

The background of the cover features a collage of aviation-related images. At the top left is a circular altimeter with a scale from 0 to 10,000 feet and a reading of 10,130. Below it is a barometer. In the center, a complex mechanical linkage system is shown. At the bottom, a helicopter is depicted in flight over a runway at night, with its landing lights illuminated. To the right of the helicopter, there are various mechanical components, including a piston and a valve.

Aviation Maintenance Technician Handbook – Airframe



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Aviation Maintenance Technician Handbook—Airframe

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Preface

The Aviation Maintenance Technician Handbook—Airframe (FAA-H-8083-31B) is one of a series of three handbooks for persons preparing for certification as an airframe or powerplant mechanic. This handbook provides basic information on principles, fundamentals, and technical procedures in the subject matter areas relating to the airframe rating. It is designed to aid students enrolled in a formal course of instruction, as well as the individual who is studying on their own. Since the knowledge requirements for the airframe and powerplant ratings closely parallel each other in some subject areas, the chapters which discuss fire protection systems and electrical systems contain some material which is also duplicated in the Aviation Maintenance Technician Handbook—Powerplant (FAA-H-8083-32B).

This handbook contains information on airframe construction features, assembly and rigging, fabric covering, structural repairs, and aircraft welding. The handbook also contains an explanation of the units that make up the various airframe systems. Because there are so many different types of aircraft in use today, it is reasonable to expect that differences exist in airframe components and systems. To avoid undue repetition, the practice of using representative systems and units is carried out throughout the handbook. Subject matter treatment is from a generalized point of view and should be supplemented by reference to manufacturers' manuals or other textbooks if more detail is desired. This handbook is not intended to replace, substitute for, or supersede official regulations or manufacturers' instructions. Occasionally the word "must" or similar language is used where the desired action is deemed critical. The use of such language is not intended to add to, interpret, or relieve a duty imposed by Title 14 of the Code of Federal Regulations (14 CFR).

The subject of Human Factors is contained in the Aviation Maintenance Technician Handbook—General (FAA-H-8083-30) (as revised).

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Chapter 1

Aircraft Structures

A Brief History of Aircraft Structures

The history of aircraft structures underlies the history of aviation in general. Advances in materials and processes used to construct aircraft have led to their evolution from simple wood truss structures to the sleek aerodynamic flying machines of today. Combined with continuous powerplant development, the structures of “flying machines” have changed significantly.

The key discovery that “lift” could be created by passing air over the top of a curved surface set the development of fixed and rotary-wing aircraft in motion. George Cayley

developed an efficient cambered airfoil in the early 1800s, as well as successful manned gliders later in that century. He established the principles of flight, including the existence of lift, weight, thrust, and drag. It was Cayley who first stacked wings and created a tri-wing glider that flew a man in 1853.

Earlier, Cayley studied the center of gravity of flying machines, as well as the effects of wing dihedral. Furthermore, he pioneered directional control of aircraft by including the earliest form of a rudder on his gliders. [Figure 1-1]

In the late 1800s, Otto Lilienthal built upon Cayley’s discoveries. He manufactured and flew his own gliders on over 2,000 flights. His willow and cloth aircraft had wings designed from extensive study of the wings of birds. Lilienthal also made standard use of vertical and horizontal fins behind the wings and pilot station. Above all, Lilienthal proved that man could fly. [Figure 1-2]

Octave Chanute, a retired railroad and bridge engineer, was active in aviation during the 1890s. [Figure 1-3] His interest was so great that, among other things, he published a definitive work called “Progress in Flying Machines.” This was the culmination of his effort to gather and study all of the information available on aviation. With the assistance of others, he built gliders similar to Lilienthal’s and then his own. In addition to his publication, Chanute advanced aircraft structure development by building a glider with stacked wings incorporating the use of wires as wing supports.

The work of all of these men was known to the Wright Brothers when they built their successful, powered airplane in 1903. The first of its kind to carry a man aloft, the Wright Flyer had thin, cloth-covered wings attached to what was primarily truss structures made of wood. The wings contained forward and rear spars and were supported with both struts and wires. Stacked wings (two sets) were also part of the Wright Flyer. [Figure 1-4]

Powered heavier-than-air aviation grew from the Wright design. Inventors and fledgling aviators began building their own aircraft. Early on, many were similar to that constructed by the Wrights using wood and fabric with wires and struts to support the wing structure. In 1909, Frenchman Louis Bleriot produced an aircraft with notable design differences. He built a successful mono-wing aircraft. The wings were still supported by wires, but a mast extending above the

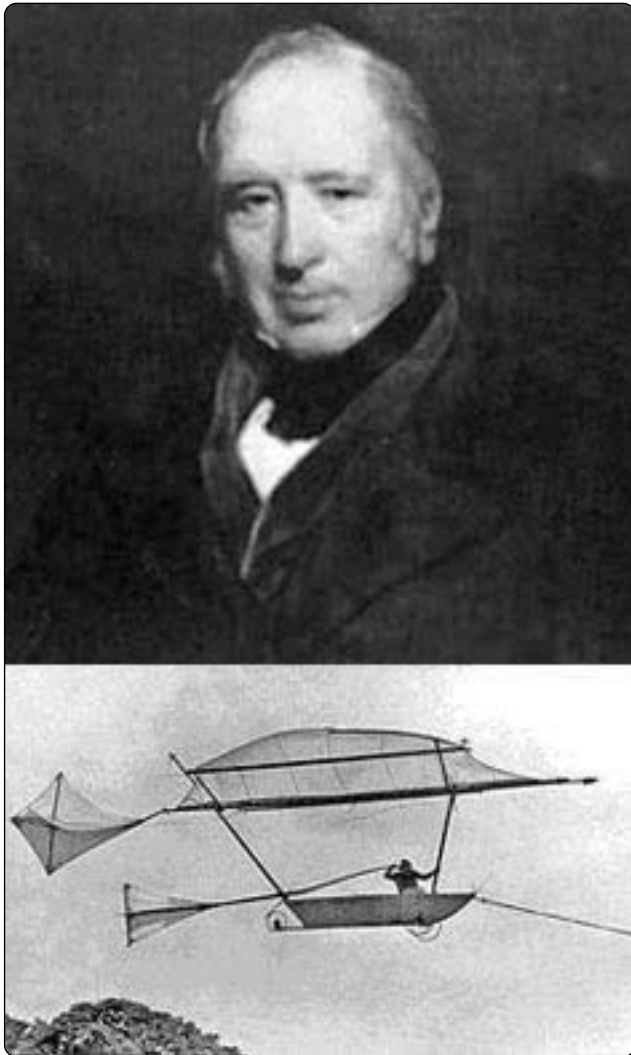


Figure 1-1. George Cayley, the father of aeronautics (top) and a flying replica of his 1853 glider (bottom).



Figure 1-2. Master of gliding and wing study, Otto Lilienthal (top) and one of his more than 2,000 glider flights (bottom).

fuselage enabled the wings to be supported from above, as well as underneath. This made possible the extended wing length needed to lift an aircraft with a single set of wings. Bleriot used a Pratt truss-type fuselage frame. [Figure 1-5]

More powerful engines were developed, and airframe structures changed to take advantage of the benefits. As early as 1910, German Hugo Junkers was able to build an aircraft with metal truss construction and metal skin due to the availability of stronger powerplants to thrust the plane forward and into the sky. The use of metal instead of wood for the primary structure eliminated the need for external wing braces and wires. His J-1 also had a single set of wings (a monoplane) instead of a stacked set. [Figure 1-6]



Figure 1-3. Octave Chanute gathered and published all of the aeronautical knowledge known to date in the late 1890s. Many early aviators benefited from this knowledge.



Figure 1-4. The Wright Flyer was the first successful powered aircraft. It was made primarily of wood and fabric.



Figure 1-5. The world's first mono-wing by Louis Bleriot.

Leading up to World War I (WWI), stronger engines also allowed designers to develop thicker wings with stronger spars. Wire wing bracing was no longer needed. Flatter, lower wing surfaces on high-camber wings created more lift. WWI expanded the need for large quantities of reliable aircraft. Used mostly for reconnaissance, stacked-wing tail draggers



Figure 1-6. *The Junker J-1 all metal construction in 1910.*

with wood and metal truss frames with mostly fabric skin dominated the wartime sky. [Figure 1-7] The Red Baron's Fokker DR-1 was typical.

In the 1920s, the use of metal in aircraft construction increased. Fuselages able to carry cargo and passengers were developed. The early flying boats with their hull-type construction from the shipbuilding industry provided the blueprints for semimonocoque construction of fuselages. [Figure 1-8] Truss-type designs faded. A tendency toward cleaner mono-wing designs prevailed.

Into the 1930s, all-metal aircraft accompanied new lighter and more powerful engines. Larger semimonocoque fuselages were complimented with stress-skin wing designs. Fewer truss and fabric aircraft were built. World War II (WWII) brought about a myriad of aircraft designs using all metal technology. Deep fuel-carrying wings were the norm, but the desire for higher flight speeds prompted the development of thin-winged aircraft in which fuel was carried in the fuselage. The first composite structure aircraft, the De Havilland Mosquito, used a balsa wood sandwich material in the construction of the fuselage. [Figure 1-9] The fiberglass radome was also developed during this period.

After WWII, the development of turbine engines led to higher altitude flight. The need for pressurized aircraft pervaded aviation. Semimonocoque construction needed to be made even stronger as a result. Refinements to the



Figure 1-7. *World War I aircraft were typically stacked-wing fabric-covered aircraft like this Breguet 14 (circa 1917).*

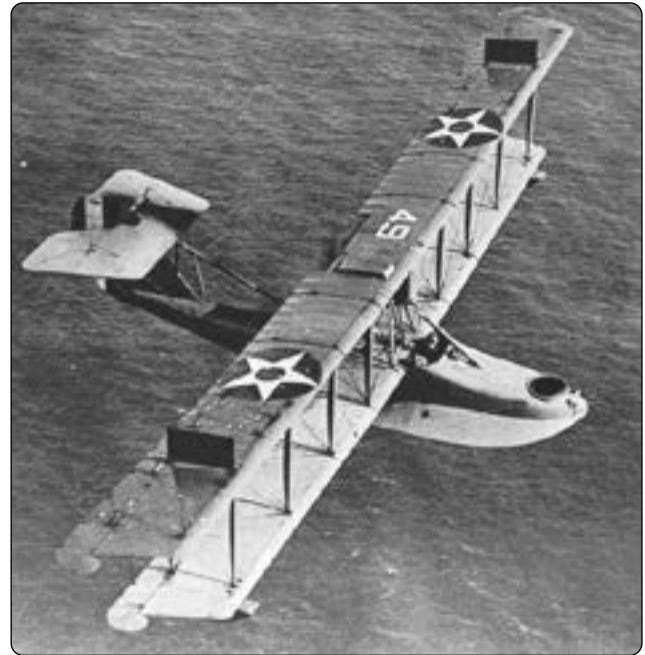


Figure 1-8. *The flying boat hull was an early semimonocoque design like this Curtiss HS-2L.*

all-metal semimonocoque fuselage structure were made to increase strength and combat metal fatigue caused by the pressurization-depressurization cycle. Rounded window and door openings were developed to avoid weak areas where cracks could form. Integrally machined copper alloy aluminum skin resisted cracking and allowed thicker skin and controlled tapering. Chemical milling of wing skin structures provided great strength and smooth high-performance surfaces. Variable contour wings became easier to construct. Increases in flight speed accompanying jet travel brought about the need for thinner wings. Wing loading also increased greatly. Multispar and box beam wing designs were developed in response.

In the 1960s, ever larger aircraft were developed to carry passengers. As engine technology improved, the jumbo jet was engineered and built. Still primarily aluminum with a



Figure 1-9. The De Havilland Mosquito used a laminated wood construction with a balsa wood core in the fuselage.

semimonocoque fuselage, the sheer size of the airliners of the day initiated a search for lighter and stronger materials from which to build them. The use of honeycomb constructed panels in Boeing's airline series saved weight while not compromising strength. Initially, aluminum core with aluminum or fiberglass skin sandwich panels were used on wing panels, flight control surfaces, cabin floor boards, and other applications.

A steady increase in the use of honeycomb and foam core sandwich components and a wide variety of composite materials characterizes the state of aviation structures from the 1970s to the present. Advanced techniques and material combinations have resulted in a gradual shift from aluminum to carbon fiber and other strong, lightweight materials. These new materials are engineered to meet specific performance requirements for various components on the aircraft. Many airframe structures are made of more than 50 percent advanced composites, with some airframes approaching



Figure 1-10. The nearly all composite Cessna Citation Mustang very light jet (VLJ).

100 percent. The term “very light jet” (VLJ) has come to describe a new generation of jet aircraft made almost entirely of advanced composite materials. [Figure 1-10] It is possible that noncomposite aluminum aircraft structures will become obsolete as did the methods and materials of construction used by Cayley, Lilienthal, and the Wright Brothers.

General

An aircraft is a device that is used for, or is intended to be used for, flight in the air. Major categories of aircraft are airplane, rotorcraft, glider, and lighter-than-air vehicles. [Figure 1-11] Each of these may be divided further by major distinguishing features of the aircraft, such as airships and balloons. Both are lighter-than-air aircraft but have differentiating features and are operated differently.

The concentration of this handbook is on the airframe of aircraft; specifically, the fuselage, booms, nacelles, cowlings,



Figure 1-11. Examples of different categories of aircraft, clockwise from top left: lighter-than-air; glider; rotorcraft, and airplane.

fairings, airfoil surfaces, and landing gear. Also included are the various accessories and controls that accompany these structures. Note that the rotors of a helicopter are considered part of the airframe since they are actually rotating wings. By contrast, propellers and rotating airfoils of an engine on an airplane are not considered part of the airframe.

The most common aircraft is the fixed-wing aircraft. As the name implies, the wings on this type of flying machine are attached to the fuselage and are not intended to move independently in a fashion that results in the creation of lift. One, two, or three sets of wings have all been successfully utilized. [Figure 1-12] Rotary-wing aircraft such as helicopters are also widespread. This handbook discusses features and maintenance aspects common to both fixed-wing and rotary-wing categories of aircraft. Also, in certain cases, explanations focus on information specific to only one or the other. Glider airframes are very similar to fixed-wing aircraft. Unless otherwise noted, maintenance practices described for fixed-wing aircraft also apply to gliders. The same is true for lighter-than-air aircraft, although thorough coverage of the unique airframe structures and maintenance practices for lighter-than-air flying machines is not included in this handbook.

The airframe of a fixed-wing aircraft consists of five principal units: the fuselage, wings, stabilizers, flight control surfaces, and landing gear. [Figure 1-13] Helicopter airframes consist of the fuselage, main rotor and related gearbox, tail rotor (on helicopters with a single main rotor), and the landing gear.

Airframe structural components are constructed from a wide variety of materials. The earliest aircraft were constructed primarily of wood. Aircraft structures were later made of steel tubing and are now most commonly made of aluminum. Many newly certified aircraft are built from molded composite materials, such as carbon fiber. Structural members of an aircraft's fuselage include stringers, longerons, ribs, bulkheads, and more. The main structural member in a wing is called the wing spar.

The skin of aircraft can also be made from a variety of materials, ranging from impregnated fabric to plywood, aluminum, or composites. Under the skin and attached to the structural fuselage are the many components that support airframe function. The entire airframe and its components are joined by rivets, bolts, screws, and other fasteners. Welding, adhesives, and special bonding techniques are also used.

Major Structural Stresses

Aircraft structural members are designed to carry a load or to resist stress. In designing an aircraft, every square inch of wing and fuselage, every rib, spar, and even each metal fitting



Figure 1-12. A monoplane (top), biplane (middle), and tri-wing aircraft (bottom).

must be considered in relation to the physical characteristics of the material of which it is made. Every part of the aircraft must be planned to carry the load to be imposed upon it.

A single member of the structure may be subjected to a combination of stresses. In most cases, the structural members are designed to carry end loads rather than side loads: that is, to be subjected to tension or compression rather than bending.

The determination of such loads is called stress analysis. Although planning the design is not the function of the aircraft technician, it is, nevertheless, important that the technician understand and appreciate the stresses involved in order to avoid changes in the original design through improper repairs.

