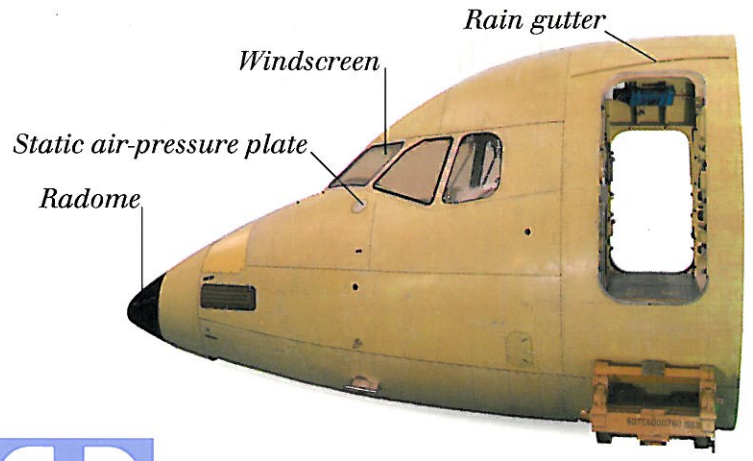
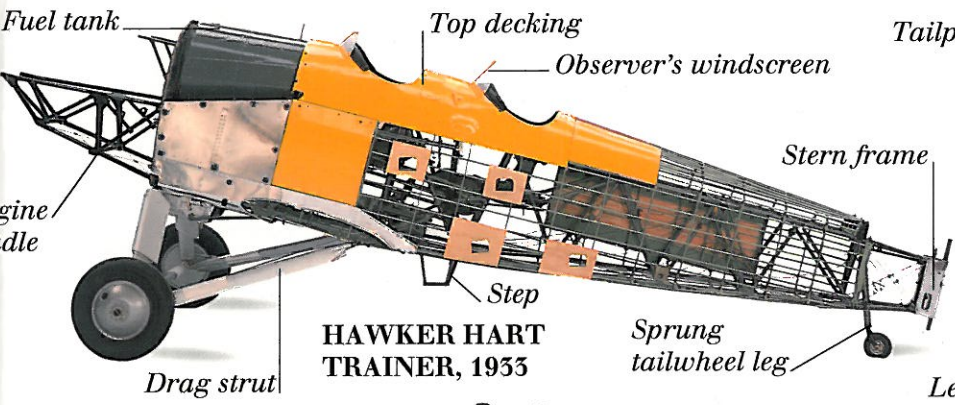


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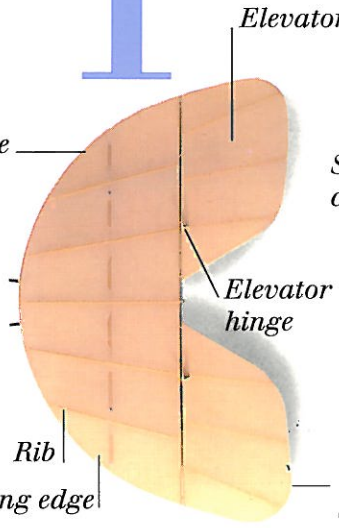
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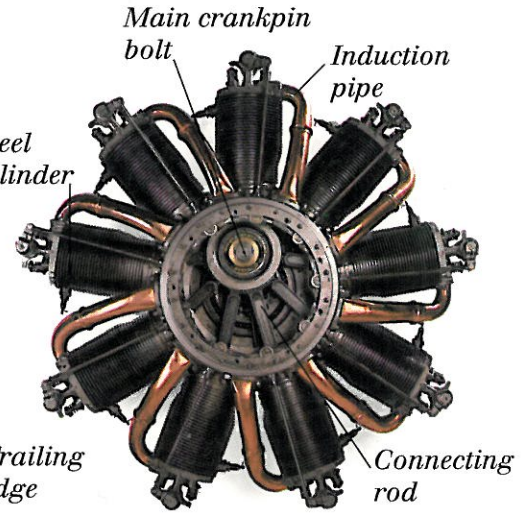
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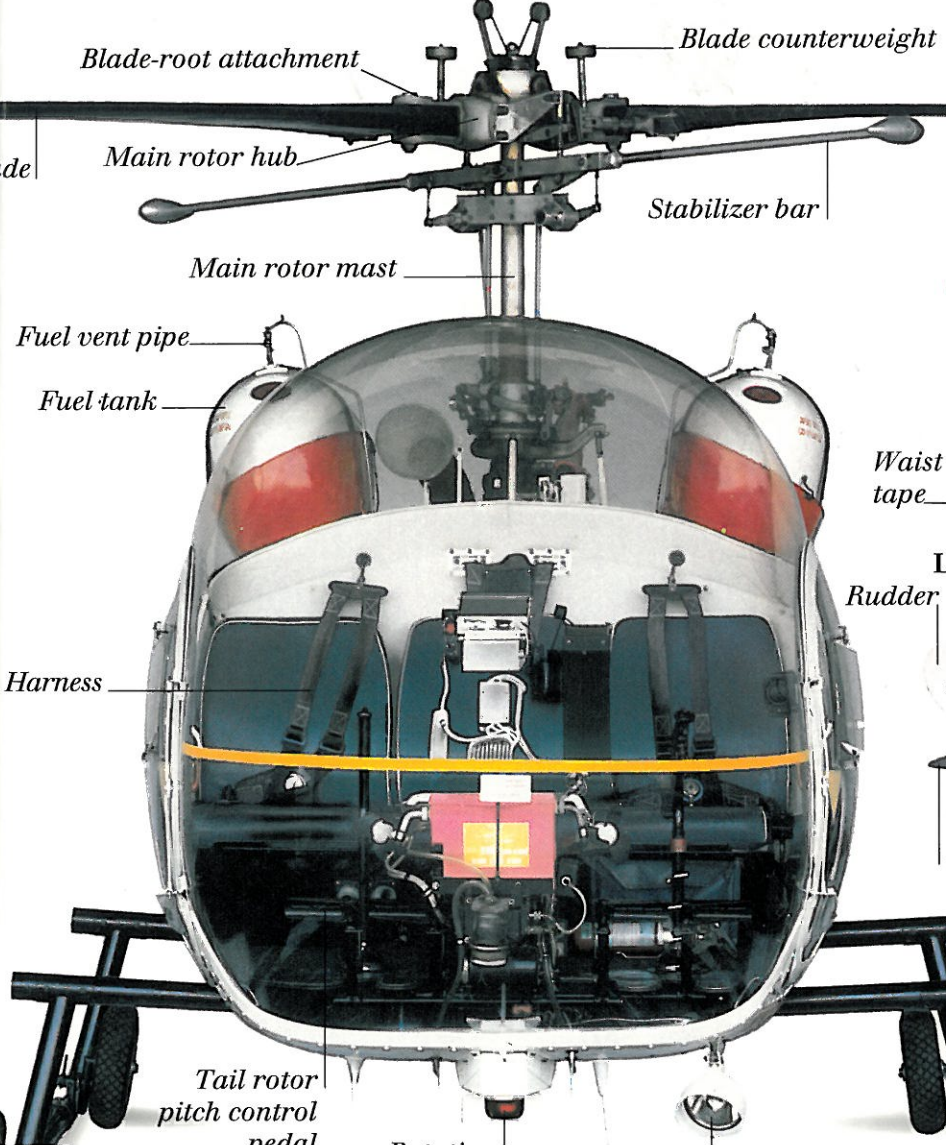
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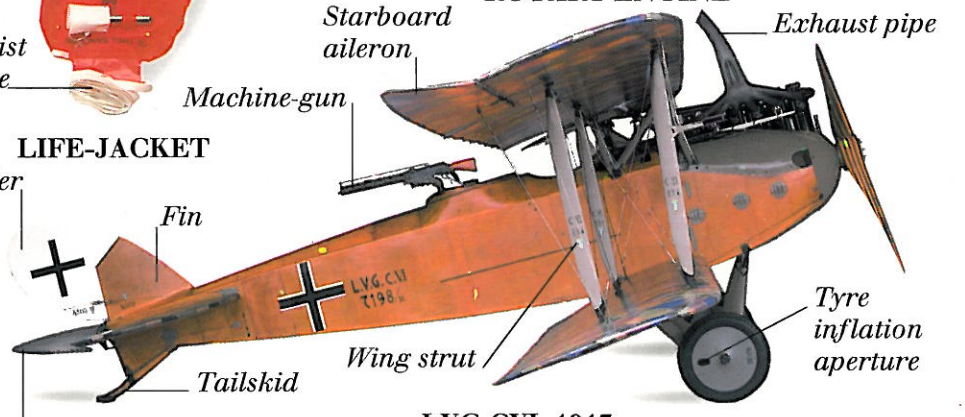
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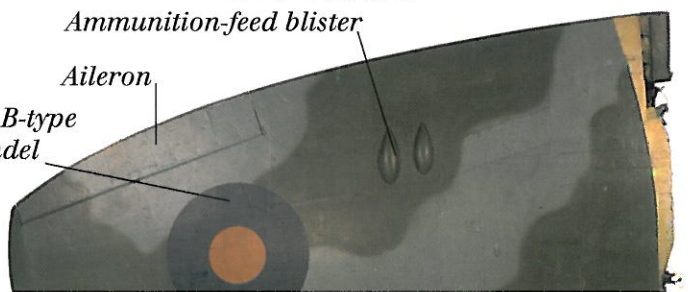
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HOUSINGS FROM A MODERN
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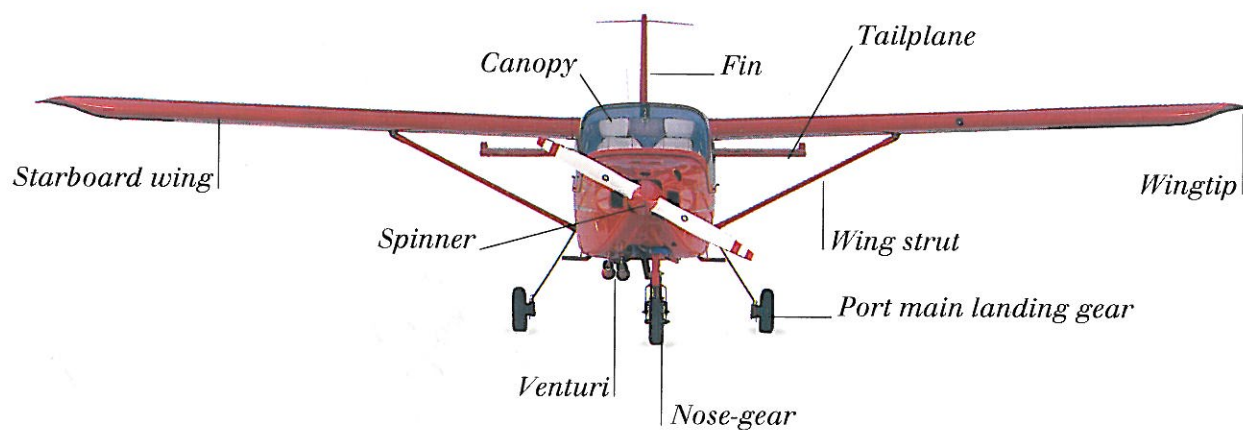
LVG CVI, 1917



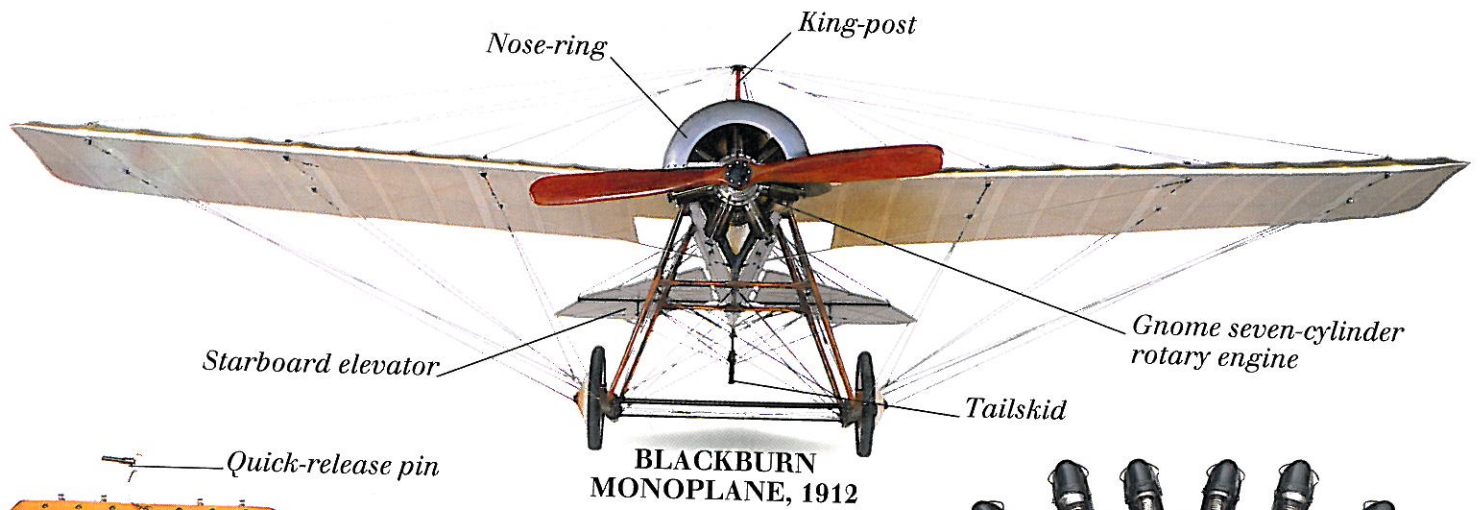
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roundel

EYEWITNESS VISUAL DICTIONARIES

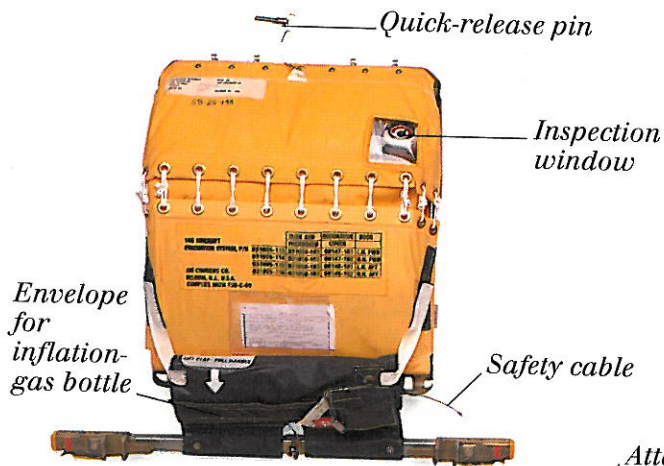
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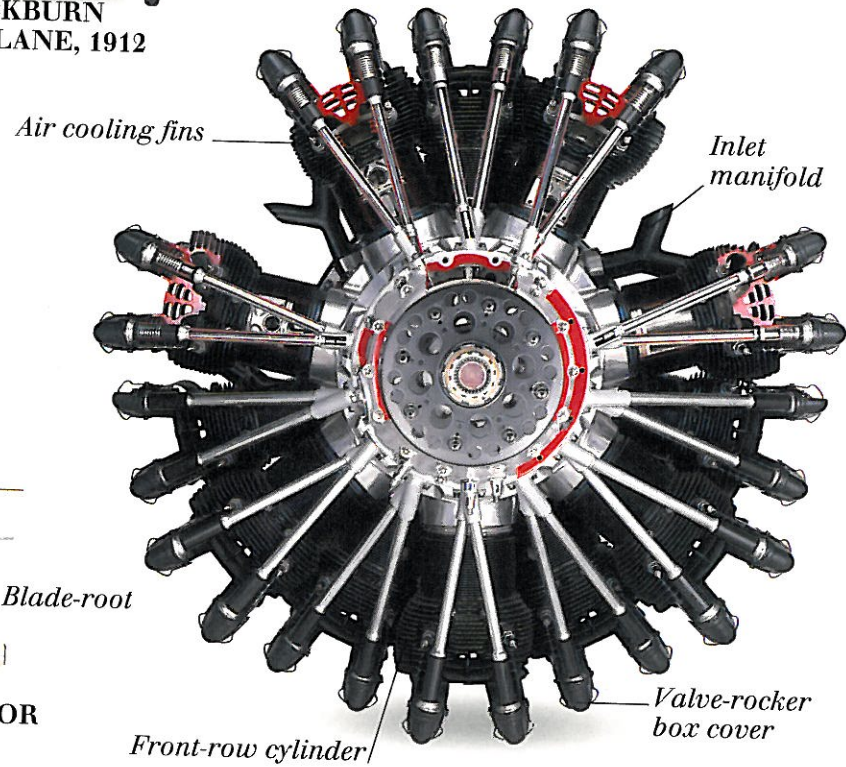
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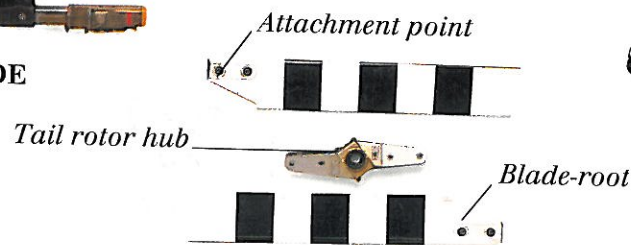
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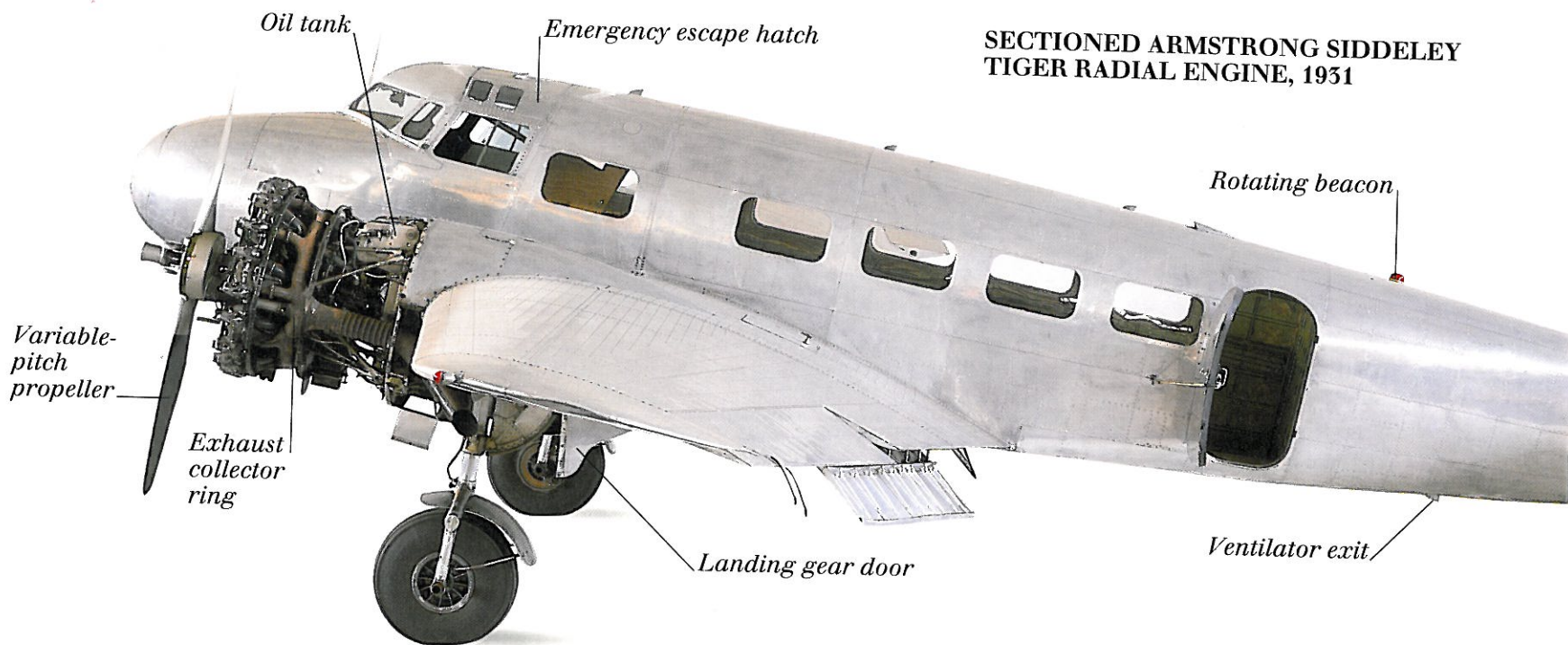
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**SECTIONED ARMSTRONG SIDDELEY
TIGER RADIAL ENGINE, 1931**



