaft. The turbine, like the compressor, is composed of one row or several rows of airfoil cascades; rotors and stators. Turbine blades experience flow temperatures of around 3,000 degrees Fahrenheit since they sit just downstream of the burner. Turbine blades must, therefore, be either made of special metals that can withstand the heat, or they must be actively cooled.

The *combustor*, or *burner*, is where the fuel is combined with high-pressure air and burned (Figure 1.54). The resulting high temperature/high pressure exhaust gas is used to turn the power turbine and to produce thrust. The burner sits between the compressor and the power turbine and is arranged like an annulus, or a doughnut. The central shaft that connects the turbine and compressor passes through the engine's center. Burners are made from materials that can withstand the high temperatures of combustion.

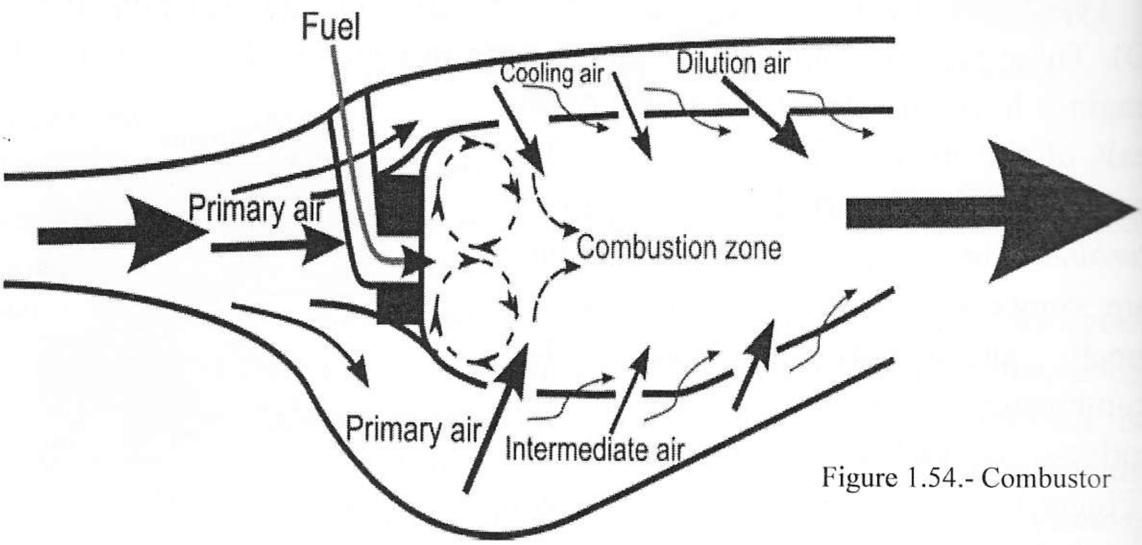


Figure 1.54.- Combustor

The *nozzle* produces thrust while introducing the exhaust gases back to the free stream. The nozzle sits downstream of the power turbine. The flow then passes through the nozzle, which is shaped to accelerate the flow. Nozzles come in a variety of shapes and sizes epending on the mission of the aircraft. Changing the direction of the thrust with the nozzle makes the aircraft much more maneuverable.

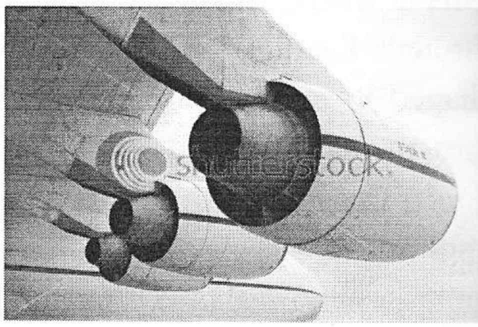


Figure 1.55.- Jet Nozzle

The turbine engine produces thrust by increasing the velocity of the air flowing through the engine. The turbine engine has the following advantages over a reciprocating engine: less vibration, increased aircraft performance, reliability, and ease of operation.

Turbine engines are classified according to the type of compressors they use. The compressor types fall into three categories - centrifugal flow, axial flow, and centrifugal-axial flow. Compression of inlet air is achieved in a centrifugal flow engine by accelerating air outward perpendicular to the longitudinal axis of the machine. The axial-flow engine compresses air by a series of rotating and stationary airfoils moving the air parallel to the longitudinal axis. The centrifugal-axial flow design uses both kinds of compressors to achieve the desired compression.

The path the air takes through the engine and how power is produced determines the type of engine. There are four types of aircraft turbine engines - turbojet, turboprop, turbofan, and turboshaft.

Turbojet

The turbojet engine contains four sections: compressor, combustion chamber, turbine section, and exhaust. The compressor section passes inlet air at a high rate of speed to the combustion chamber. The combustion chamber contains the fuel inlet and igniter for combustion. The expanding air drives a turbine, which is connected by a shaft to the compressor, sustaining engine operation. The accelerated exhaust gases from the engine provide thrust. This is a basic application of compressing air, igniting the fuel-air mixture, producing power to self-sustain the engine operation, and exhaust for propulsion.

Turbojet engines are limited on range and endurance. They are also slow to respond to throttle applications at slow compressor speeds.

Turboprop

A turboprop engine is a turbine engine that drives a propeller through a reduction gear. The exhaust gases drive a power turbine connected by a shaft that drives the reduction gear assembly. Reduction gearing is necessary in turboprop engines because optimum propeller performance is achieved at much slower speeds than the engine's operating r.p.m. Turboprop engines are a compromise between turbojet engines and reciprocating powerplants. Turboprop engines are most efficient at speeds between 250 and 400 m.p.h. and altitudes between 18,000 and 30,000 feet. They also perform well at the slow airspeeds required for takeoff and landing, and are fuel efficient. The minimum specific fuel consumption of the turboprop engine is normally available in the altitude range of 25,000 feet to the tropopause.

Turbofan

Turbofans were developed to combine some of the best features of the turbojet and the turboprop. Turbofan engines are designed to create additional thrust by diverting a secondary airflow around the combustion chamber. The turbofan bypass air generates increased thrust, cools the engine, and aids in exhaust noise suppression. This provides turbojet-type cruise speed and lower fuel consumption.

The inlet air that passes through a turbofan engine is usually divided into two separate streams of air. One stream passes through the engine core, while a second stream bypasses the engine core. It is this bypass stream of air that is responsible for the term "bypass engine." A turbofan's bypass ratio refers to the ratio of the mass airflow that passes through the fan divided by the mass airflow that passes through the engine core.

Turboshaft

The fourth common type of jet engine is the turboshaft. It delivers power to a shaft that drives something other than a propeller. The biggest difference between a turbojet and turboshaft engine is that on a turboshaft engine, most of the energy produced by the expanding gases is used to drive a turbine rather than produce thrust. Many helicopters use a turboshaft gas turbine engine. In addition, turboshaft engines are widely used as auxiliary power units on large aircraft.

Engines placement

The arrangement of engines influences the aircraft in many important ways. Safety, structural weight, flutter, drag, control, maximum lift, propulsive efficiency, maintainability, and aircraft growth potential are all affected.

Engines may be

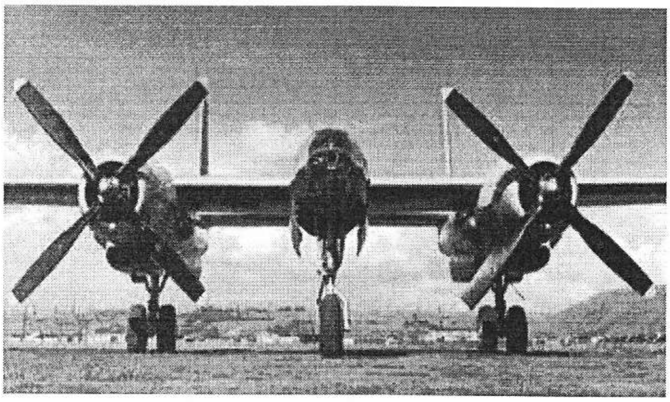
1. ***Wing-mounted***

- in the wings (wing-root mounted engines, Figure 1.56,a)
- on the wings (Figure 1.56,b),
- above the wings (Figure 1.56,c),
- suspended on pylons below the wings (Figure 1.56,d).

2. ***Fuselage-mounted***

- mounted on the aft fuselage (Figure 1.57,a),
- top of the fuselage (Figure 1.57,b),
- on the sides of the fuselage (Figure 1.57,c).

a *b*



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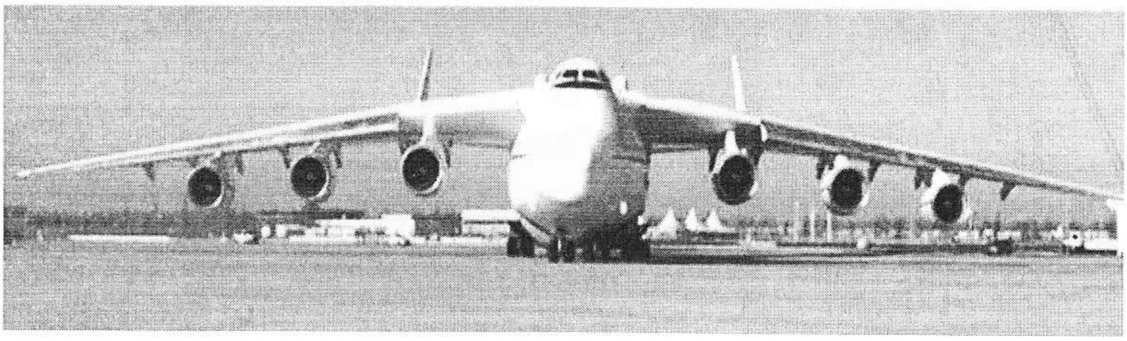
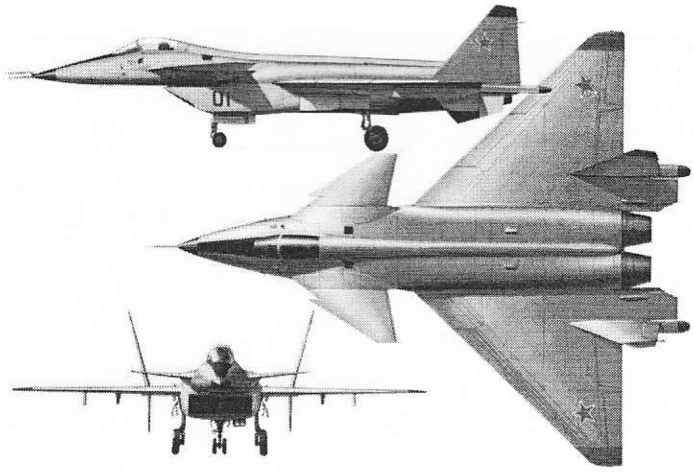


d

Figure 1.56.- Wing Mounted Engines



a

b

d

Figure 1.57.- Fuselage Mounted Engines

2. BASICS OF AN AIRCRAFT FLIGHT

Airfiol

An *airfoil* or, more properly, an *airfoil section,* is a slice of a wing (Figure 2.1).

Airfoil terminology is shown on Figures 2.2-2.3.

Leading edge: The foremost edge of an airfoil section.

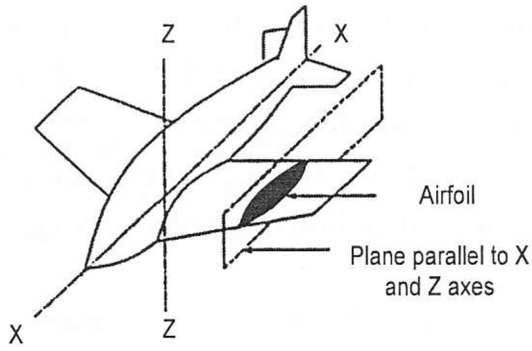


Figure 2.1.- Airfoil

Trailing edge: The aft edge of an airfoil or wing. Portion of wing that the air passes last.

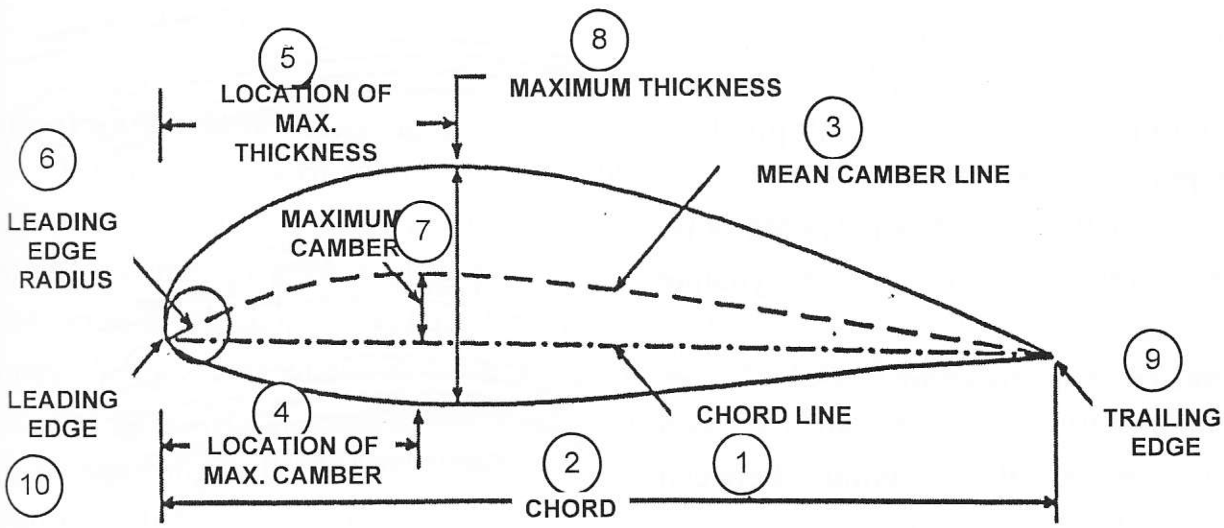


Figure 2.2.- Airfoil Terminology

Chordline: A straight line connecting the leading edge and the trailing edge of the airfoil.

Chord: The length of the chord line. Airfoil dimensions are measured in terms of the chord.

Mean camber line: A line drawn halfway between the upper surface and the lower surface.

Maximum camber: The maximum distance between the mean camber line and the chordline. The location of maximum camber is important in determining the aerodynamic characteristics of the airfoil.

Maximum thickness: The maximum distance between the upper and lower surfaces. The location of maximum thickness is also important.

Leading edge radius: A measure of the sharpness of the leading edge. It may vary from zero, for a knife edge supersonic airfoil, to about 2 % (of the chord) for blunt leading edge airfoils.

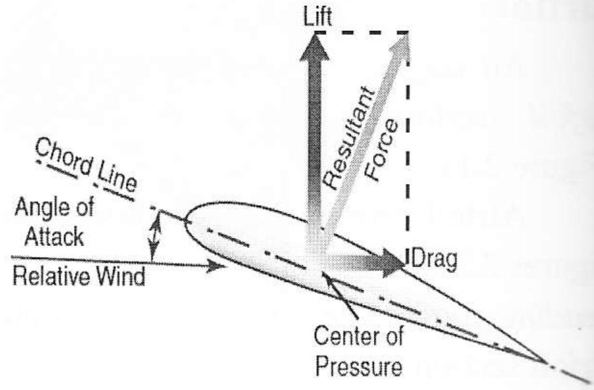


Figure 2.3.- Force Vectors on an Airfoil

Flight Path Velocity: The speed and direction of a body passing through the air.

Relative Wind, (RW): The speed and direction of the air impinging on a body passing through it. It is equal and opposite in direction to the flight path velocity.

`Angle of Attack, (AOA or alpha, α): The acute angle between the relative wind and the chordline of an airfoil.

Aerodynamic Force, (AF): The net resulting static pressure multiplied by the planform area of an airfoil.

Center of Pressure, (CP): The point on the chord line where the aerodynamic force acts.

Laminar and turbulent flows

Laminar Flow: Smooth airflow with little transfer of momentum between parallel layers. *Turbulent Flow:* Flow where the streamlines break up and there is much mixing of the layers (Figure 2.4).

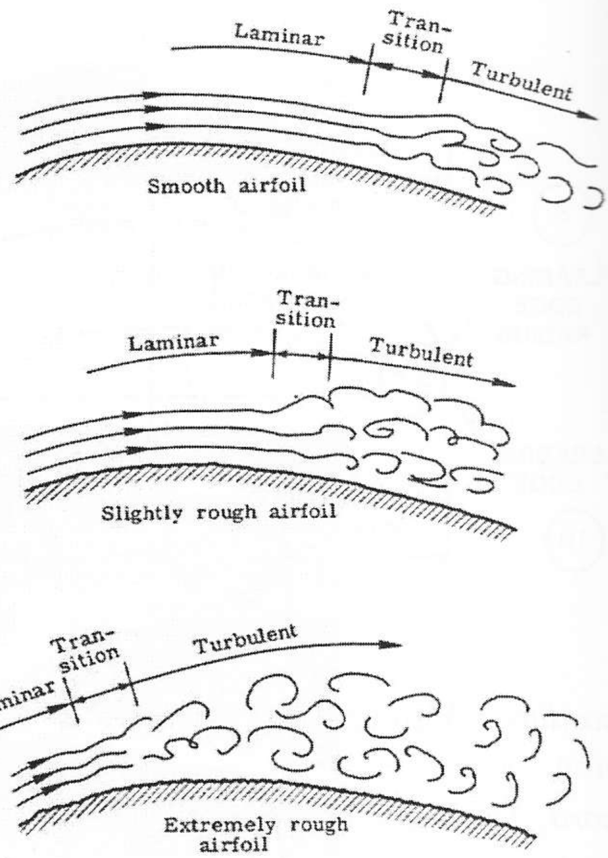


Figure 2.4.- Laminar and Turbulent Flows

It should be understood that different airfoils have different flight characteristics. The weight, speed, and purpose of each airplane dictate the shape of its airfoil.

On the other hand, an airfoil that is perfectly streamlined and offers little wind resistance sometimes does not have enough lifting power to take the airplane off the ground. Thus, modern airplanes have airfoils which strike a medium between extremes in design, the shape varying according to the needs of the airplane for which it is designed. Figure 2.5 shows some of the more common airfoil sections.

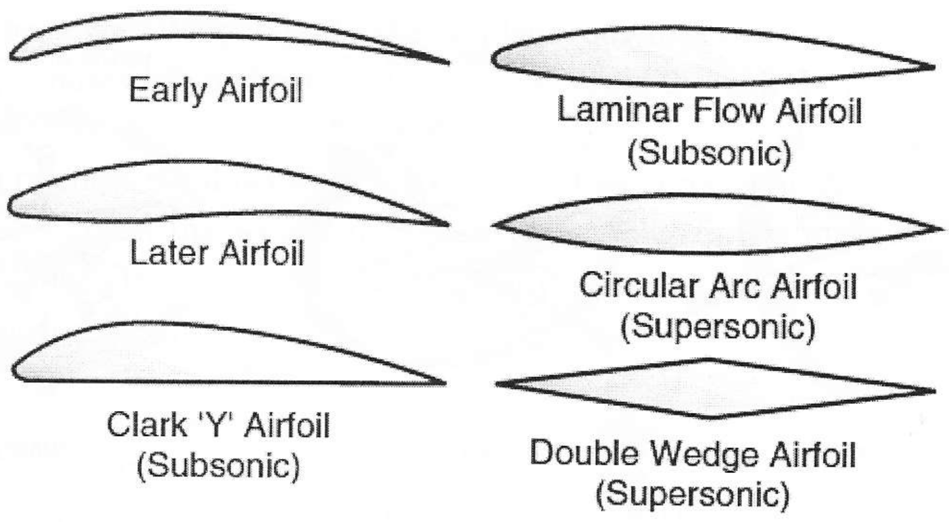


Figure 2.5.- Airfoil Designs

Axes of an airplane

Whenever an airplane changes its flight attitude or position in flight, it rotates about one or more of three axes, which are imaginary lines that pass through the airplane's center of gravity. The axes of an airplane can be considered as imaginary axles around which the airplane turns, much like the axle around which a wheel rotates. At the point where all three axes intersect, each is at a 90° angle to the other two. The axis, which extends lengthwise through the fuselage from the nose to the tail, is the longitudinal axis. The axis, which extends crosswise from wingtip to wingtip, is the lateral axis. The axis, which passes vertically through the center of gravity, is the vertical axis (Figure 2.6). The airplane's motion about its longitudinal axis resembles the roll of a ship from side to side. In fact, the names used in describing the motion about an airplane's three axes were originally nautical terms.

They have been adapted to aeronautical terminology because of the similarity of motion between an airplane and the seagoing ship.

In light of the adoption of nautical terms, the motion about the airplane's longitudinal axis is called "rolling"; motion about its lateral axis is referred to as "pitching."

Finally, an airplane moves about its vertical axis in a motion, which is termed "yawing" that is, a horizontal (left and right) movement of the airplane's nose.

The three motions of the airplane (roll, pitch, and yaw) are controlled by three control surfaces. Roll is controlled by the ailerons; pitch is controlled by the elevators; yaw is controlled by the rudder.

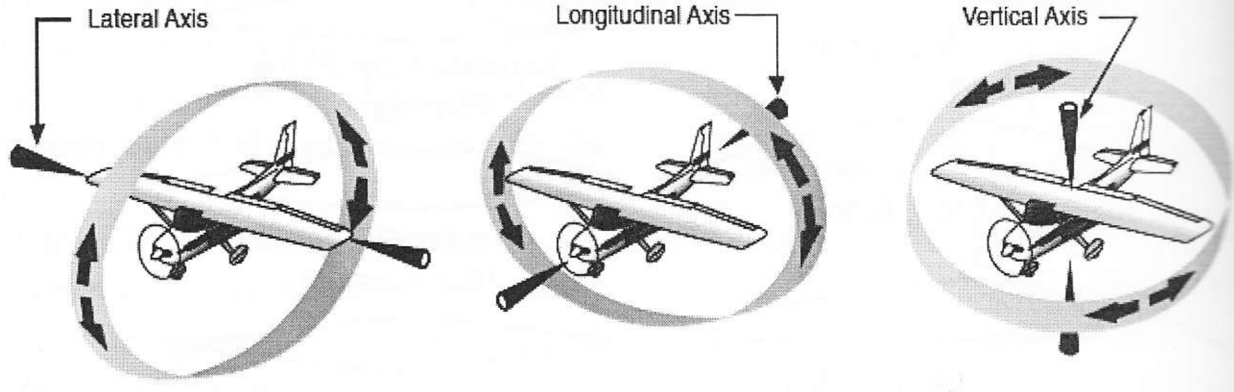


Figure 2.6.- Axes of an Airplane

Forces acting on the airplane

The total resultant pressure is represented by the resultant force vector shown in Figure 2.3.