The term “stress” is often used interchangeably with the word “strain.” While related, they are not the same thing. External loads or forces cause stress. Stress is a material’s

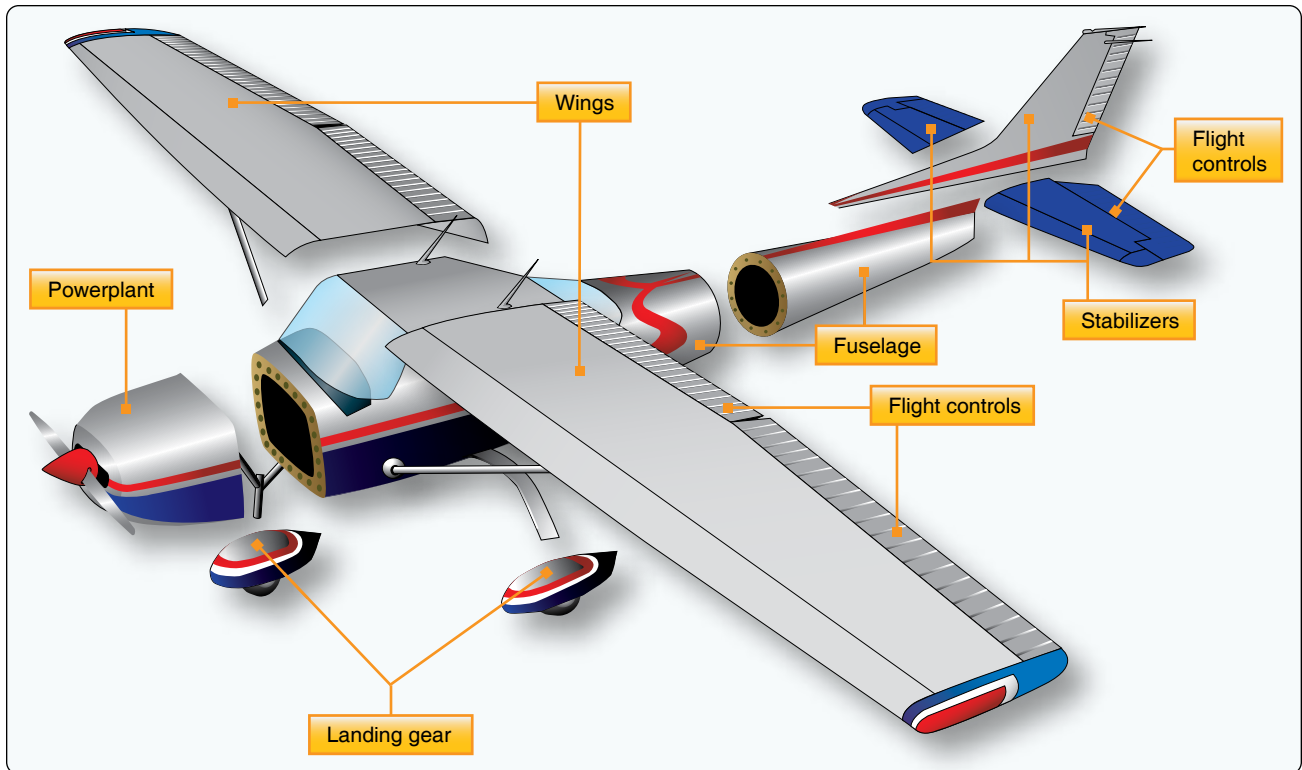


Figure 1-13. *Principal airframe units.*

internal resistance, or counterforce, that opposes deformation. The degree of deformation of a material is strain. When a material is subjected to a load or force, that material is deformed, regardless of how strong the material is or how light the load is.

There are five major stresses [Figure 1-14] to which all aircraft are subjected:

- Tension
- Compression
- Torsion
- Shear
- Bending

Tension is the stress that resists a force that tends to pull something apart. [Figure 1-14A] The engine pulls the aircraft forward, but air resistance tries to hold it back. The result is tension, which stretches the aircraft. The tensile strength of a material is measured in pounds per square inch (psi) and is calculated by dividing the load (in pounds) required to pull the material apart by its cross-sectional area (in square inches).

Compression is the stress that resists a crushing force. [Figure 1-14B] The compressive strength of a material is also measured in psi. Compression is the stress that tends to

shorten or squeeze aircraft parts.

Torsion is the stress that produces twisting. [Figure 1-14C] While moving the aircraft forward, the engine also tends to twist it to one side, but other aircraft components hold it on course. Thus, torsion is created. The torsion strength of a material is its resistance to twisting or torque.

Shear is the stress that resists the force tending to cause one layer of a material to slide over an adjacent layer. [Figure 1-14D] Two riveted plates in tension subject the rivets to a shearing force. Usually, the shearing strength of a material is either equal to or less than its tensile or compressive strength. Aircraft parts, especially screws, bolts, and rivets, are often subject to a shearing force.

Bending stress is a combination of compression and tension. The rod in Figure 1-14E has been shortened (compressed) on the inside of the bend and stretched on the outside of the bend. A single member of the structure may be subjected to a combination of stresses. In most cases, the structural members are designed to carry end loads rather than side loads. They are designed to be subjected to tension or compression rather than bending.

Strength or resistance to the external loads imposed during operation may be the principal requirement in certain

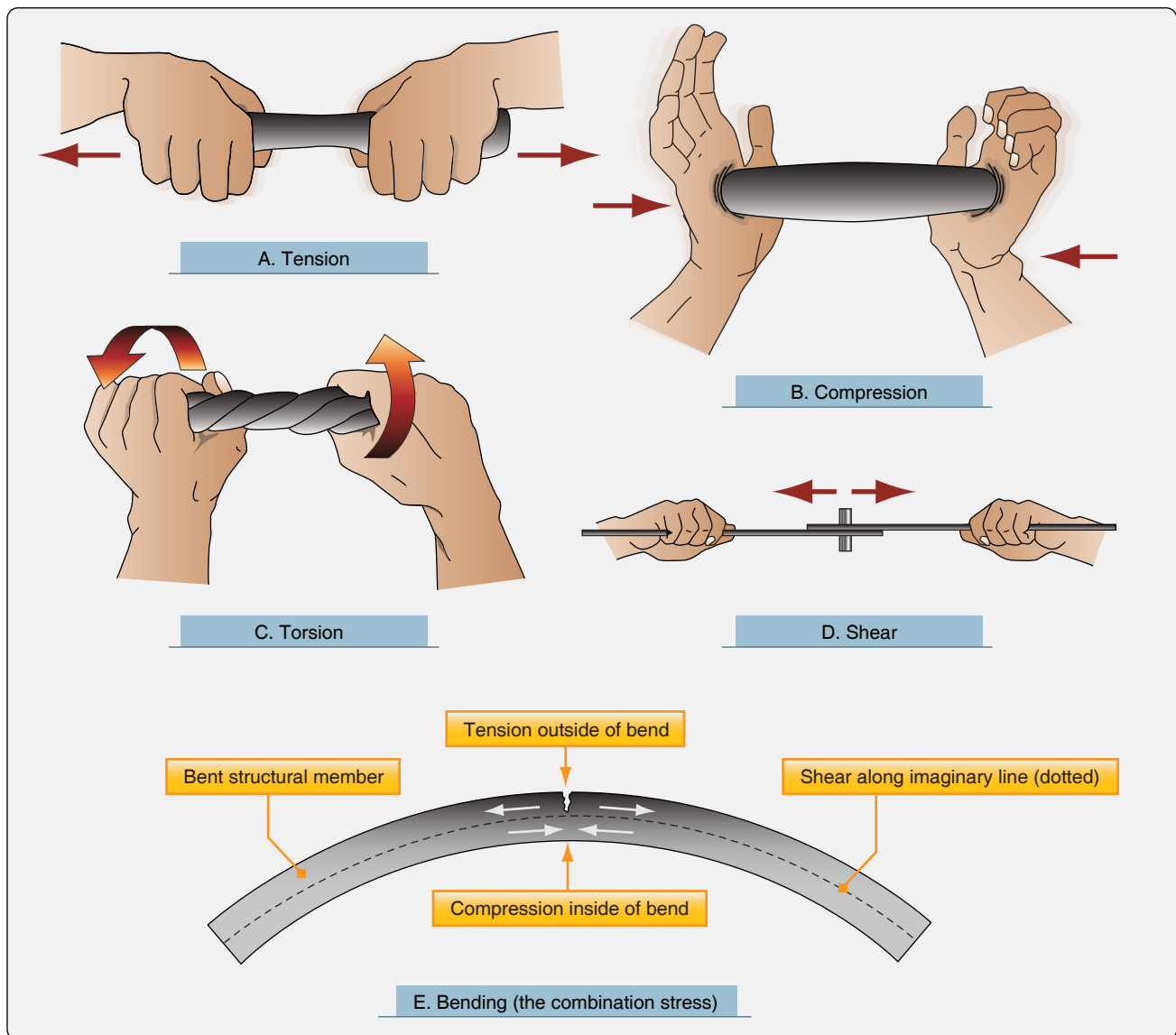


Figure 1-14. *The five stresses that may act on an aircraft and its parts.*

structures. However, there are numerous other characteristics in addition to designing to control the five major stresses that engineers must consider. For example, cowling, fairings, and similar parts may not be subject to significant loads requiring a high degree of strength. However, these parts must have streamlined shapes to meet aerodynamic requirements, such as reducing drag or directing airflow.

Fixed-Wing Aircraft

Fuselage

The fuselage is the main structure or body of the fixed-wing aircraft. It provides space for cargo, controls, accessories, passengers, and other equipment. In single-engine aircraft, the fuselage houses the powerplant. In multiengine aircraft, the engines may be either in the fuselage, attached to the fuselage, or suspended from the wing structure. There are two

general types of fuselage construction: truss and monocoque.

Truss-Type

A truss is a rigid framework made up of members, such as beams, struts, and bars to resist deformation by applied loads. The truss-framed fuselage is generally covered with fabric. The truss-type fuselage frame is usually constructed of steel tubing welded together in such a manner that all members of the truss can carry both tension and compression loads. [Figure 1-15] In some aircraft, principally the light, single-engine models, truss fuselage frames may be constructed of aluminum alloy and may be riveted or bolted into one piece, with cross-bracing achieved by using solid rods or tubes.

Monocoque Type

The monocoque (single shell) fuselage relies largely on the

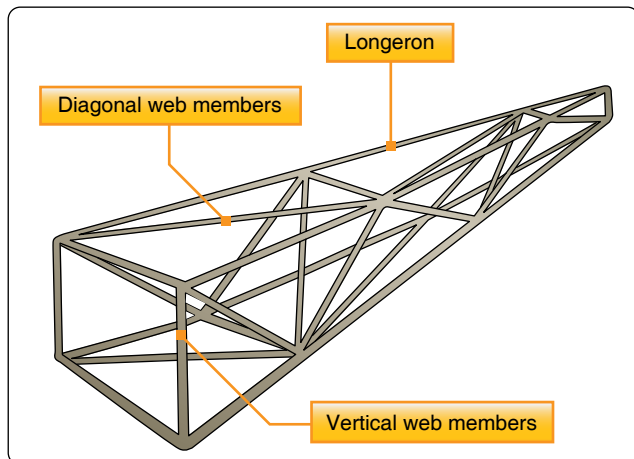


Figure 1-15. A truss-type fuselage. A Warren truss uses mostly diagonal bracing.

strength of the skin or covering to carry the primary loads. The design may be divided into three classes:

1. Monocoque
2. Semimonocoque
3. Reinforced shell

Different portions of the same fuselage may belong to either of the three classes, but most modern aircraft are considered to be of semimonocoque type construction.

The true monocoque construction uses formers, frame assemblies, and bulkheads to give shape to the fuselage. [Figure 1-16] The heaviest of these structural members are located at intervals to carry concentrated loads and at points where fittings are used to attach other units such as wings, powerplants, and stabilizers. Since no other bracing members are present, the skin must carry the primary stresses and keep the fuselage rigid. Thus, the biggest problem involved in monocoque construction is maintaining enough strength while keeping the weight within allowable limits.

Semimonocoque Type

To overcome the strength/weight problem of monocoque construction, a modification called semimonocoque construction was developed. It also consists of frame assemblies, bulkheads, and formers as used in the monocoque design but, additionally, the skin is reinforced by longitudinal members called longerons. Longerons usually extend across several frame members and help the skin support primary bending loads. They are typically made of aluminum alloy either of a single piece or a built-up construction. The longerons are supplemented by other longitudinal members called stringers.

Stringers are typically more numerous and lighter in weight

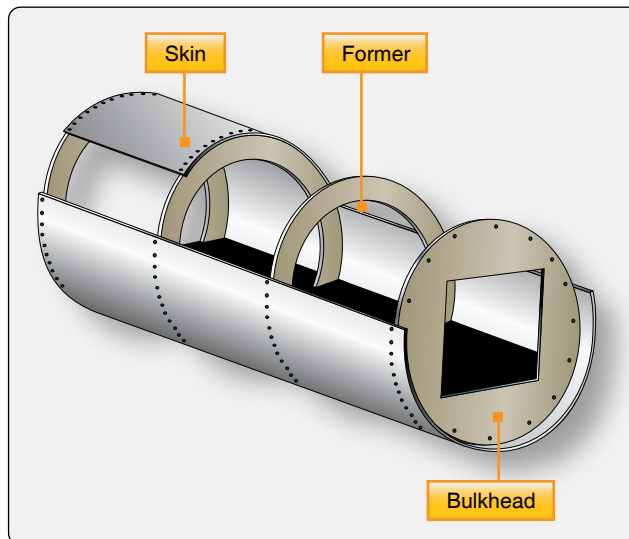


Figure 1-16. An airframe using monocoque construction.

than the longerons. They come in a variety of shapes and are usually made from single piece aluminum alloy extrusions or formed aluminum. Stringers have some rigidity but are chiefly used for giving shape and for attachment of the skin. Stringers and longerons together prevent tension and compression from bending the fuselage. [Figure 1-17]

Other bracing between the longerons and stringers can also be used. Often referred to as web members, these additional support pieces may be installed vertically or diagonally. It must be noted that manufacturers use different nomenclature to describe structural members. For example, there is often little difference between some rings, frames, and formers. One manufacturer may call the same type of brace a ring or

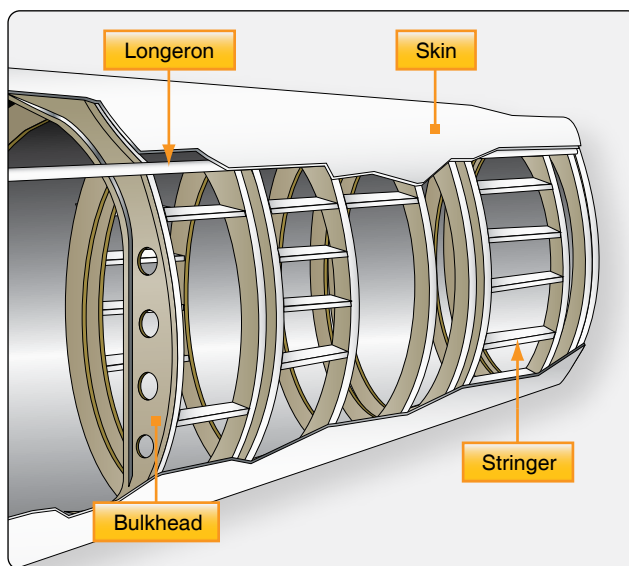


Figure 1-17. The most common airframe construction is semimonocoque.

a frame. Manufacturer instructions and specifications for a specific aircraft are the best guides.

The semimonocoque fuselage is constructed primarily of alloys of aluminum and magnesium, although steel and titanium are sometimes found in areas of high temperatures. Individually, not one of the aforementioned components is strong enough to carry the loads imposed during flight and landing. But, when combined, those components form a strong, rigid framework. This is accomplished with gussets, rivets, nuts and bolts, screws, and even friction stir welding. A gusset is a type of connection bracket that adds strength. [Figure 1-18]

To summarize, in semimonocoque fuselages, the strong, heavy longerons hold the bulkheads and formers, and these, in turn, hold the stringers, braces, web members, etc. All are designed to be attached together and to the skin to achieve the full-strength benefits of semimonocoque design. It is important to recognize that the metal skin or covering carries part of the load. The fuselage skin thickness can vary with the load carried and the stresses sustained at a particular location.

The advantages of the semimonocoque fuselage are many. The bulkheads, frames, stringers, and longerons facilitate the design and construction of a streamlined fuselage that is both rigid and strong. Spreading loads among these structures and the skin means no single piece is failure critical. This means that a semimonocoque fuselage, because of its stressed-skin construction, may withstand considerable damage and still be strong enough to hold together.