HELICOPTER TAIL ROTOR

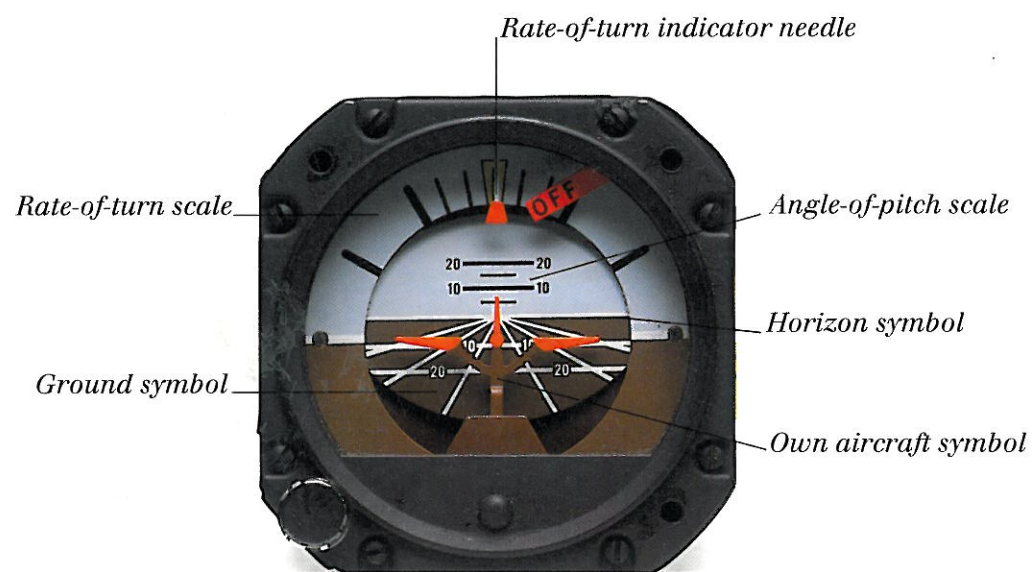


LOCKHEED ELECTRA, 1934

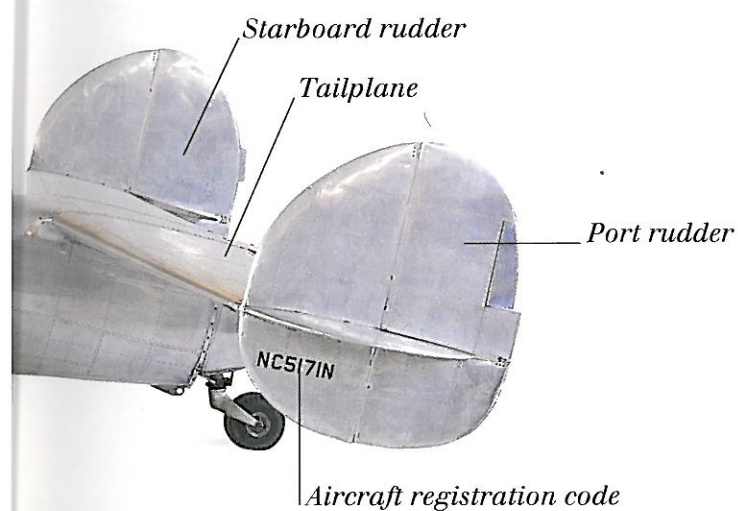
EYEWITNESS VISUAL DICTIONARIES

THE VISUAL
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FLIGHT



ARTIFICIAL HORIZON FLIGHT INSTRUMENT



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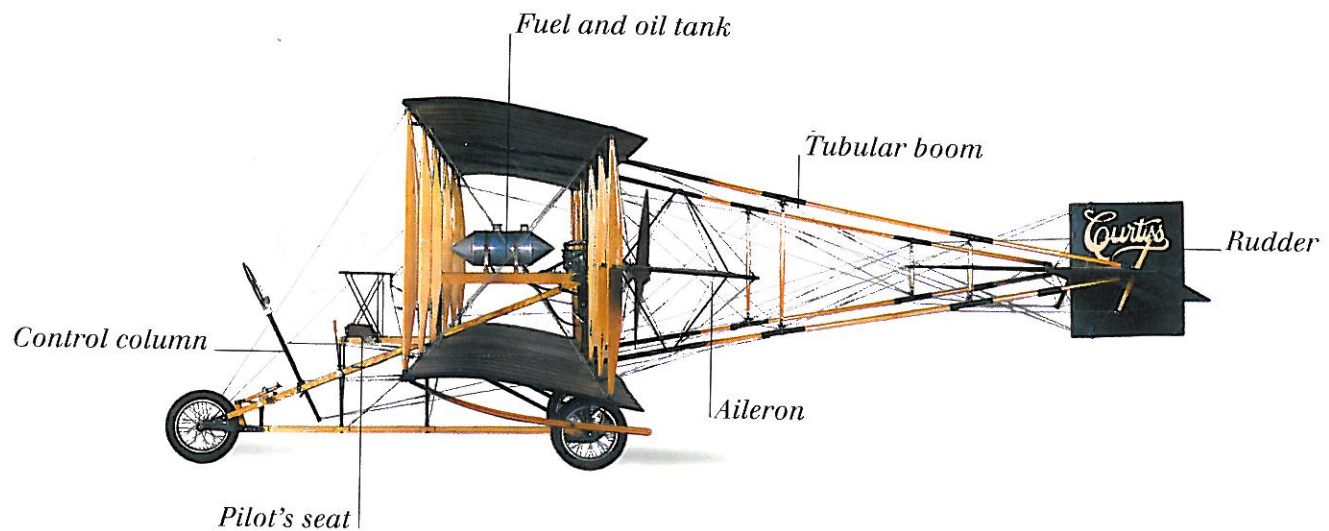
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CURTISS MODEL-D PUSHER, 1911

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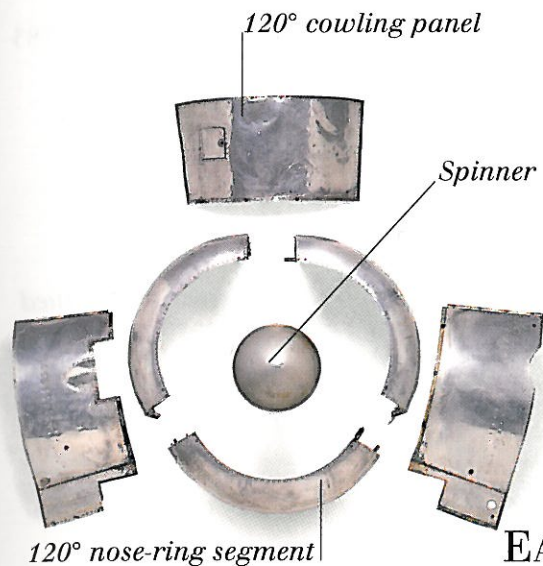
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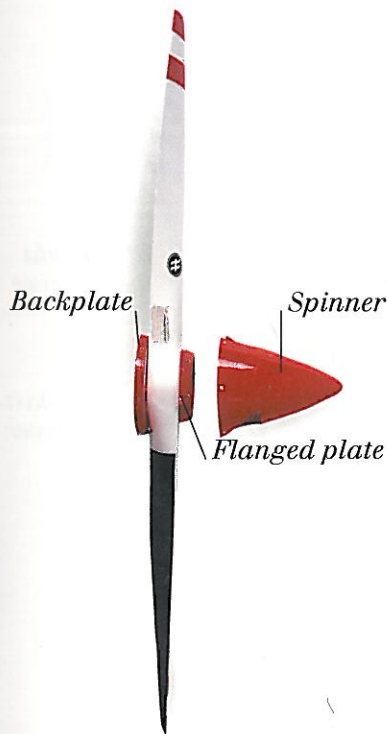
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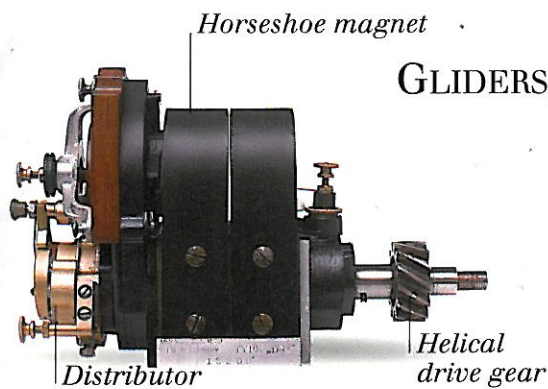
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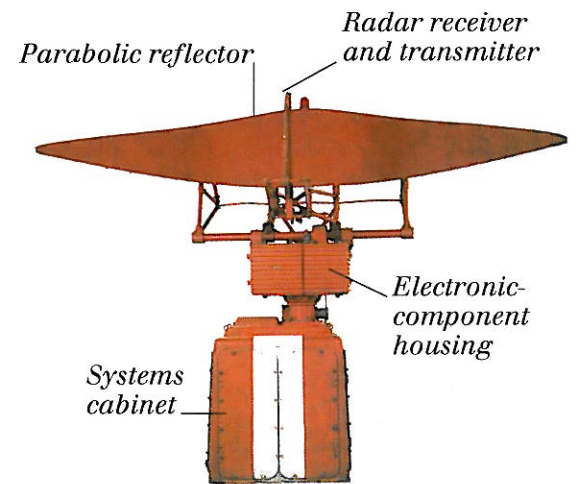
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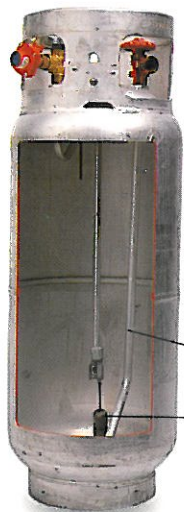
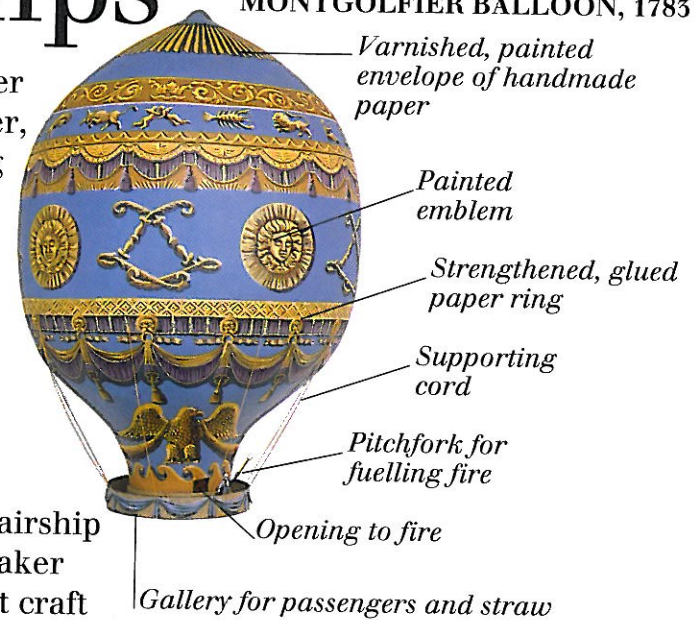
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Balloons and airships

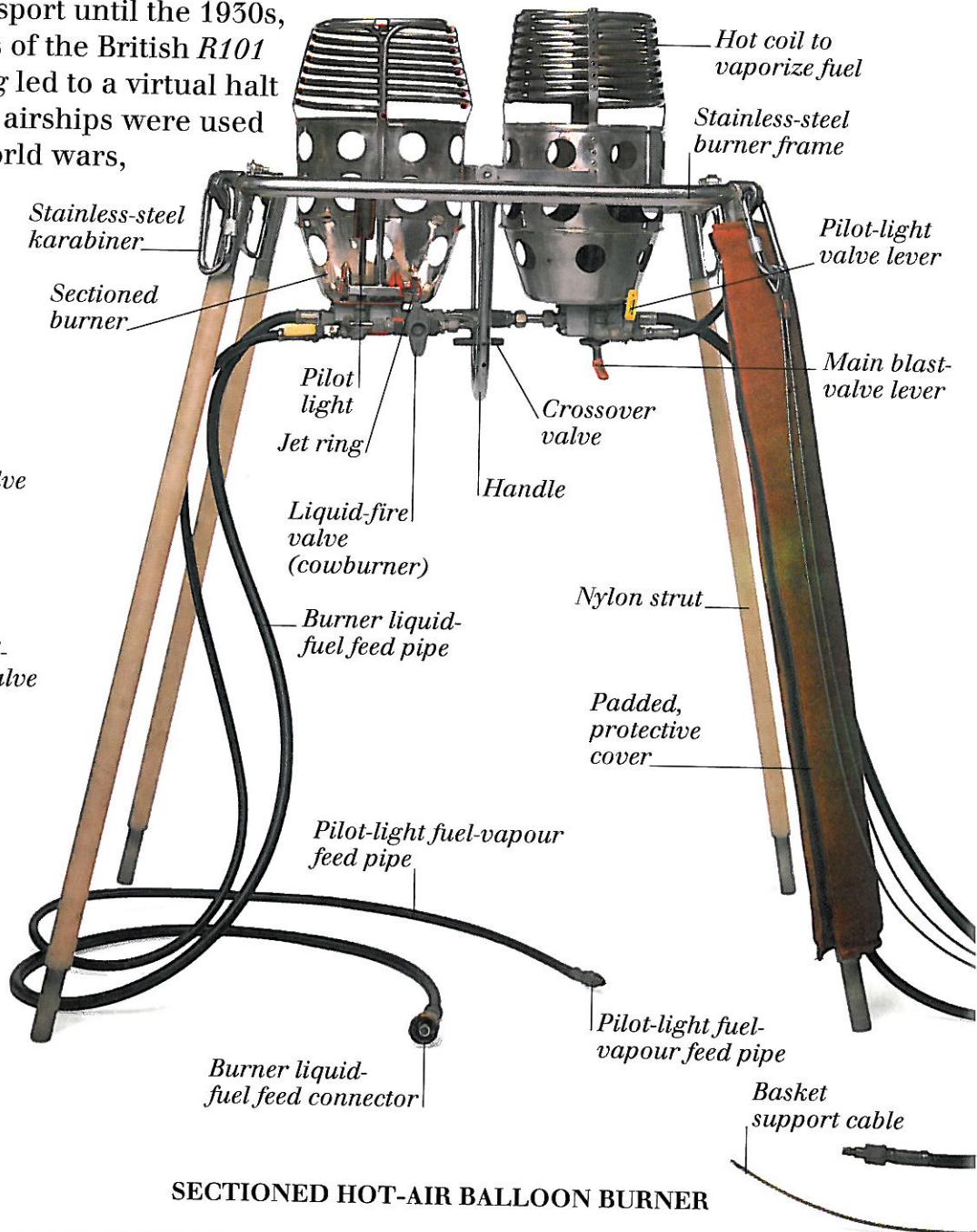
THE FIRST SUSTAINED FLIGHT was made by the French Montgolfier brothers' hot-air balloon in 1783. Their balloon was made of paper, and the hot air (which provided the lift) was produced by burning straw. Later balloons were filled with various lighter-than-air gases (hydrogen, helium, or coal gas) until about 1970, when hot-air balloons again became fashionable. In modern hot-air balloons, the air is heated by propane burners carried in the balloon's basket. Modern airships may be filled with helium or hot air (hydrogen, used in early airships, is dangerously inflammable). Unlike balloons, airships have some means of propulsion and can be steered. Many modern airships also have swivelling propellers to assist with take-off and landing. The first airship was made in Paris, France, in 1852, but the best-known airship-maker was the German Count Ferdinand von Zeppelin, who built his first craft in 1900. Airships made the first intercontinental passenger flights, and

were a popular form of transport until the 1930s, when the disastrous crashes of the British *R101* and the German *Hindenburg* led to a virtual halt in airship production. Small airships were used as convoy escorts in both world wars, and today they are used for surveillance and for aerial advertising.