The point of application of this force vector is termed the "center of pressure" (CP). For any given angle of attack, the center of pressure is the point where the resultant force crosses the chord line. This point is expressed as a percentage of the chord of the airfoil.

The balance of an airplane in flight depends, therefore, on the relative position of the center of gravity (CG) and the center of pressure (CP) of the airfoil.

In some respects at least, how well a pilot performs in flight depends upon the ability to plan and coordinate the use of the power and flight controls for changing the forces of thrust, drag, lift, and weight. It is the balance between these forces that the pilot must always control. The better the understanding of the forces and means of controlling them, the greater will be the pilot's skill at doing so.

The following defines these forces in relation to straight-and-level, unaccelerated flight (Figure 2.7).

Thrust is the forward force produced by the powerplant/propeller. It opposes or overcomes the force of drag. As a general rule, it is said to act parallel to the longitudinal axis. However, this is not always the case as will be explained later.

Drag is a rearward, retarding force, and is caused by disruption of airflow by the wing, fuselage, and other protruding objects. Drag opposes thrust, and acts rearward parallel to the relative wind.

Weight is the combined load of the airplane itself, the crew, the fuel, and the cargo or baggage. Weight pulls the airplane downward because of the force of gravity. It opposes lift, and acts vertically downward through the airplane's center of gravity.

Lift opposes the downward force of weight, is produced by the dynamic effect of the air acting on the wing, and acts perpendicular to the flightpath through the wing's center of lift.

In steady flight, the sum of these opposing forces is equal to zero. There can be no unbalanced forces in steady, straight flight (Newton's Third Law). This is true whether flying level or when climbing or descending. This is not the same thing as saying that the four forces are all equal. It simply means that the opposing forces are equal to, and thereby cancel the effects of, each other.

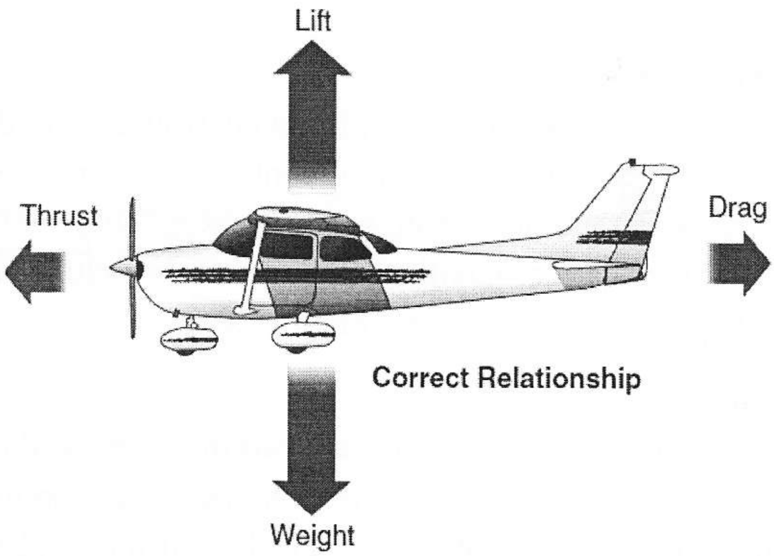


Figure 2.7.- Forces Acting on Airplane

Every pilot who has flown numerous types of airplanes has noted that each airplane handles somewhat differently—that is, each resists or responds to control pressures in its own way. A training type airplane is quick to respond to control applications, while a transport airplane usually feels heavy on the controls and responds to control pressures more slowly. These features can be designed into an airplane to facilitate the particular purpose the airplane is to fulfill by considering certain stability and maneuvering requirements. In the following discussion, it is intended to summarize the more important aspects of an airplane's stability; its maneuvering and controllability qualities; how they are analyzed; and their relationship to various flight conditions. In brief, the basic differences between stability, maneuverability, and controllability are as follows:

- *Stability*—The inherent quality of an airplane to correct for conditions that may disturb its equilibrium, and to return or to continue on the original flightpath. It is primarily an airplane design characteristic.
- *Maneuverability*—The quality of an airplane that permits it to be maneuvered easily and to withstand the stresses imposed by maneuvers. It is governed by the airplane's weight, inertia, size and location of flight controls, structural strength, and powerplant. It too is an airplane design characteristic.
- *Controllability*—The capability of an airplane to respond to the pilot's control, especially with regard to flightpath and attitude. It is the quality of the airplane's response to the pilot's control application when maneuvering the airplane, regardless of its stability characteristics.

Flight controls

On high-speed airplanes, flight controls are divided into primary flight controls and secondary or auxiliary flight controls. The primary flight controls maneuver the airplane about the pitch, roll, and yaw axes. They include the ailerons, elevator, and rudder. Secondary or auxiliary flight controls include tabs, leading edge flaps, trailing edge flaps, spoilers, and slats (Figure 2.8).

Primary flight controls

Airplane control systems are carefully designed to provide a natural feel, and at the same time, allow adequate responsiveness to control inputs. At low airspeeds, the controls usually feel soft and sluggish, and the airplane responds slowly to control applications.

At high speeds, the controls feel firm and the response is more rapid.

Movement of any of the three primary flight control surfaces changes the airflow and pressure distribution over and around the airfoil. These changes affect the lift and drag produced, by the airfoil/control surface combination, and allow a pilot to control the airplane about its three axes of rotation.

A properly designed airplane should be stable and easily controlled during maneuvering. Control surface inputs cause movement about the three axes of rotation.

The types of stability an airplane exhibits also relate to the three axes of rotation (Figure 2.9).

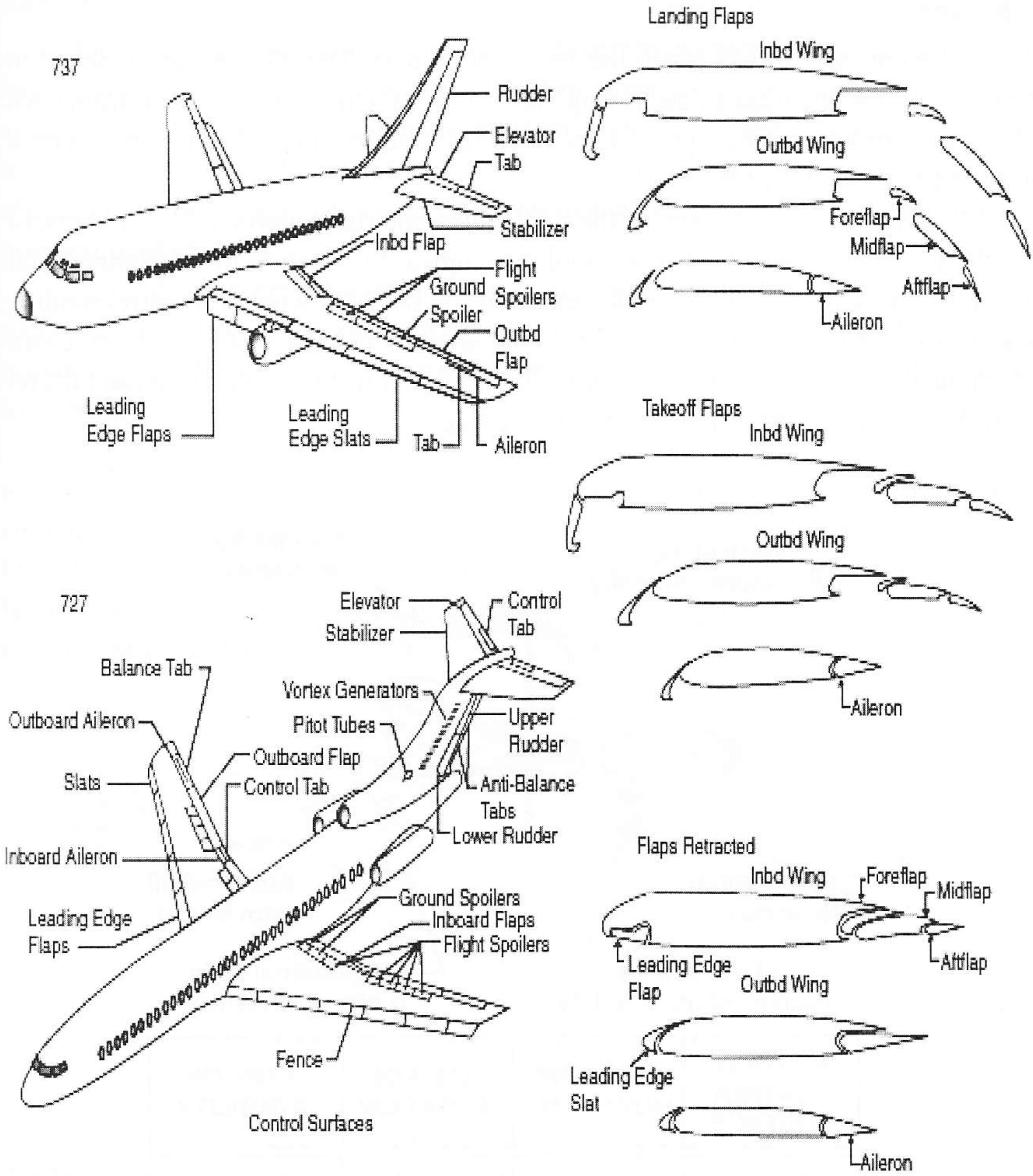
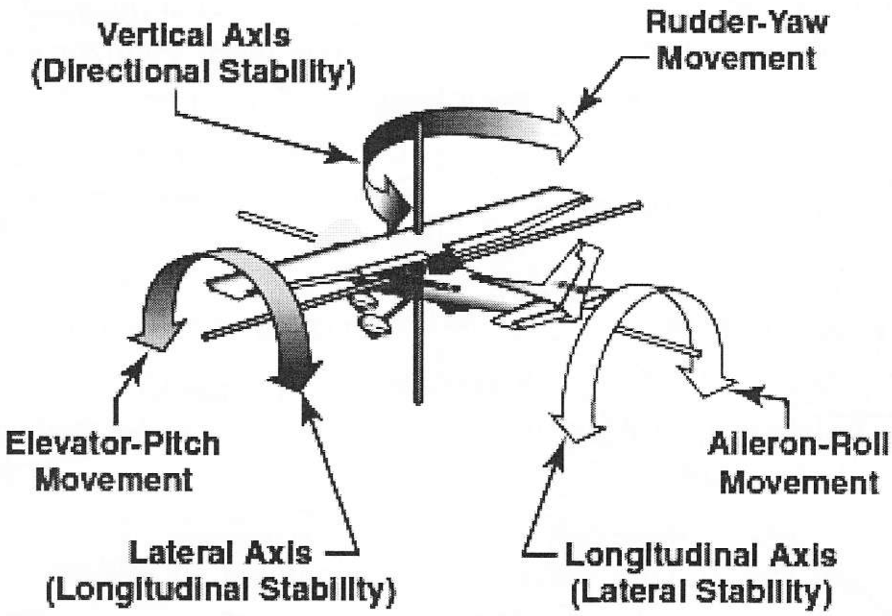


Figure 2.8.- Boeing 737 Control Surfaces

Ailerons

Ailerons control roll about the longitudinal axis. The ailerons are attached to the outboard trailing edge of each wing and move in the opposite direction from each other. Ailerons are connected by cables, bellcranks, pulleys or push-pull tubes to each other and to the control wheel.

Moving the control wheel to the right causes the right aileron to deflect upward and the left aileron to deflect downward. The upward deflection of the right aileron decreases the camber resulting in decreased lift on the right wing. The corresponding downward deflection of the left aileron increases the camber resulting in increased lift on the left wing. Thus, the increased lift on the left wing and the decreased lift on the right wing cause the airplane to roll to the right.



PRIMARY CONTROL SURFACE	AIRPLANE MOVEMENT	AXES OF ROTATION	TYPE OF STABILITY
Aileron	Roll	Longitudinal	Lateral
Elevator/ Stabilator	Pitch	Lateral	Longitudinal
Rudder	Yaw	Vertical	Directional

Figure 2.9.- Airplane Controls and Movement

Rudder

On an aircraft, the rudder is a directional control surface along with the rudder-like elevator (usually attached to horizontal tail structure, if not a slab elevator) and ailerons (attached to the wings) that control pitch and roll, respectively. The rudder is usually attached to the fin (or vertical stabilizer) which allows the pilot to control yaw about the vertical axis, i.e. change the horizontal direction in which the nose is pointing (Figure 2.10).

A rudder is a device used to steer an aircraft primarily to counter the adverse yaw. Adverse yaw is a yaw aircraft movement opposite to the direction change initiated by a roll movement. It is a secondary effect of the application of the ailerons in aircraft.

All turns are coordinated by use of ailerons, rudder, and elevator. Applying aileron pressure is necessary to place the airplane in the desired angle of bank, while simultaneously applying rudder pressure to counteract the resultant adverse yaw. During a turn, the angle of attack must be increased by applying elevator pressure because more lift is required than when in straight-andlevel flight. The steeper the turn, the more back elevator pressure is needed.

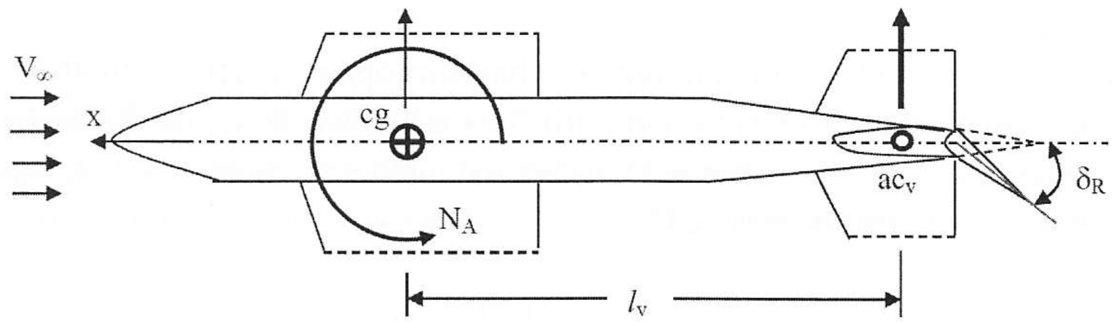


Figure 2.10.- Directional Control via Rudder Deflection

Elevator

The elevator controls pitch about the lateral axis (Figure 2.11). Like the ailerons on small airplanes, the elevator is connected to the control column in the cockpit by a series of mechanical linkages. Aft movement of the control column deflects the trailing edge of the elevator surface up. This is usually referred to as up elevator.

The up-elevator position decreases the camber of the elevator and creates a downward aerodynamic force, which is greater than the normal tail-down force that exists in straight-and-level flight. The overall effect causes the tail of the airplane to move down and the nose to pitch up. The pitching moment occurs about the center of gravity (CG). The strength of the pitching moment is determined by the distance between the CG and the horizontal tail surface, as well as by the aerodynamic effectiveness of the horizontal tail surface.

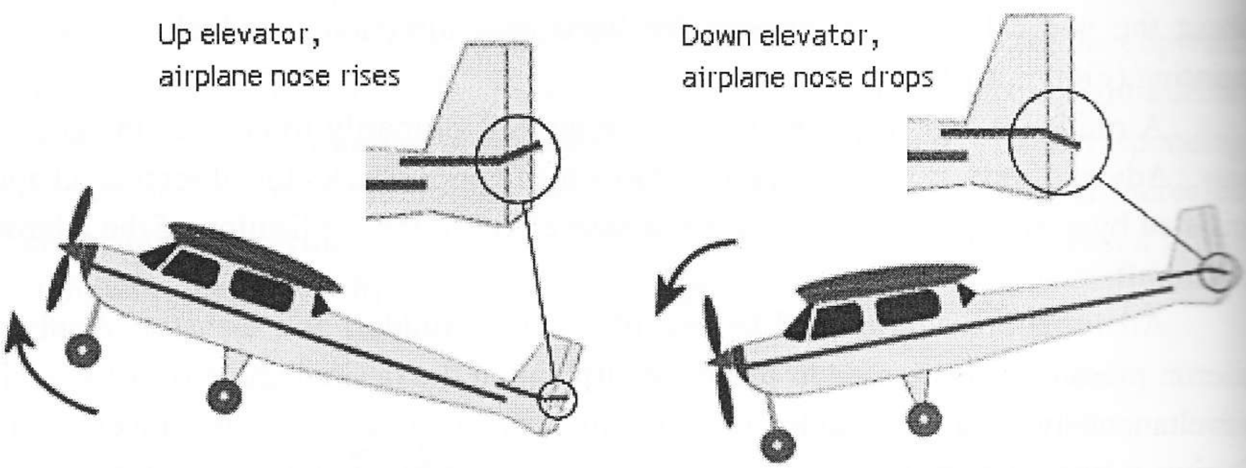


Figure 2.11.- Lateral Control via Elevator

Moving the control column forward has the opposite effect. In this case, elevator camber increases, creating more lift (less tail-down force) on the horizontal stabilizer/elevator. This moves the tail upward and pitches the nose down. Again, the pitching moment occurs about the CG.

Secondary flight controls

Secondary flight control systems may consist of the flaps, leading edge devices, spoilers, and trim devices.

Flaps

Flaps are hinged surfaces mounted on the trailing edges of the wings of a fixed-wing aircraft to reduce the speed at which an aircraft can be safely flown and to increase the angle of descent for landing. They shorten takeoff and landing distances.

Flaps are the most common high-lift devices used on practically all airplanes. These surfaces, which are attached to the trailing edge of the wing, increase both lift and induced drag for any given angle of attack.

Flaps allow a compromise between high cruising speed and low landing speed, because they may be extended when needed, and retracted into the wing's structure when not needed. There are four common types of flaps: plain, split, slotted, and Fowler flaps (Figure 2.12).

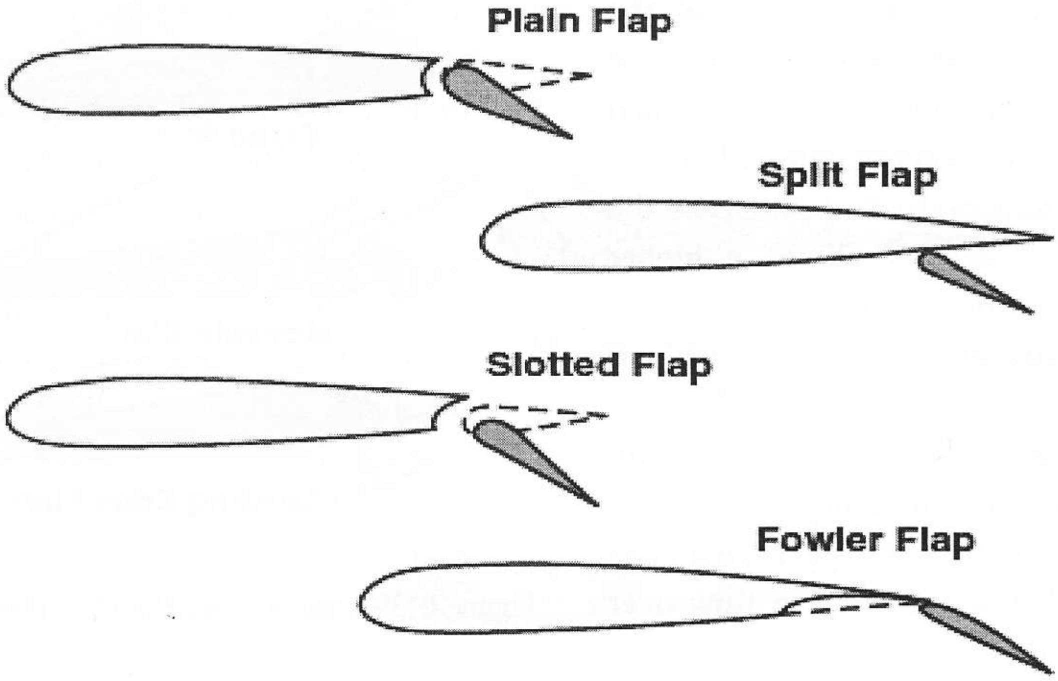


Figure 2.12.- Four Common Types of Flaps

Plain flap: the rear portion of airfoil rotates downwards on a simple hinge mounted at the front of the flap. A modern variation on the plain flap exploits the ability of composites to be designed to be rigid in one direction, while flexible in another.

Split flap: the rear portion of the lower surface of the airfoil hinges downwards from the leading edge of the flap, while the upper surface stays immobile. Like the plain flap, this can cause large changes in longitudinal trim, pitching the nose either down or up, and tends to produce more drag than lift.

Slotted flap: a gap between the flap and the wing forces high pressure air from below the wing over the flap helping the airflow remain attached to the flap, increasing lift compared to a split flap. Additionally, lift across the entire chord of the primary airfoil is greatly increased as the velocity of air leaving its trailing edge is raised, from the typical non-flap 80% of freestream, to that of the higher-speed, lower-pressure air flowing around the leading edge of the slotted flap. Any flap that allows air to pass between the wing and the flap is considered a slotted flap.

Fowler flap: split flap that slides backwards flat, before hinging downwards, thereby increasing first chord, then camber. The flap may form part of the uppersurface of the wing, like a plain flap, or it may not, like a split flap but it must slide rearward before lowering.

High-lift devices also can be applied to the leading edge of the airfoil. The most common types are fixed slots, movable slats, and leading edge flaps. (Figure 2.13).

The slot does not increase the wing camber, but allows a higher maximum coefficient of lift.

Movable slats consist of leading edge segments, which move on tracks. Some slats are pilot operated and can be deployed at any angle of attack. Opening a slat allows the air below the wing to flow over the wing's upper surface, delaying airflow separation.