Fuselages are generally constructed in two or more sections. On small aircraft, they are generally made in two or three sections, while larger aircraft may be made up of as many as six sections or more before being assembled.



Figure 1-18. Gussets are used to increase strength.

Reinforced Shell Type

The reinforced shell has the skin reinforced by a complete framework of structural members.

Pressurization

Many aircraft are pressurized. This means that air is pumped into the cabin after takeoff and a difference in pressure between the air inside the cabin and the air outside the cabin is established. This differential is regulated and maintained. In this manner, enough oxygen is made available for passengers to breathe normally and move around the cabin without special equipment at high altitudes.

Pressurization causes significant stress on the fuselage structure and adds to the complexity of design. In addition to withstanding the difference in pressure between the air inside and outside the cabin, cycling from unpressurized to pressurized and back again on each flight causes metal fatigue. To deal with these impacts and the other stresses of flight, nearly all pressurized aircraft are semimonocoque in design. Pressurized fuselage structures undergo extensive periodic inspections to ensure that any damage is discovered and repaired. Repeated weakness or failure in an area of structure may require that section of the fuselage be modified or redesigned.

Wings

Wing Configurations

Wings are airfoils that, when moved rapidly through the air, create lift. They are built in many shapes and sizes. Wing design can vary to provide certain desirable flight characteristics. Control at various operating speeds, the amount of lift generated, balance, and stability all change as the shape of the wing is altered. Both the leading edge and the trailing edge of the wing may be straight or curved, or one edge may be straight and the other curved. One or both edges may be tapered so that the wing is narrower at the tip than at the root where it joins the fuselage. The wing tip may be square, rounded, or even pointed. *Figure 1-19* shows a number of typical wing leading and trailing edge shapes.

The wings of an aircraft can be attached to the fuselage at the top, mid-fuselage, or at the bottom. They may extend perpendicular to the horizontal plane of the fuselage or can angle up or down slightly. This angle is known as the wing dihedral. The dihedral angle affects the lateral stability of the aircraft. *Figure 1-20* shows some common wing attach points and dihedral angle.

Wing Structure

The wings of an aircraft are designed to lift it into the air. Their particular design for any given aircraft depends on a number of factors, such as size, weight, use of the aircraft,

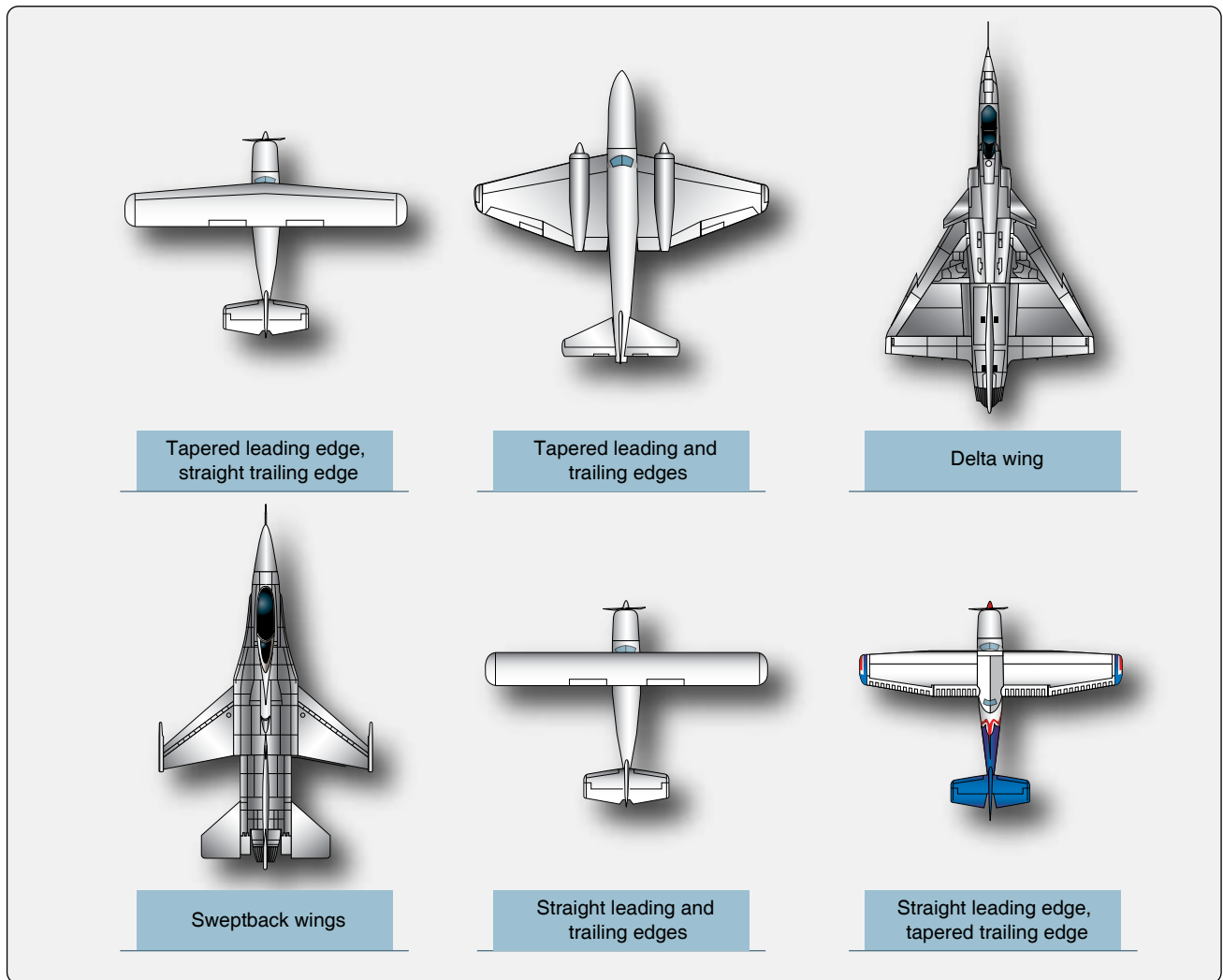


Figure 1-19. Various wing design shapes yield different performance.

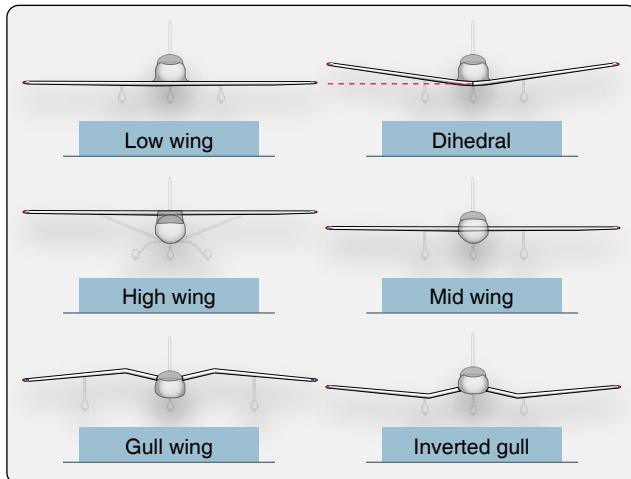


Figure 1-20. Wing attach points and wing dihedrals.

desired speed in flight and at landing, and desired rate of climb. The wings of aircraft are designated left and right, corresponding to the left and right sides of the operator when seated in the flight deck. [Figure 1-21]

Often wings are of full cantilever design. This means they are built so that no external bracing is needed. They are supported internally by structural members assisted by the skin of the aircraft. Other aircraft wings use external struts or wires to assist in supporting the wing and carrying the aerodynamic and landing loads. Wing support cables and struts are generally made from steel. Many struts and their attach fittings have fairings to reduce drag. Short, nearly vertical supports called jury struts are found on struts that attach to the wings a great distance from the fuselage. This serves to subdue strut movement and oscillation caused by the air flowing around the strut in flight. Figure 1-22 shows samples of wings using external bracing, also known as semicantilever wings. Cantilever wings built with no external

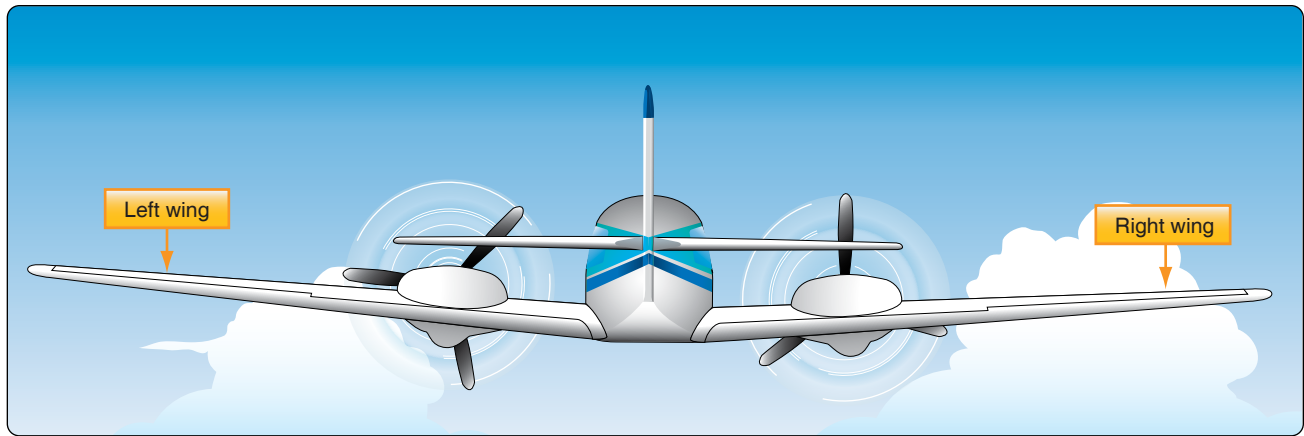


Figure 1-21. “Left” and “right” on an aircraft are oriented to the perspective of a pilot sitting in the flight deck.

bracing are also shown.

Aluminum is the most common material from which to construct wings, but they can be wood covered with fabric, and occasionally a magnesium alloy has been used. Moreover, modern aircraft are tending toward lighter and stronger materials throughout the airframe and in wing construction. Wings made entirely of carbon fiber or other composite materials exist, as well as wings made of a combination of materials for maximum strength to weight performance.

The internal structures of most wings are made up of spars and stringers running spanwise and ribs and formers or bulkheads running chordwise (leading edge to trailing edge). The spars are the principle structural members of a wing. They support all distributed loads, as well as concentrated weights such as the fuselage, landing gear, and engines. The skin, which is attached to the wing structure, carries part of the loads imposed during flight. It also transfers the stresses to the wing ribs. The ribs, in turn, transfer the loads to the wing spars. [Figure 1-23]

In general, wing construction is based on one of three fundamental designs:

1. Monospar
2. Multispar
3. Box beam

Modification of these basic designs may be adopted by various manufacturers.

The monospar wing incorporates only one main spanwise or longitudinal member in its construction. Ribs or bulkheads supply the necessary contour or shape to the airfoil. Although the strict monospar wing is not common, this type of design modified by the addition of false spars or light shear webs along the trailing edge for support of control surfaces is sometimes used.

The multispar wing incorporates more than one main longitudinal member in its construction. To give the wing contour, ribs or bulkheads are often included.

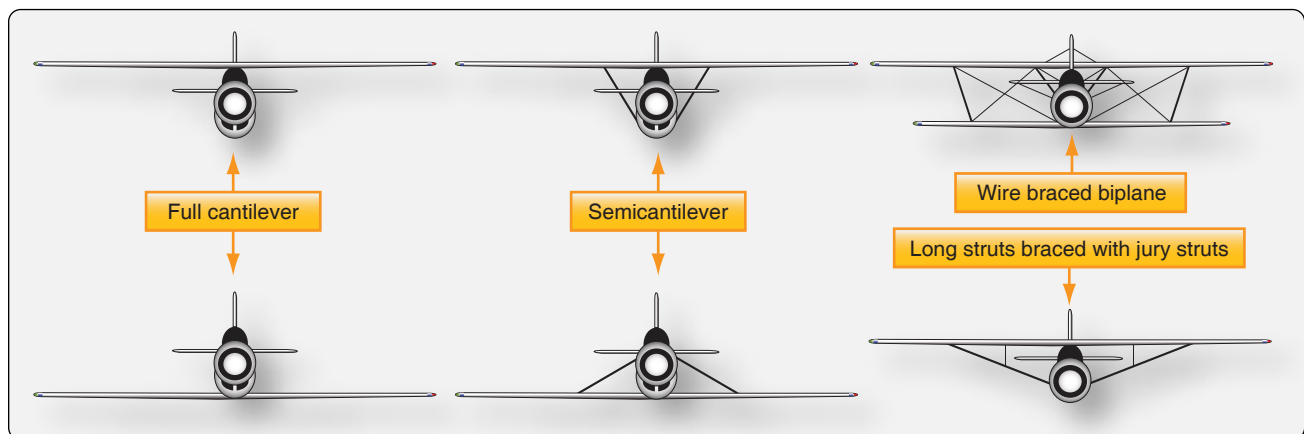


Figure 1-22. Externally braced wings, also called semicantilever wings, have wires or struts to support the wing. Full cantilever wings have no external bracing and are supported internally.

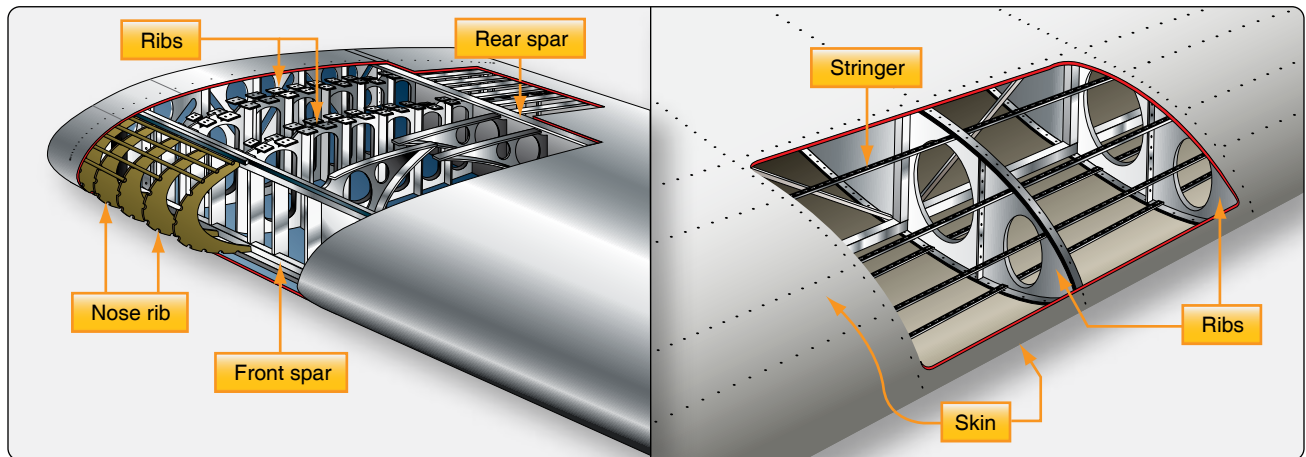


Figure 1-23. *Wing structure nomenclature.*

The box beam type of wing construction uses two main longitudinal members with connecting bulkheads to furnish additional strength and to give contour to the wing. [Figure 1-24] A corrugated sheet may be placed between the bulkheads and the smooth outer skin so that the wing can better carry tension and compression loads. In some cases, heavy longitudinal stiffeners are substituted for the upper surface of the wing and stiffeners on the lower surface corrugated sheets. A combination of corrugated sheets on the upper surface of the wing and stiffeners on the lower surface is sometimes used. Air transport category aircraft often utilize box beam wing construction.

Wing Spars

Spars are the principal structural members of the wing. They correspond to the longerons of the fuselage. They run parallel to the lateral axis of the aircraft, from the fuselage toward the tip of the wing, and are usually attached to the fuselage by wing fittings, plain beams, or a truss.

Spars may be made of metal, wood, or composite materials depending on the design criteria of a specific aircraft. Wooden spars are usually made from spruce. They can be generally classified into four different types by their cross-sectional configuration. As shown in Figure 1-25, they may be (A) solid, (B) box-shaped, (C) partly hollow, or (D) in the form of an I-beam. Lamination of solid wood spars is often used to increase strength. Laminated wood can also be found in box-shaped spars. The spar in Figure 1-25E has had material removed to reduce weight but retains the strength of a rectangular spar. As can be seen, most wing spars are basically rectangular in shape with the long dimension of the cross-section oriented up and down in the wing.