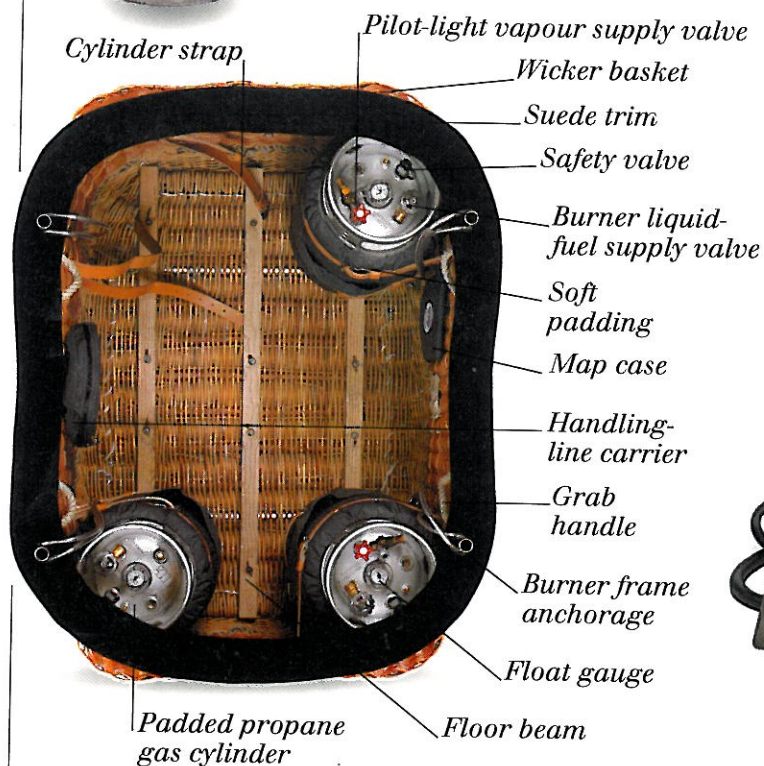
MONTGOLFIER BALLOON, 1783



SECTIONED GAS CYLINDER

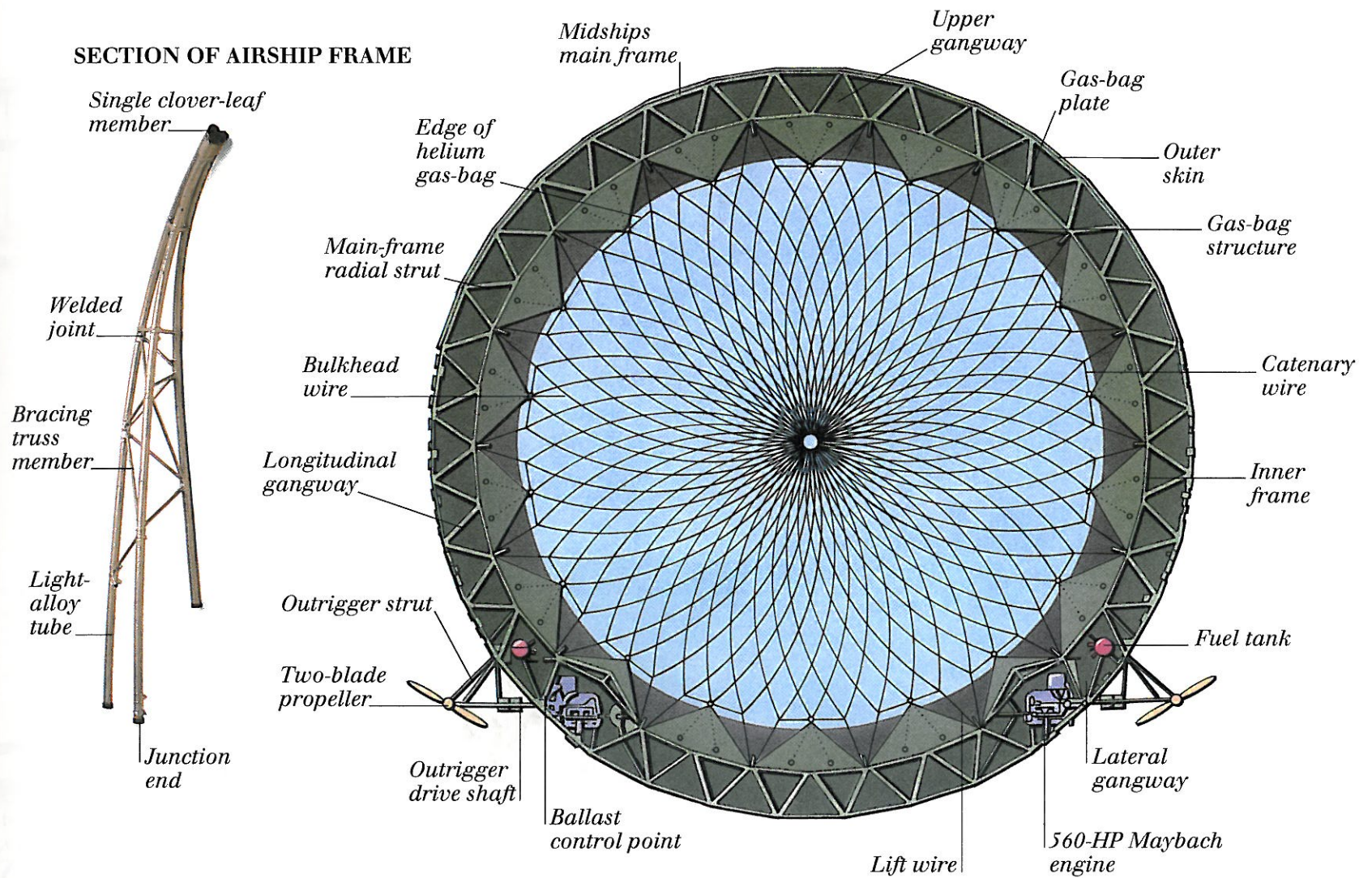


SECTIONED HOT-AIR BALLOON BURNER

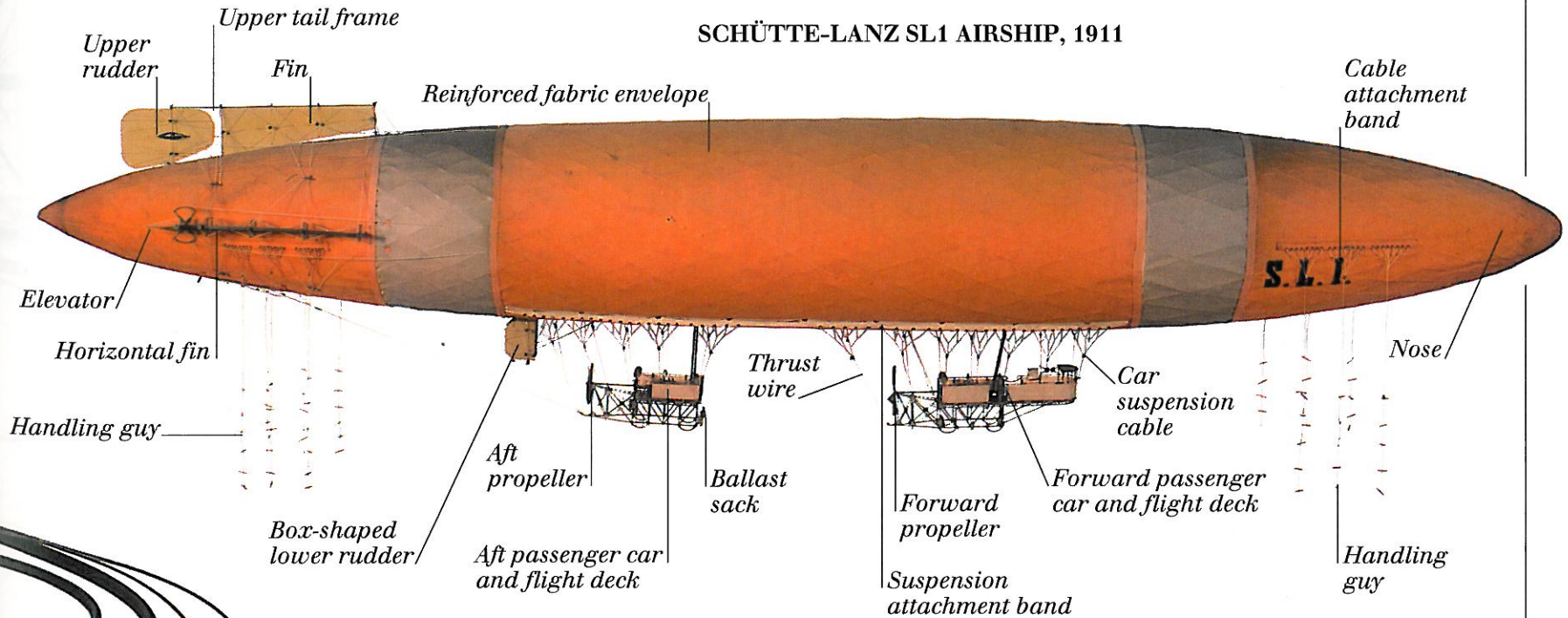


HOT-AIR BALLOON BASKET

CROSS-SECTION OF USS AKRON AIRSHIP, 1931



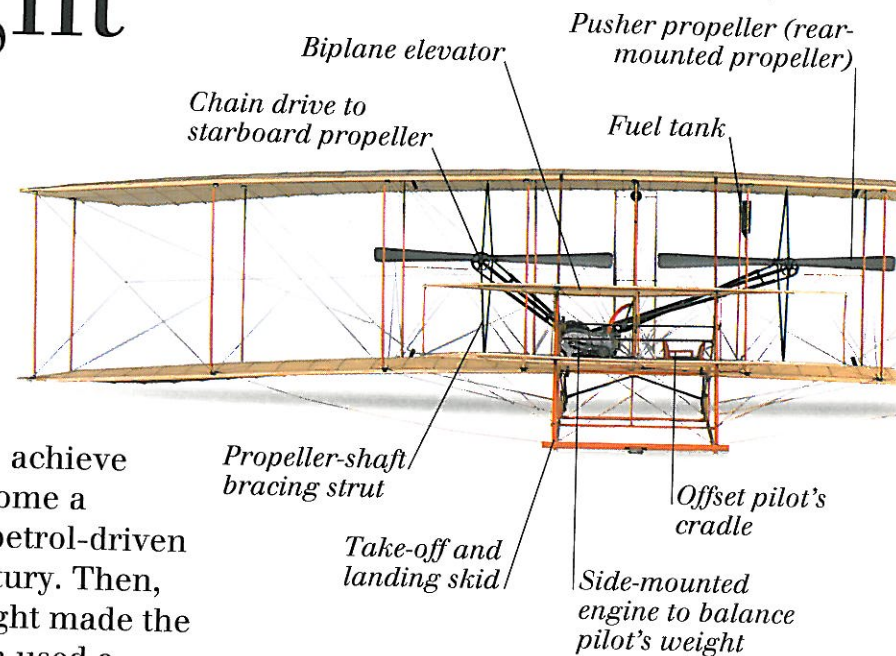
SCHÜTTE-LANZ SL1 AIRSHIP, 1911



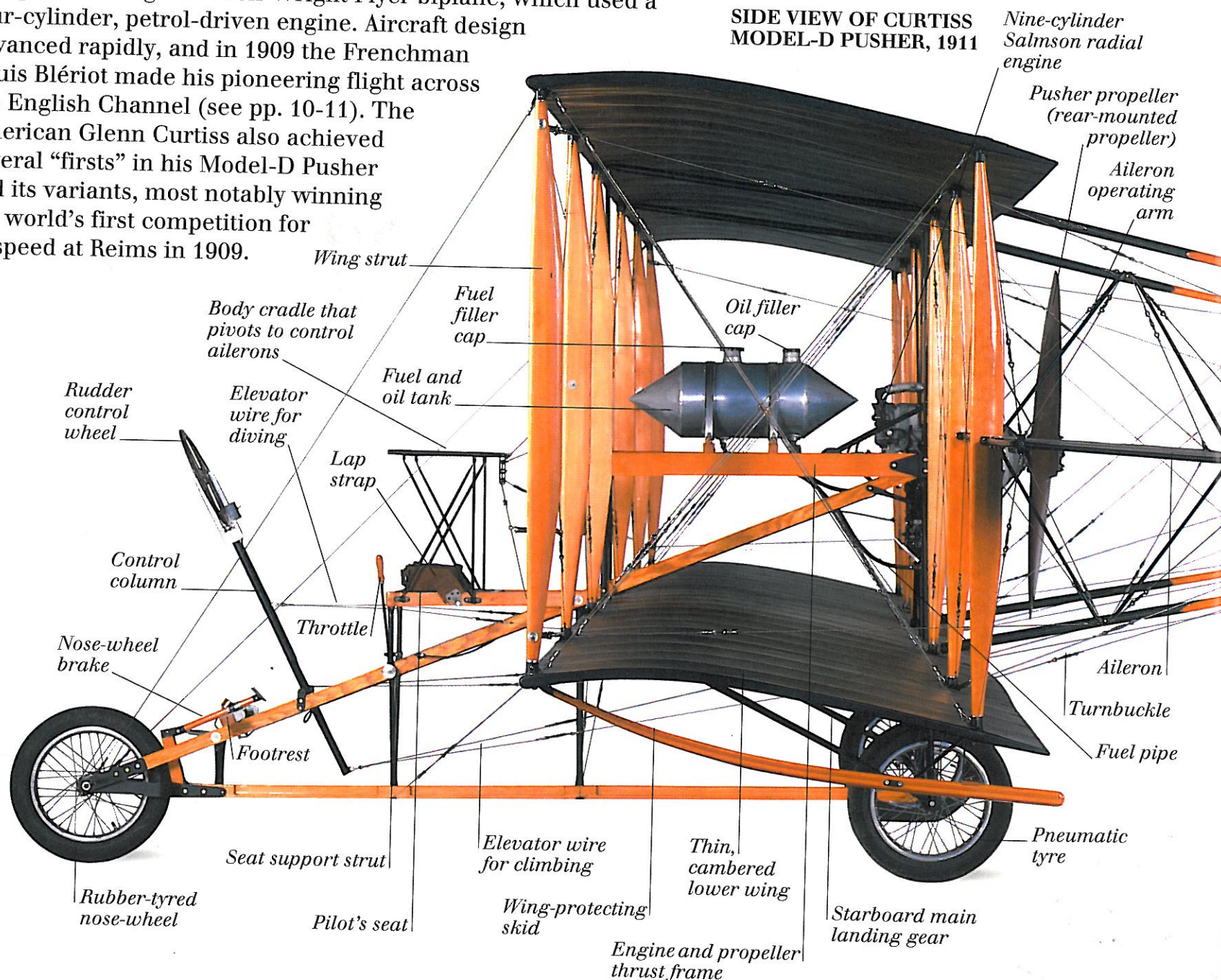
Pioneers of flight

FLIGHT HAS FASCINATED MANKIND for centuries, and countless unsuccessful flying machines have been designed. The first successful flight was made by the French Montgolfier brothers in 1783, when they flew a balloon over Paris (see pp. 6-7). The next major advance was the development of gliders, notably by the Englishman Sir George Cayley, who in 1845 designed the first glider to make a sustained flight, and by the German Otto Lilienthal, who became known as the world's first pilot because he managed to achieve controlled flights. However, powered flight did not become a practical possibility until the invention of lightweight, petrol-driven internal combustion engines at the end of the 19th century. Then, in 1903, the American brothers Orville and Wilbur Wright made the first powered flight in their Wright Flyer biplane, which used a four-cylinder, petrol-driven engine. Aircraft design advanced rapidly, and in 1909 the Frenchman Louis Blériot made his pioneering flight across the English Channel (see pp. 10-11). The American Glenn Curtiss also achieved several "firsts" in his Model-D Pusher and its variants, most notably winning the world's first competition for airspeed at Reims in 1909.