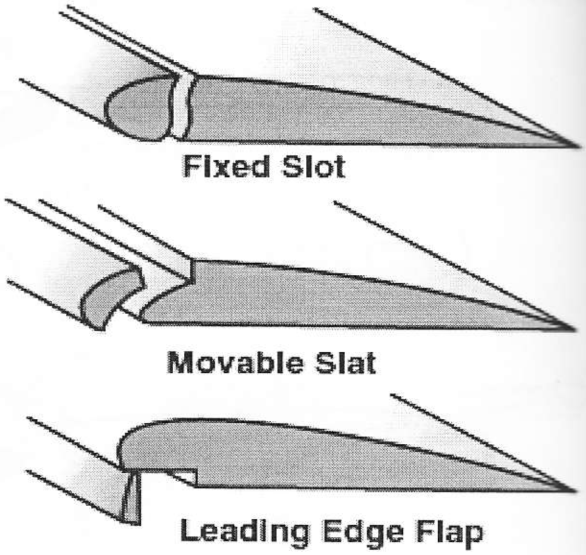


Figure 2.13.- Leading Edge High Lift Devices

Spoilers

On some airplanes, high-drag devices called spoilers are deployed from the wings to spoil the smooth airflow, reducing lift and increasing drag. (Figure 2.14).

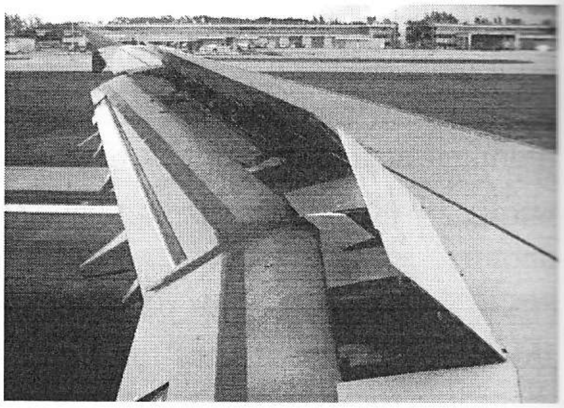


Figure 2.14.- Spoilers

Trim systems

Although the airplane can be operated throughout a wide range of attitudes, airspeeds, and power settings, it can only be designed to fly hands off within a very limited combination of these variables.

Therefore, trim systems are used to relieve the pilot of the need to maintain constant pressure on the flight controls. Trim systems usually consist of cockpit controls and small hinged devices attached to the trailing edge of one or more of the primary flight control surfaces. They are designed to help minimize a pilot's workload by aerodynamically assisting movement and position of the flight control surface to which they are attached. Common types of trim systems include trim tabs, balance tabs, antiservo tabs, ground adjustable tabs, and an adjustable stabilizer.

Trim tabs

The most common installation on small airplanes is a single trim tab attached to the trailing edge of the elevator. Most trim tabs are manually operated by a small, vertically mounted control wheel. However, a trim crank may be found in some airplanes. The cockpit control includes a tab position indicator.

Placing the trim control in the full nose-down position moves the tab to its full up position. With the tab up and into the airstream, the airflow over the horizontal tail surface tends to force the trailing edge of the elevator down. This causes the tail of the airplane to move up, and results in a nose-down pitch change (Figure 2.15).

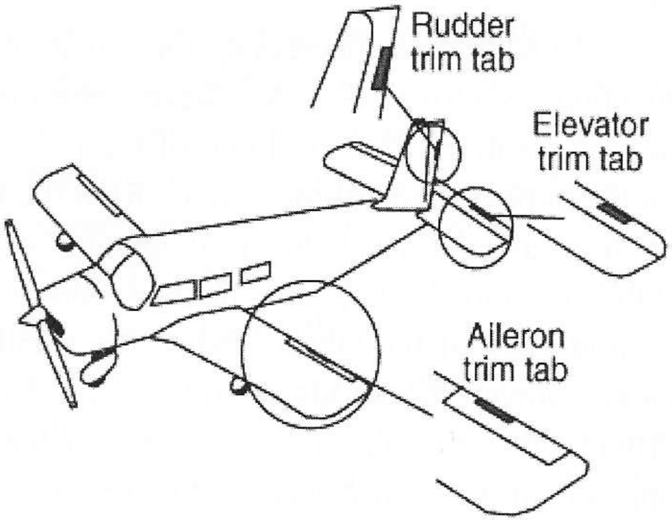


Figure 2.15.- Trim Tabs

Balance tabs

The control forces may be excessively high in some airplanes, and in order to decrease them, the manufacturer may use balance tabs. They look like trim tabs and are hinged in approximately the same places as trim tabs (Figure 2.16). The essential difference between the two is that the balancing tab is coupled to the control surface rod so that when the primary control surface is moved in any direction, the tab automatically moves in the opposite direction. In this manner, the airflow striking the tab counter-balances some of the air pressure against the primary control surface, and enables the pilot to more easily move and hold the control surface in position.

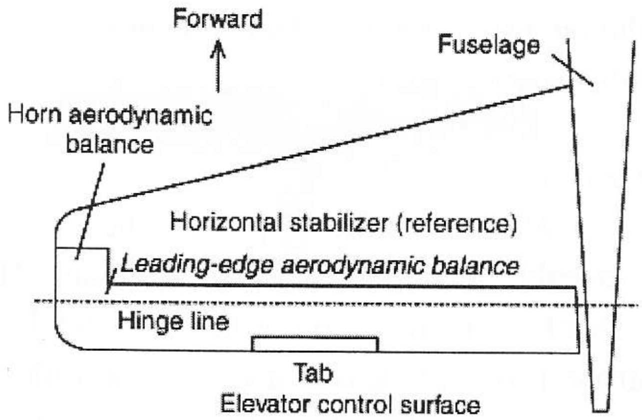


Figure 2.16.- Balance Tabs

If the linkage between the tab and the fixed surface is adjustable from the cockpit, the tab acts as a combination trim and balance tab, which can be adjusted to any desired deflection. Any time the control surface is deflected, the tab moves in the opposite direction and eases the load on the pilot.

Antiservo tabs

In addition to decreasing the sensitivity of the stabilator, an antiservo tab also functions as a trim device to relieve control pressure and maintain the stabilator in the desired position. The fixed end of the linkage is on the opposite side of the surface from the horn on the tab, and when the trailing edge of the stabilator moves up, the linkage forces the trailing edge of the tab up. When the stabilator moves down, the tab also moves down. This is different than trim tabs on elevators, which move opposite of the control surface (Figure 2.17).

This tab works in the same manner as the balance tab except that, instead of moving in the opposite direction, it moves in the same direction as the trailing edge of the stabilator. For example, when the trailing edge of the stabilator moves up, the linkage forces the trailing edge of the tab up. When the stabilator moves down, the tab also moves down.

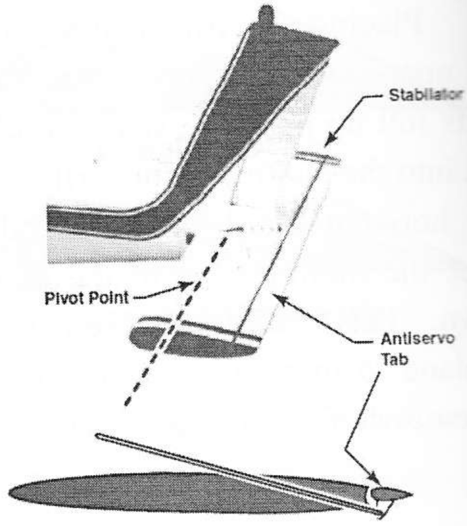


Figure 2.17.- Antiservo Tab

Ground adjustable tabs

Many small airplanes have a non-moveable metal trim tab on the rudder. This tab is bent in one direction or the other while on the ground to apply a trim force to the rudder. The correct displacement is determined by trial-and-error process. Usually, small adjustments are necessary until you are satisfied that the airplane is no longer skidding left or right during normal cruising flight (Figure 2.18).

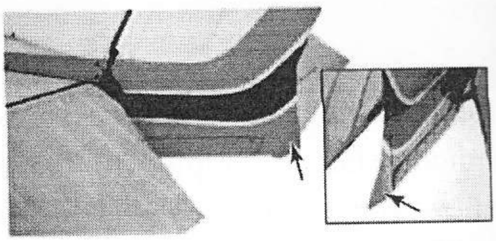
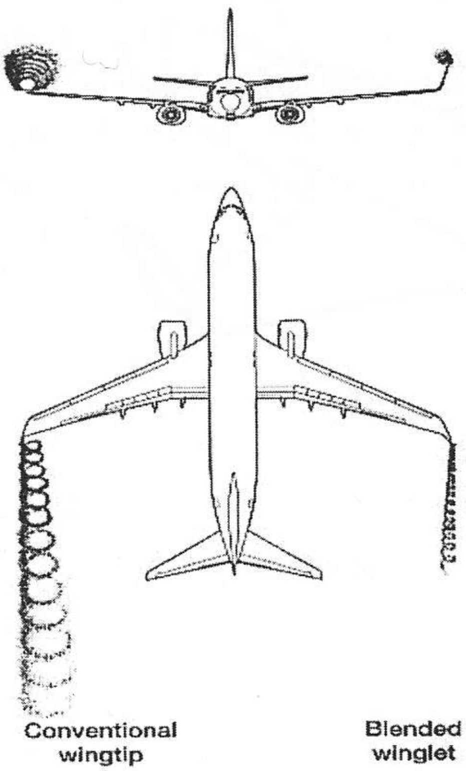


Figure 2.18.- Ground Adjustable Tabs

Wingtip vortices

The action of the airfoil that gives an airplane lift also causes induced drag. It was determined that when a wing is flown at a positive angle of attack, a pressure differential exists between the upper and lower surfaces of the wing—that is, the pressure above the wing is less than atmospheric pressure and the pressure below the wing is equal to or greater than atmospheric pressure. Since air always moves from high pressure toward low pressure, and the path of least resistance is toward the airplane's wingtips, there is a spanwise movement of air from the bottom of the wing outward from the fuselage around the wingtips. This flow of air results in "spillage" over the wingtips, thereby setting up a whirlpool of air called a "vortex" (Figure 2.19). At the same time, the air on the upper surface of the wing has a tendency to flow in toward the fuselage and off the trailing edge. This air current forms a similar vortex at the inboard portion of the trailing edge of the wing, but because the fuselage limits the inward flow, the vortex is insignificant. Consequently, the deviation in flow direction is greatest at the wingtips where the unrestricted lateral flow is the strongest. As the air curls upward around the wingtip, it combines with the wing's downwash to form a fast spinning trailing vortex. These vortices increase drag because of energy spent in producing the turbulence.



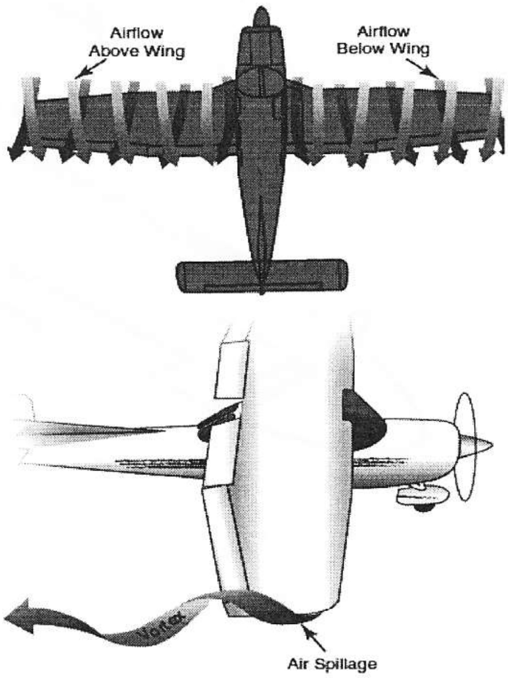


Figure 2.19.- Wingtip Virtices

It can be seen, then, that whenever the wing is producing lift, induced drag occurs, and wingtip vortices are created.

Minor aerodynamic surfaces

Additional minor aerodynamic surfaces may form part of the overall wing configuration:

Winglet - a small vertical fin at the wingtip, usually turned upwards. Reduces the size of vortices shed by the wingtip, and hence also tip drag.

Chine - narrow extension to the leading edge wing root, extending far along the forward fuselage. As well as improving low speed (high angle of attack) handling, provides extra lift at supersonic speeds for minimal increase in drag.

Moustache - small high-aspect-ratio canard surface having no movable control surface. Typically is retractable for high speed flight (Figure 2.20).

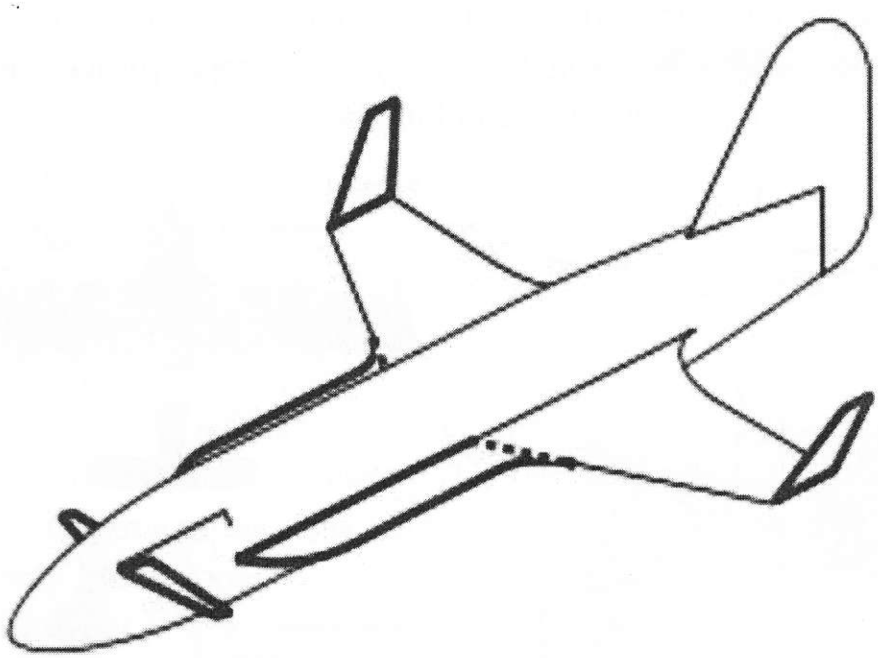


Figure 2.20.- Moustache, Chines and Winglets

Fairings of various kinds, such as blisters, pylons and wingtip pods, containing equipment which cannot fit inside the wing, and whose only aerodynamic purpose is to reduce the drag created by the equipment (Figure 2.21).

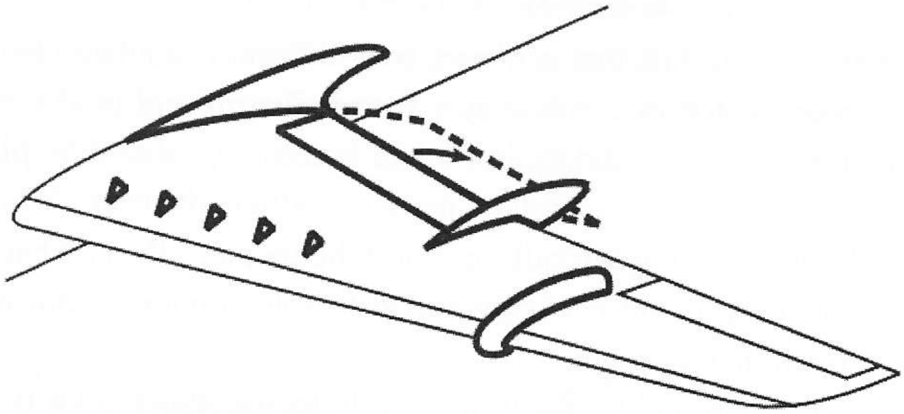


Figure 2.21.- Vortex generators, root fillet, flap, anti-shock body and wing fence

Wing fence - a thin surface extending along the wing chord and for a short distance vertically. Used to control spanwise airflow over the wing.

Vortex generator - small triangular protrusion on the upper leading wing surface; usually, several are spaced along the span of the wing. The vortices are used to re-energise the boundary layer and reduce drag.

Anti-shock body - a streamlined "pod" shaped body added to the leading or trailing edge of an aerodynamic surface, to delay the onset of shock stall and reduce transonic wave drag. Examples include the Küchemann carrots on the wing trailing edge of the Handley Page Victor B.2, and the tail fairing on the Hawker Sea Hawk.

Fillet - a small curved infill at the junction of two surfaces, such as a wing and fuselage, blending them smoothly together to reduce drag.

The main terminology of an airplain is given in Appendix E, Appendix F, Appendix G.

3. HELICOPTERS

Helicopter - powered aircraft that achieves both lift and propulsion by means of a rotary wing, or rotor, on top of the fuselage. It can take off and land vertically, move in any direction, or remain stationary in the air. It can be powered by piston or jet engine.

Helicopters truly are amazing aircraft, and how helicopters fly is what makes them such versatile machines, being perfectly suited to roles ranging from military use to fire fighting and search and rescue.

Helicopters have been around for centuries - well, the principle anyway - but it was Russian aircraft pioneer *Igor Sikorsky* who designed, built and in 1939 flew the first fully controllable single rotor / tail rotor helicopter - the fundamental concept that would shape all future helicopters.

A normal airplane can fly forward, up, down, left and right. A helicopter can do all this *plus* has the ability to fly backwards, rotate 360 degrees on the spot and hover *ie* stay airborne with no directional movement at all.

Helicopters may be limited in their speed, but the incredible maneuverability mentioned above is what makes them so useful in so many situations

Main elements

Main elements of helicopter are shown on Figures 3.1-3.2.

Rotor Blade: The rotary wing that provides lift for the helicopter.
Stabilizer Bar: Dampens control inputs to make smoother changes to the rotor system.
Swashplate: Transfers non-moving control inputs into the spinning rotor system.
Cowling: The aerodynamic covering for the engine.
Mast: Connects the transmission to the rotor system.
Engine: Provides power to the rotor systems.
Transmission: Takes power from the engine and drives both rotor systems.
Greenhouse Window: A tinted window above each of the pilot seats.
Fuselage: The body of the helicopter.
Cabin Door: Allows access to the cabin and cockpit.
Skids: Landing gear that usually have no wheels or brakes.
Crosstube: The mounting tubes and connection for the skids.
Motor Mount: A flexible way to attach the engine to the fuselage.
Tailboom: Also known as an "empenage" is the tail of the helicopter.
Synchronized Elevator: A movable wing that helps stabilize the helicopter in flight.

Tailrotor: Provides anti-torque and in-flight trim for the helicopter.
Tail Rotor Driveshaft: Provides power to the tailrotor from the transmission.
45 Degree Gearbox: Transfers power up the vertical fin to the 90 degree gearbox.
90 Degree Gearbox: Transfers power from the 45 degree gearbox to the tailrotor.
Vertical Fin: Holds the tailrotor and provides lateral stabilization.
Tail Skid: Protects the tailboom when landing.

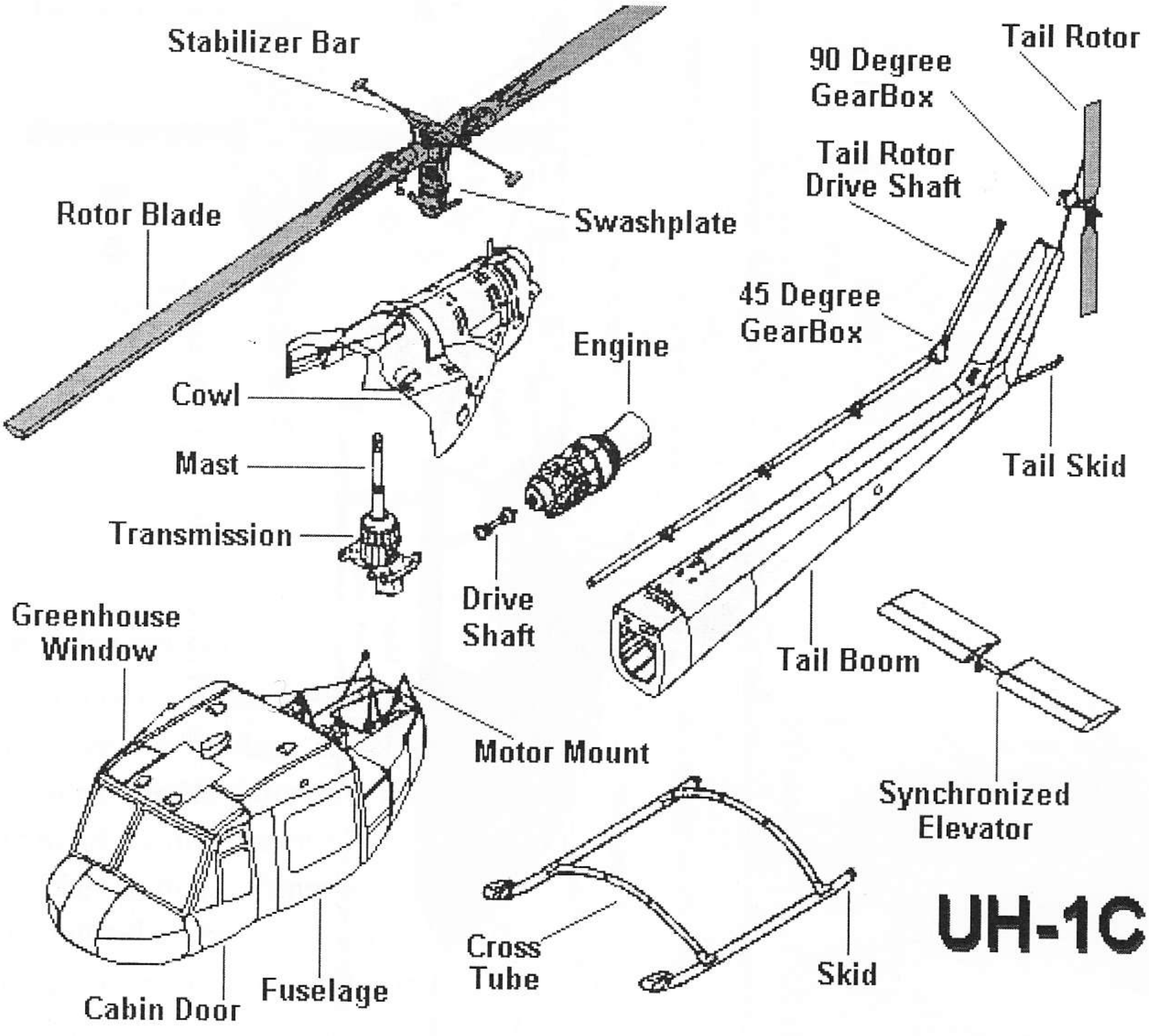


Figure 3.1.- Main Elements of Helicopter

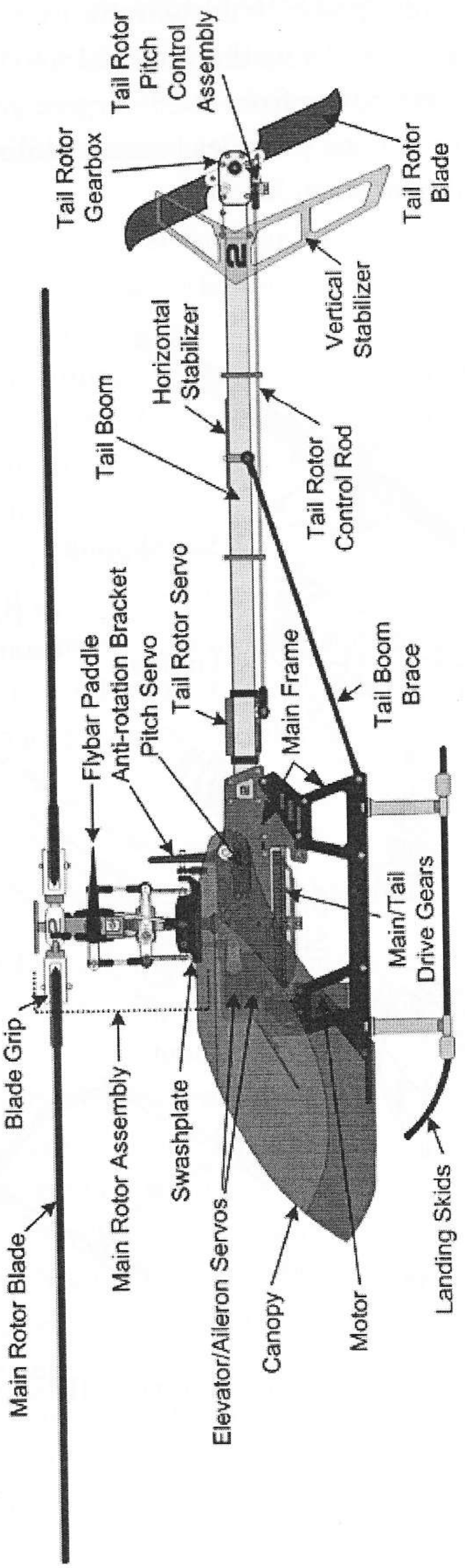


Figure 3.2.- Helicopter Anatomy

Helicopter controls

Figure 3.3 illustrates how the helicopter moves when using the appropriate controls. Up and Down movements are controlled by the "Collective". Side to Side and Forward and Back motions are controlled by the "Cyclic". Lateral control (Also called directional control or "Yaw") is achieved by using the "Foot Pedals".