Currently, most manufactured aircraft have wing spars made of solid extruded aluminum or aluminum extrusions riveted together to form the spar. The increased use of

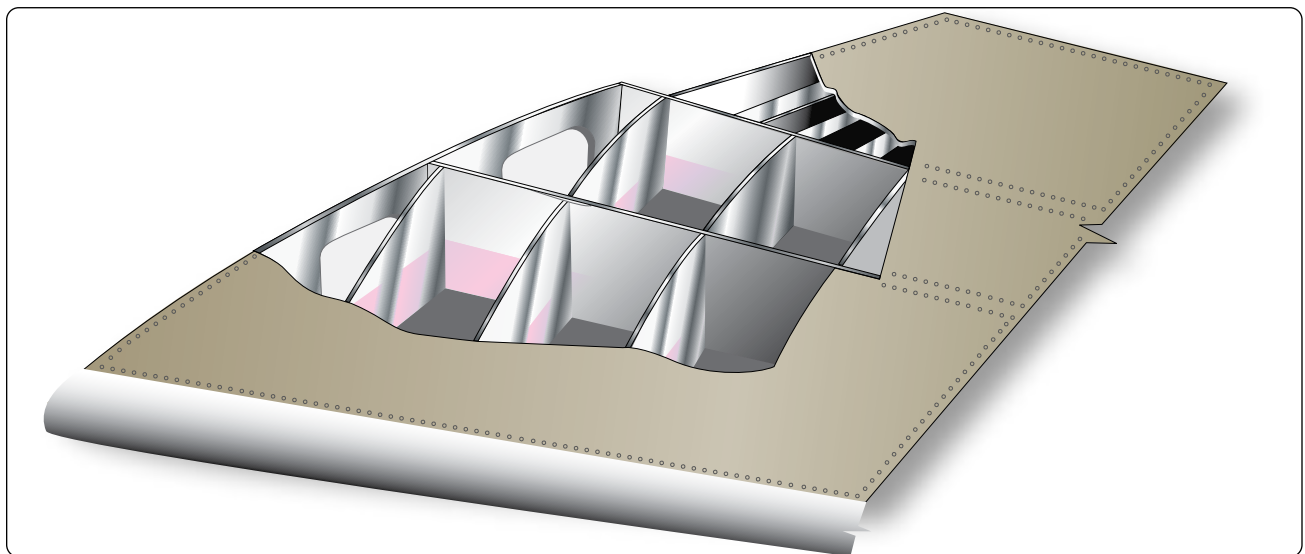


Figure 1-24. *Box beam construction.*

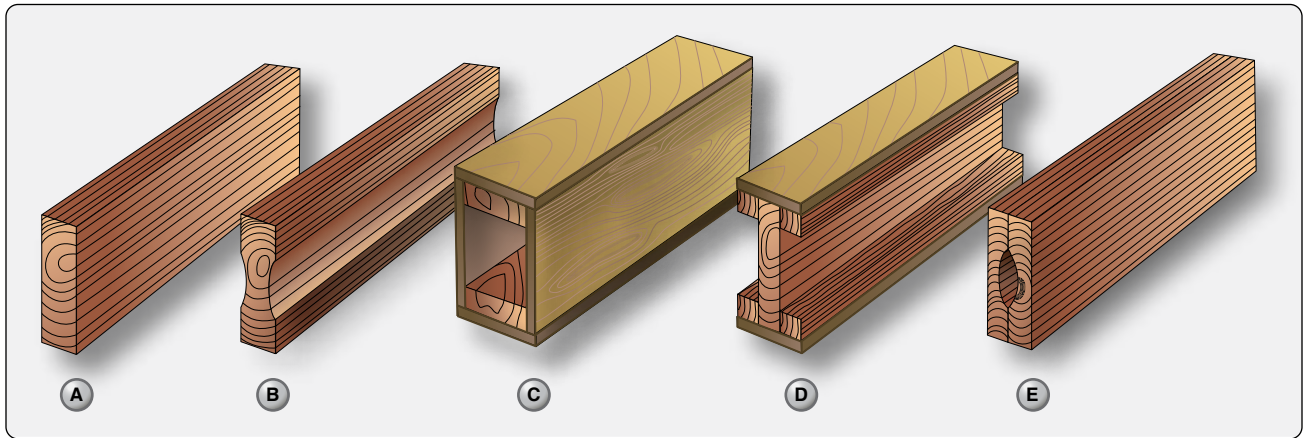


Figure 1-25. Typical wooden wing spar cross-sections.

composites and the combining of materials should make airmen vigilant for wings spars made from a variety of materials. *Figure 1-26* shows examples of metal wing spar cross-sections.

In an I-beam spar, the top and bottom of the I-beam are called the caps and the vertical section is called the web. The entire spar can be extruded from one piece of metal but often it is built up from multiple extrusions or formed angles. The web forms the principal depth portion of the spar and the cap strips (extrusions, formed angles, or milled sections) are attached to it. Together, these members carry the loads caused by wing bending, with the caps providing a foundation for attaching the skin. Although the spar shapes in *Figure 1-26* are typical, actual wing spar configurations assume many forms. For example, the web of a spar may be a plate or a truss as shown in *Figure 1-27*. It could be built up from lightweight materials with vertical stiffeners employed for strength. [*Figure 1-28*]

It could also have no stiffeners but might contain flanged holes for reducing weight while maintaining strength. Some metal and composite wing spars retain the I-beam concept

but use a sine wave web. [*Figure 1-29*]

Additionally, fail-safe spar web design exists. Fail-safe means that should one member of a complex structure fail, some other part of the structure assumes the load of the failed member and permits continued operation. A spar with fail-safe construction is shown in *Figure 1-30*. This spar is made in two sections. The top section consists of a cap riveted to the upper web plate. The lower section is a single extrusion consisting of the lower cap and web plate. These two sections are spliced together to form the spar. If either section of this type of spar breaks, the other section can still carry the load. This is the fail-safe feature.

As a rule, a wing has two spars. One spar is usually located near the front of the wing, and the other about two-thirds of the distance toward the wing's trailing edge. Regardless of type, the spar is the most important part of the wing. When other structural members of the wing are placed under load, most of the resulting stress is passed on to the wing spar.

False spars are commonly used in wing design. They are longitudinal members like spars but do not extend the entire spanwise length of the wing. Often, they are used as hinge

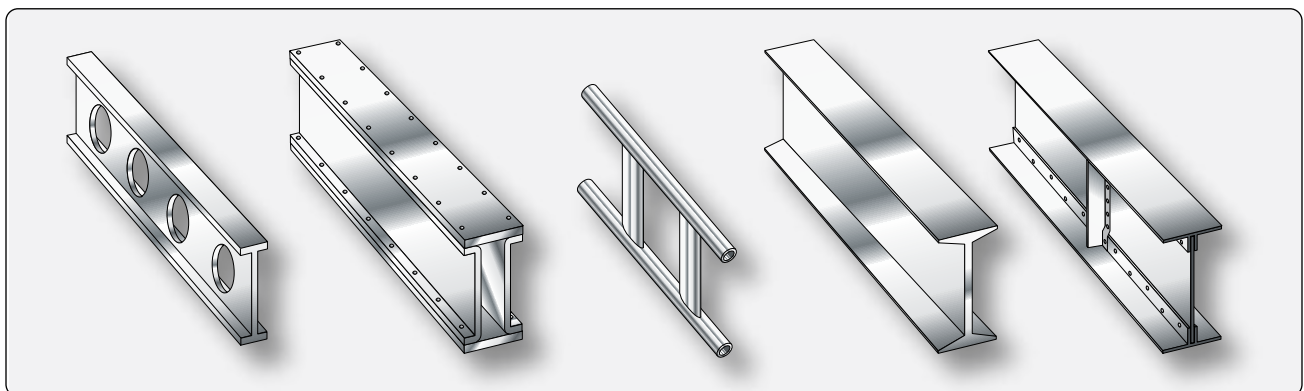


Figure 1-26. Examples of metal wing spar shapes.

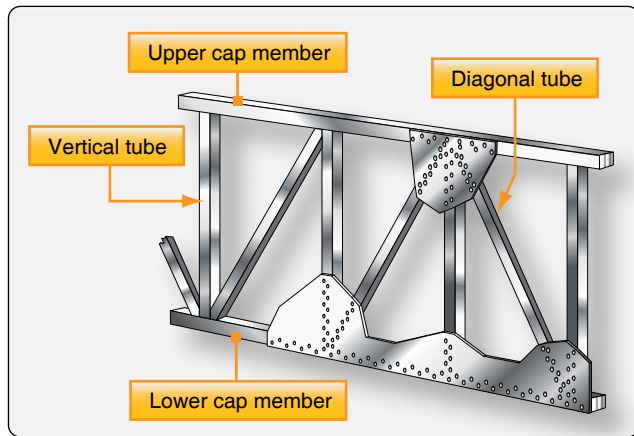


Figure 1-27. A truss wing spar.

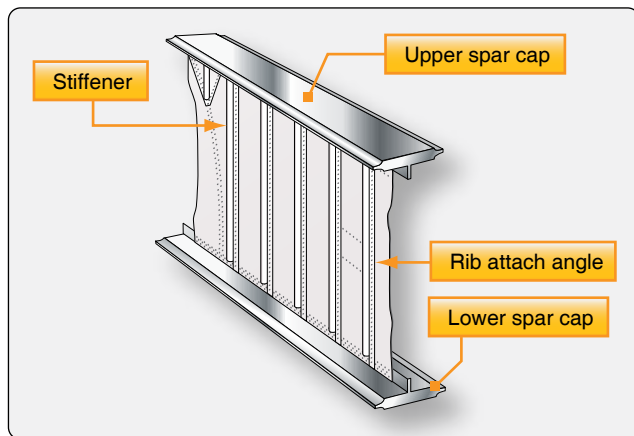


Figure 1-28. A plate web wing spar with vertical stiffeners.

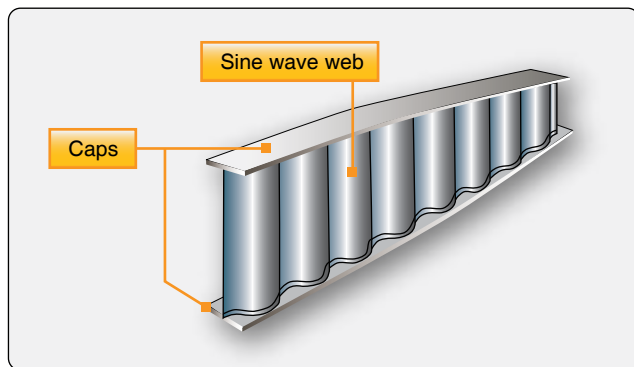


Figure 1-29. A sine wave wing spar can be made from aluminum or composite materials.

attach points for control surfaces, such as an aileron spar.

Wing Ribs

Ribs are the structural crosspieces that combine with spars and stringers to make up the framework of the wing. They usually extend from the wing leading edge to the rear spar or to the trailing edge of the wing. The ribs give the wing its cambered shape and transmit the load from the skin and stringers to the spars. Similar ribs are also used in ailerons,

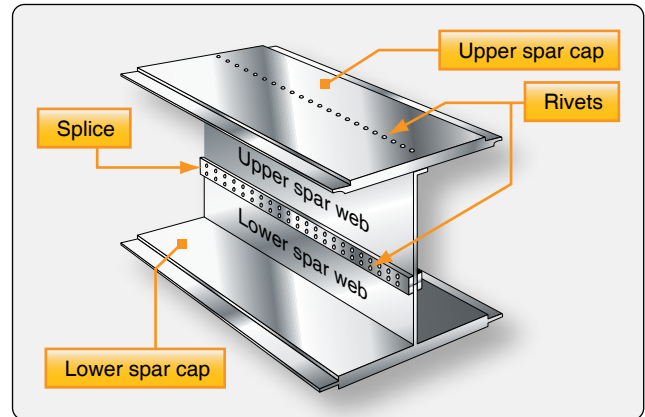


Figure 1-30. A fail-safe spar with a riveted spar web.

elevators, rudders, and stabilizers.

Wing ribs are usually manufactured from either wood or metal. Aircraft with wood wing spars may have wood or metal ribs while most aircraft with metal spars have metal ribs. Wood ribs are usually manufactured from spruce. The three most common types of wooden ribs are the plywood web, the lightened plywood web, and the truss types. Of these three, the truss type is the most efficient because it is strong and lightweight, but it is also the most complex to construct.

Figure 1-31 shows wood truss web ribs and a lightened plywood web rib. Wood ribs have a rib cap or cap strip fastened around the entire perimeter of the rib. It is usually made of the same material as the rib itself. The rib cap stiffens and strengthens the rib and provides an attaching surface for the wing covering. In Figure 1-31A, the cross-section of a wing rib with a truss-type web is illustrated. The dark rectangular sections are the front and rear wing spars. Note that to reinforce the truss, gussets are used. In Figure 1-31B, a truss web rib is shown with a continuous gusset. It provides greater support throughout the entire rib with very little additional weight. A continuous gusset stiffens the cap strip in the plane of the rib. This aids in preventing buckling and helps to obtain better rib/skin joints where nail-gluing is used. Such a rib can resist the driving force of nails better than the other types. Continuous gussets are also more easily handled than the many small separate gussets otherwise required. Figure 1-31C shows a rib with a lightened plywood web. It also contains gussets to support the web/cap strip interface. The cap strip is usually laminated to the web, especially at the leading edge.

A wing rib may also be referred to as a plain rib or a main rib. Wing ribs with specialized locations or functions are given names that reflect their uniqueness. For example, ribs that are located entirely forward of the front spar that are used to shape and strengthen the wing leading edge are called nose ribs or false ribs. False ribs are ribs that do not span the entire

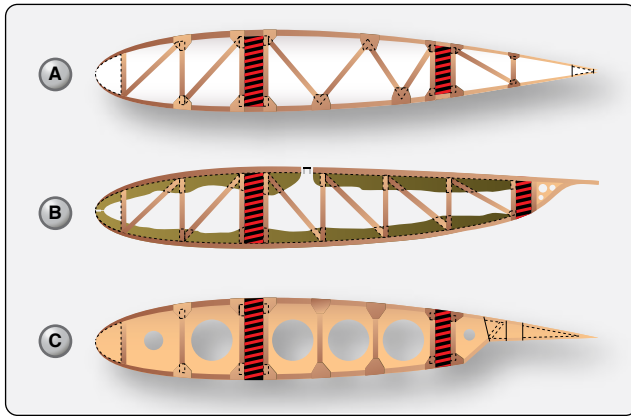


Figure 1-31. Examples of wing ribs constructed of wood.

wing chord, which is the distance from the leading edge to the trailing edge of the wing. Wing butt ribs may be found at the inboard edge of the wing where the wing attaches to the fuselage. Depending on its location and method of attachment, a butt rib may also be called a bulkhead rib or a compression rib if it is designed to receive compression loads that tend to force the wing spars together.

Since the ribs are laterally weak, they are strengthened in some wings by tapes that are woven above and below rib sections to prevent sidewise bending of the ribs. Drag and anti-drag wires may also be found in a wing. In *Figure 1-32*, they are

shown crisscrossed between the spars to form a truss to resist forces acting on the wing in the direction of the wing chord. These tension wires are also referred to as tie rods. The wire designed to resist the backward forces is called a drag wire; the anti-drag wire resists the forward forces in the chord direction. *Figure 1-32* illustrates the structural components of a basic wood wing.