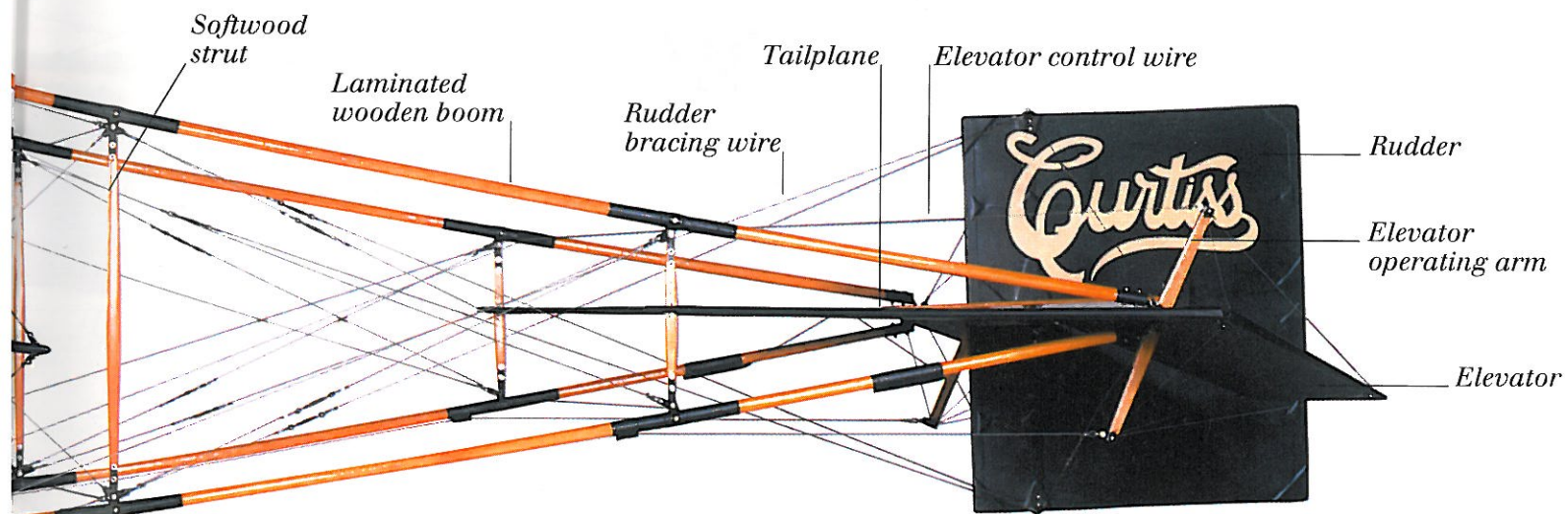
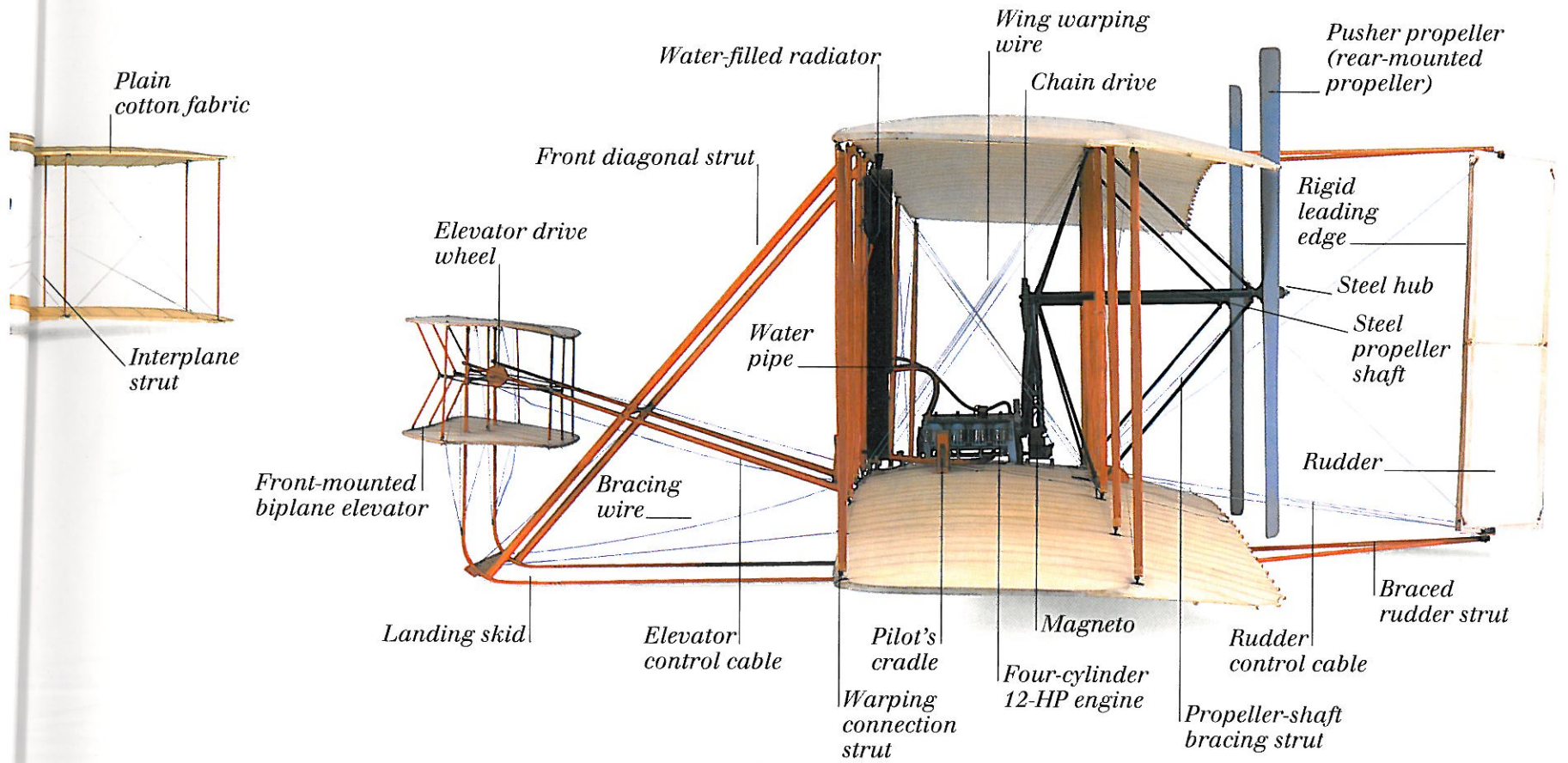
FRONT VIEW OF WRIGHT FLYER, 1903



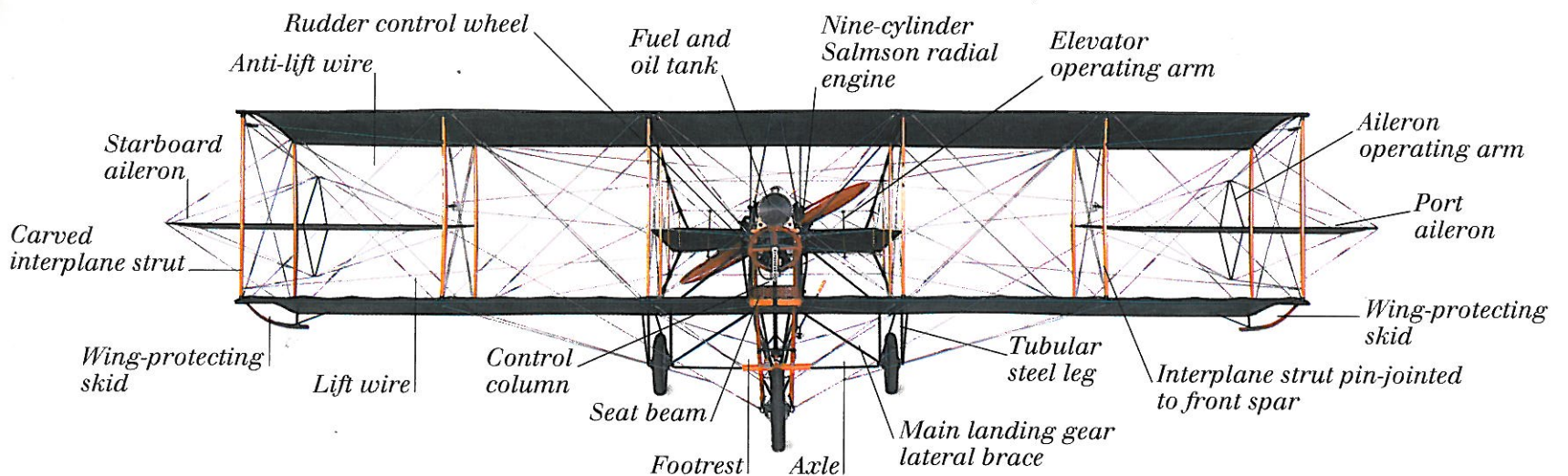
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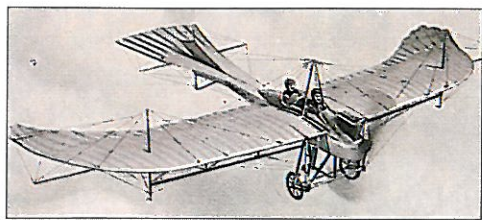
SIDE VIEW OF WRIGHT FLYER, 1905



FRONT VIEW OF CURTISS MODEL-D PUSHER, 1911



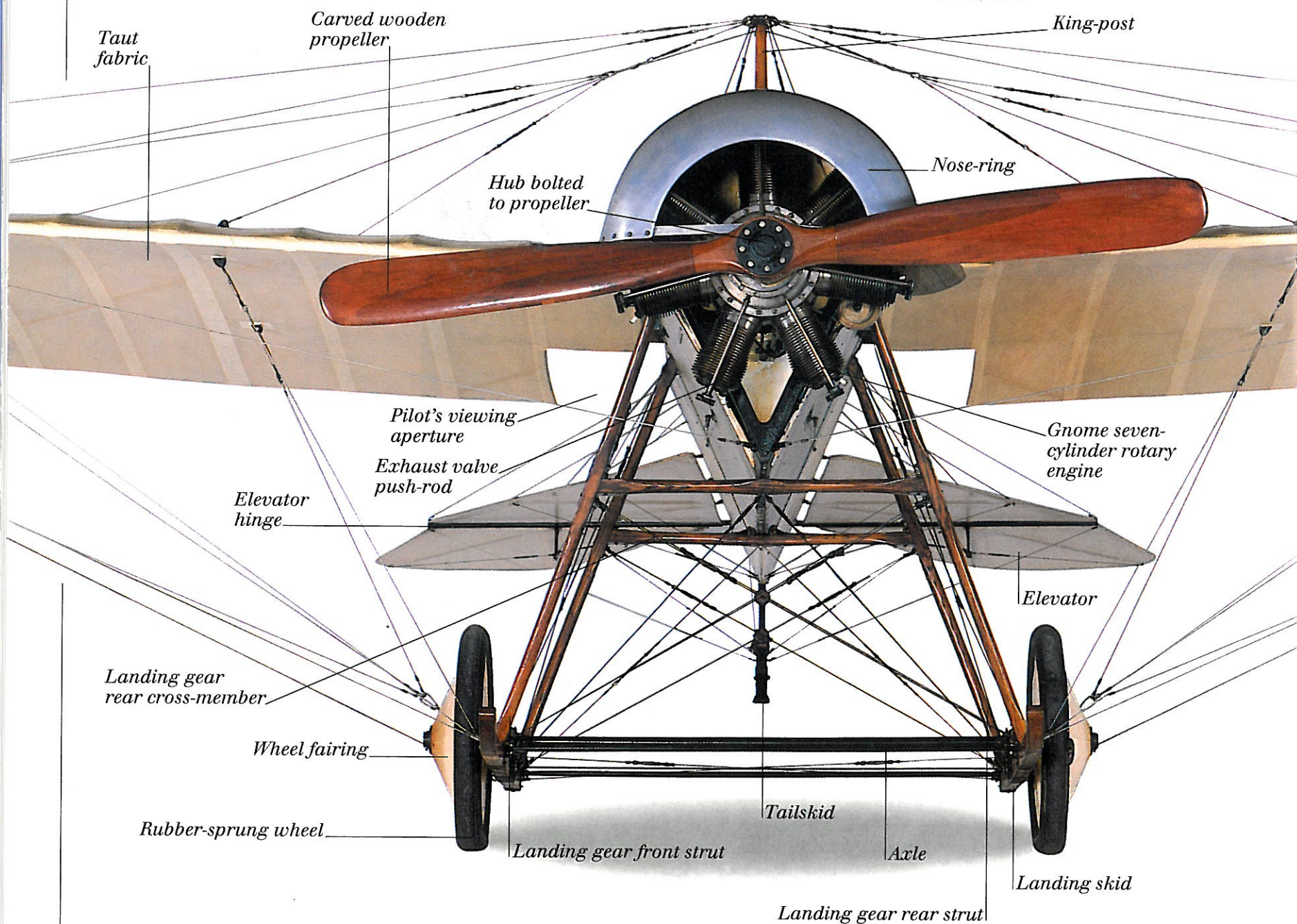
Early monoplanes

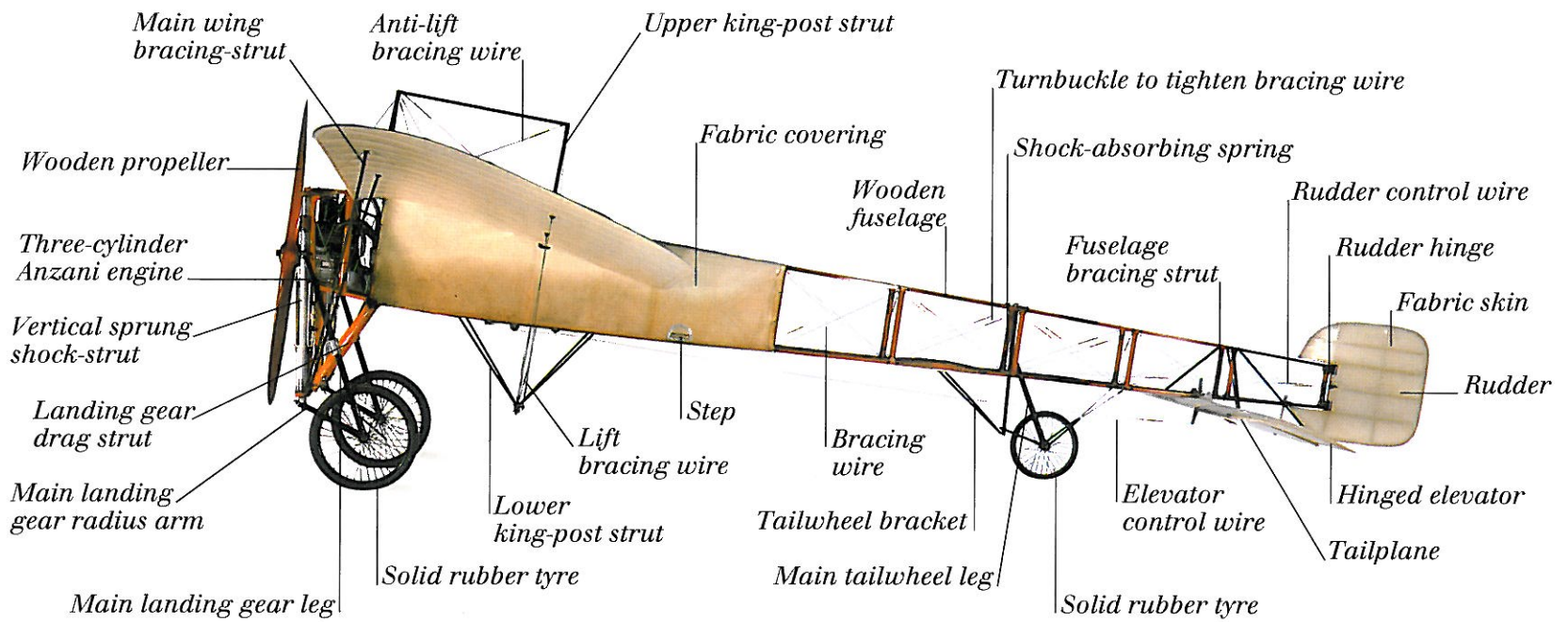


RUMPLER MONOPLANE, 1908

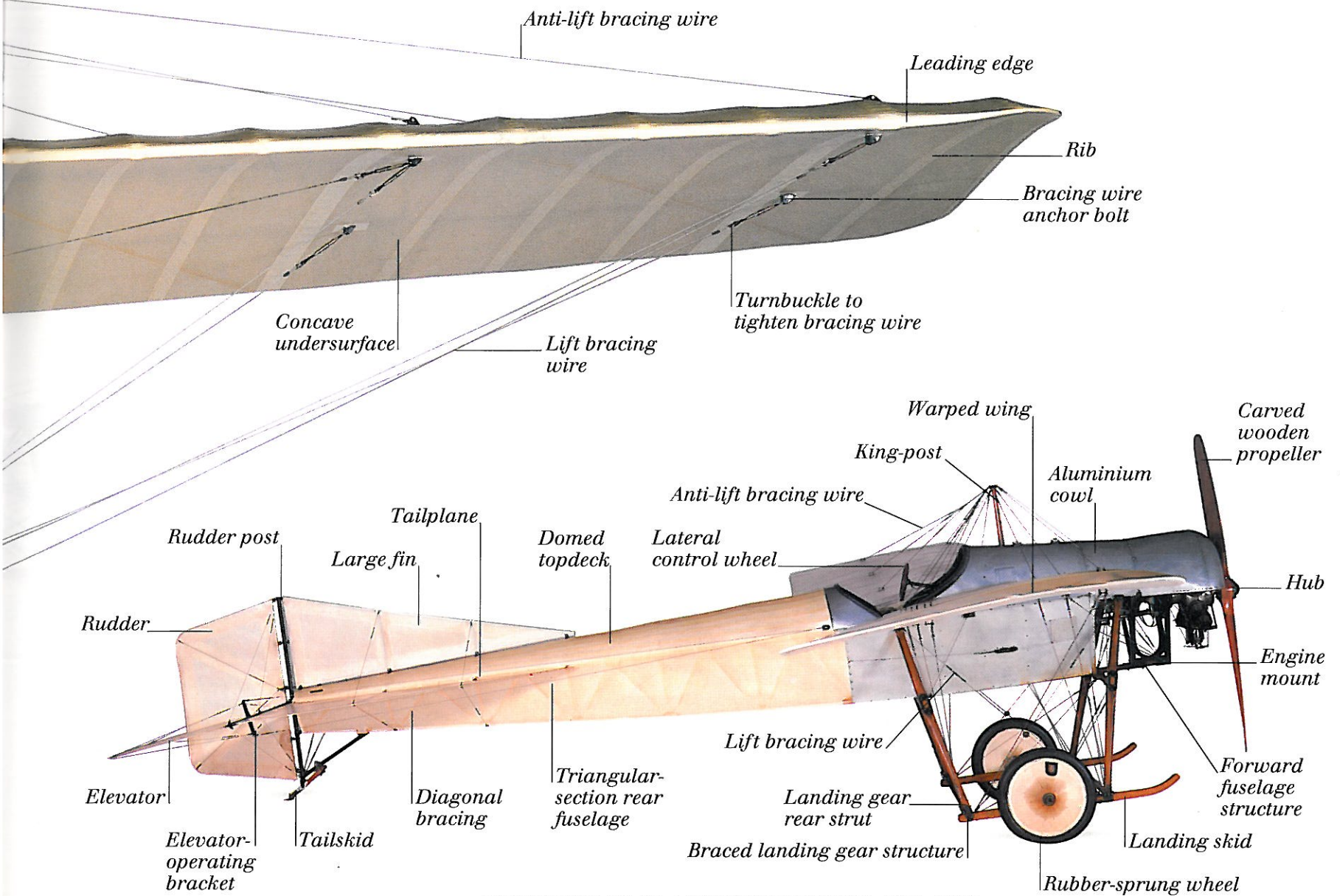
MONOPLANES HAVE ONE WING on each side of the fuselage. The principal disadvantage of this arrangement in early, wooden-framed aircraft was that single wings were weak and required strong wires to brace them to king-posts above and below the fuselage. However, single wings also had advantages: they experienced less drag than multiple wings, allowing greater speed; they also made aircraft more manoeuvrable because single wings were easier to warp (twist) than double wings, and warping the wings was how pilots controlled the roll of early aircraft. By 1912, the French pilot Louis Blériot had used a monoplaner to make the first flight across the English Channel, and the Briton Robert Blackburn and the Frenchman Armand Deperdussin had proved the greater speed of monoplanes. However, a spate of crashes caused by broken wings discouraged monoplaner production, except in Germany, where all-metal monoplanes were developed in 1917. The wings of all-metal monoplanes did not need strengthening by struts or bracing wires, but despite this, such planes were not widely adopted until the 1930s.