Helicopters require a completely different method of control than airplanes and are much harder to master. Flying a helicopter requires constant concentration by the pilot, and a near-continuous flow of control corrections.

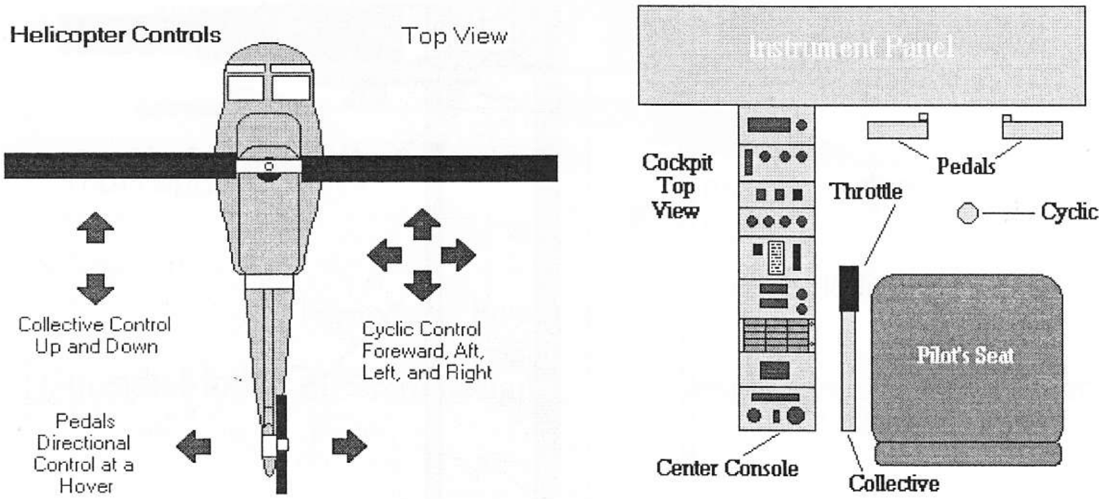


Figure 3.3.- Helicopter Controls

Main rotor system

A conventional helicopter has its main rotor above the fuselage which consists of 2 or more **rotor blades** extending out from a central **rotor head**, or hub, assembly (Figure 3.4).

The primary component is the **swash plate**, located at the base of the rotor head. This swash plate consists of one non-revolving disc and one revolving disc mounted directly on top. The swash plate is connected to the cockpit control sticks and can be made to tilt in any direction, according to the cyclic stick movement made by the pilot, or moved up and down according to the collective lever movement.

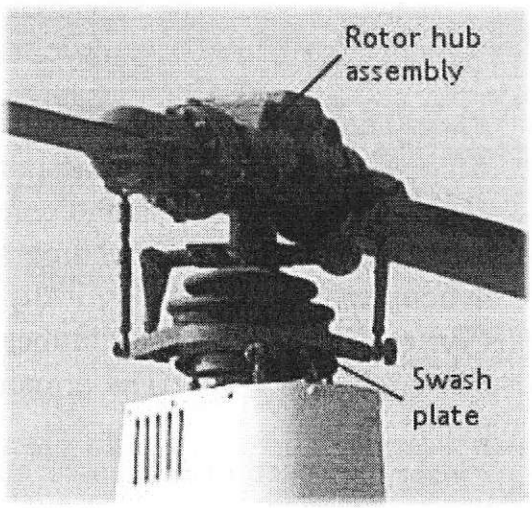


Figure 3.4.- Main Rotor System

Elements of Main Rotor System

Elements of main rotor stsem are shown on Figure 3.5.

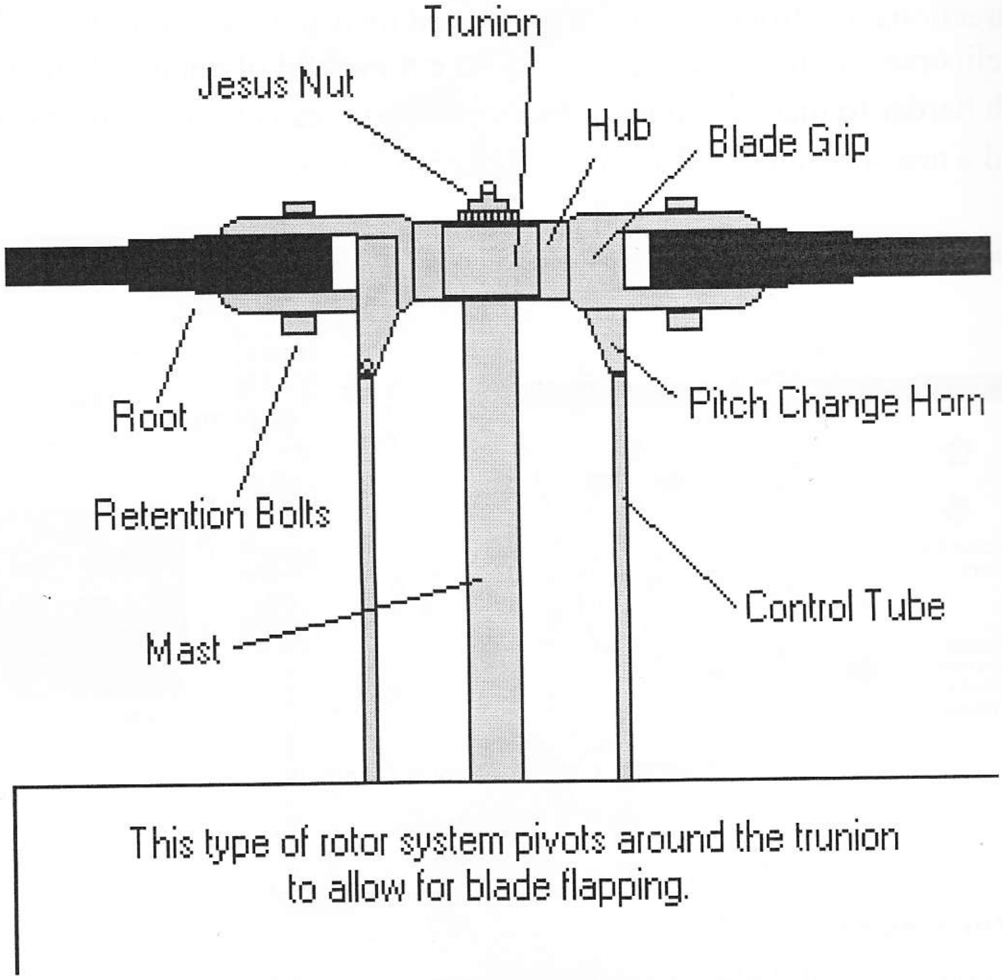


Figure 3.5 -Main Rotor System Elements

- ***Root***: The inner end of the blade where the rotors connect to the blade grips.
- ***Blade Grips***: Large attaching points where the rotor blade connects to the hub.
- ***Hub***: Sits atop the mast, and connects the rotor blades to the control tubes.
- ***Mast***: Rotating shaft from the transmission, which connects the rotor blades to the helicopter.
- ***Control Tubes***: Push \ Pull tubes that change the pitch of the rotor blades.
- ***Pitch Change Horn***: The armature that converts control tube movement to blade pitch.
- ***Pitch***: Increased or decreased angle of the rotor blades to raise, lower, or change the direction of the rotors thrust force.
- ***Jesus Nut***: Is the singular nut that holds the hub onto the mast. (If it fails, the next person you see will be Jesus).

Each rotor blade has an airfoil profile similar to that of an airplane wing, and as the blades rotate through the air they generate lift in exactly the same way as an airplane wing does. The amount of lift generated is determined by the **pitch angle** (*and speed*) of each rotor blade as it moves through the air. Pitch angle is known as the **Angle of Attack** when the rotors are in motion(Figure 3.6).

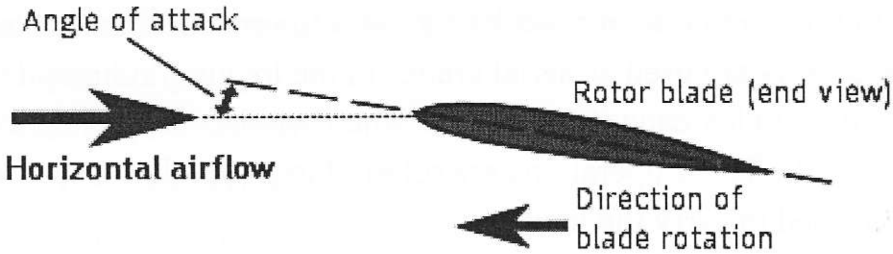


Figure 3.6. – Rotor Blade Airfoil

Helicopters are of different design. Some examples are shown on Figure 3.7.

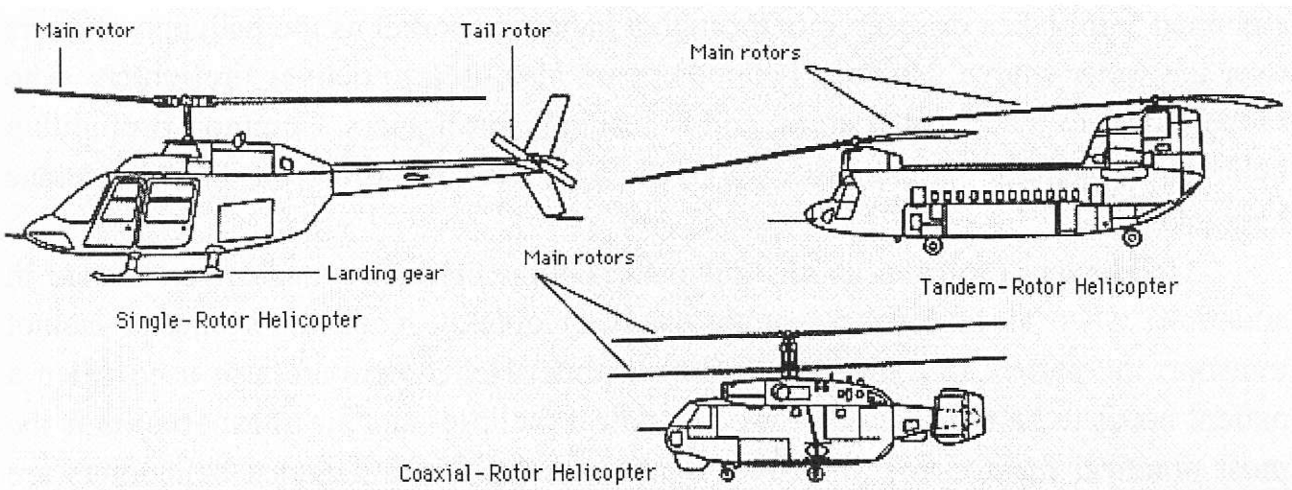


Figure 3.7.-Some Types of Helicopters

The general design of helicopter is also shown in Appendix H.

The main terminology on helicopter is given in Appendix I.

Due to the operating characteristics of the helicopter—its ability to takeoff and land vertically, and to hover for extended periods of time, as well as the aircraft's handling properties under low airspeed conditions—it has been chosen to conduct tasks that were previously not possible with other aircraft, or were time- or work-intensive to accomplish on the ground. Today, helicopter uses include transportation of people and cargo, military uses, construction, firefighting, search and rescue, tourism, medical transport, and aerial observation, among others.

A helicopter used to carry loads connected to long cables or slings is called an aerial crane. Aerial cranes are used to place heavy equipment, like radio transmission towers and large air conditioning units, on the tops of tall buildings, or when an item must be raised up in a remote area, such as a radio tower raised on the top of a hill or mountain. Helicopters are used as aerial cranes in the logging industry to lift trees out of terrain where vehicles cannot travel and where environmental concerns prohibit the building of roads. These operations are referred to as longline because of the long, single sling line used to carry the load.

Helitack is the use of helicopters to combat wildland fires. The helicopters are used for aerial firefighting (or water bombing) and may be fitted with tanks or carry helibuckets. Helibuckets, such as the Bambi bucket, are usually filled by submerging the bucket into lakes, rivers, reservoirs, or portable tanks. Tanks fitted onto helicopters are filled from a hose while the helicopter is on the ground or water is siphoned from lakes or reservoirs through a hanging snorkel as the helicopter hovers over the water source. Helitack helicopters are also used to deliver firefighters, who rappel down to inaccessible areas, and to resupply firefighters. Common firefighting helicopters include variants of the Bell 205 and the Erickson S-64 Aircrane helitanker.

Helicopters are used as air ambulances for emergency medical assistance in situations when an ambulance cannot easily or quickly reach the scene, or cannot transport the patient to a medical facility in time. Helicopters are also used when a patient needs to be transported between medical facilities and air transportation is the most practical method for the safety of the patient. Air ambulance helicopters are equipped to provide medical treatment to a patient while in flight. The use of helicopters as air ambulances is often referred to as MEDEVAC, and patients are referred to as being "airlifted", or "medevaced".

Police departments and other law enforcement agencies use helicopters to pursue suspects. Since helicopters can achieve a unique aerial view, they are often used in conjunction with police on the ground to report on suspects' locations and movements. They are often mounted with lighting and heat-sensing equipment for night pursuits.

Military forces use attack helicopters to conduct aerial attacks on ground targets. Such helicopters are mounted with missile launchers and miniguns. Transport helicopters are used to ferry troops and supplies where the lack of an airstrip would make transport via fixed-wing aircraft impossible. The use of transport helicopters to deliver troops as an attack force on an objective is referred to as Air Assault. Unmanned Aerial Systems (UAS) helicopter systems of varying sizes are being developed by companies for military reconnaissance and surveillance duties. Naval forces also use helicopters equipped with dipping sonar for anti-submarine warfare, since they can operate from small ships.

Other uses of helicopters include, but are not limited to:

- Aerial photography
- Motion picture photography
- Electronic news gathering
- Reflection seismology
- Search and Rescue
- Tourism or recreation
- Transport.

4. AIRPORT AND AIRCRAFT GROUND HANDLING

An airport is a location where aircraft such as fixed-wing aircraft, helicopters, and blimps take off and land. Aircraft may be stored or maintained at an airport. An airport consists of at least one surface such as a runway for a plane to take off and land, a helipad, or water for takeoffs and landings, and often includes buildings such as control towers, hangars and terminal buildings (Figure 4.1).

Larger airports may have fixed base operator services, seaplane docks and ramps, air traffic control, passenger facilities such as restaurants and lounges, and emergency services. A military airport is known as an airbase or air station.

A water airport is a water aerodrome (an area of open water used regularly by seaplanes or amphibious aircraft for landing and taking off), usually with passenger facilities on adjacent land, which acts as an airport.

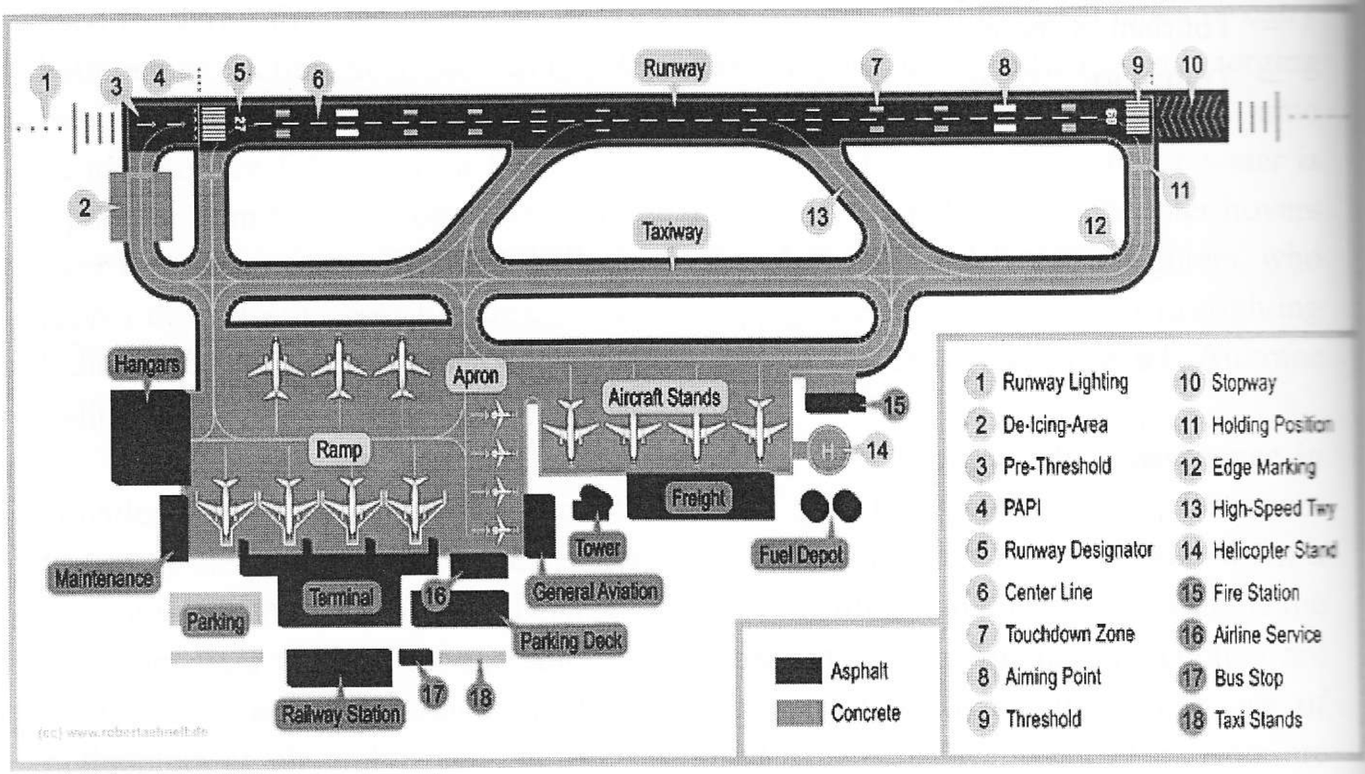


Figure 4.1- Airport Structure

Airports are divided into landside and airside areas. Landside areas include parking lots, public transportation train stations and access roads. Airside areas include all areas accessible to aircraft, including runways, taxiways and ramps. Access from landside areas to airside areas is tightly controlled at most airports. Passengers on commercial flights access airside areas through terminals, where they can purchase tickets, clear security check, or claim luggage and board aircraft through gates. The waiting areas which provide passenger access to aircraft are typically called concourses, although this term is often used interchangeably with terminal.

Ramp and Apron

The area where aircraft park next to a terminal to load passengers and baggage is known as a ramp (or "the tarmac"). Parking areas for aircraft away from terminals are called aprons ((Figure 4.2 -4.3).

Figure 4.2- Apron

Airports can be towered or non-towered, depending on air traffic density and available funds. Due to their high capacity and busy airspace, many international airports have air traffic control located on site.