At the inboard end of the wing spars is some form of wing attach fitting as illustrated in *Figure 1-32*. These provide a strong and secure method for attaching the wing to the fuselage. The interface between the wing and fuselage is often covered with a fairing to achieve smooth airflow in this area. The fairing(s) can be removed for access to the wing attach fittings. [*Figure 1-33*]

The wing tip is often a removable unit, bolted to the outboard end of the wing panel. One reason for this is the vulnerability of the wing tips to damage, especially during ground handling and taxiing. *Figure 1-34* shows a removable wing tip for a large aircraft wing. Others are different. The wing tip assembly is of aluminum alloy construction. The wing tip cap is secured to the tip with countersunk screws and is secured to the interspar structure at four points with ¼-inch diameter bolts. To prevent ice from forming on the leading edge of the wings of large aircraft, hot air from an engine is often channeled through the leading edge from wing root to wing tip. A louver on the top surface of the wing tip allows this warm air to be

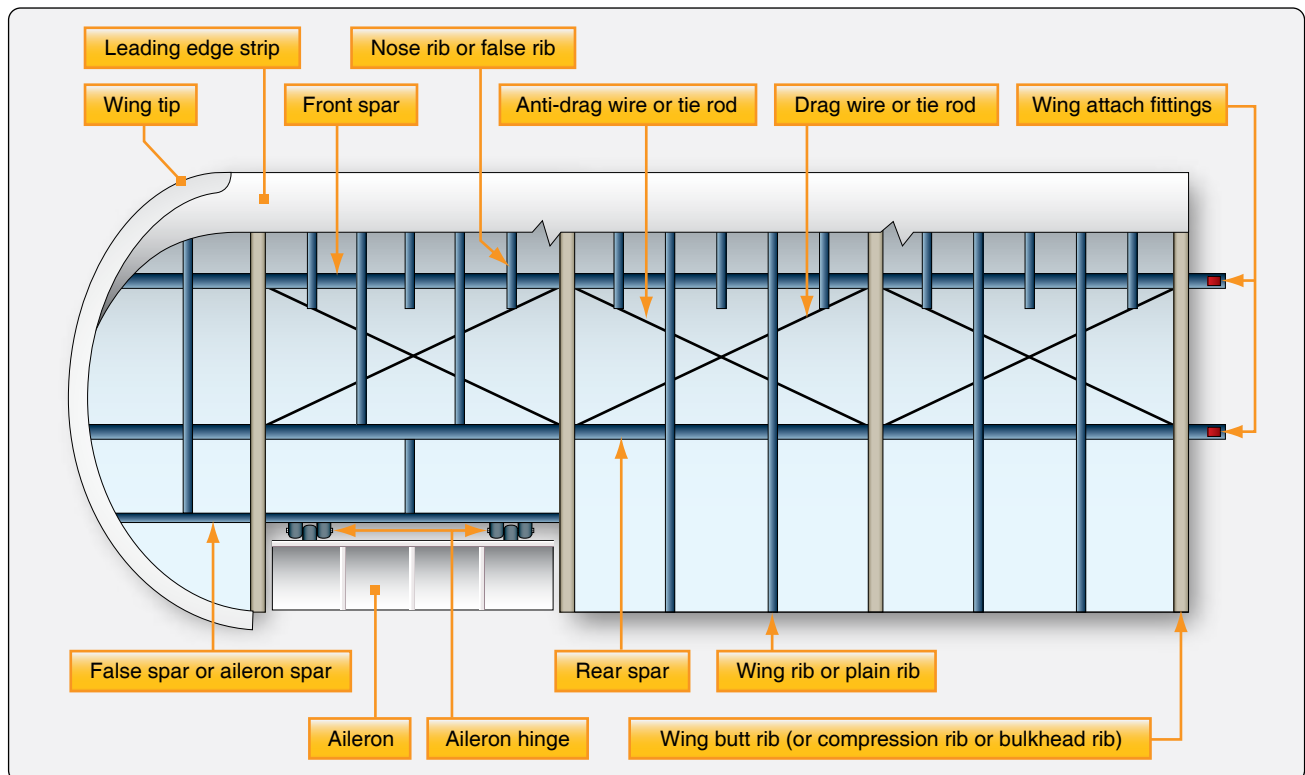


Figure 1-32. Basic wood wing structure and components.



Figure 1-33. Wing root fairings smooth airflow and hide wing attach fittings.

exhausted overboard. Wing position lights are located at the center of the tip and are not directly visible from the flight deck. As an indication that the wing tip light is operating, some wing tips are equipped with a Lucite rod to transmit the light to the leading edge.

Wing Skin

Often, the skin on a wing is designed to carry part of the flight and ground loads in combination with the spars and ribs. This is known as a stressed-skin design. The all-metal, full cantilever wing section illustrated in *Figure 1-35* shows the structure of one such design. The lack of extra internal or external bracing requires that the skin share some of the load. Notice the skin is stiffened to aid with this function.

Fuel is often carried inside the wings of a stressed-skin aircraft. The joints in the wing can be sealed with a special fuel resistant sealant enabling fuel to be stored directly inside the structure. This is known as wet wing design. Alternately, a fuel-carrying bladder or tank can be fitted inside a wing. *Figure 1-36* shows a wing section with a box beam structural design such as one that might be found in a transport category aircraft. This structure increases strength while reducing weight. Proper sealing of the structure allows fuel to be stored in the box sections of the wing.

The wing skin on an aircraft may be made from a wide variety of materials such as fabric, wood, or aluminum. But a single thin sheet of material is not always employed. Chemically

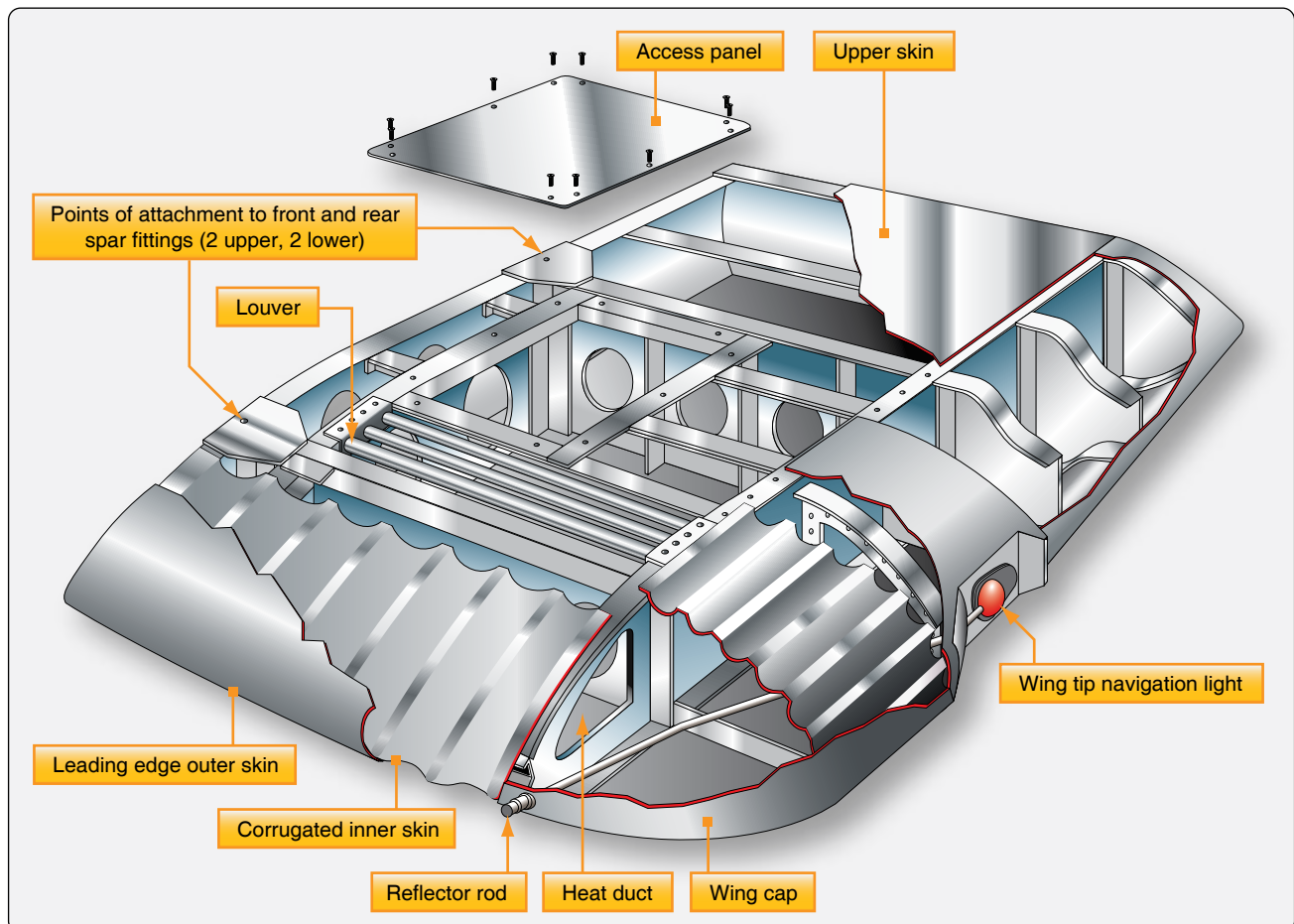


Figure 1-34. A removable metal wing tip.

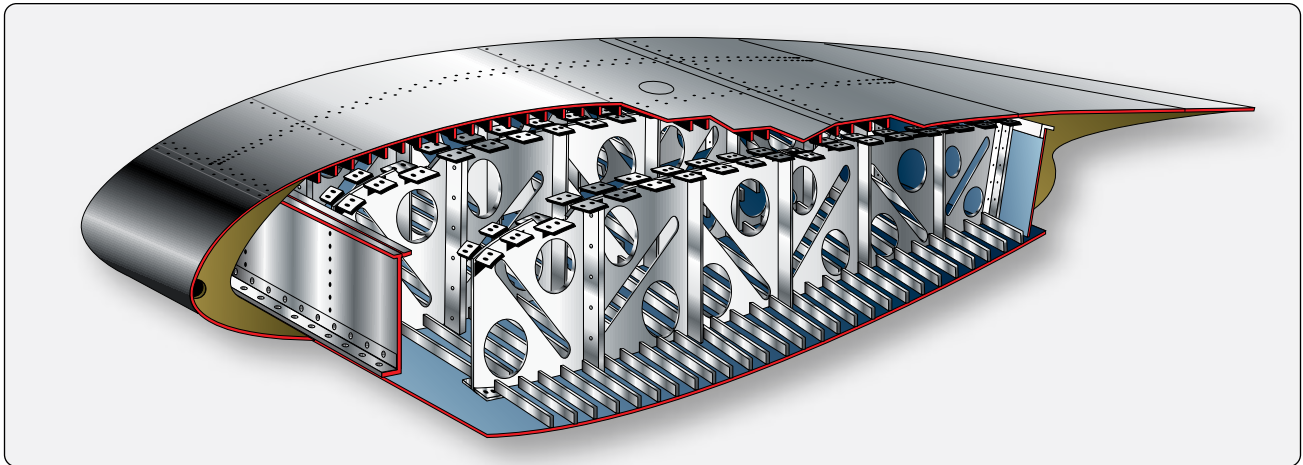


Figure 1-35. The skin is an integral load carrying part of a stressed skin design.

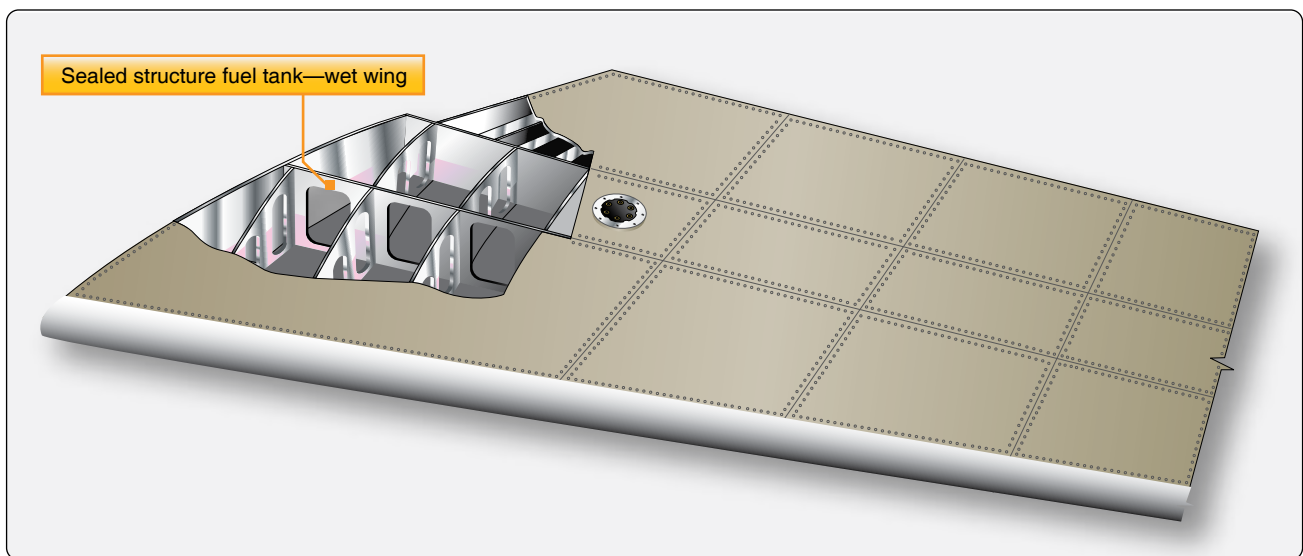


Figure 1-36. Fuel is often carried in the wings.

milled aluminum skin can provide skin of varied thicknesses. On aircraft with stressed-skin wing design, honeycomb structured wing panels are often used as skin. A honeycomb structure is built up from a core material resembling a bee hive's honeycomb which is laminated or sandwiched between thin outer skin sheets. *Figure 1-37* illustrates honeycomb panes and their components. Panels formed like this are lightweight and very strong. They have a variety of uses on the aircraft, such as floor panels, bulkheads, and control surfaces, as well as wing skin panels. *Figure 1-38* shows the locations of honeycomb construction wing panels on a jet transport aircraft.

A honeycomb panel can be made from a wide variety of materials. Aluminum core honeycomb with an outer skin of aluminum is common. But honeycomb in which the core is an Arimid[®] fiber and the outer sheets are coated Phenolic[®] is common as well. In fact, a myriad of other material combinations such as those using fiberglass, plastic, Nomex[®],

Kevlar[®], and carbon fiber all exist. Each honeycomb structure possesses unique characteristics depending upon the materials, dimensions, and manufacturing techniques employed. *Figure 1-39* shows an entire wing leading edge formed from honeycomb structure.

Nacelles

Nacelles (sometimes called “pods”) are streamlined enclosures used primarily to house the engine and its components. They usually present a round or elliptical profile to the wind thus reducing aerodynamic drag. On most single-engine aircraft, the engine and nacelle are at the forward end of the fuselage. On multiengine aircraft, engine nacelles are built into the wings or attached to the fuselage at the empennage (tail section). Occasionally, a multiengine aircraft is designed with a nacelle in line with the fuselage aft of the passenger compartment. Regardless of its location, a nacelle contains the engine and accessories, engine mounts, structural members, a firewall, and skin and cowling on the

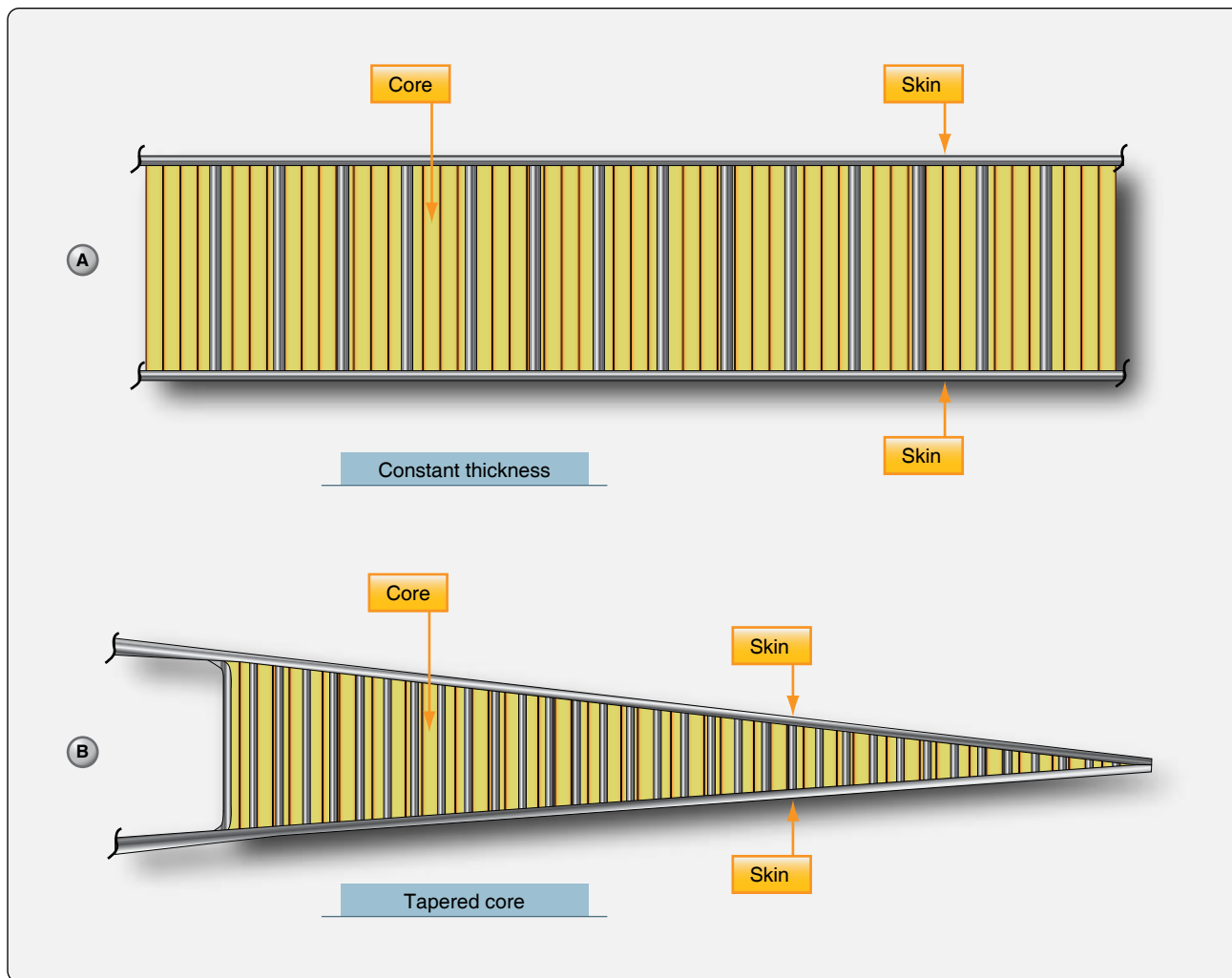


Figure 1-37. The honeycomb panel is a staple in aircraft construction. Cores can be either constant thickness (A) or tapered (B). Tapered core honeycomb panels are frequently used as flight control surfaces and wing trailing edges.

exterior to fair the nacelle to the wind.