FRONT VIEW OF BLACKBURN MONOPLANE, 1912





SIDE VIEW OF BLÉRIOT XI, 1909



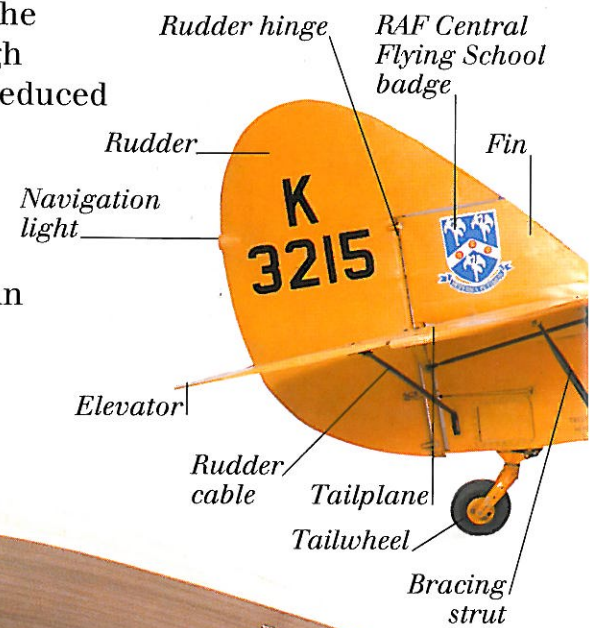
SIDE VIEW OF BLACKBURN MONOPLANE, 1912

Biplanes and triplanes



LAMINATED PROPELLER

BIPLANES DOMINATED AIRCRAFT DESIGN until the 1930s, largely because some early monoplanes (see pp. 10-11) were too fragile to withstand the stresses of flight. The struts between biplanes' wings made the wings strong compared with those of early monoplanes, although the greater surface area of biplanes' wings increased drag and reduced speed. Many aircraft designers also developed triplanes, which had a particular advantage over biplanes: more wings meant a shorter wingspan to achieve the same lifting power, and a shorter wingspan gave greater manoeuvrability. Triplanes were most successful as fighters during World War I, the German Fokker triplane being a notable example. However, the greater manoeuvrability of triplanes was no advantage for normal flying and so most manufacturers continued to make biplanes. Many other aircraft designs were attempted. Some were quadruplanes, with four pairs of wings. Some had tandem wings (two pairs of monoplane wings, one behind the other). One of the most bizarre designs was by the Englishman Horatio Phillips: it had 20 sets of narrow wings and looked rather like a Venetian blind.