Airports with international flights have customs and immigration facilities. However, as some countries have agreements that allow travel between them without

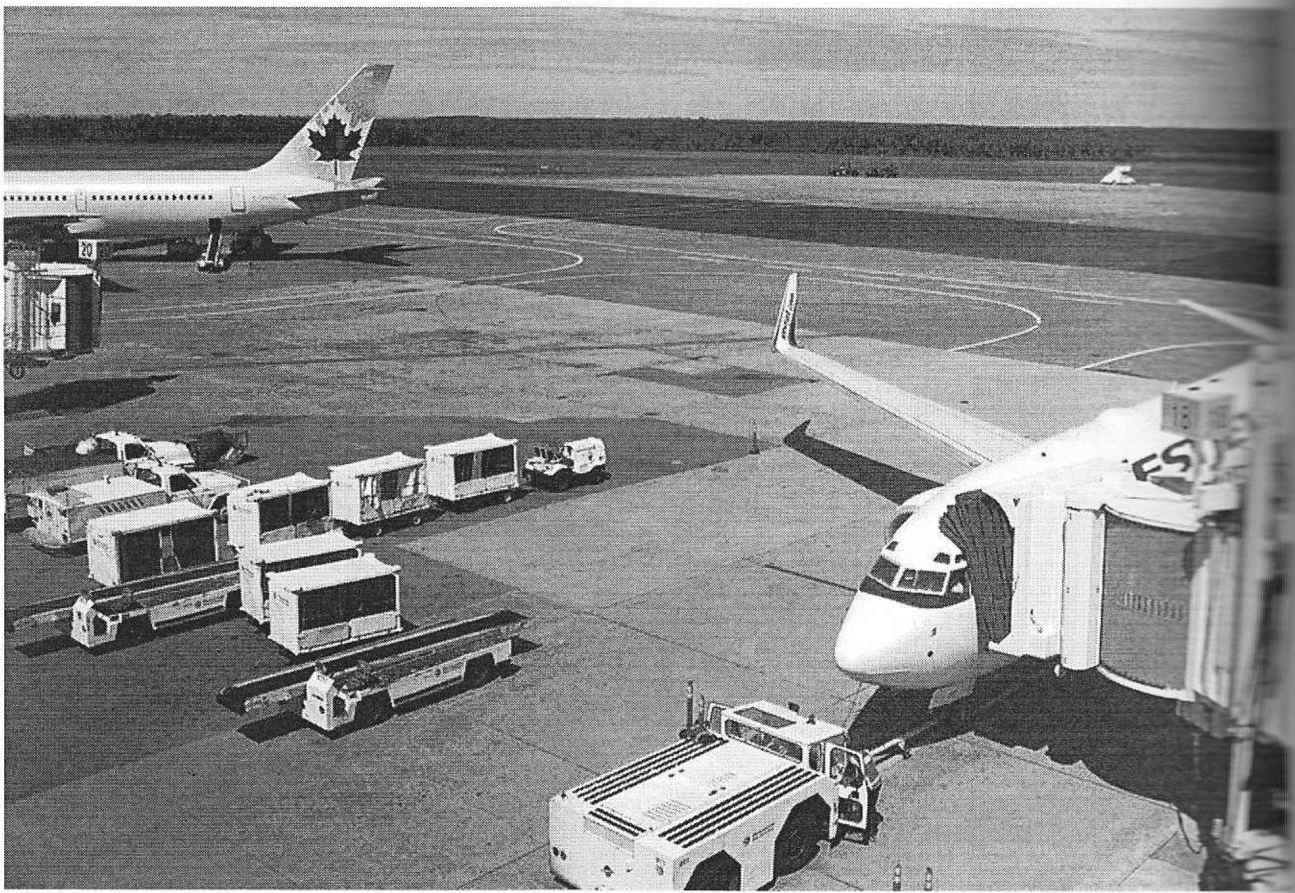


Figure 4.3- Ramp

customs and immigrations, such facilities are not a definitive need for an international airport. International flights often require a higher level of physical security, although in recent years, many countries have adopted the same level of security for international and domestic travel.

Some airport structures include on-site hotels built within or attached to a terminal building. Airport hotels have grown popular due to their convenience for transient passengers and easy accessibility to the airport terminal. Many airport hotels also have agreements with airlines to provide overnight lodging for displaced passengers.

Floating airports" are being designed which could be located out at sea and which would use designs such as pneumatic stabilized platform technology.

All airports use a traffic pattern (often called a traffic circuit outside the U.S.) to assure smooth traffic flow between departing and arriving aircraft.

At extremely large airports, a circuit is in place but not usually used. Rather, aircraft (usually only commercial with long routes) request approach clearance while they are still hours away from the airport, often before they even takeoff from their departure point. Large airports have a frequency called Clearance Delivery which is used by departing aircraft specifically for this purpose. This then allows airplanes to take the most direct approach path to the runway and land without worrying about interference from other aircraft. While this system keeps the airspace free and is simpler for pilots, it requires detailed knowledge of how aircraft are planning to use the airport ahead of time and is therefore only possible with large commercial airliners on pre-scheduled flights. The system has recently become so advanced that controllers can predict whether an aircraft will be delayed on landing before it even takes off; that aircraft can then be delayed on the ground, rather than wasting expensive fuel waiting in the air.

A taxiway is a path on an airport connecting runways with ramps, hangars, terminals and other facilities. They mostly have hard surface such as asphalt or concrete, although smaller airports sometimes use gravel or grass.

Busy airports typically construct high-speed or rapid-exit taxiways in order to allow aircraft to leave the runway at higher speeds. This allows the aircraft to vacate the runway quicker, permitting another to land or depart in a shorter space of time.

Runway

According to the International Civil Aviation Organization (ICAO) a runway is a "defined rectangular area on a land aerodrome prepared for the landing and takeoff of aircraft". Runways may be a man-made surface (often asphalt, concrete, or a mixture of both) or a natural surface (grass, dirt, gravel, ice, or salt). The general view of runway is shown on Figure 4.4.

The operational zones of runway are shown on Figure 4.5.

Figure 4.4- Runway General View

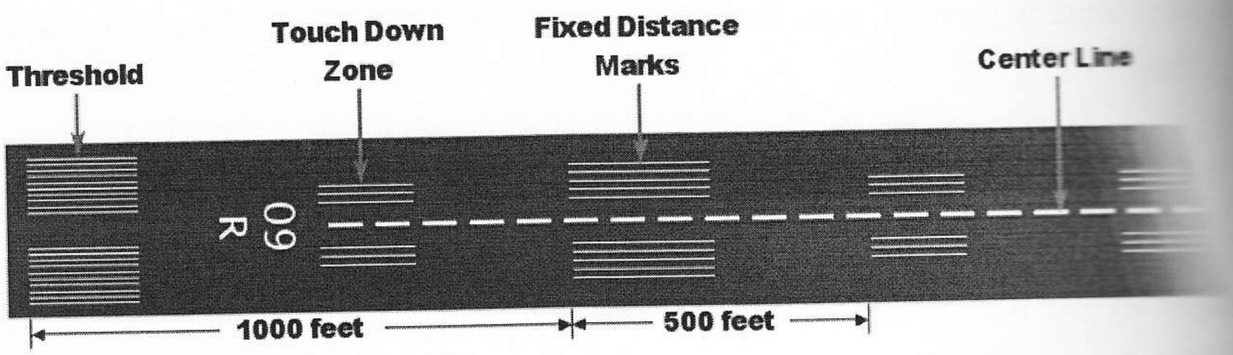


Figure 4.5- Runway Operatonal Zones

The choice of material used to construct the runway depends on the use and the local ground conditions. For a major airport, where the ground conditions permit, the most satisfactory type of pavement for long-term minimum maintenance is concrete. Although certain airports have used reinforcement in concrete pavements, this is generally found to be unnecessary, with the exception of expansion joints across the runway where a dowel assembly, which permits relative movement of the concrete slabs, is placed in the concrete. Where it can be anticipated that major settlements of the runway will occur over the years because of unstable ground conditions, it is preferable to install asphaltic concrete surface, as it is easier to patch on a periodic basis. For fields with very low traffic of light planes, it is possible to use a sod surface. Some runways also make use of salt flat runways.

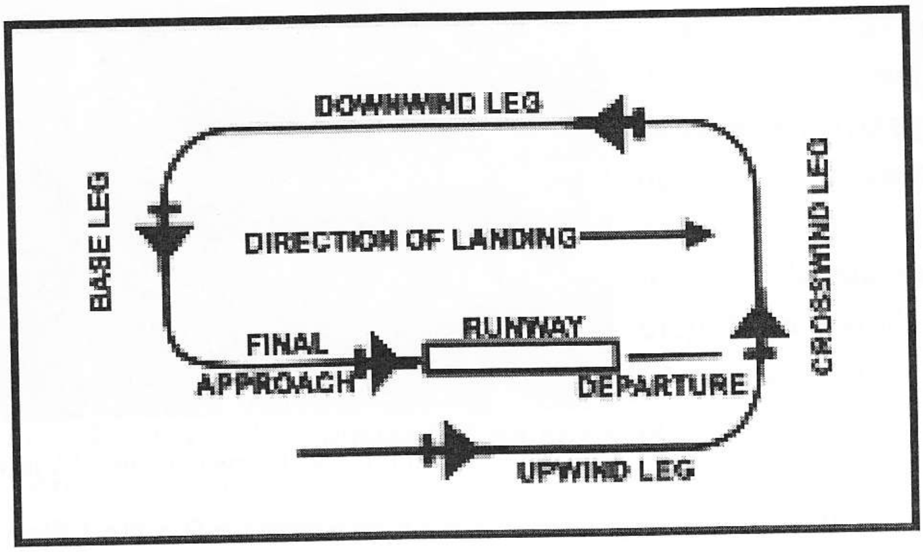


Figure 4.6- Airplane Approach Scheme

During the taking off and, approaching to the airport, an aircraft should follow strongly defined rules (Figure 4.6). Approach schemes and landing parameters are specified for eash airport in special landing diagrams (Figure 4.7).

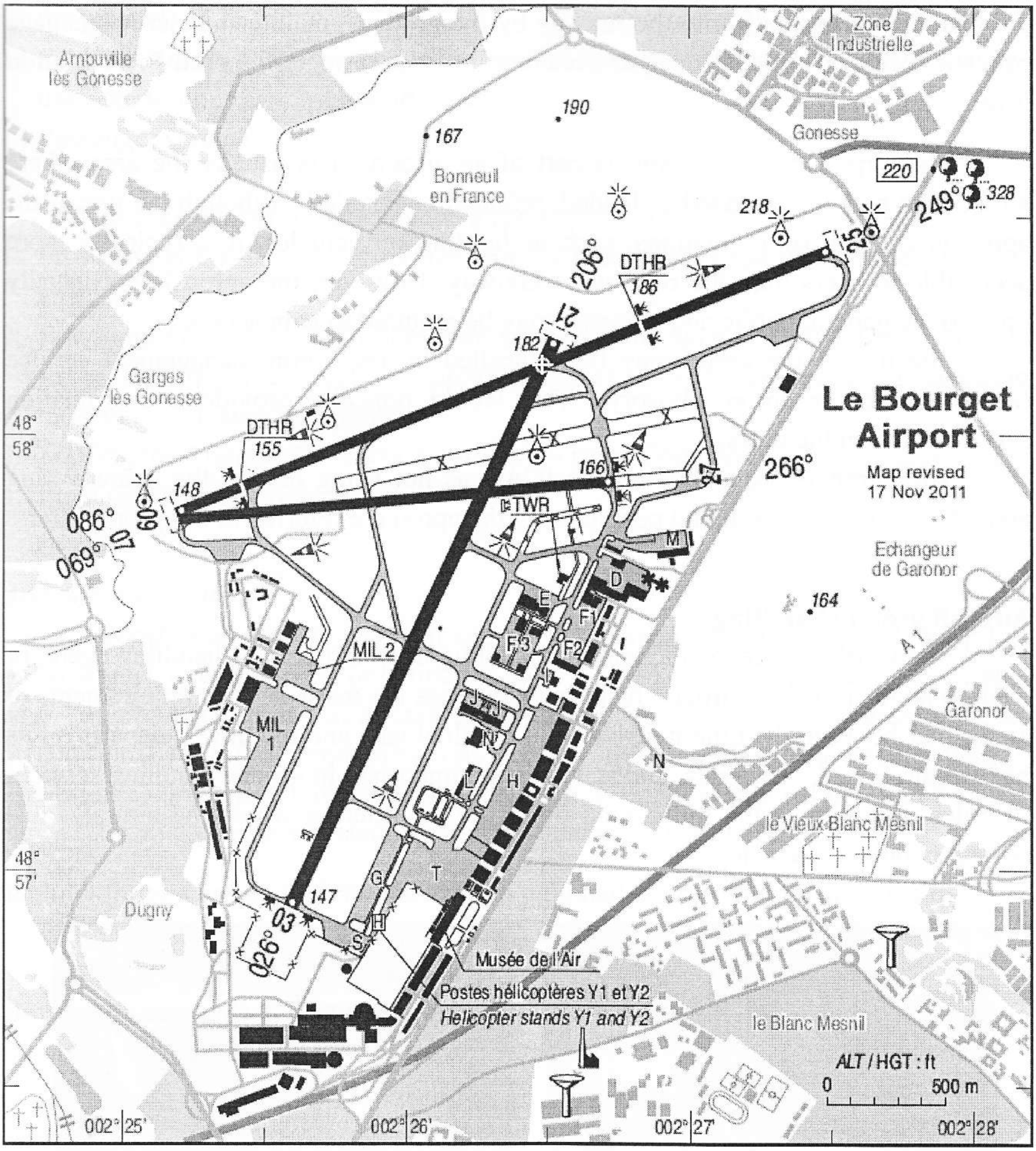


Figure 4.7- Landing Diagram

Runway pavement surface is prepared and maintained to maximize friction for wheel braking. To minimize hydroplaning following heavy rain, the pavement surface is usually grooved so that the surface water film flows into the grooves and the peaks between grooves will still be in contact with the aircraft tires. To maintain the macrotexturing built into the runway by the grooves, maintenance crews engage in airfield rubber removal or hydrocleaning in order to meet required FAA friction levels.

The airport ramp or apron is part of an airport. It is usually the area where aircraft are parked, unloaded or loaded, refueled or boarded. Although the use of the apron is covered by regulations, such as lighting on vehicles, it is typically more accessible to users than the runway or taxiway. However, the apron is not usually open to the general public and a license may be required to gain access.

The use of the apron may be controlled by the apron management service (apron control or apron advisory). This would typically provide a coordination service between the users.

The apron is designated by the ICAO as not being part of the maneuvering area. All vehicles, aircraft and people using the apron are referred to as apron traffic.

Aircraft ground handling

Many airlines subcontract ground handling to an airport or a handling agent, or even to another airline. Ground handling addresses the many service requirements of an airliner between the time it arrives at a terminal gate and the time it departs on its next flight. Speed, efficiency, and accuracy are important in ground handling services in order to minimize the turnaround time (the time during which the aircraft must remain parked at the gate).

In aviation, aircraft ground handling defines the servicing of an aircraft while it is on the ground and (usually) parked at a terminal gate of an airport: ramp service.

This includes services on the ramp or apron, such as:

1. Guiding the aircraft into and out of the parking position (by way of aircraft marshalling),
2. Towing with pushback tractors
3. Lavatory drainage
4. Water cartage (to refill fresh water tanks)
5. Air conditioning (more common for smaller aircraft)
6. Airstart units (for starting engines)
7. Luggage handling, usually by means of beltloaders and baggage carts
8. Gate checked luggage, often handled on the tarmac as passengers disembark

9. Air cargo handling, usually by means of cargo dollies, and cargo loaders
10. Catering trucks
11. Refueling, which may be done with a refueling tanker truck or refuelling pumper
12. Ground power (so that engines need not be running to provide aircraft power on the ground)
13. Passenger stairs (used instead of an aerobridge or airstairs, some budget airlines use both to improve turnaround speed)
14. Passenger service

This includes services inside the airport terminal such as:

1. Providing check-in counter services for the passengers departing on the customer airlines.
2. Providing Gate arrival and departure services. The agents are required to meet a flight on arrival as well as provide departure services including boarding passengers, closing the flight, etc.
3. Staffing the Transfer Counters, Customer Service Counters, Airline Lounges, etc.
4. Field operation service

Aircraft marchalling

Aircraft marshalling is visual signalling between ground personnel and pilots on an airport, aircraft carrier or helipad (Figure 4.8). Marshalling is one-on-one visual communication and a part of aircraft ground handling. It may be as an alternative to, or additional to, radio communications between the aircraft and air traffic control, The usual equipment of a marshaller is a reflecting safety vest, a helmet with acoustic earmuffs, and gloves or marshalling wands, handheld illuminated beacons.

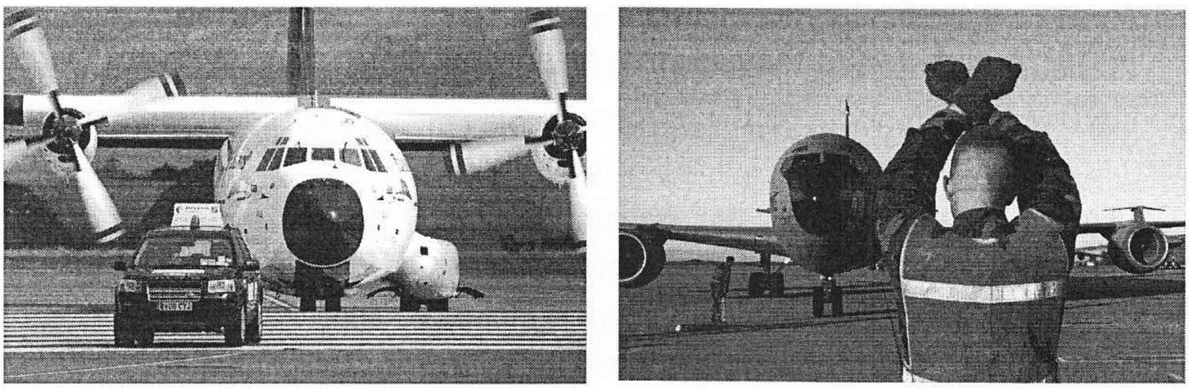


Figure 4.8- Aircraft Marchalling

At airports, the marshaller signals the pilot to keep turning, slow down, stop, and shut down engines, leading the aircraft to its parking stand or to the runway. Sometimes, the marshaller indicates directions to the pilot by driving a "Follow-Me" car (usually a yellow van or pick-up truck with a checkerboard pattern) prior to disembarking and resuming signalling.

Aircraft fueling

Aircraft fueling, or tanking, is the process of transferring fuel from ground source (the tanker) to the aircraft (the receiver) on ground, as usual – in the airport (Figure 4.9).

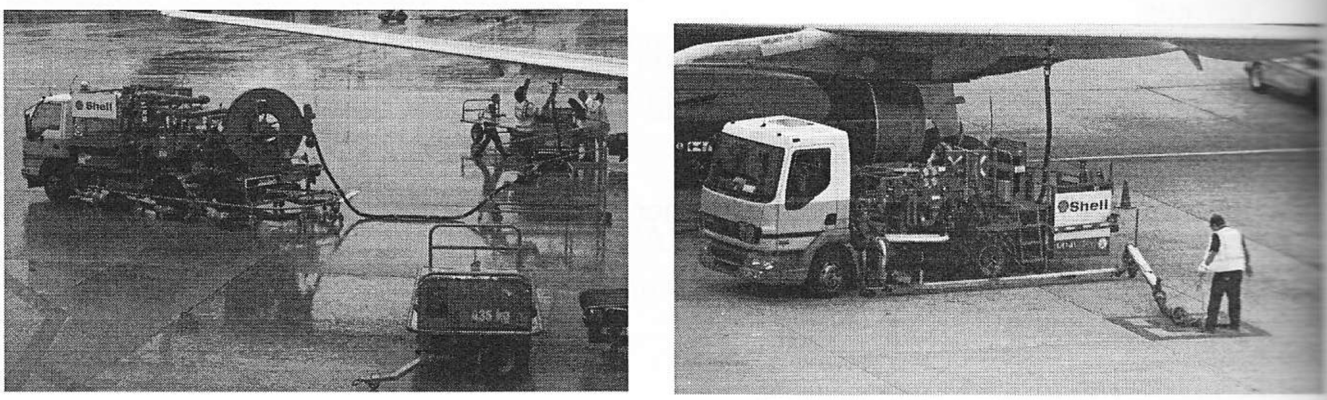


Figure 4.9- Airplane Fueling

Aircraft refuelers can be either a self contained fuel truck, or a hydrant truck or cart. Fuel trucks are self contained, typically containing up to 10,000 US gallons of fuel and have their own pumps, filters, hoses, and other equipment. A hydrant cart or truck hooks into a central pipeline network and provides fuel to the aircraft. There is a significant advantage with hydrant systems when compared to fuel trucks, as fuel trucks must be periodically replenished.

Aerial refueling, also called air refueling, in-flight refueling (IFR), air-to-air refueling (AAR) or tanking, is the process of transferring fuel from one aircraft (the tanker) to another (the receiver) during flight (Figure 4.10).

The procedure allows the receiving aircraft to remain airborne longer, extending its range or loiter time on station. A series of air refuelings can give range limited only by crew fatigue and engineering factors such as engine oil consumption. Because the receiver aircraft can be topped up with extra fuel in the air, air refueling can allow a takeoff with a greater payload which could be weapons, cargo or personnel: the maximum take-off weight is maintained by carrying less fuel and topping up once airborne. Alternatively, a shorter take-off roll can be achieved because take-off can be at a lighter weight before refueling once airborne. Aerial refueling has also been considered as a means to reduce fuel consumption on long distance flights greater than 3000 nautical miles. Potential fuel savings in the range of 35-40% have been estimated for long haul flights (including the fuel used during the tanker missions).