Some aircraft have nacelles that are designed to house the landing gear when retracted. Retracting the gear to reduce wind resistance is standard procedure on high-performance/high-speed aircraft. The wheel well is the area where the landing gear is attached and stowed when retracted. Wheel wells can be located in the wings and/or fuselage when not part of the nacelle. *Figure 1-40* shows an engine nacelle incorporating the landing gear with the wheel well extending into the wing root.

The framework of a nacelle usually consists of structural members similar to those of the fuselage. Lengthwise members, such as longerons and stringers, combine with horizontal/vertical members, such as rings, formers, and bulkheads, to give the nacelle its shape and structural integrity. A firewall is incorporated to isolate the engine compartment from the rest of the aircraft. This is basically a

stainless steel or titanium bulkhead that contains a fire in the confines of the nacelle rather than letting it spread throughout the airframe. [*Figure 1-41*]

Engine mounts are also found in the nacelle. These are the structural assemblies to which the engine is fastened. They are usually constructed from chrome/molybdenum steel tubing in light aircraft and forged chrome/nickel/molybdenum assemblies in larger aircraft. [*Figure 1-42*]

The exterior of a nacelle is covered with a skin or fitted with a cowl which can be opened to access the engine and components inside. Both are usually made of sheet aluminum or magnesium alloy with stainless steel or titanium alloys being used in high-temperature areas, such as around the exhaust exit. Regardless of the material used, the skin is typically attached to the framework with rivets.

Cowling refers to the detachable panels covering those areas

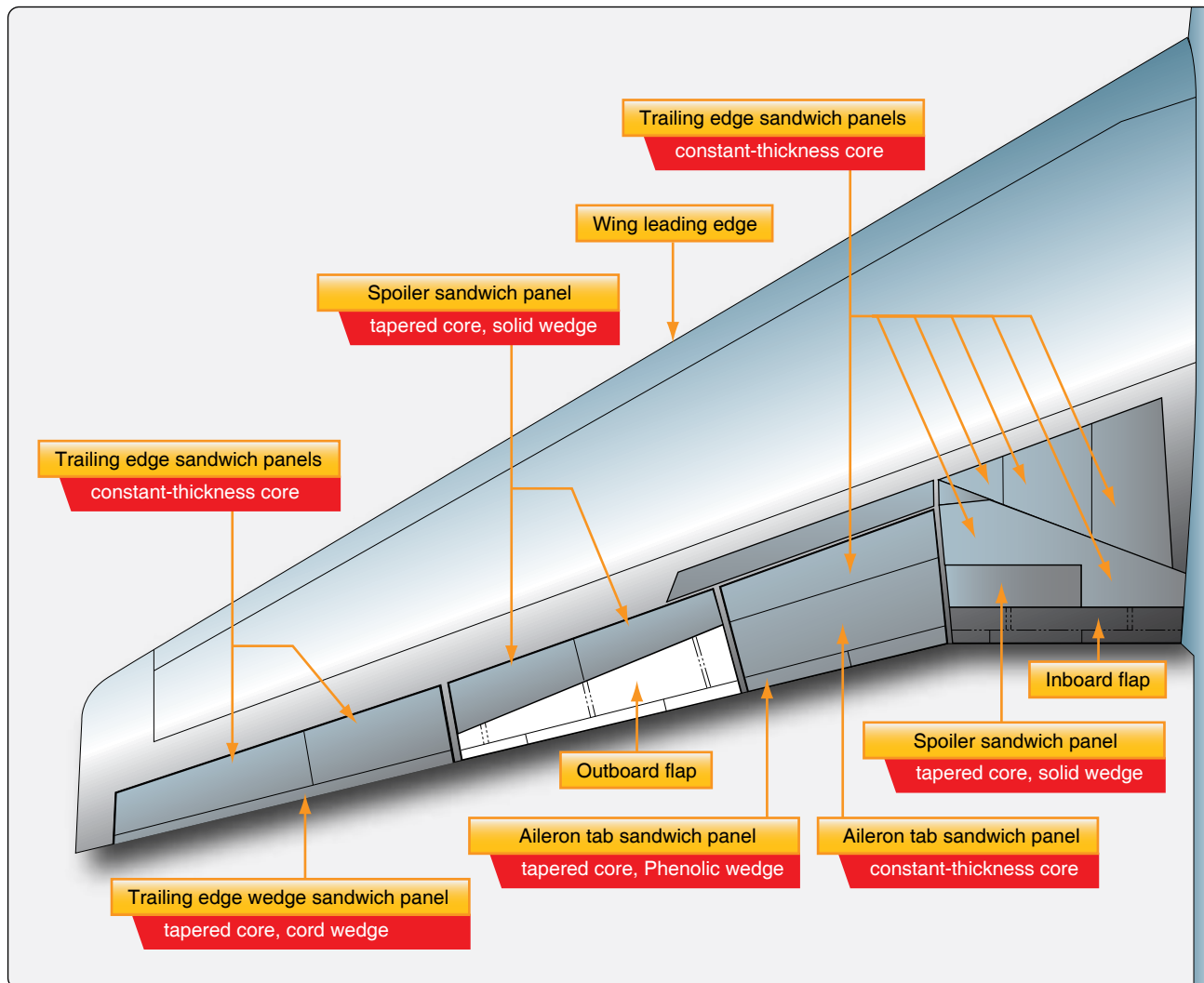


Figure 1-38. Honeycomb wing construction on a large jet transport aircraft.

into which access must be gained regularly, such as the engine and its accessories. It is designed to provide a smooth airflow over the nacelle and to protect the engine from damage. Cowl panels are generally made of aluminum alloy construction. However, stainless steel is often used as the inner skin aft of the power section and for cowl flaps and near cowl flap openings. It is also used for oil cooler ducts. Cowl flaps are moveable parts of the nacelle cowl that open and close to regulate engine temperature.

There are many engine cowl designs. *Figure 1-43* shows an exploded view of the pieces of cowl for a horizontally opposed engine on a light aircraft. It is attached to the nacelle by means of screws and/or quick release fasteners. Some large reciprocating engines are enclosed by “orange peel” cowlings which provide excellent access to components inside the nacelle. [Figure 1-44] These cowl panels are attached to the forward firewall by mounts which also serve as hinges for opening the cowl. The lower cowl mounts are

secured to the hinge brackets by quick release pins. The side and top panels are held open by rods and the lower panel is retained in the open position by a spring and a cable. All of the cowl panels are locked in the closed position by over-center steel latches which are secured in the closed position by spring-loaded safety catches.

An example of a turbojet engine nacelle can be seen in *Figure 1-45*. The cowl panels are a combination of fixed and easily removable panels which can be opened and closed during maintenance. A nose cowl is also a feature on a jet engine nacelle. It guides air into the engine.

Empennage

The empennage of an aircraft is also known as the tail section. Most empennage designs consist of a tail cone, fixed aerodynamic surfaces or stabilizers, and movable aerodynamic surfaces.

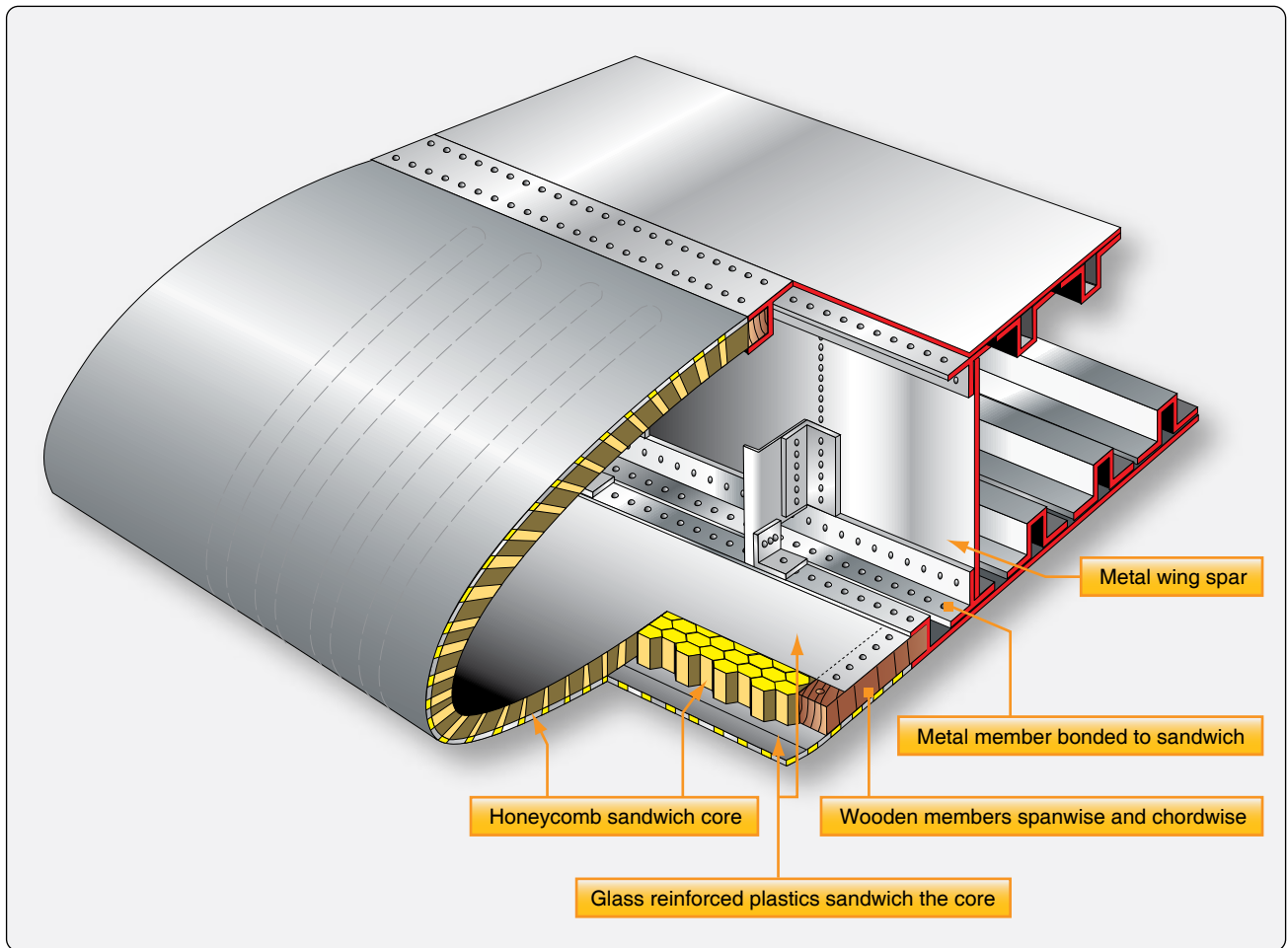


Figure 1-39. A wing leading edge formed from honeycomb material bonded to the aluminum spar structure.



Figure 1-40. Engine nacelle incorporating the landing gear with the wheel well extending into the wing root.



Figure 1-41. An engine nacelle firewall.

The tail cone serves to close and streamline the aft end of most fuselages. The cone is made up of structural members like those of the fuselage; however, cones are usually of lighter construction since they receive less stress than the fuselage. [Figure 1-46]

The other components of the typical empennage are of heavier construction than the tail cone. These members include fixed surfaces that help stabilize the aircraft and movable surfaces that help to direct an aircraft during flight. The fixed surfaces are the horizontal stabilizer and vertical stabilizer. The movable surfaces are usually a rudder located at the aft edge of the vertical stabilizer and an elevator located at the aft edge the horizontal stabilizer. [Figure 1-47]

The structure of the stabilizers is very similar to that which is used in wing construction. Figure 1-48 shows a typical vertical stabilizer. Notice the use of spars, ribs, stringers, and skin like those found in a wing. They perform the same functions shaping and supporting the stabilizer and transferring stresses. Bending, torsion, and shear created by air loads in flight pass from one structural member to another. Each member absorbs some of the stress and passes the remainder on to the others. Ultimately, the spar transmits any overloads to the fuselage. A horizontal stabilizer is built



Figure 1-42. Various aircraft engine mounts.

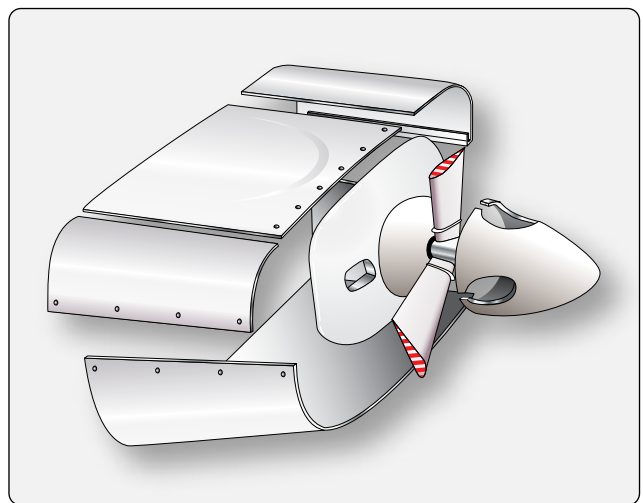


Figure 1-43. Typical cowling for a horizontally opposed reciprocating engine.

the same way.

The rudder and elevator are flight control surfaces that are also part of the empennage discussed in the next section of this chapter.

Flight Control Surfaces

The directional control of a fixed-wing aircraft takes place around the lateral, longitudinal, and vertical axes by means of flight control surfaces designed to create movement about these axes. These control devices are hinged or movable surfaces through which the attitude of an aircraft is controlled during takeoff, flight, and landing. They are usually divided into two major groups: 1) primary or main flight control surfaces and 2) secondary or auxiliary control surfaces.