Rudder hinge
RAF Central Flying School badge

Rudder
Fin

Navigation light

K
3215

Elevator

Rudder cable

Tailplane

Tailwheel

Bracing strut

SIDE VIEW OF AVRO TRIPLANE IV, 1910

Valve rocker

Air cooling baffle

Magneto

Crankcase breather pipe

Directly driven propeller

Wing strut

Fuel tank

Throttle

Harness

Pilot's seat

Main front strut to engine mount

Skid upper bracing strut

Limit of fuselage skin

Ash skid

Rubber cord suspension

Turnbuckle

Lateral bracing strut

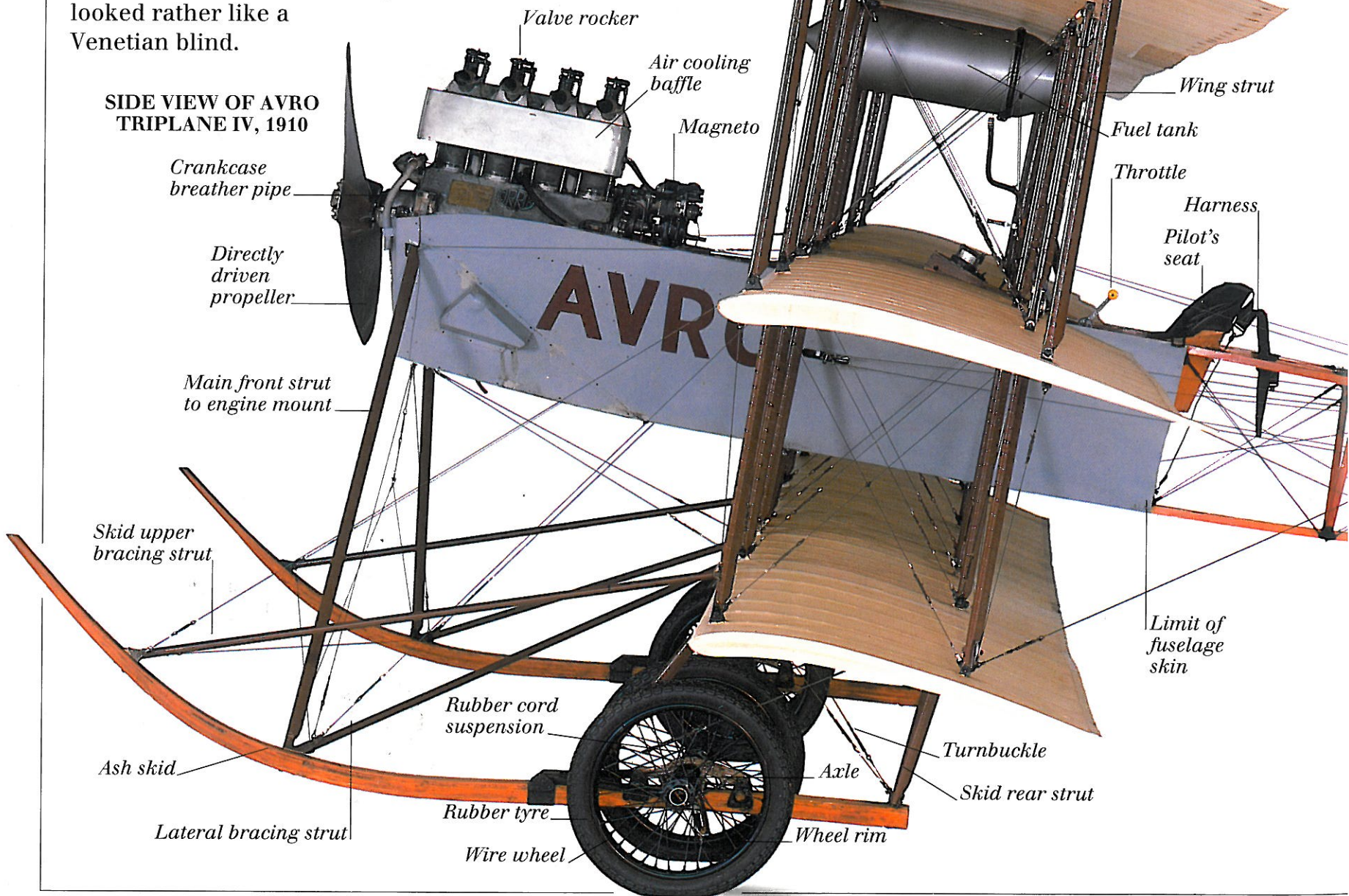
Rubber tyre

Axle

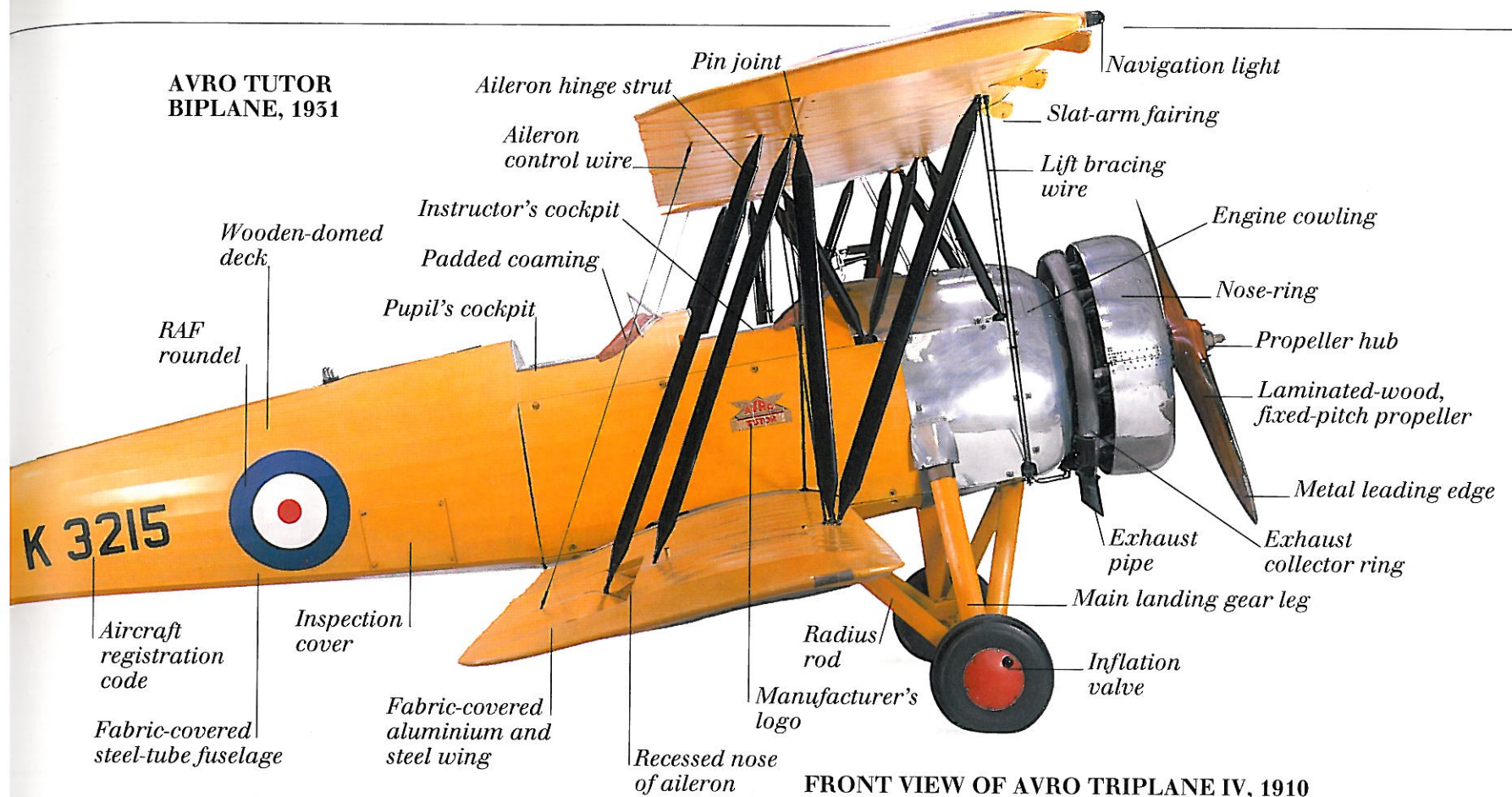
Skid rear strut

Wire wheel

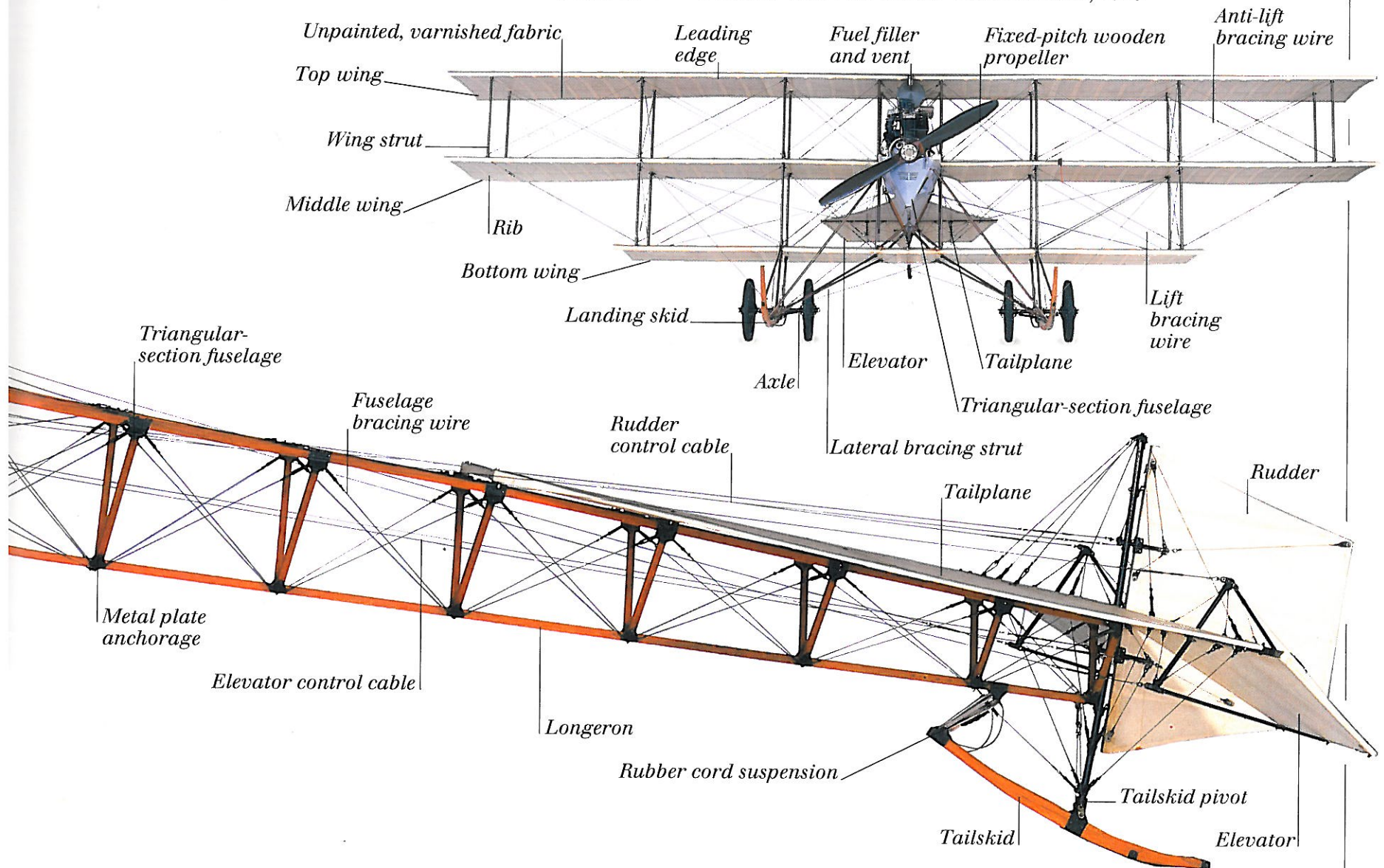
Wheel rim



**AVRO TUTOR
BIPLANE, 1931**



FRONT VIEW OF AVRO TRIPLANE IV, 1910



World War I aircraft

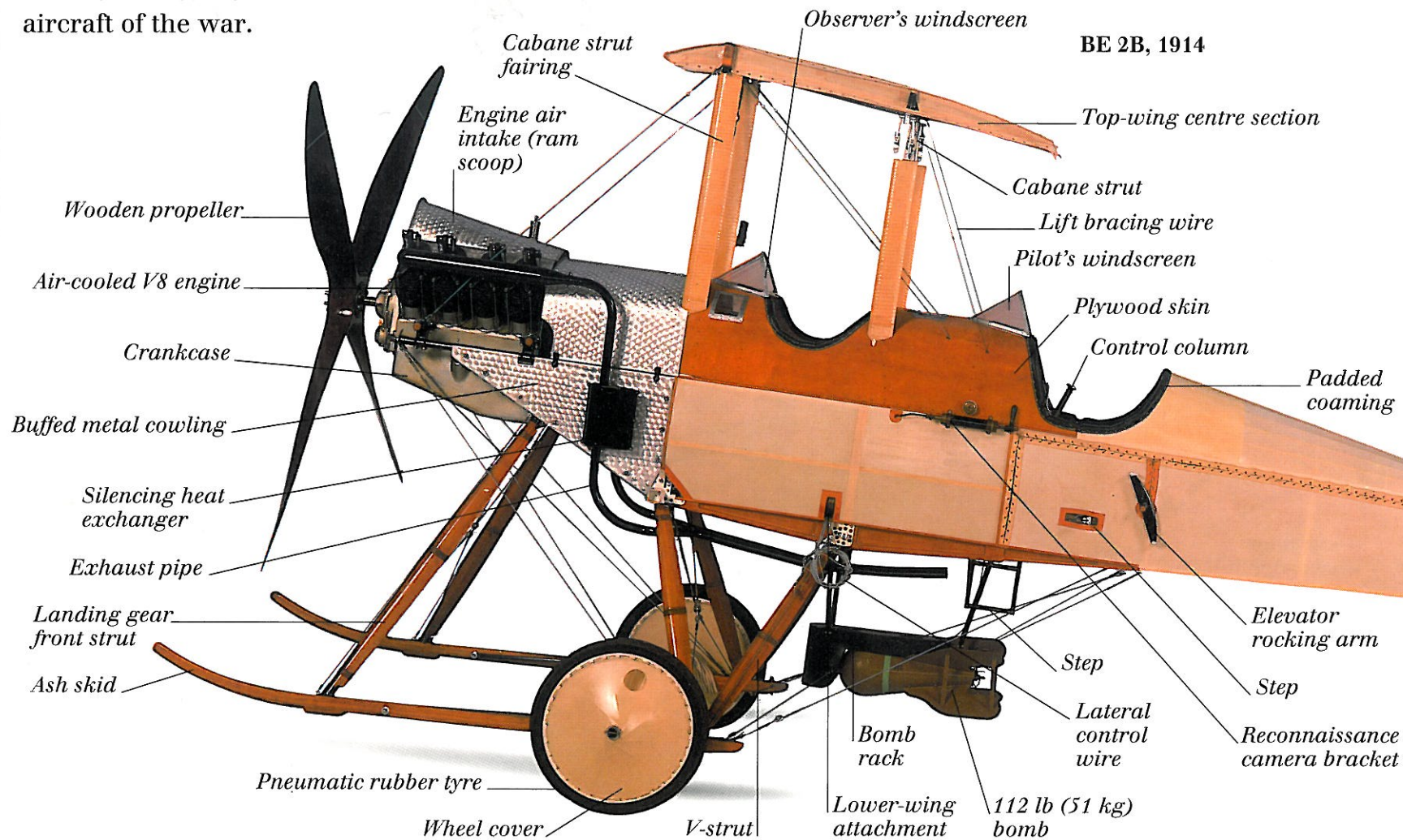
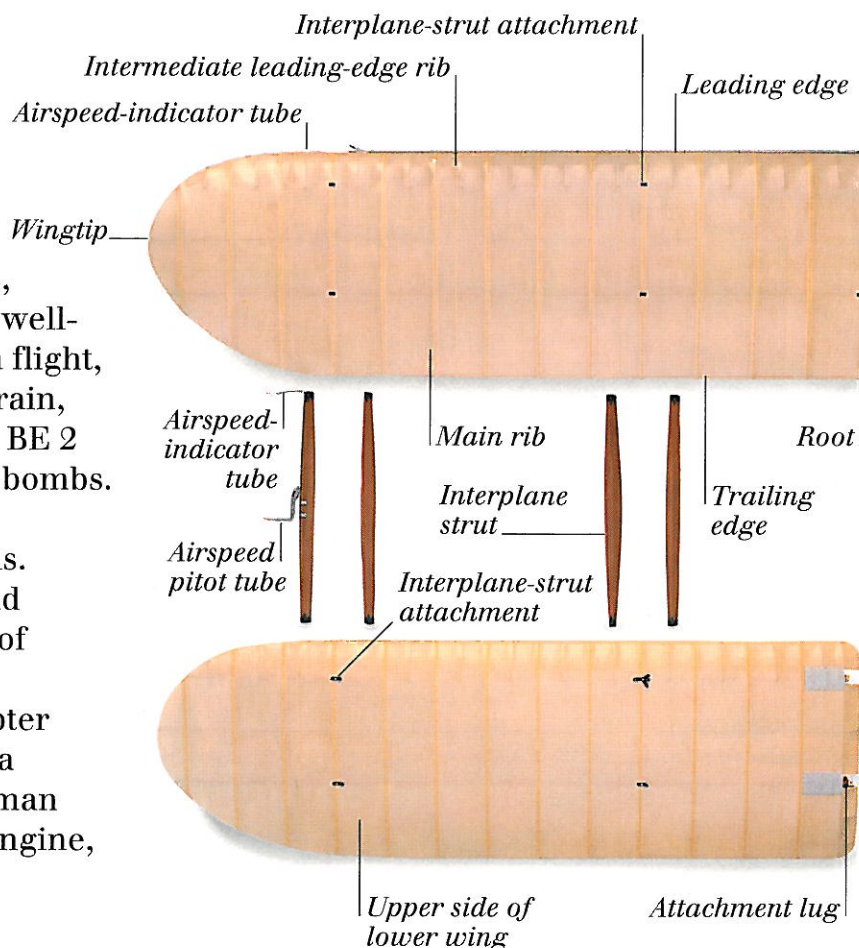


FLYING
HELMET

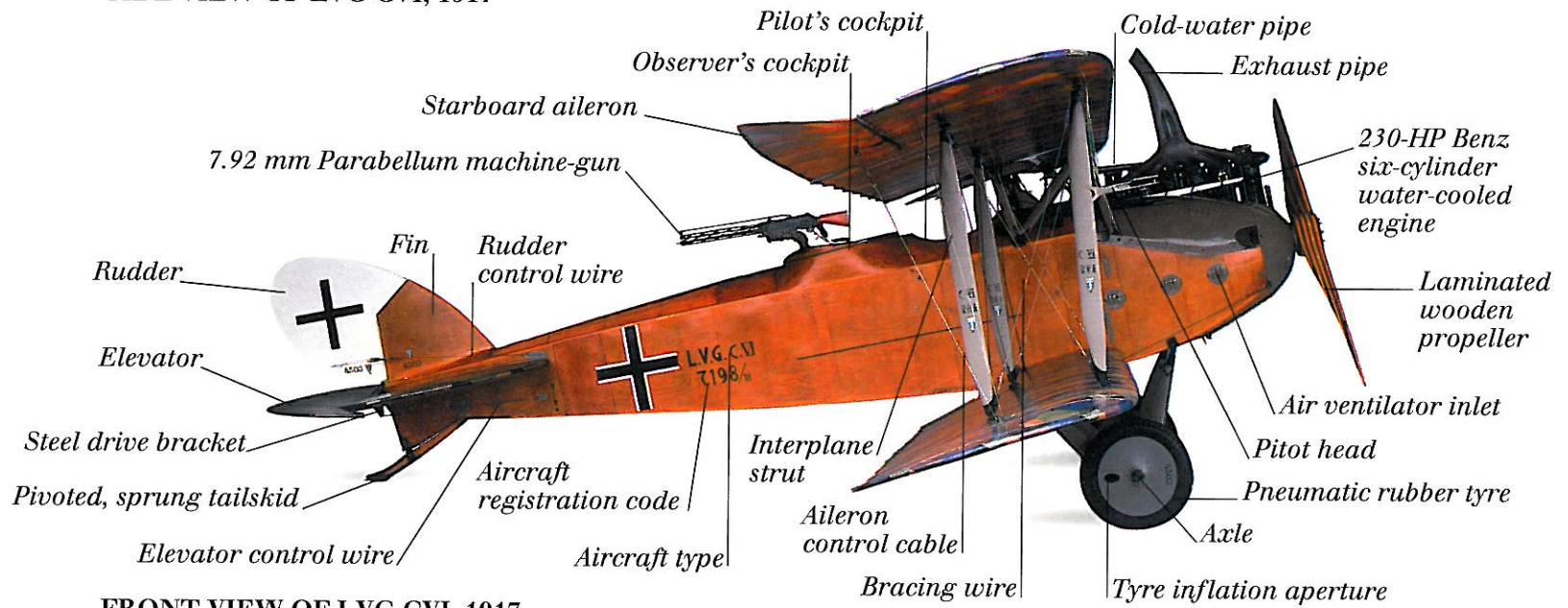
WHEN WORLD WAR I STARTED in 1914, the main purpose of military aircraft was reconnaissance. The British-built BE 2, of which the BE 2B was a variant, was well-suited to this duty; it was very stable in flight, allowing the occupants to study the terrain, take photographs, and make notes. The BE 2 was also one of the first aircraft to drop bombs. One of the biggest problems for aircraft

designers during the war was mounting machine-guns. On aircraft that had front-mounted propellers, the field of fire was restricted by the propeller and other parts of the aircraft. The problem was solved in 1915 by the Dutchman Anthony Fokker, who designed an interrupter gear that prevented a machine-gun from firing when a propeller blade passed in front of the barrel. The German LVG CVI had a forward-firing gun to the right of the engine, as well as a rear-cockpit gun, and a bombing capability. It was one of the most versatile aircraft of the war.

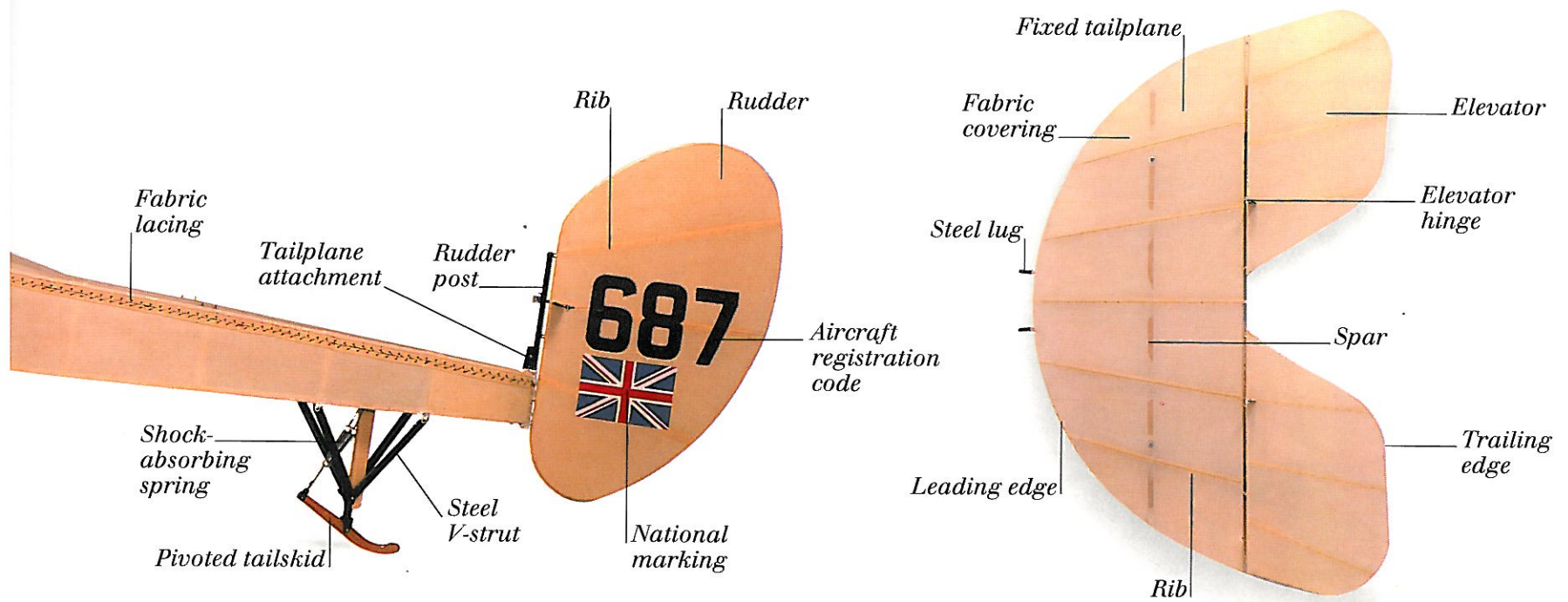
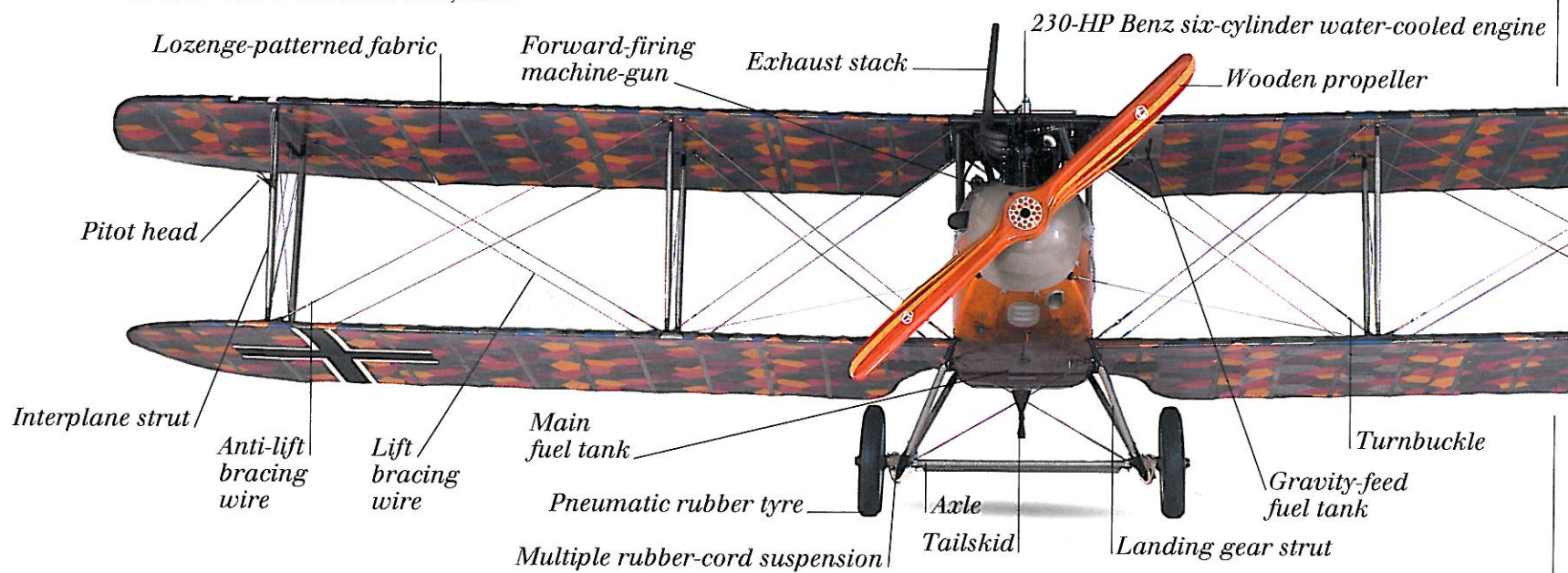
PORT WINGS FROM A BE 2B



SIDE VIEW OF LVG CVI, 1917

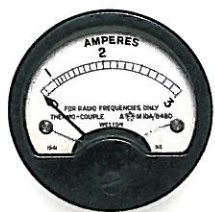


FRONT VIEW OF LVG CVI, 1917



HORIZONTAL TAIL OF A BE 2B

Early cockpits and instruments

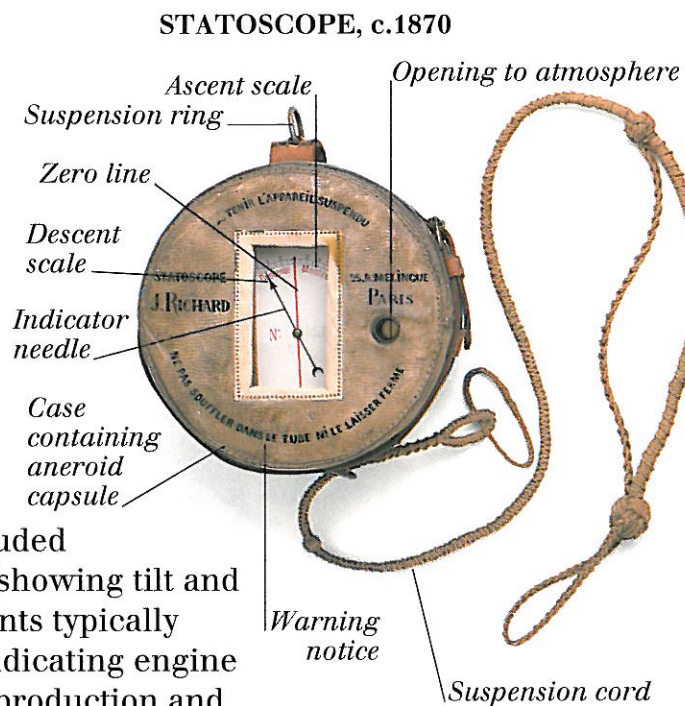
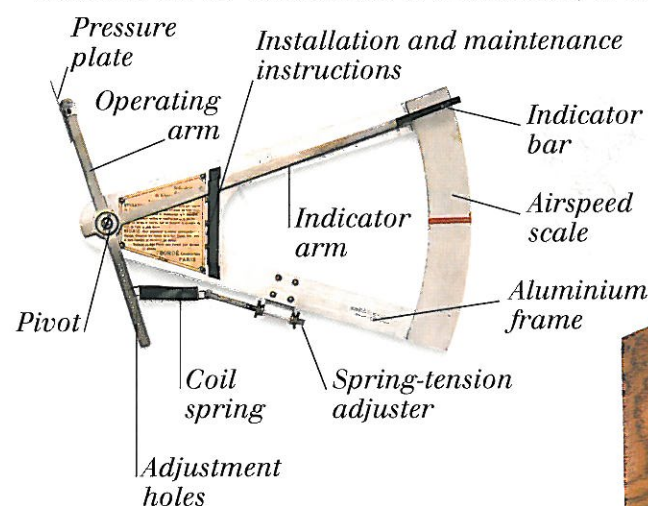