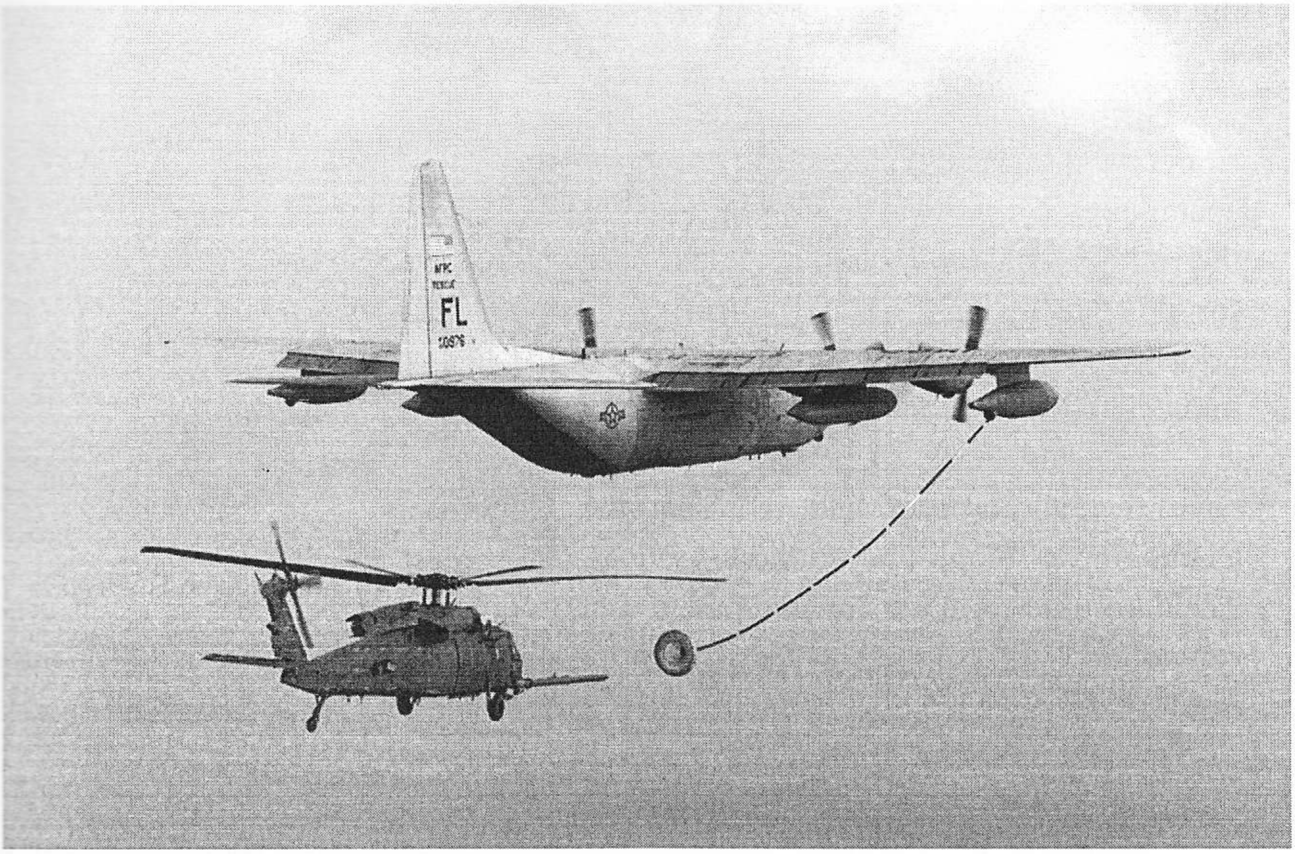


Figure 4.10- Aerial Refueling

The two main refueling systems are probe-and-drogue, which is simpler to adapt to existing aircraft, and the flying boom, which offers faster fuel transfer, but requires a dedicated operator station.

Usually, the aircraft providing the fuel is specially designed for the task, although refueling pods can be fitted to existing aircraft designs if the "probe-and-drogue" system is to be used . The cost of the refueling equipment on both tanker and receiver aircraft and the specialized aircraft handling of the aircraft to be refueled (very close "line astern" formation flying) has resulted in the activity only being used in military operations. There is no known regular civilian in-flight refueling activity.

Aircraft taxiing

Taxiing is the movement of an aircraft on the ground, under its own power, in contrast to towing or push-back where the aircraft is moved by a tug (Figure 4.11). The aircraft usually moves on wheels, but the term also includes aircraft with skis or floats (for water-based travel).

An airplane uses taxiways to taxi from one place on an airport to another; for example, when moving from a terminal to the runway. The term "taxiing" is not used for the accelerating run along a runway prior to takeoff, or the decelerating run immediately after landing.

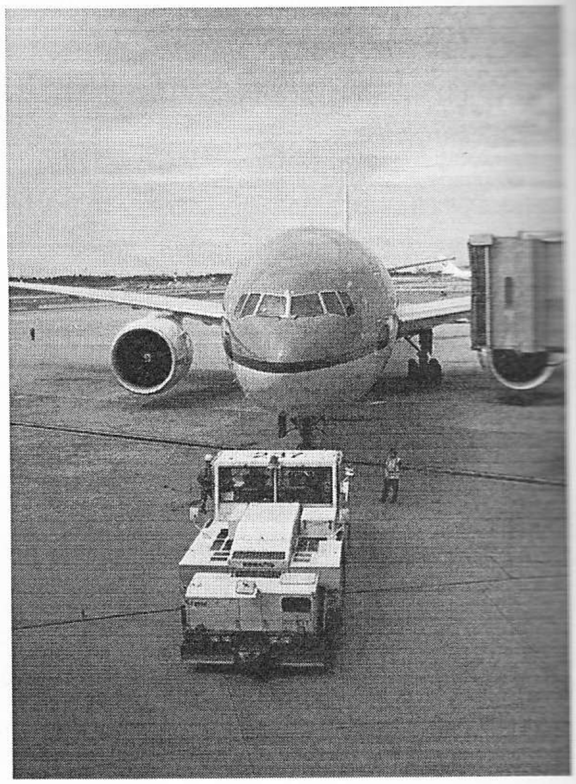


Figure 4.11- Airplane Taxiing

The tugs and tractors at an airport have several purposes and represent the essential part of ground support services. They are used to move any equipment that can not move itself. This includes bag carts, mobile air conditioning units, air starters, lavatory carts, and other equipment.

Catering

Catering includes the unloading of unused food and drink from the aircraft, and the loading of fresh food and drink for passengers and crew. Airline meals are typically delivered in trolleys. Empty or trash-filled trolley from the previous flight are replaced with fresh ones. Meals are prepared mostly on the ground in order to minimize the amount of preparation (apart from chilling or reheating) required in the air.

Passengers boarding

A jet bridge (also termed jetway, loading bridge, aerobridge/airbridge, air jetty, portal, passenger walkway or passenger boarding bridge) is an enclosed, movable connector which extends from an airport terminal gate to an airplane, allowing passengers to board and disembark without having to go outside (Figure 4.12,a). Depending on building design, sill heights, fueling positions and operational requirements, it may be fixed or movable, swinging radially or extending in length.Wheelchair lifts, if required

Hydraulic mules (units that provide hydraulic power to an aircraft externally).

Passenger boarding stairs, sometimes referred to as 'air-stairs', 'boarding ramps' or 'aircraft steps', provide a mobile means to traverse between aircraft doors and the ground (Figure 4.12,b).

a

b

Figure 4.12- Passengers Boarding

Because larger aircraft have door sills 5 to 20 feet high, stairs facilitate safe boarding and deboarding. While smaller units are generally moved by being towed or pushed, larger units are self-powered. Most models have adjustable height to accommodate various aircraft. Optional features may include canopy, heat, supplementary lighting and red carpet.

Cabin service

These services ensure passenger comfort. The cabin cleaning is the main job in the cabin service. They include such tasks as cleaning the passenger cabin and replenishment of on-board consumables or washable items such as soap, pillows, tissues, blankets, etc.

Ground support equipment

Ground support equipment (GSE) is the support equipment found at an airport, usually on the ramp, the servicing area by the terminal. This equipment is used to service the aircraft between flights. As its name implies, GSE is there to support the operations of aircraft on the ground. The functions that this equipment plays generally involve ground power operations, aircraft mobility, and loading operations (for both cargo and passengers).

Chocks

Chocks are used to prevent an aircraft from moving while parked at the gate or in a hangar (Figure 4.13). Chocks are placed in the front ('fore') and back ('aft') of the wheels of landing gear. They are made out of hard wood or hard rubber. Corporate safety guidelines in the USA almost always specify that chocks must be used in a pair on the same wheel and they must be placed in physical contact with the wheel. Therefore, "Chocks" refers to a pair of chocks connected by a segment of rope or cable.

Figure 4.13.- Chocks

Bag carts

Baggage carts are used for the transportation of luggage, mail, cargo and other materials between the aircraft and the terminal or sorting facility (Figure 4.14). Carts are fitted with a brake system which blocks the wheels from moving when the connecting rod is not attached to a tug. Most carts are completely enclosed except for the sides which use plastic curtains to protect items from weather.

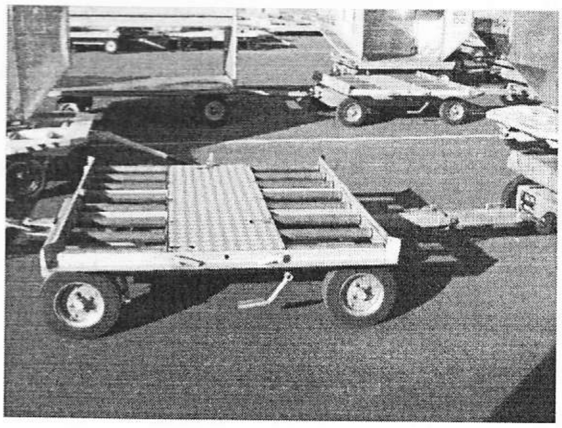


Figure 4.14.-Baggage Cart

Trolleys for containers and pallets

The trolley or dollie are for containers and palettes are used for the transport of loads placed in containers and on pallets (Figure 4.15). Both kinds of trolley have inbuilt rollers or balls in the space for the acceptance of containers or pallets for their easier moving. The containers or pallets on trolleys must obligatory be secured with built-in Stops. The mechanical brake, depending on construction blocks the wheels when the towbar of the trolley is raised to 90°. The trolleys for containers have revolving deck to make containers turn to the direction of loading on aircraft. On all trolleys the parts as brake for wheels blocking, the wheels, the towbar, the hook for connecting, stops on the revolving platform, and stops for locking the containers or pallets must be in order or with them is prohibited any transport.

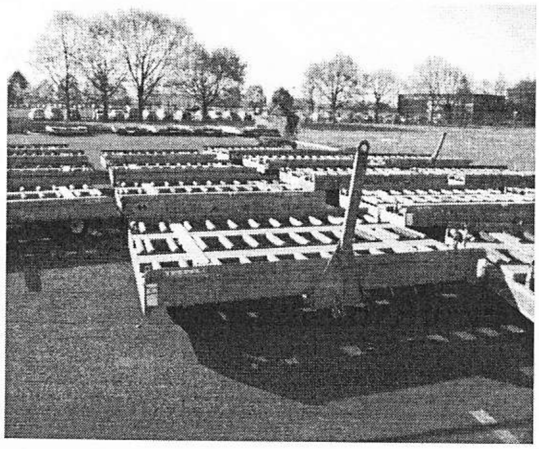


Figure 4.15.- Trolley

Ground power unit

A ground power unit is a vehicle capable of supplying power to aircraft parked on the ground Figure 4.16). Ground power units may also be built into the jetway, making it even easier to supply electrical power to aircraft.

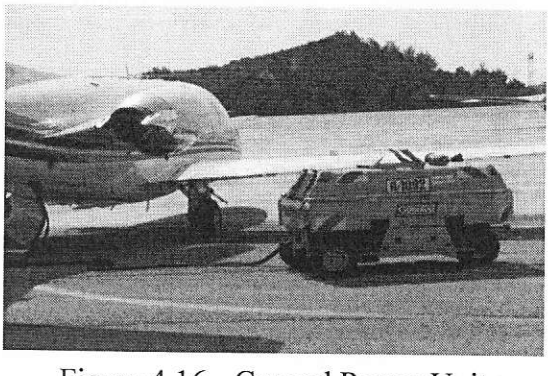


Figure 4.16.- Ground Power Unit

Buses

Buses at airports are used to move people from the terminal to either an aircraft or another terminal (Figure 4.17). Some airports use buses that are raised to the level of a passenger terminal and can only be accessed from a door on the 2nd level of the terminal. These odd looking buses are usually referred to as "people movers" or "mobile lounges".

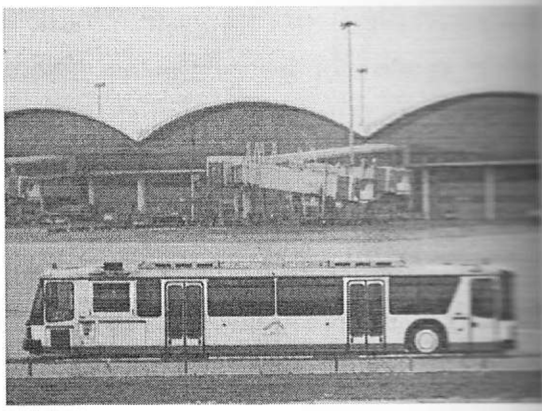
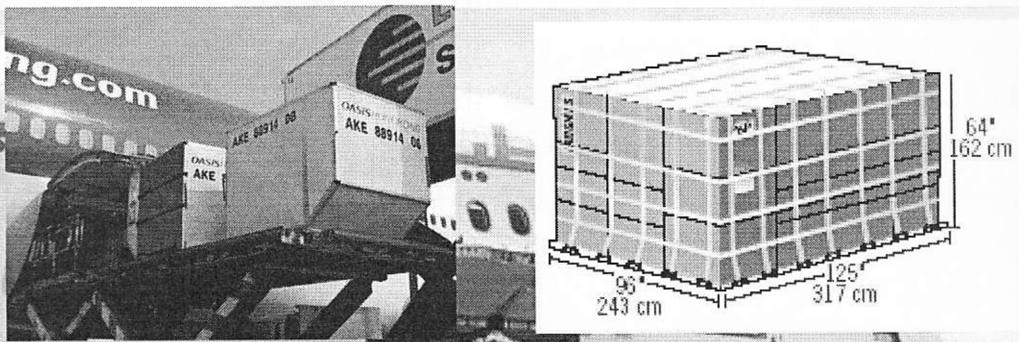


Figure 4.17.- Airport Bus

Container loader

The loader for widebodied aircraft (cargo platform) (Figure 4.18) is used for loading and unloading of cargo placed in containers (Figure 4.19,a) or on pallet (Figure 4.19,b). The loader has two platforms which independently raise or come down. The containers or palettes on the loader are moved with the help of built-in rollers or wheels, and are carried in aircraft across the platforms.



a *b*

Figure 4.19.- Cargo Container and Pallet

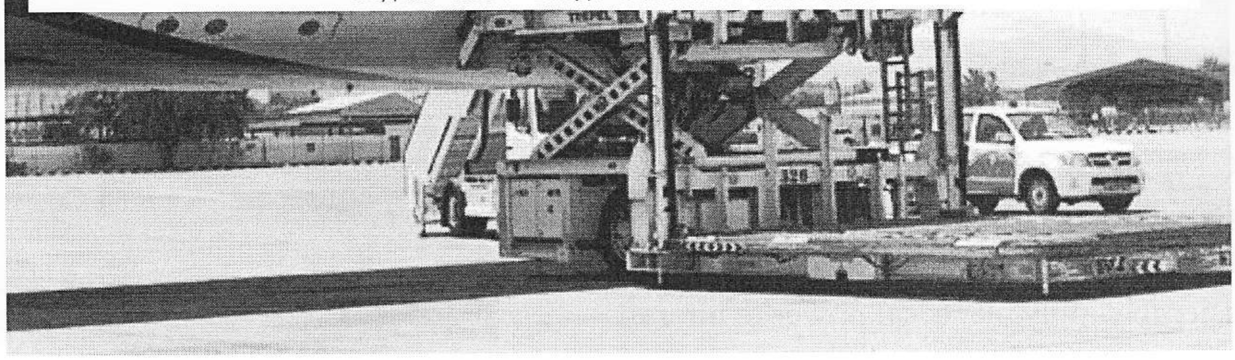


Figure 4.18.- Cargo Platform

Container transporter

The transporters are cargo platforms constructed so that beside loading and unloading can transport cargo (Figure 4.20). Depending on the type and load capacity the containers could be transported, and the same is valid for greater transporters and palettes.

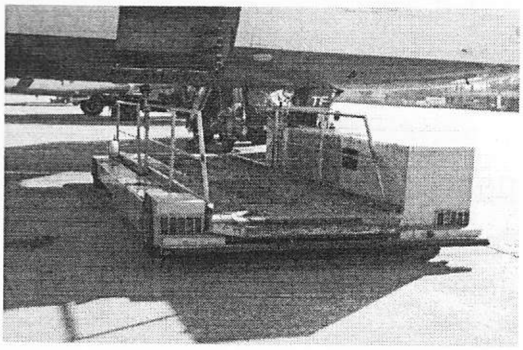


Figure 4.20.- Container Transporter Unit

Air starter

An air starter is a vehicle with a built-in gas turbine engine which, during the start of aircraft engine, gives the necessary quantity of air to start the engine (Figure 4.21). While a compressor cannot deliver the necessary quantity of air for its own work, the air is provided by an air starter. An air starter blows air in by a hose attached to aircraft.

Figure 4.21.- Air Starter

Potable water trucks

Potable water trucks are special vehicles that fill up drinking water tanks in aircraft (Figure 4.22). The water is filtered and protected from the elements while being stored on the vehicle. A pump in the vehicle assists in moving the water from the truck to the aircraft.

Fi

Lavatory drainage

Lavatory service vehicles empty and refill lavatories onboard aircraft (Figure 4.23). Waste is stored in tanks on the aircraft until these vehicles can empty them and get rid of the waste. After the tank is emptied, it is refilled with a mixture of water and a disinfecting concentrate, commonly called 'blue juice'. Instead of a self-powered vehicle, some airports have lavatory carts, which are smaller and must be pulled by tug.

Figure 4.23.- Lavatory Service Vehicle

Catering vehicle. Catering includes the unloading of unused food and drink from the aircraft, and the loading of fresh food and drinks for passengers and crew. The meals are typically delivered in standardized carts (Figure 4.24). Meals are prepared mostly on the ground in order to minimize the amount of preparation (apart from chilling or reheating) required in the air.

The catering vehicle consists of a rear body, lifting system, platform and an electro-hydraulic control mechanism. The vehicle can be lifted up, down and the platform can be moved to place in front of the aircraft.

Figure 4.24.- Catering Cart

In-flight food is prepared in the flight kitchen which is completely HACCP certified facility where food is made in sterile and controlled environments. The packed food is then placed in trollies and wheeled into the Catering truck at the flight kitchen, which can be located within a 5 km radius of the airport.

Thereon the vehicle drives to the airport and is parked in front of the plane. The stabilizers are deployed and the van body is lifted. The platform can be fine controlled to move left-right as well as in-out so that it is aligned with the door correctly.

The body is made of insulated panels and is capable of maintaining temperatures of 0 degrees by means of refrigeration unit.

Luggage downloading

Belt loaders are vehicles with movable belts for unloading and loading of baggage and cargo of aircraft (Figerw 4.25). A belt loader is positioned to the door sill of an aircraft hold (baggage compartment) for the operation. Belt loaders are used for narrow body aircraft (e.g. 737) and bulk hold of wide body aircraft (e.g. 767 and 747). Baggage stored without containers is known as bulk loading.

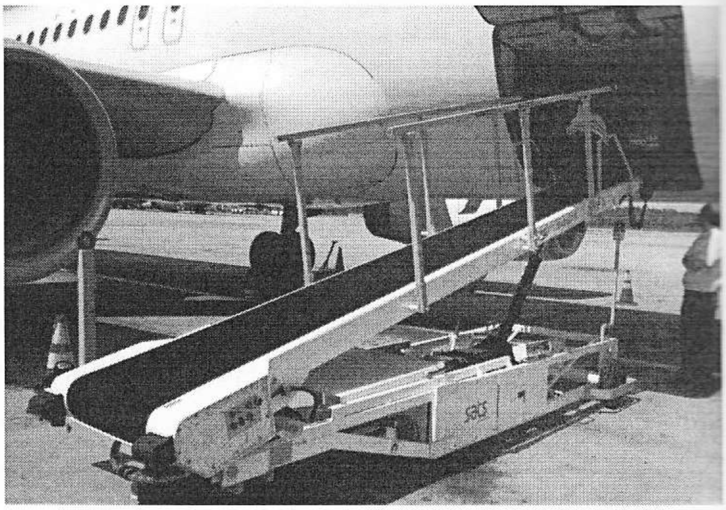


Figure 4.25.- Belt Loader

Pushback tugs and tractors

Pushback tugs are mostly used to push an aircraft away from the gate when it is ready to leave (Figure 4.26). These tugs are very powerful and because of the large engines, are sometimes referred to as an engine with wheels. Pushback tugs can also be used to pull aircraft in various situations, such as to a hangar. Different size tugs are required for different size aircraft. Some tugs use a tow-bar as a connection between the tug and the aircraft, while other tugs lift the nose gear off the ground to make it easier to tow or push.

Figure 4.26.- Pushback Tug

Deicing

De-icing is defined as removal of snow, ice or frost from a surface. Anti-icing is understood to be the application of chemicals that not only de-ice, but also remain on a surface and continue to delay the reformation of ice up to a certain period of time, or prevent adhesion of ice to make mechanical removal easier.

De/anti-icing vehicles. The procedure of de/anti-icing, protection from fluids freezing up on aircraft, is done from special vehicles. These vehicles have booms, like a cherry picker, to allow easy access to the entire aircraft (Figure 4.27).

Figure 4.27.- Deicing Vehicles

A hose sprays a special mixture that melts current ice on the aircraft and also prevents some ice from building up while waiting on the ground.

5. AIRCRAFT MAINTENANCE

A properly maintained aircraft is a safe aircraft

Maintenance is defined as the preservation, inspection, overhaul, and repair of an aircraft, including the replacement of parts.

. In addition, regular and proper maintenance ensures that an aircraft meets an acceptable standard of airworthiness throughout its operational life.

Although maintenance requirements vary for different types of aircraft, experience shows that aircraft need some type of preventive maintenance every 25 hours of flying time or less, and minor maintenance at least every 100 hours. This is influenced by the kind of operation, climatic conditions, storage facilities, age, and construction of the aircraft. Manufacturers supply maintenance manuals, parts catalogs, and other service information that should be used in maintaining the aircraft.

Aircraft checks

Scheduled maintenance tasks are grouped into work packages known as blocks. The complete package is sometimes referred to as a complete overhaul cycle. The concept is called block maintenance or sometimes progressive maintenance.

Daily check

This check travels under several common names and post-flight, maintenance pre-flight, service check, and overnight to name a few. It is the lowest scheduled check. Walk around inspection by flight crew is not normally a part of a maintenance program. A daily check is a cursory inspection of the aircraft to look for obvious damage and deterioration. It checks for "general condition and security" and reviews the aircraft log for discrepancies and corrective action. The accomplishment of the daily check requires little in the way of specific equipment, tools, or facilities. A basic requirement is that the airplane remains airworthy. Usually, a daily check is accomplished every 24 to 60 hours of accumulated flight time. Examples of daily check items include:

- Visually inspect tail skid shock strut pop-up indicator
- Check fluid levels
- Check general security and cleanliness of the flight deck
- Check that emergency equipment is installed

'A' check

This is the next higher level of scheduled maintenance. It is normally accomplished at a designated maintenance station in the route structure and includes the opening of access panels to check and service certain items. Some limited special tooling, servicing, and test equipment is required. The 'A' check includes the lower check, i.e. Daily check. Examples of 'A' check items include:

- General external visual inspection of aircraft structure for evidence of damage, deformation, corrosion, missing parts
- Check crew oxygen system pressure
- Operationally check emergency lights
- Lubricate nose gear retract actuator
- Check parking brake accumulator pressure
- Perform Built-in Test Equipment (BITE) test of Flap/Slat Electronics Unit

'B' check

This is a slightly more detailed check of components and systems. Special equipment and tests may be required. It does not involve, however, detailed disassembly or removal of components.