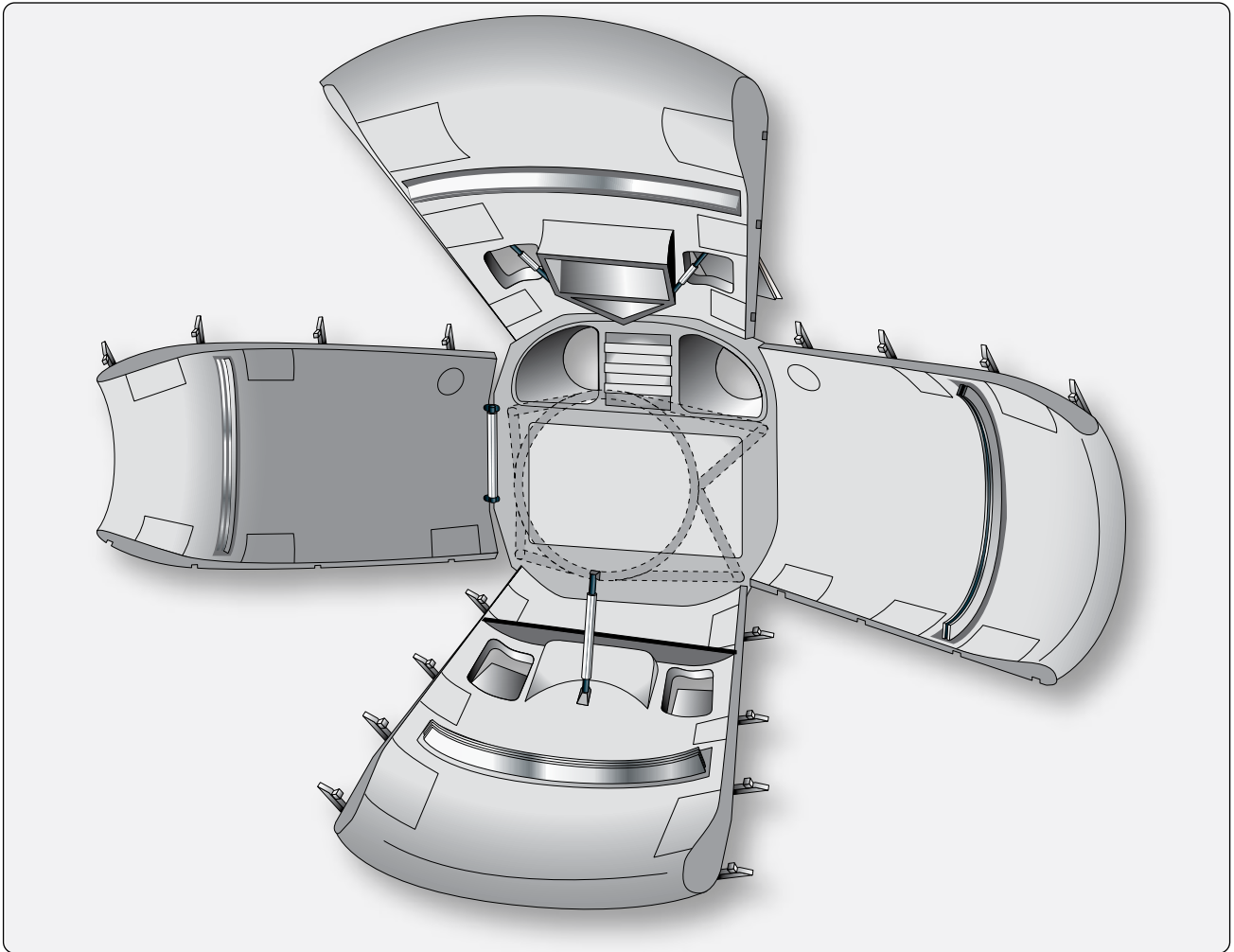


Figure 1-44. Orange peel cowling for large radial reciprocating engine.



Figure 1-45. Cowling on a transport category turbine engine nacelle.

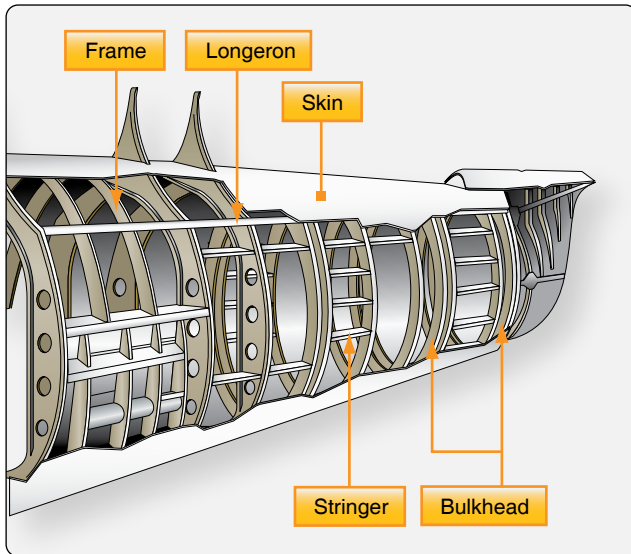


Figure 1-46. The fuselage terminates at the tail cone with similar but more lightweight construction.

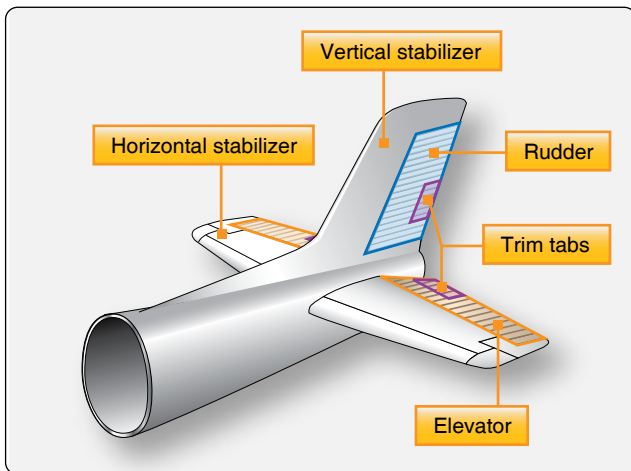


Figure 1-47. Components of a typical empennage.

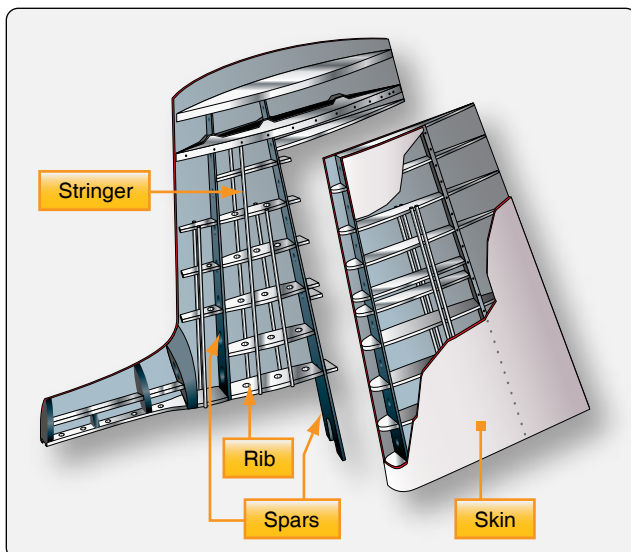


Figure 1-48. Vertical stabilizer.

Primary Flight Control Surfaces

The primary flight control surfaces on a fixed-wing aircraft include: ailerons, elevators, and the rudder. The ailerons are attached to the trailing edge of both wings and when moved, rotate the aircraft around the longitudinal axis. The elevator is attached to the trailing edge of the horizontal stabilizer. When it is moved, it alters aircraft pitch, which is the attitude about the horizontal or lateral axis. The rudder is hinged to the trailing edge of the vertical stabilizer. When the rudder changes position, the aircraft rotates about the vertical axis (yaw). *Figure 1-49* shows the primary flight controls of a light aircraft and the movement they create relative to the three axes of flight.

Primary control surfaces are usually similar in construction to one another and vary only in size, shape, and methods of attachment. On aluminum light aircraft, their structure is often similar to an all-metal wing. This is appropriate because the primary control surfaces are simply smaller aerodynamic devices. They are typically made from an aluminum alloy structure built around a single spar member or torque tube to which ribs are fitted and a skin is attached. The lightweight ribs are, in many cases, stamped out from flat aluminum sheet stock. Holes in the ribs lighten the assembly. An aluminum skin is attached with rivets. *Figure 1-50* illustrates this type of structure, which can be found on the primary control surfaces of light aircraft as well as on medium and heavy aircraft.

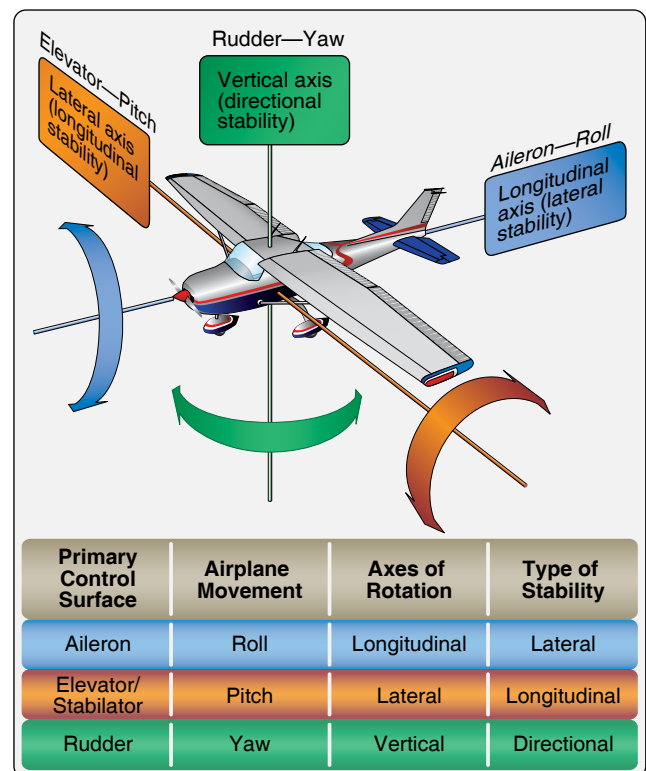


Figure 1-49. Flight control surfaces move the aircraft around the three axes of flight.

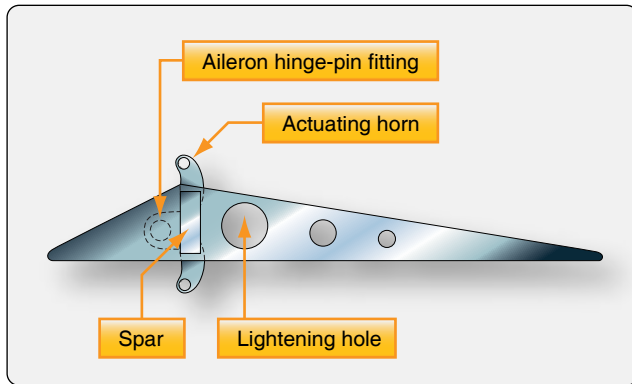


Figure 1-50. Typical structure of an aluminum flight control surface.



Figure 1-51. Composite control surfaces and some of the many aircraft that utilize them.

Primary control surfaces constructed from composite materials are also commonly used. These are found on many heavy and high-performance aircraft, as well as gliders, home-built, and light-sport aircraft. The weight and strength advantages over traditional construction can be significant. A wide variety of materials and construction techniques are employed. *Figure 1-51* shows examples of aircraft that use composite technology on primary flight control surfaces. Note that the control surfaces of fabric-covered aircraft often have fabric-covered surfaces just as aluminum-skinned (light) aircraft typically have all-aluminum control surfaces. There is a critical need for primary control surfaces to be balanced so they do not vibrate or flutter in the wind.

Performed to manufacturer's instructions, balancing usually consists of assuring that the center of gravity of a particular device is at or forward of the hinge point. Failure to properly balance a control surface could lead to catastrophic failure. *Figure 1-52* illustrates several aileron configurations with their hinge points well aft of the leading edge. This is a common design feature used to prevent flutter.

Ailerons

Ailerons are the primary flight control surfaces that move the aircraft about the longitudinal axis. In other words, movement of the ailerons in flight causes the aircraft to roll. Ailerons are usually located on the outboard trailing edge of each of the wings. They are built into the wing and are calculated as part of the wing's surface area. *Figure 1-53* shows aileron locations on various wing tip designs.

Ailerons are controlled by a side-to-side motion of the control stick in the flight deck or a rotation of the control yoke. When the aileron on one wing deflects down, the aileron on the opposite wing deflects upward. This amplifies the movement of the aircraft around the longitudinal axis. On the wing on which the aileron trailing edge moves downward, camber is increased, and lift is increased. Conversely, on the other wing, the raised aileron decreases lift. [*Figure 1-54*] The result is a sensitive response to the control input to roll the aircraft.

The pilot's request for aileron movement and roll are transmitted from the flight deck to the actual control surface in a variety of ways depending on the aircraft. A system of control cables and pulleys, push-pull tubes, hydraulics, electric, or a combination of these can be employed. [*Figure 1-55*]

Simple, light aircraft usually do not have hydraulic or electric fly-by-wire aileron control. These are found on heavy and high-performance aircraft. Large aircraft and some high-performance aircraft may also have a second set of ailerons located inboard on the trailing edge of the wings. These

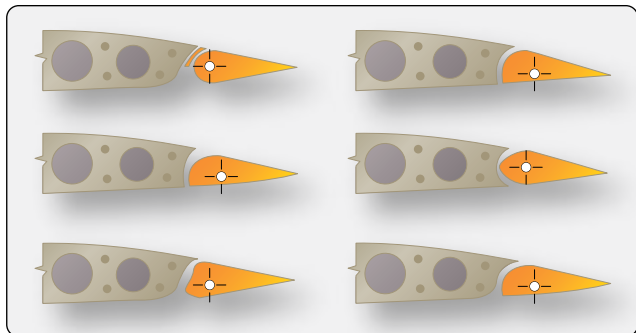


Figure 1-52. Aileron hinge locations are very close to but aft of the center of gravity to prevent flutter.

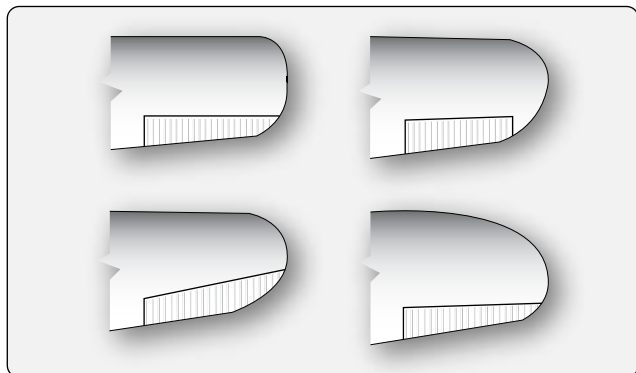


Figure 1-53. Aileron location on various wings.

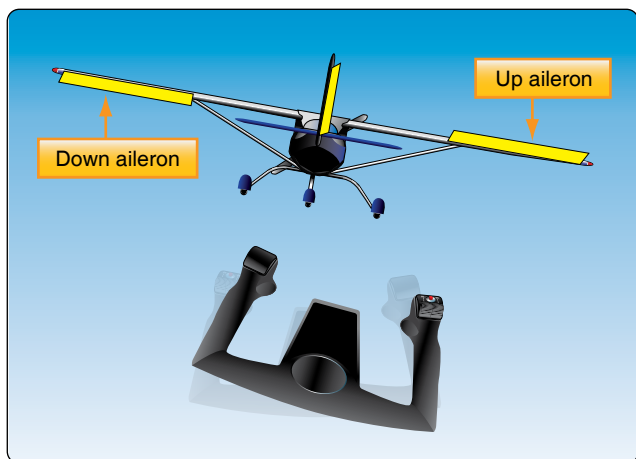


Figure 1-54. Differential aileron control movement. When one aileron is moved down, the aileron on the opposite wing is deflected upward.

are part of a complex system of primary and secondary control surfaces used to provide lateral control and stability in flight. At low speeds, the ailerons may be augmented by the use of flaps and spoilers. At high speeds, only inboard aileron deflection is required to roll the aircraft while the other control surfaces are locked out or remain stationary. *Figure 1-56* illustrates the location of the typical flight control surfaces found on a transport category aircraft.