THERMOCOUPLE AMMETER, c.1940

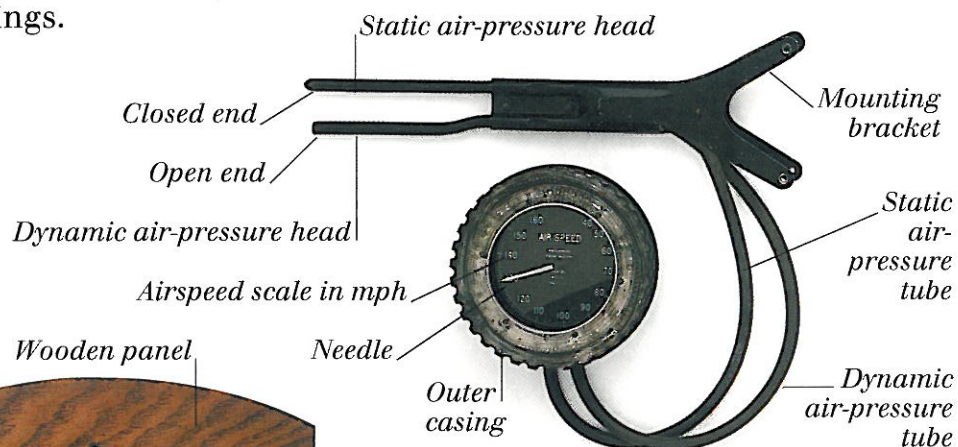
ONE OF THE FIRST FLIGHT instruments, the statoscope, was used in early balloon flights to indicate ascent and descent. The development of powered flight led to the introduction of cockpits and more instruments. Early cockpits had rudder pedals; a control column (for manoeuvring); and flight, engine, and systems instruments. Flight instruments commonly included

an airspeed indicator, altimeter (showing altitude), clinometer (showing tilt and pitch), and magnetic compass (for navigation). Engine instruments typically included an oil-pressure gauge, fuel-level gauge, tachometer (indicating engine speed), and a dual electric power indicator (showing electricity production and consumption). One of the earliest systems instruments was the flap indicator, which showed the position of the flaps on the wings.