Contemporary maintenance programs do not use the 'B' check interval. For a number of reasons, the tasks formerly defined for this interval have, for many airplanes, been distributed between the 'A' and 'C' check.

Heavy checks

The following two checks are traditionally known as heavy checks. They are normally accomplished at the main maintenance base of the airline where specialized manpower, materials, tooling, and hangar facilities are available.

'C' check: This is an extensive check of individual systems and components for serviceability and function. It requires a thorough visual inspection of specified areas, components and systems as well as operational or functional checks. It is a high-level check that involves extensive tooling, test equipment, and special skill levels. 'C' checks remove the airplane from the revenue schedule for 3 to 5 days. The 'C' check includes the lower checks, i.e. 'A,' 'B,' and Daily checks.

Examples of 'C' check items:

- Visually check flight compartment escape ropes for condition and security
- Check operation of DC bus tie control unit
- Visually check the condition of entry door seals

- Operationally check flap asymmetry system
- Pressure decay check APU fuel line shroud
- Inspect engine inlet TAI ducting for cracks

'D' check: This can also be referred to as the Structural check. It includes detailed visual and other non-destructive test inspections of the aircraft structure. It is an intense inspection of the structure for evidence of corrosion, structural deformation, cracking, and other signs of deterioration or distress and involves extensive disassembly to gain access for inspection. Special equipment and techniques are used. Structural checks are man-hour and calendar-time intensive. The 'D' check includes the lower checks, i.e. 'A,' 'B,' 'C,' and Daily checks. This check removes the airplane from service for 20 or more days. Examples of 'D' check items include:

- Inspect stabilizer attach bolts
- Inspect floor beams
- Detailed inspection of wing box structure

Variations

There are variations of block maintenance. One of those variations is called a phase check - don't be confused by the variety of names. The number of scheduled maintenance tasks for a large airplane like the 747 are extensive, and this is particularly true for the higher 'C' and 'D' checks. Their accomplishment can remove the airplane from service for several weeks. This is considered unacceptable as it defeats the concept of removing the airplane from service in small, manageable blocks. One solution is to divide these higher checks into segmented blocks or phases.

A typical phase check provides for a thorough visual inspection of specified areas, components, and systems as well as operational or functional checks of specified components and systems. Each check includes the requirements of traditional lower check work items and portions of 'C' and 'D' checks at the required task intervals.

Phase checks are typically accomplished at 200 to 800 flight-hour intervals, depending upon the work packaging plan and other airline operating variables.

Block maintenance is further modified when examining the special requirements of high-time/high-cycle airplanes. Older airplanes have increased maintenance tasks defined. This includes supplemental structural inspections, corrosion control programs, and aging system checks.

Executive and VIP airplanes have low utilization and represent another variation of block concepts. Task, intervals and blocks defined by the MRB are based upon the higher utilization levels of air carrier operations. They don't work for VIP airplanes. Consequently, separate packages are developed for VIP airplanes that are predominantly based upon calendar time.

Minimum equipment lists and operations with inoperative equipment

The Code of Federal Regulations (CFRs) requires that all aircraft instruments and installed equipment are operative prior to each departure. When the FAA adopted the minimum equipment list (MEL) concept for 14 CFR part 91 operations, this allowed for the first time, operations with inoperative items determined to be nonessential for safe flight. At the same time, it allowed part 91 operators, without an MEL, to defer repairs on nonessential equipment within the guidelines of part 91.

The FAA has developed master minimum equipment lists (MMELs) for aircraft in current use. Upon written request by an operator, the local FSDO may issue the appropriate make and model MMEL, along with an LOA, and the preamble. The operator then develops operations and maintenance (O&M) procedures from the MMEL. This MMEL with O&M procedures now becomes the operator's MEL. The MEL, LOA, preamble, and procedures document developed by the operator must be on board the aircraft when it is operated.

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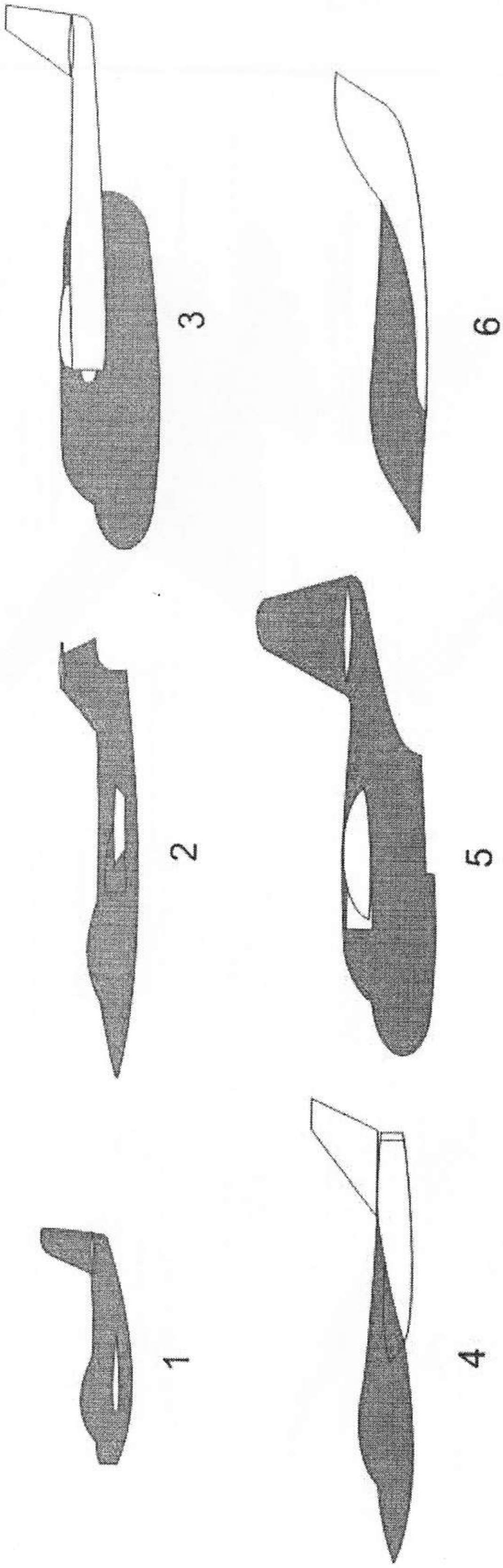
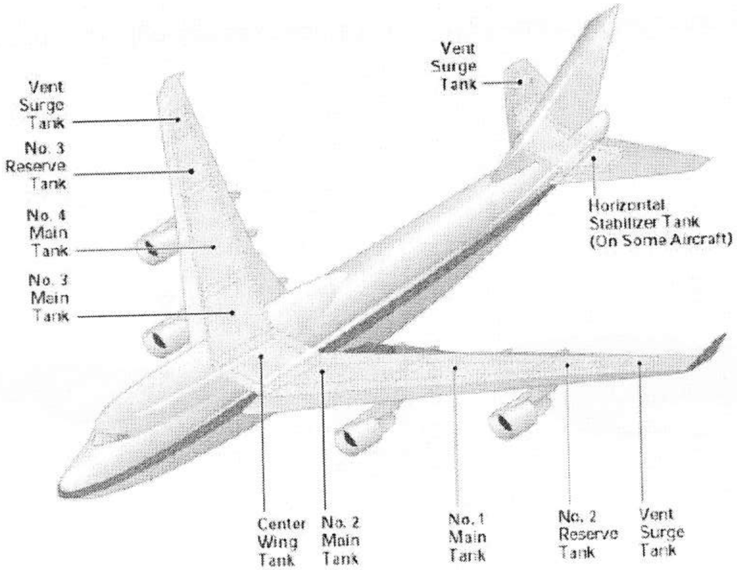
Appendix A



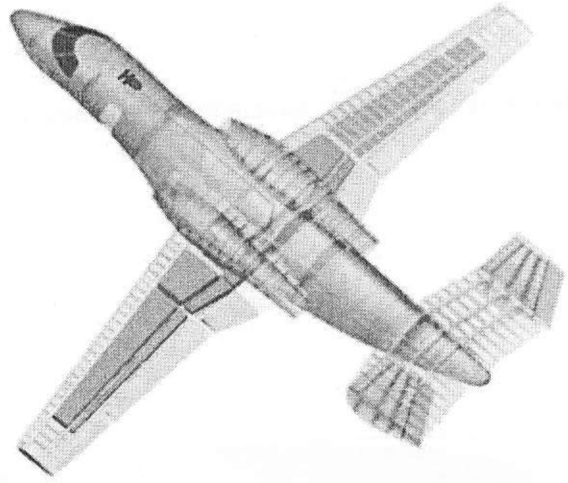
1: Subsonic. 2: High-speed / supersonic. 3: High-capacity subsonic. 4: Highly-maneuverable supersonic. 5: Flying boat. 6: Hypersonic.

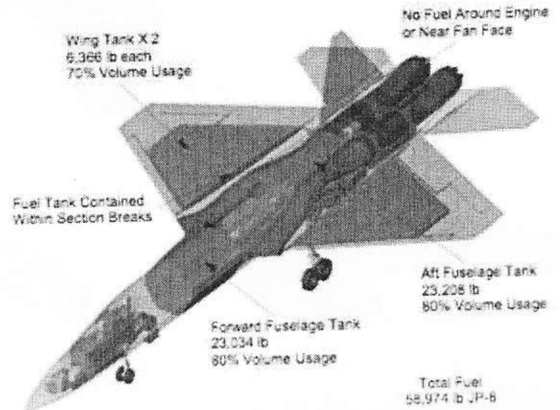
Fuel Volume Examples



Total Usable Fuel

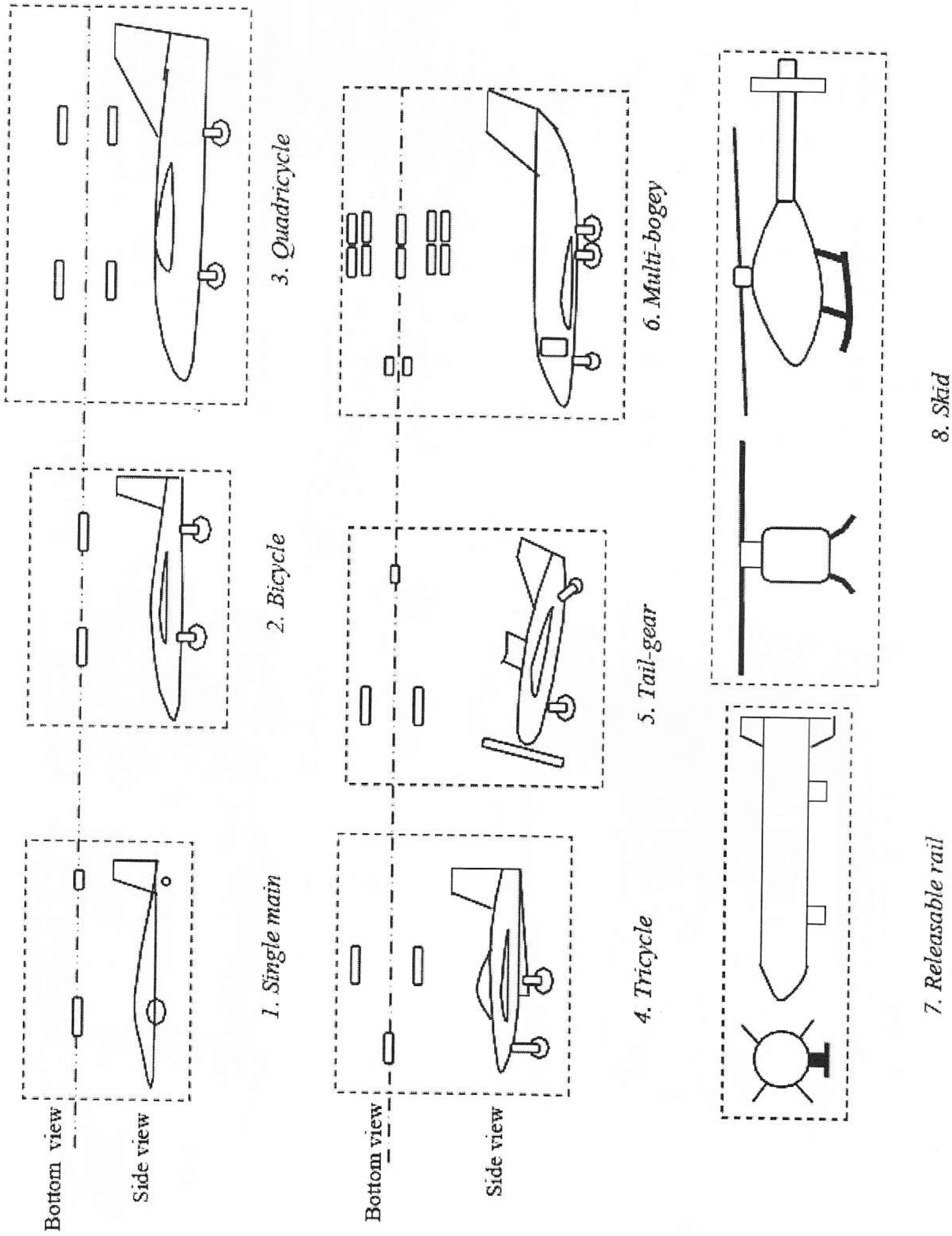
Airplanes With a Horizontal Stabilizer Fuel Tank	216,389 liters (57,164 U.S. gallons)
Airplanes Without a Horizontal Stabilizer Fuel Tank	203,897 liters (53,864 U.S. gallons)





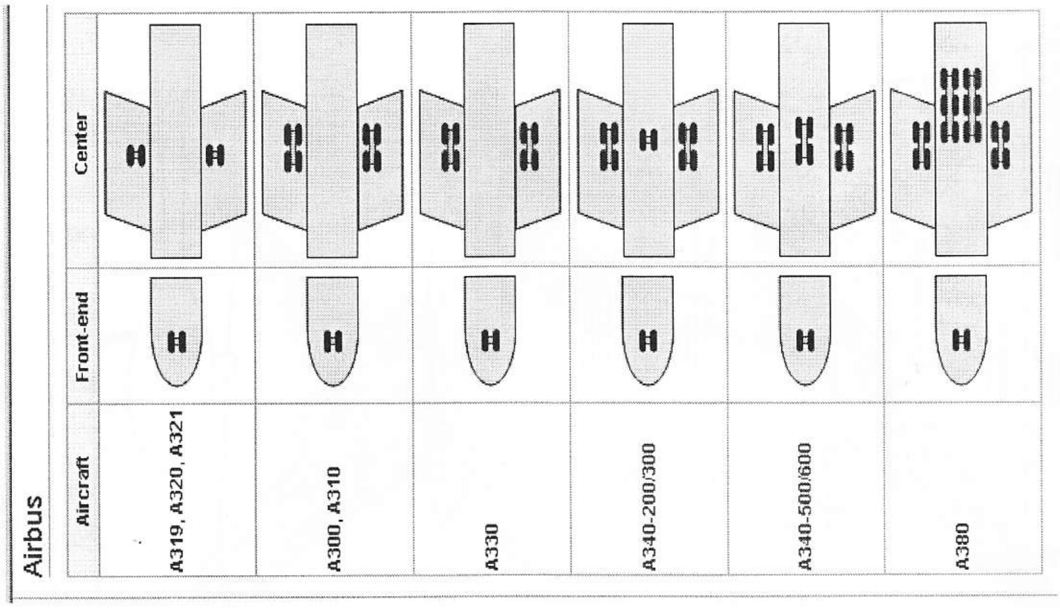
Appendix C

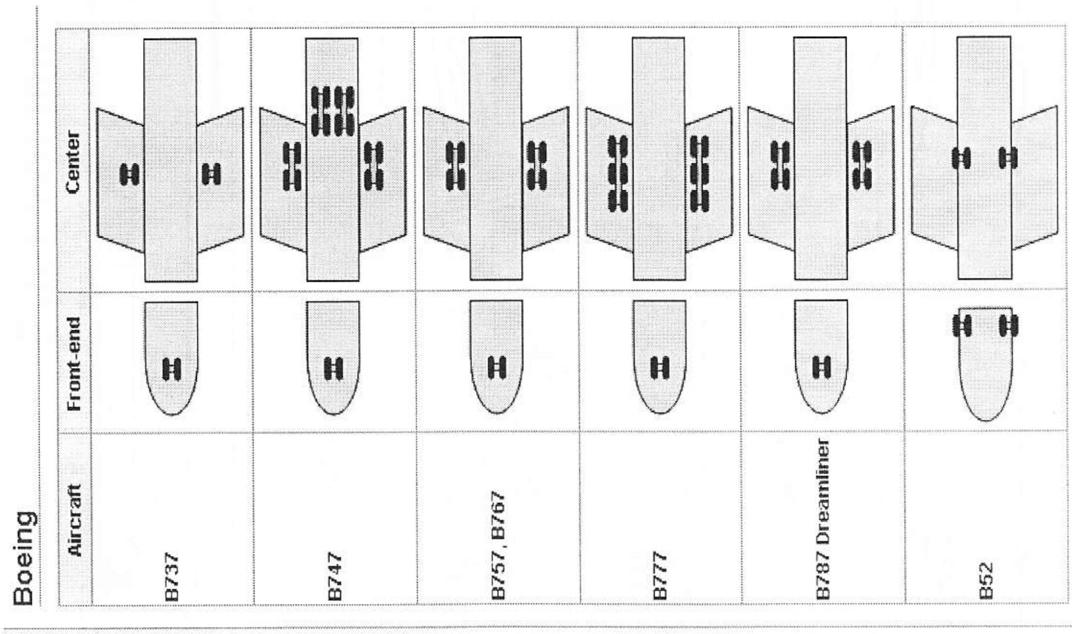
LANDING GEAR TYPES



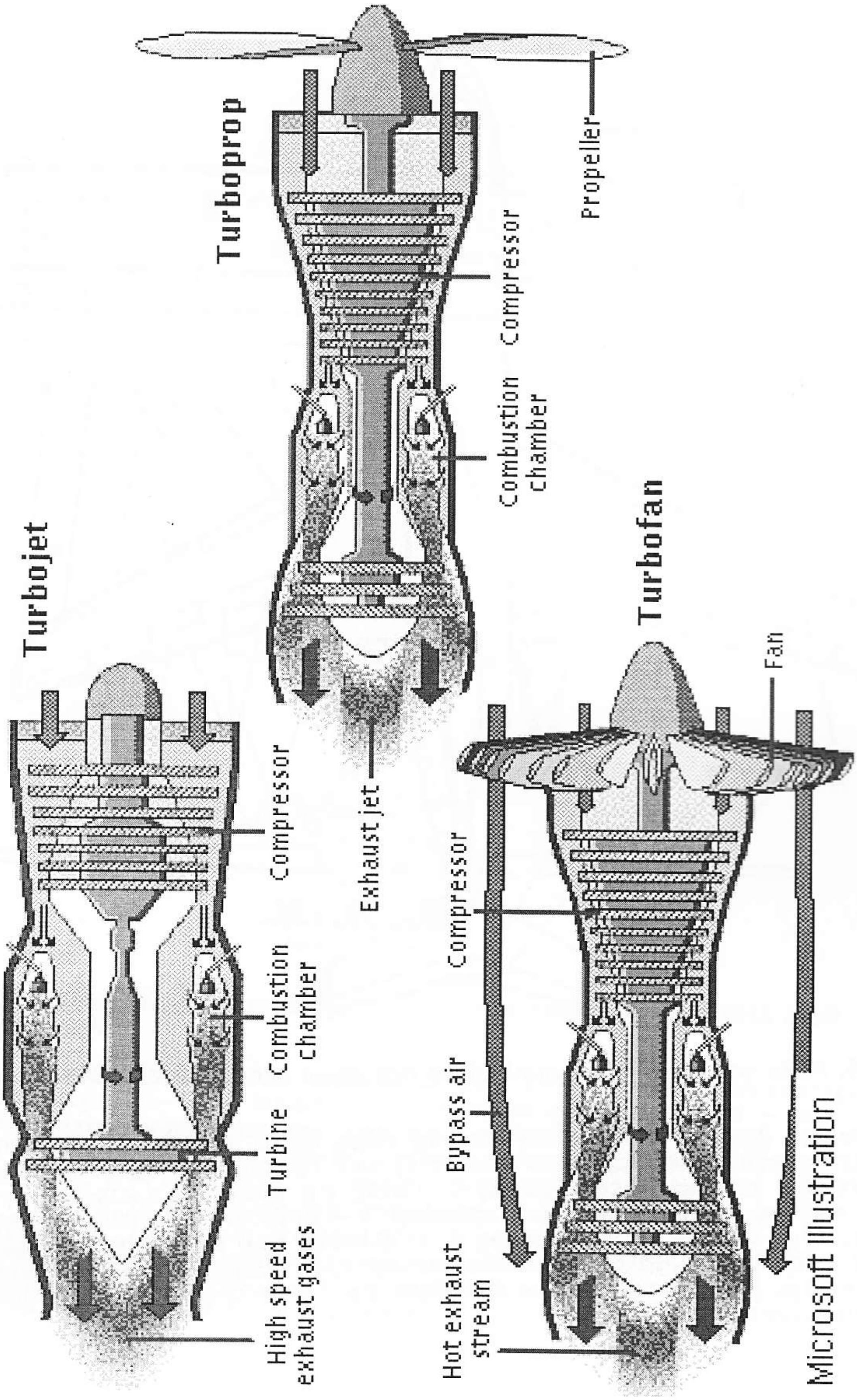
Appendix C

LANDING GEAR LAYOUT





Appendix D


Turboprop
Propeller
Compressor
Combustion chamber
Exhaust jet
Turbojet
Compressor
Combustion chamber
Turbine
High speed exhaust gases
Turbofan
Fan
Compressor
Bypass air
Hot exhaust stream
Microsoft Illustration