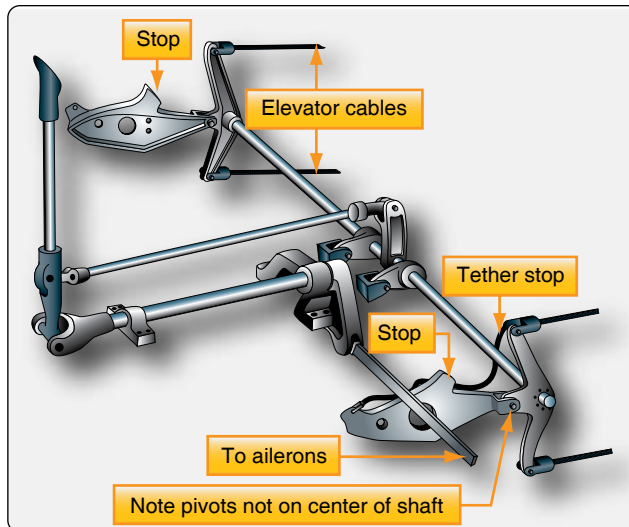


Figure 1-55. Transferring control surface inputs from the flight deck.

Elevator

The elevator is the primary flight control surface that moves the aircraft around the horizontal or lateral axis. This causes the nose of the aircraft to pitch up or down. The elevator is hinged to the trailing edge of the horizontal stabilizer and typically spans most or all of its width. It is controlled in the flight deck by pushing or pulling the control stick or yoke forward or aft.

Light aircraft use a system of control cables and pulleys or push-pull tubes to transfer flight deck inputs to the movement of the elevator. High-performance and large aircraft typically employ more complex systems. Hydraulic power is commonly used to move the elevator on these aircraft. On aircraft equipped with fly-by-wire controls, a combination of electrical and hydraulic power is used.

Rudder

The rudder is the primary control surface that causes an aircraft to yaw or move about the vertical axis. This provides directional control and thus points the nose of the aircraft in the direction desired. Most aircraft have a single rudder hinged to the trailing edge of the vertical stabilizer. It is controlled by a pair of foot-operated rudder pedals in the flight deck. When the right pedal is pushed forward, it deflects the rudder to the right which moves the nose of the aircraft to the right. The left pedal is rigged to simultaneously move aft. When the left pedal is pushed forward, the nose of the aircraft moves to the left.

As with the other primary flight controls, the transfer of the movement of the flight deck controls to the rudder varies with the complexity of the aircraft. Many aircraft incorporate the directional movement of the nose or tail wheel into the rudder control system for ground operation. This allows the operator

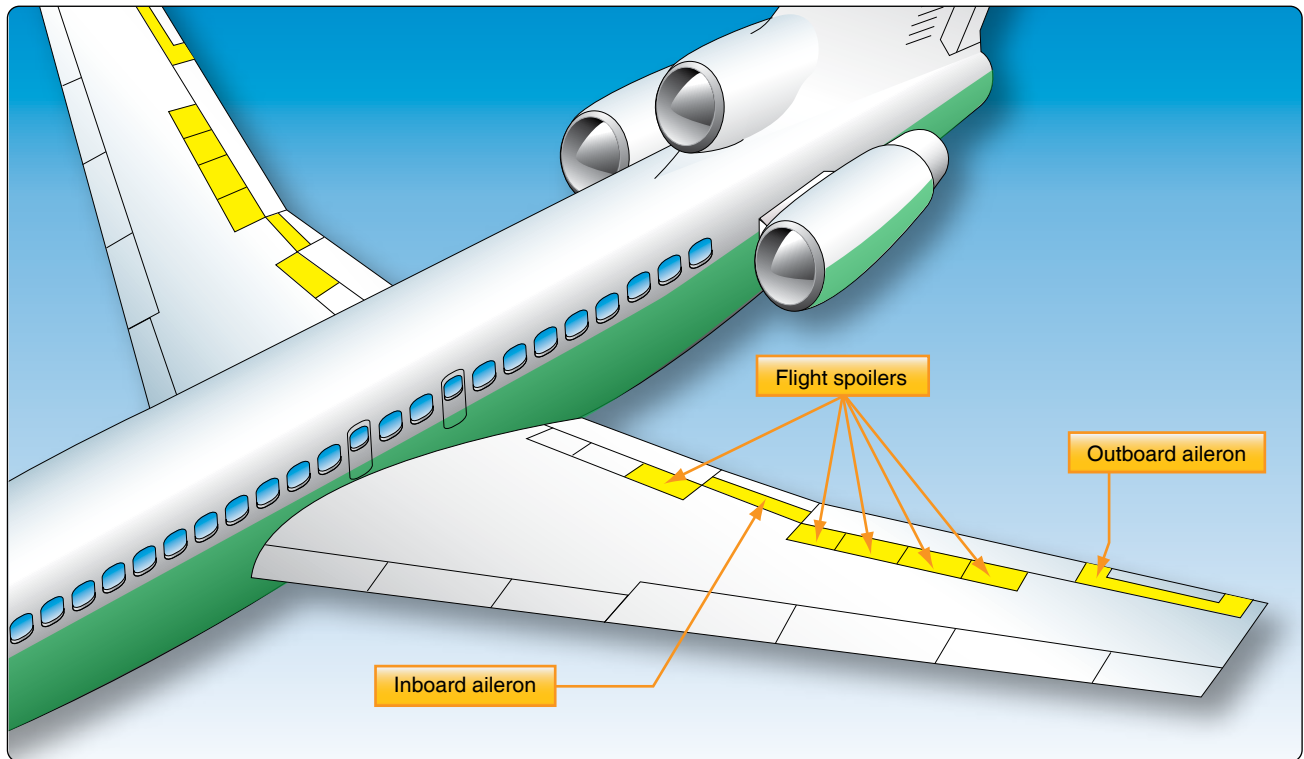


Figure 1-56. Typical flight control surfaces on a transport category aircraft.

to steer the aircraft with the rudder pedals during taxi when the airspeed is not high enough for the control surfaces to be effective. Some large aircraft have a split rudder arrangement. This is actually two rudders, one above the other. At low speeds, both rudders deflect in the same direction when the pedals are pushed. At higher speeds, one of the rudders becomes inoperative as the deflection of a single rudder is aerodynamically sufficient to maneuver the aircraft.

Dual Purpose Flight Control Surfaces

The ailerons, elevators, and rudder are considered conventional primary control surfaces. However, some aircraft are designed with a control surface that may serve a dual purpose. For example, elevons perform the combined functions of the ailerons and the elevator. [Figure 1-57]

A movable horizontal tail section, called a stabilator, is a control surface that combines the action of both the horizontal stabilizer and the elevator. [Figure 1-58] Basically, a stabilator is a horizontal stabilizer that can also be rotated about the horizontal axis to affect the pitch of the aircraft.

A ruddervator combines the action of the rudder and elevator. [Figure 1-59] This is possible on aircraft with V-tail empennages where the traditional horizontal and vertical stabilizers do not exist. Instead, two stabilizers angle upward and outward from the aft fuselage in a “V” configuration. Each contains a movable ruddervator built into the trailing



Figure 1-57. Elevons.

edge. Movement of the ruddervators can alter the movement of the aircraft around the horizontal and/or vertical axis. Additionally, some aircraft are equipped with flaperons. [Figure 1-60] Flaperons are ailerons which can also act as flaps. Flaps are secondary control surfaces on most wings, discussed in the next section of this chapter.

Secondary or Auxiliary Control Surfaces

There are several secondary or auxiliary flight control surfaces. Their names, locations, and functions of those for most large aircraft are listed in Figure 1-61.

Flaps

Flaps are found on most aircraft. They are usually inboard



Figure 1-58. A stabilizer and index marks on a transport category aircraft.



Figure 1-60. Flaperons.



Figure 1-59. Ruddervator.

on the wings' trailing edges adjacent to the fuselage. Leading edge flaps are also common. They extend forward and down from the inboard wing leading edge. The flaps are lowered to increase the camber of the wings and provide greater lift and control at slow speeds. They enable landing at slower speeds and shorten the amount of runway required for takeoff and landing. The amount that the flaps extend and the angle they form with the wing can be selected from the flight deck. Typically, flaps can extend up to 45° – 50° . *Figure 1-62* shows various aircraft with flaps in the extended position.

Flaps are usually constructed of materials and with techniques used on the other airfoils and control surfaces of a particular aircraft. Aluminum skin and structure flaps are the norm on light aircraft. Heavy and high-performance aircraft flaps may also be aluminum, but the use of composite structures is also common.

There are various kinds of flaps. Plain flaps form the trailing edge of the wing when the flap is in the retracted position. [*Figure 1-63A*] The airflow over the wing continues over the upper and lower surfaces of the flap, making the trailing edge of the flap essentially the trailing edge of the wing. The plain flap is hinged so that the trailing edge can be lowered. This

increases wing camber and provides greater lift.

A split flap is normally housed under the trailing edge of the wing. [*Figure 1-63B*] It is usually just a braced flat metal plate hinged at several places along its leading edge. The upper surface of the wing extends to the trailing edge of the flap. When deployed, the split flap trailing edge lowers away from the trailing edge of the wing. Airflow over the top of the wing remains the same. Airflow under the wing now follows the camber created by the lowered split flap, increasing lift.

Fowler flaps not only lower the trailing edge of the wing when deployed but also slide aft, effectively increasing the area of the wing. [*Figure 1-63C*] This creates more lift via the increased surface area, as well as the wing camber. When stowed, the Fowler flap typically retracts up under the wing trailing edge similar to a split flap. The sliding motion of a Fowler flap can be accomplished with a worm drive and flap tracks.

An enhanced version of the Fowler flap is a set of flaps that actually contains more than one aerodynamic surface. *Figure 1-64* shows a triple-slotted flap. In this configuration, the flap consists of a fore flap, a mid flap, and an aft flap. When deployed, each flap section slides aft on tracks as it lowers. The flap sections also separate leaving an open slot between the wing and the fore flap, as well as between each of the flap sections. Air from the underside of the wing flows through these slots. The result is that the laminar flow on the upper surfaces is enhanced. The greater camber and effective wing area increase overall lift.

Heavy aircraft often have leading edge flaps that are used in conjunction with the trailing edge flaps. [*Figure 1-65*] They can be made of machined magnesium or can have an aluminum or composite structure. While they are not installed or operate independently, their use with trailing edge flaps can greatly increase wing camber and lift. When stowed, leading edge flaps retract into the leading edge of the wing.

Secondary/Auxiliary Flight Control Surfaces		
Name	Location	Function
Flaps	Inboard trailing edge of wings	Extends the camber of the wing for greater lift and slower flight. Allows control at low speeds for short field takeoffs and landings.
Trim tabs	Trailing edge of primary flight control surfaces	Reduces the force needed to move a primary control surface.
Balance tabs	Trailing edge of primary flight control surfaces	Reduces the force needed to move a primary control surface.
Anti-balance tabs	Trailing edge of primary flight control surfaces	Increases feel and effectiveness of primary control surface.
Servo tabs	Trailing edge of primary flight control surfaces	Assists or provides the force for moving a primary flight control.
Spoilers	Upper and/or trailing edge of wing	Decreases (spoils) lift. Can augment aileron function.
Slats	Mid to outboard leading edge of wing	Extends the camber of the wing for greater lift and slower flight. Allows control at low speeds for short field takeoffs and landings.
Slots	Outer leading edge of wing forward of ailerons	Directs air over upper surface of wing during high angle of attack. Lowers stall speed and provides control during slow flight.
Leading edge flap	Inboard leading edge of wing	Extends the camber of the wing for greater lift and slower flight. Allows control at low speeds for short field takeoffs and landings.

NOTE: An aircraft may possess none, one, or a combination of the above control surfaces.

Figure 1-61. Secondary or auxiliary control surfaces and respective locations for larger aircraft.



Figure 1-62. Various aircraft with flaps in the extended position.

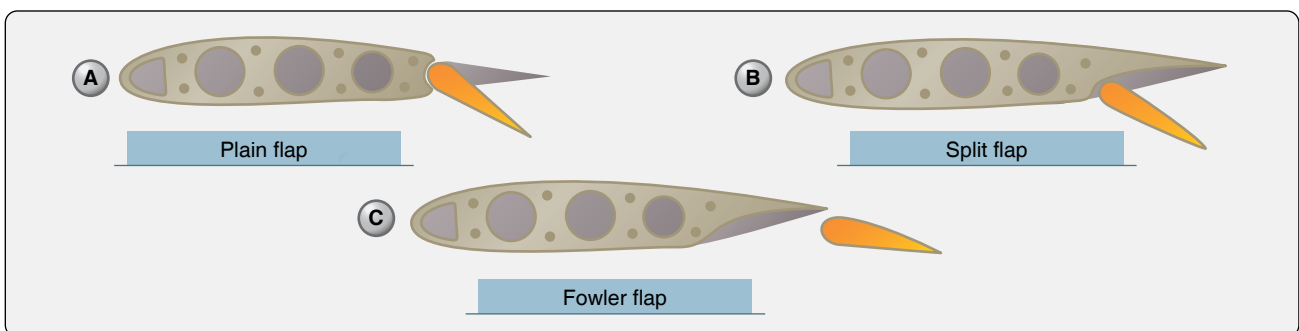


Figure 1-63. Various types of flaps.

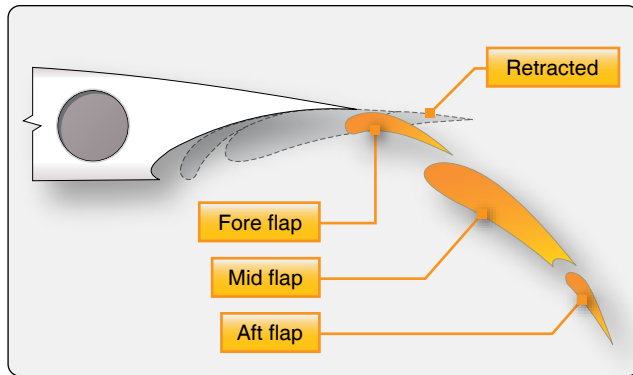


Figure 1-64. Triple-slotted flap.

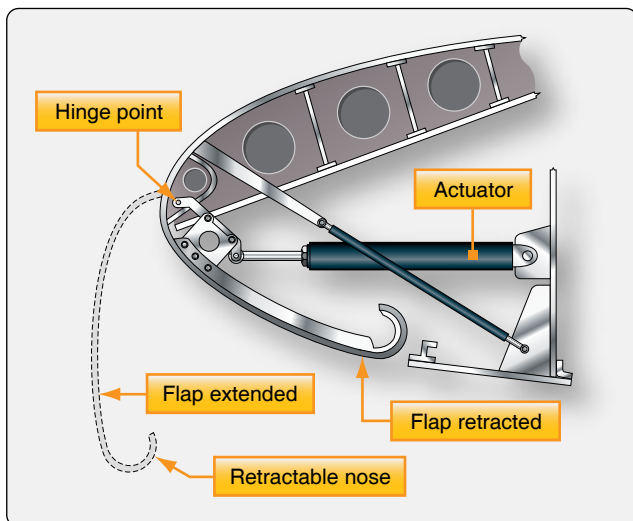


Figure 1-65. Leading edge flaps.

The differing designs of leading edge flaps essentially provide the same effect. Activation of the trailing edge flaps automatically deploys the leading edge flaps, which are driven out of the leading edge and downward, extending

the camber of the wing. *Figure 1-66* shows a Krueger flap, recognizable by its flat mid-section.

Slats

Another leading edge device which extends wing camber is a slat. Slats can be operated independently of the flaps with their own switch in the flight deck. Slats not only extend out of the leading edge of the wing increasing camber and lift, but most often, when fully deployed leave a slot between their trailing edges and the leading edge of the wing. [Figure 1-67] This increases the angle of attack at which the wing will maintain its laminar airflow, resulting in the ability to fly the aircraft slower with a reduced stall speed, and still maintain control.

Spoilers & Speed Brakes

A spoiler is a device found on the upper surface of many heavy and high-performance aircraft. It is stowed flush to the wing's upper surface. When deployed, it raises up into the airstream and disrupts the laminar airflow of the wing, thus reducing lift.

Spoilers are made with similar construction materials and techniques as the other flight control surfaces on the aircraft. Often, they are honeycomb-core flat panels. At low speeds, spoilers are rigged to operate when the ailerons operate to assist with the lateral movement and stability of the aircraft. On the wing where the aileron is moved up, the spoilers also raise thus amplifying the reduction of lift on that wing. [Figure 1-68] On the wing with downward aileron deflection, the spoilers remain stowed. As the speed of the aircraft increases, the ailerons become more effective and the spoiler interconnect disengages.

Spoilers are unique in that they may also be fully deployed on both wings to act as speed brakes. The reduced lift and increased drag can quickly reduce the speed of the aircraft in



Figure 1-66. Side view (left) and front view (right) of a Krueger flap on a Boeing 737.