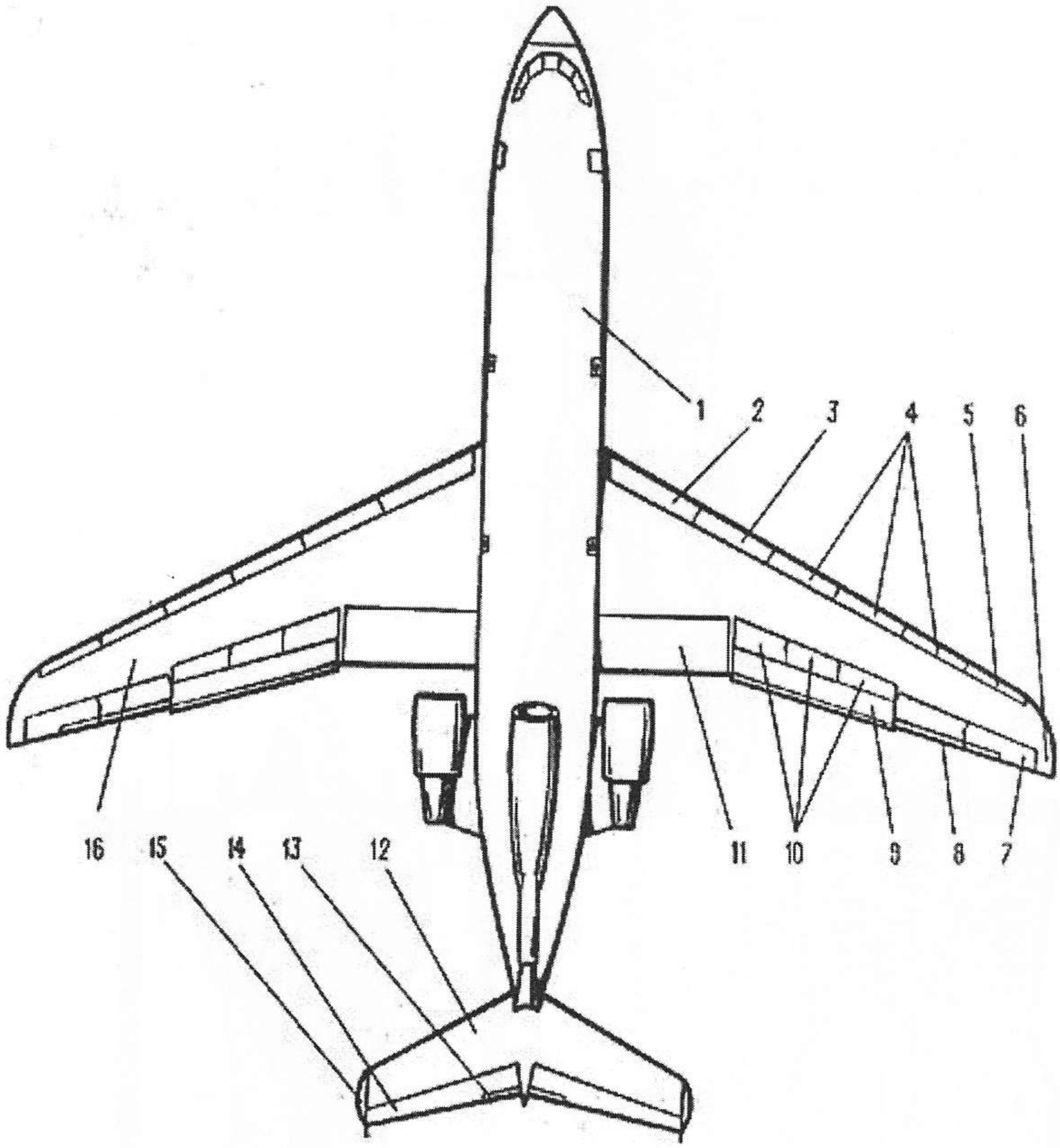


Рис. 15. Main components of an airplane основные элементы самолёта (*вид в плане*)

1 — **fuselage** фюзеляж; *2* — **wing leading edge** носок крыла; *3* — **inboard slat** внутренний предкрылок; *4* — **mid(dle) slat** средний предкрылок; *5* — **outboard slat** внешний предкрылок; *6* — **wing tip** законцовка крыла; *7* — **aileron** элерон; *8* — **trim(ming) tab** триммер; *9* — **outboard flap** внешний закрылок; *10* — **spoilers** интерцепторы; *11* — **inboard flap** внутренний закрылок; *12* — **(horizontal) stabilizer** стабилизатор; *13* — **trim(ming) tab** триммер; *14* — **elevator** руль высоты; *15* — **stabilizer tip** законцовка стабилизатора; *16* — **wing** крыло

Appendix F

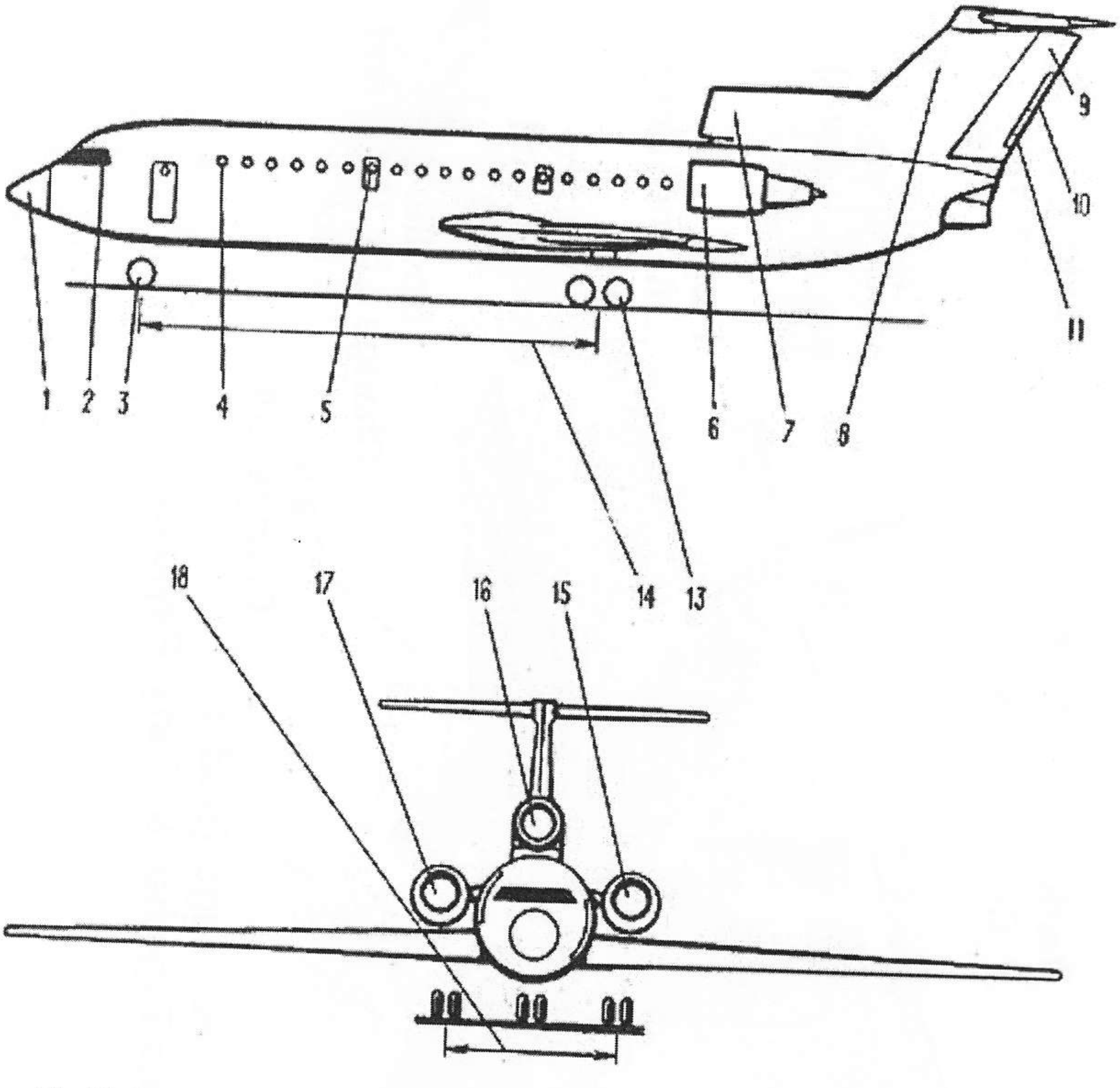
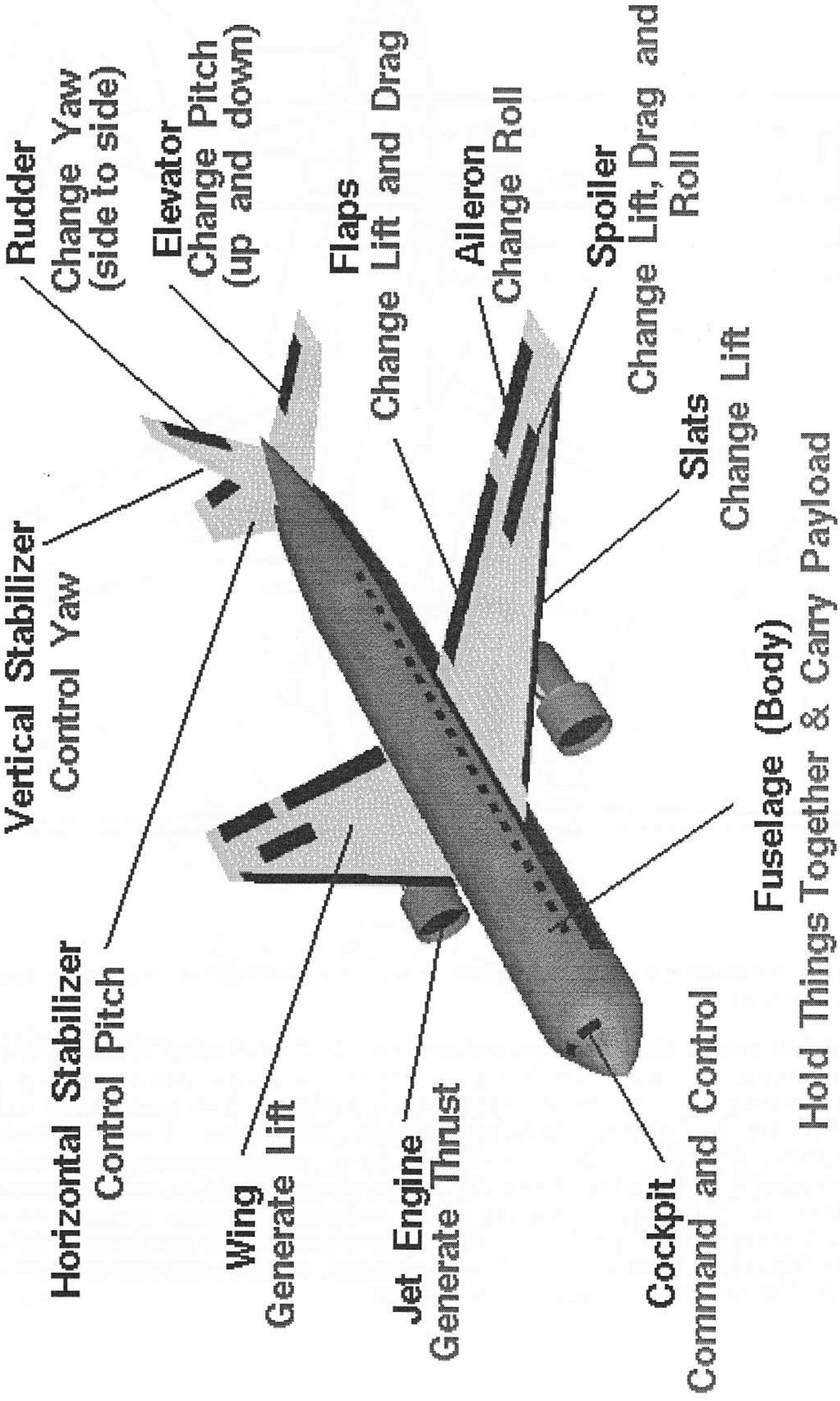


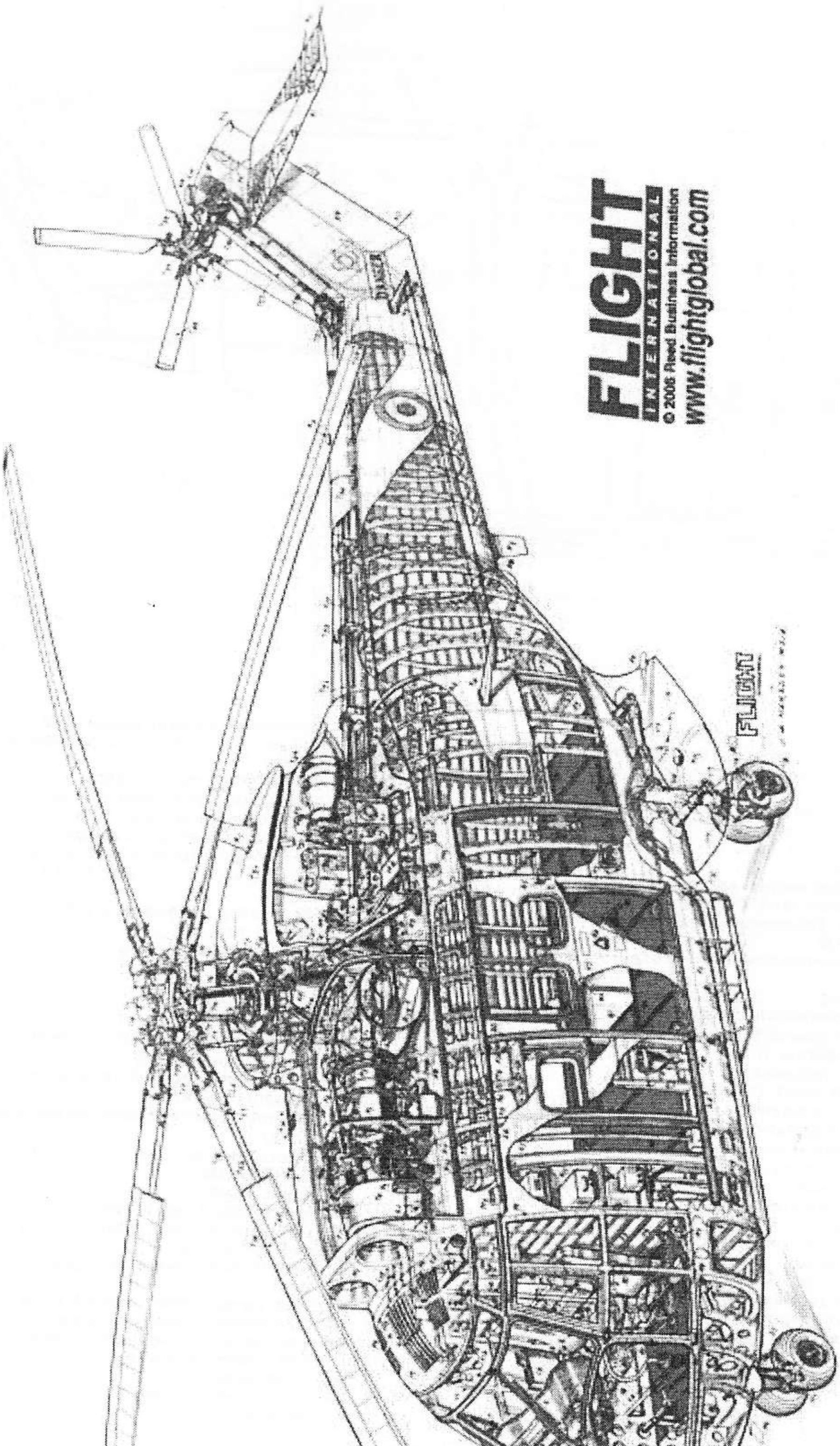
Рис. 16. Main components of an airplane основные элементы самолёта (*вид сбоку, вид спереди*)

1 — **radome** обтекатель (*антенны радиолокатора*); *2* — **canopy transparency** остекление фонаря; *3* — **nose landing gear** передняя опора шасси; *4* — **passenger cabin glazing** остекление пассажирской кабины; *5* — **emergency exit** аварийный выход; *6* — **engine nacelle** гондола двигателя; *7* — **air intake** воздухозаборник; *8* — **fin** киль; *9* — **rudder** руль направления; *10* — **trim(ming) tab** триммер; *11* — **balance tab** сервокомпенсатор; *12* — **tail cone** хвостовой обтекатель; *13* — **main landing gear** основная опора шасси; *14* — **wheelbase** база шасси; *15* — **port-side engine** левый внешний двигатель; *16* — **center engine** средний двигатель; *17* — **starboard engine** правый внешний двигатель; *18* — **main wheel track** колея шасси

Appendix G


Rudder
Change Yaw (side to side)
Elevator
Change Pitch (up and down)
Flaps
Change Lift and Drag
Aileron
Change Roll
Spoiler
Change Lift, Drag and Roll
Slats
Change Lift
Vertical Stabilizer
Control Yaw
Horizontal Stabilizer
Control Pitch
Wing
Generate Lift
Jet Engine
Generate Thrust
Cockpit
Command and Control
Fuselage (Body)
Hold Things Together & Carry Payload

Appendix H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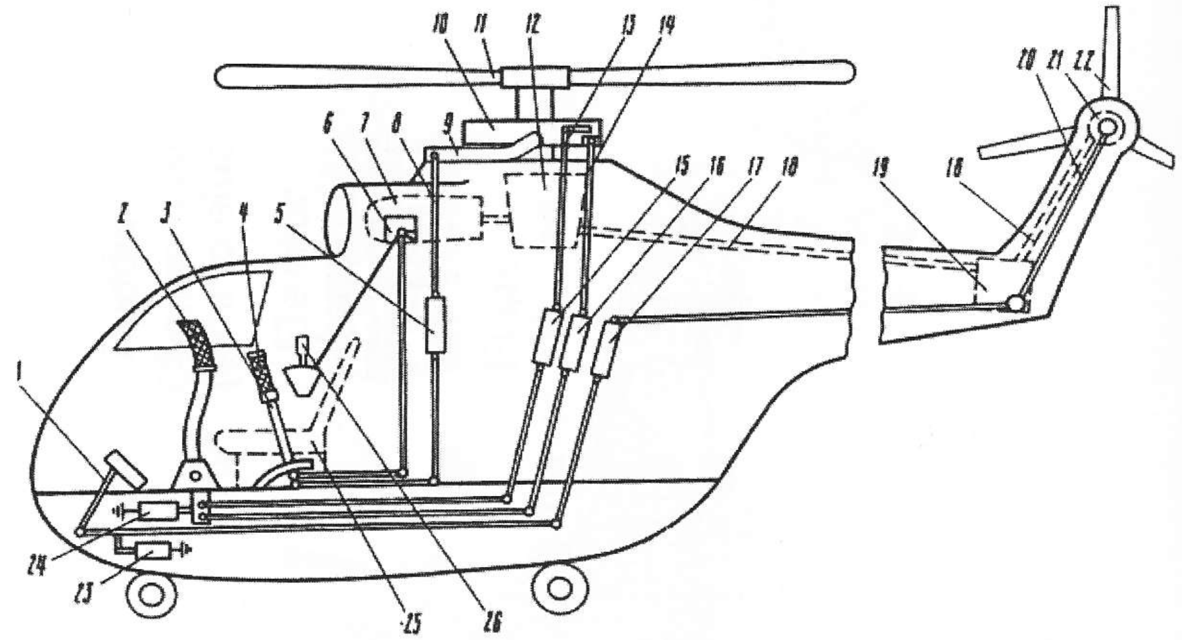
Appendix I



1. Педаль путевого управления (управления хвостовым винтом)
2. Ручка продольно-поперечного управления (управления циклическим шагом Н.В.)
3. Ручка шаг-газ (управления общим шагом Н.В. и газом двигателя)
4. Ручка коррекции газа
5. Гидроусилитель (бустер) системы управления общим шагом Н.В.
6. Командно-топливный агрегат (КТА)
7. Двигатель
8. Тяга управления общим шагом Н.В.
9. Качалка (рычаг) управления общим шагом Н.В.
10. Автомат перекоса
11. Несущий винт (Н.В.)
12. Главный редуктор
13. Тяга продольного управления
14. Тяга поперечного управления
15. Гидроусилитель продольного управления
16. Гидроусилитель поперечного управления
17. Гидроусилитель путевого управления
18. Вал трансмиссии
19. Промежуточный редуктор
20. Тяга (или трос) путевого управления
21. Хвостовой редуктор
22. Хвостовой винт
23. Триммер (загрузочный механизм путевого управления)
24. Триммер (загрузочный механизм продольно-поперечного управления
25. Сиденье летчика
26. Рычаг раздельного управления газом двигателя

1 Directional control pedal; anti-torque /tail; rudder/ rotor control pedal
2. Cyclic pitch control stick
3. Collective pitch control lever
4. Throttle control twist grip
5. Main rotor collective pitch control (hydraulic) actuator /jack/
6. Fuel (flow) control unit (FCU)
7. Engine
8. Main rotor collective pitch control rod
9. Main rotor collective pitch control arm
10. Swash plate
11. Main rotor
12. Main gear box
13. Longitudinal /fore-aft/ control rod
14. Lateral control rod
15 Longitudinal control (hydraulic) actuator /jack/
16. Lateral control (hydraulic) actuator /jack/
17 Directional control (hydraulic) actuator /jack/
18. Drive shaft
19. Intermediate gear box
20. Anti-torque /tail/ rotor control rod /or cable/
21. Anti-torque /tail/ rotor gear box
22. Anti-torque /tail; rudder/ rotor
23. Directional trimming actuatqr
24. Lateral and longitudinal (fore-aft) trimming actuator
25. Pilot seat
26. (Separate) Engine throttle control lever

Swashplate	Автомат перекоса
Cowling	Обтекатель двигателя
Rotor Mast	Колонка несущего винта
Transmission	Трансмиссия
Greenhouse window	Форточка фонаря кабины экипажа
Crosstube	Перемычка полозьев
Motor mount	Подвеска двигателя
Tailboom	Лонжерон хвостовой фермы, хвостовая балка
Driveshaft	Вал трансмиссии
Controls	Управляющие элемены
Collective	Ручка «шаг-газ»
Gearbox	Редуктор, коробка приводов двигателя
Hover	Зависать
Throttle control twist grip	Ручка коррекции газа
Blade Grip	Механизм захвата лопасти
Main Rotor Hub	Втулка несущого винта
Pitch change horn	Роговой компенсатор тангажа
Retention bolt	Крепежные болты
Trunion	Цапфа
Jesus nut	Контрагайка
Cyclic	Ручка продольно-поперечного управления