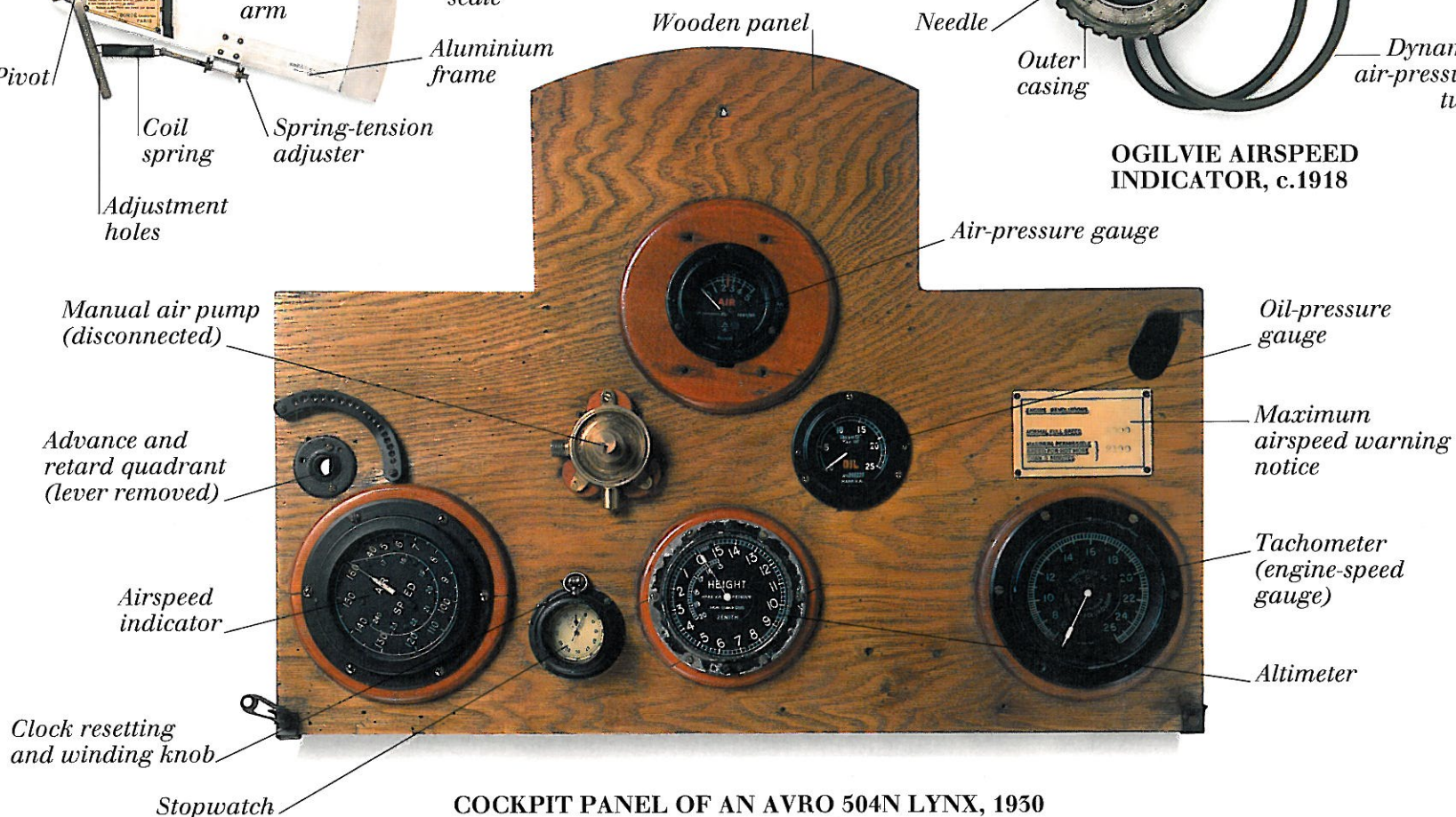
“WING SPRING” AIRSPEED INDICATOR, 1910



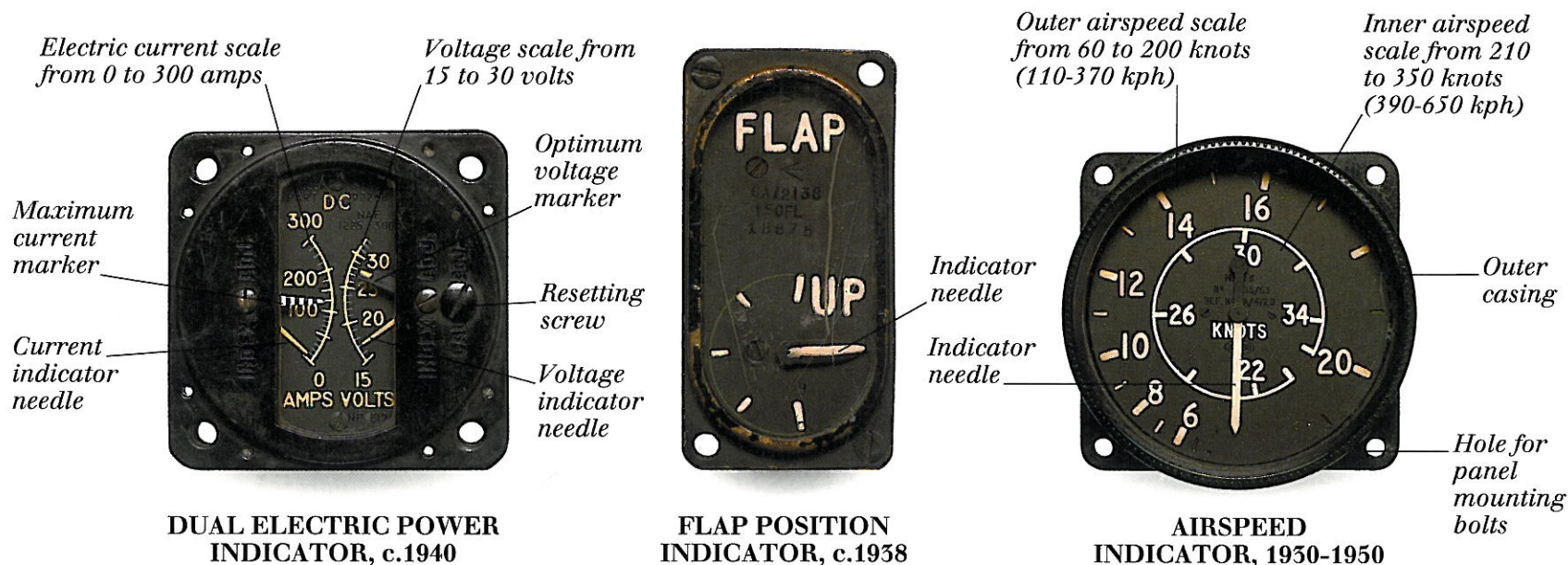
STATOSCOPE, c.1870



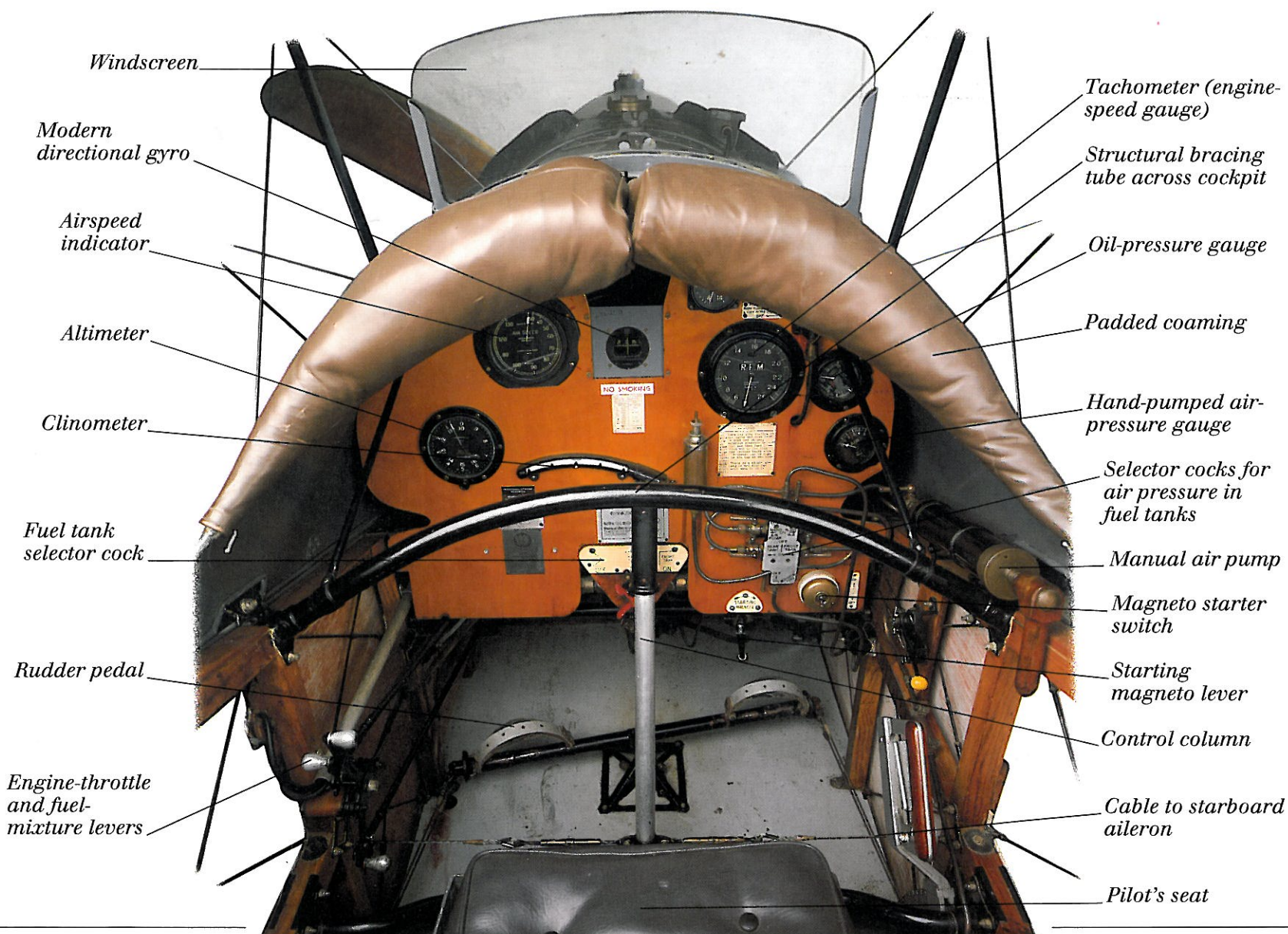
OGILVIE AIRSPEED INDICATOR, c.1918



COCKPIT PANEL OF AN AVRO 504N LYNX, 1930



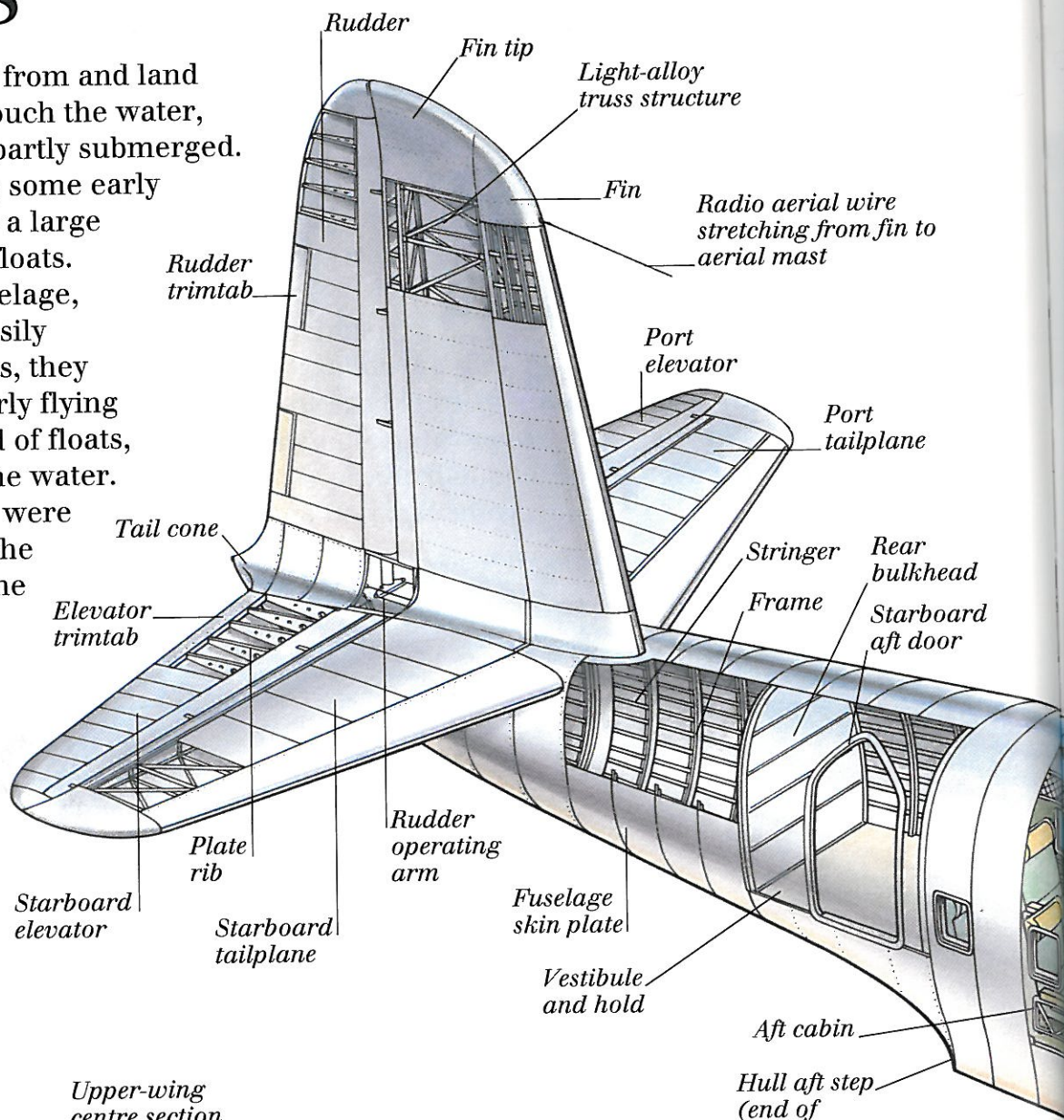
COCKPIT OF A BRISTOL FIGHTER, 1917



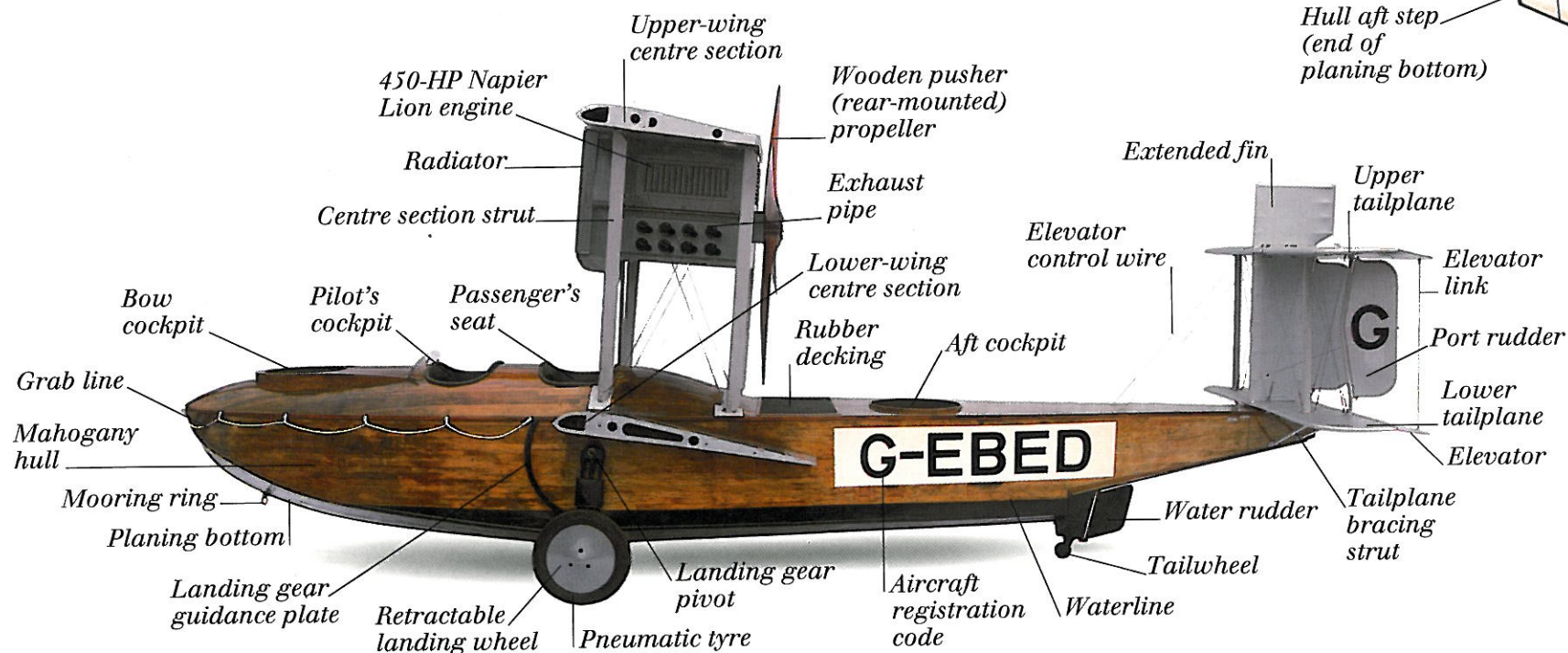
Seaplanes and flying boats

SEAPLANES AND FLYING BOATS TAKE OFF from and land on water. On seaplanes only the floats touch the water, but on flying boats the fuselage itself is partly submerged. Modern seaplanes have two large floats; some early seaplanes had an additional tail float, or a large central float balanced by small wingtip floats. Flying boats have a specially shaped fuselage, similar to the hull of a ship, that runs easily across water. Like centre-float seaplanes, they need stabilizing wingtip floats. A few early flying boats had twin hulls, and others, instead of floats, had deep, stubby wings that rested on the water. Due to the lack of runways, flying boats were widely used as passenger aircraft until the end of World War II. Both types of marine aircraft were also used for various military tasks, including dropping torpedoes, bombing, reconnaissance, and transport. Today, they are used mainly for racing, and for special purposes such as dumping water on large fires.

SHORT S23 EMPIRE FLYING BOAT, 1936



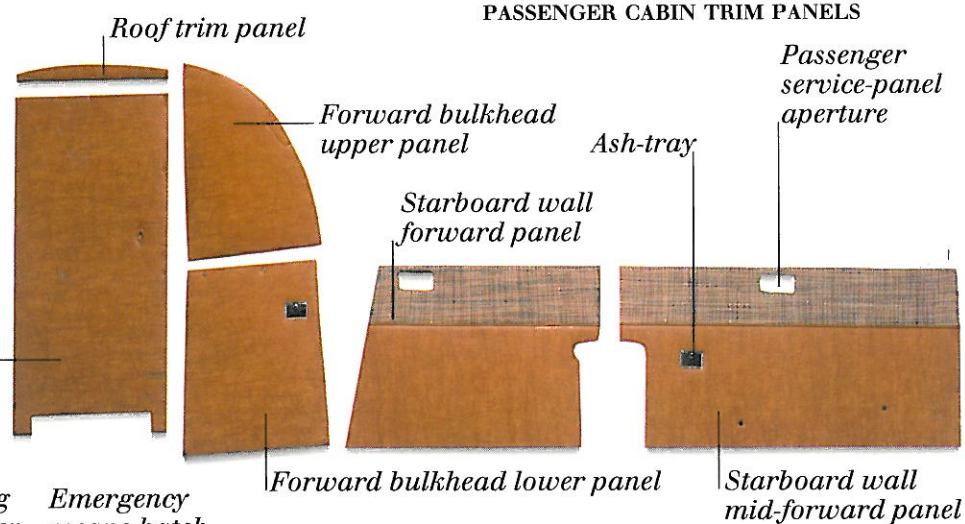
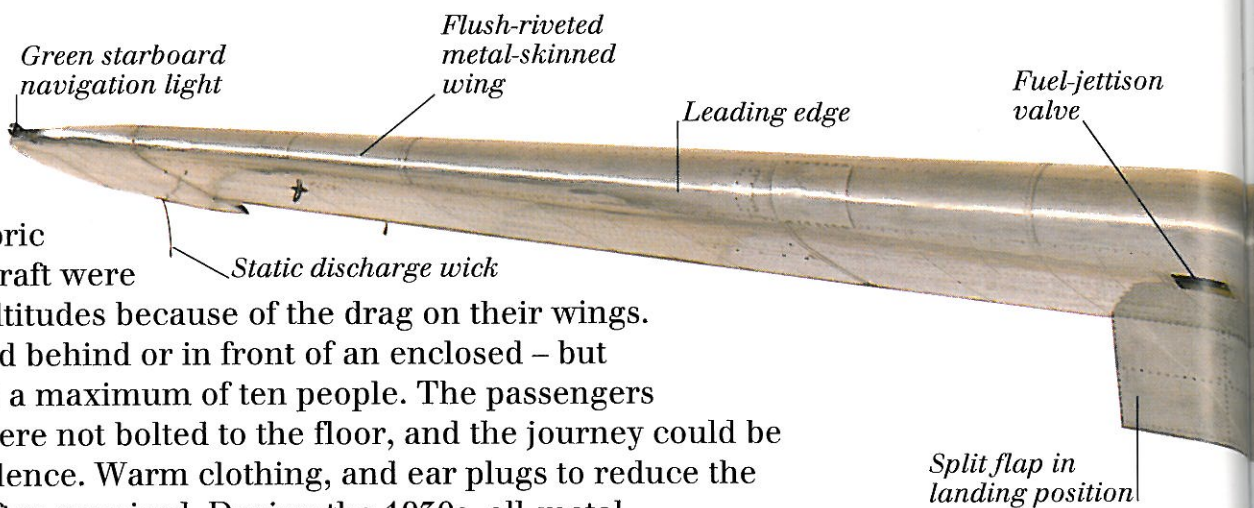
VICKERS VIKING FLYING BOAT FUSELAGE, 1921



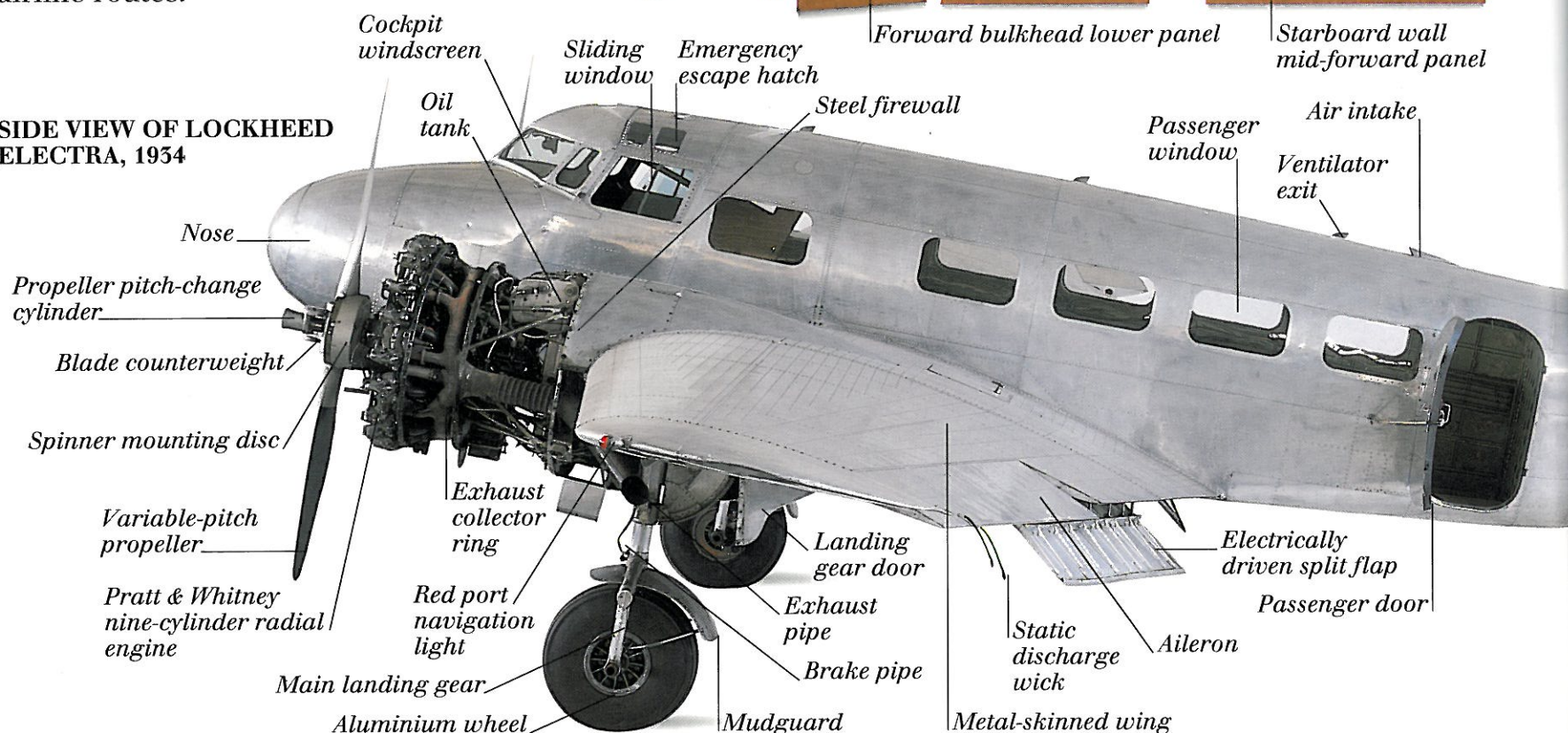
Early passenger aircraft

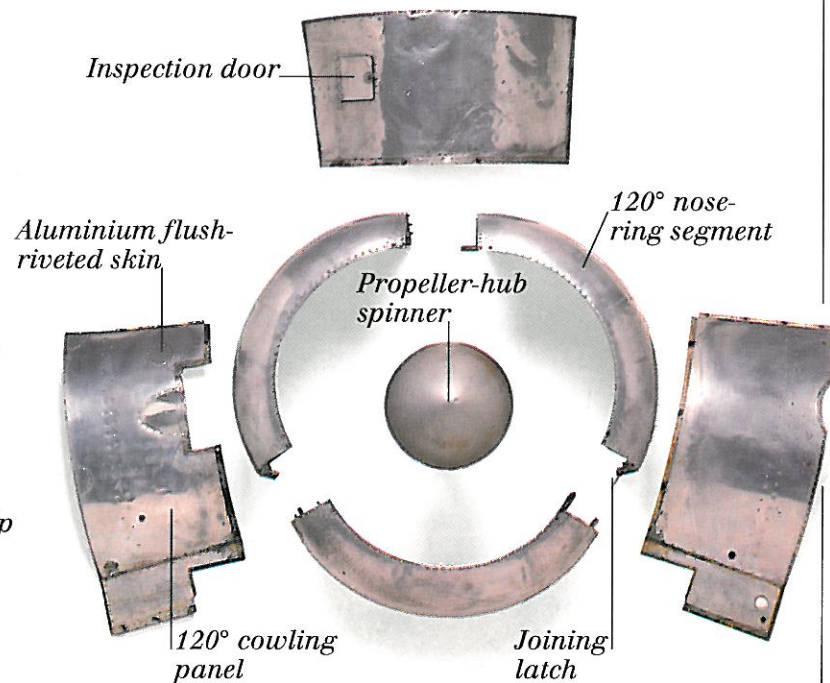
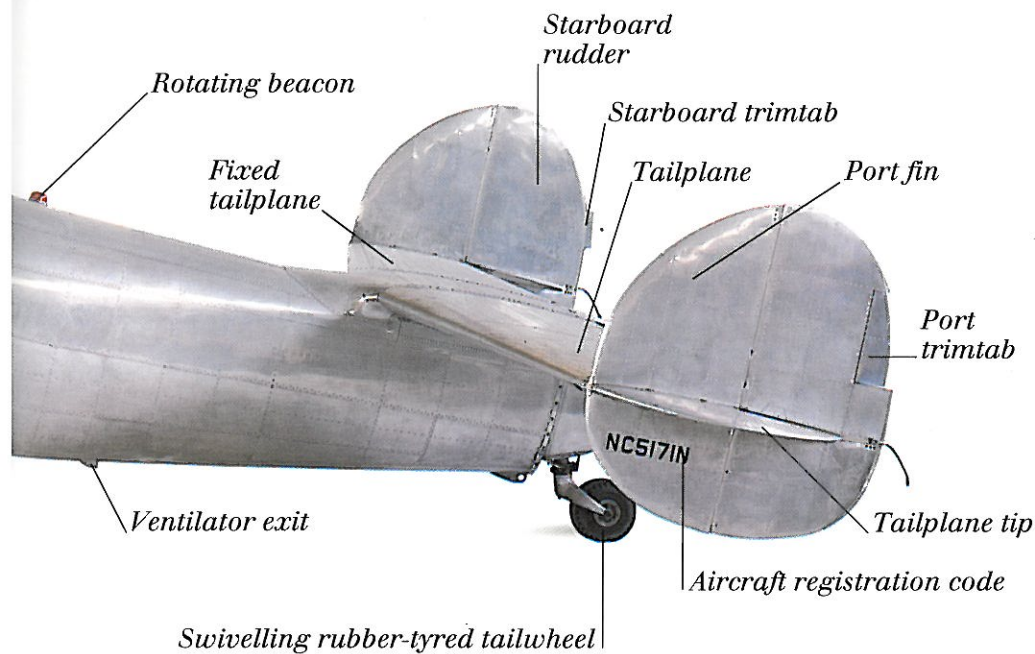
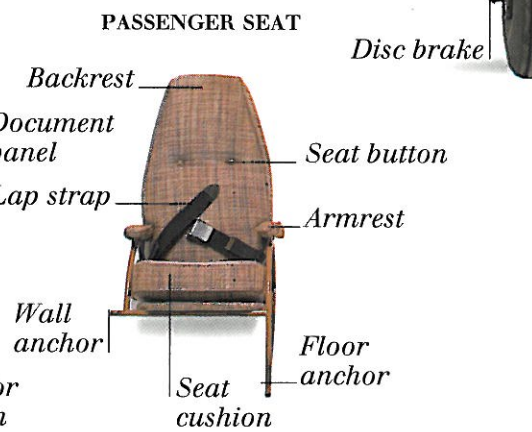
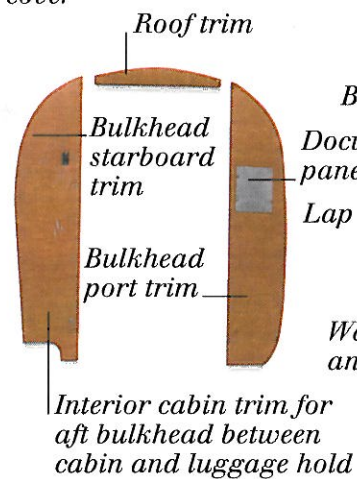
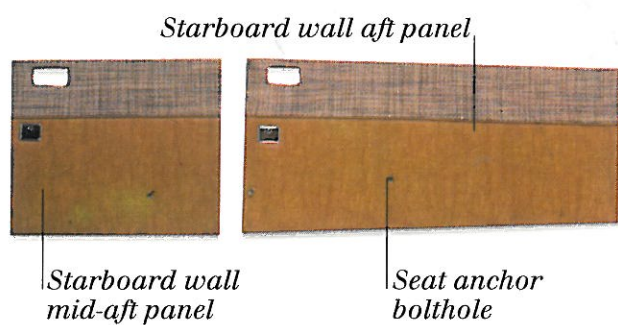
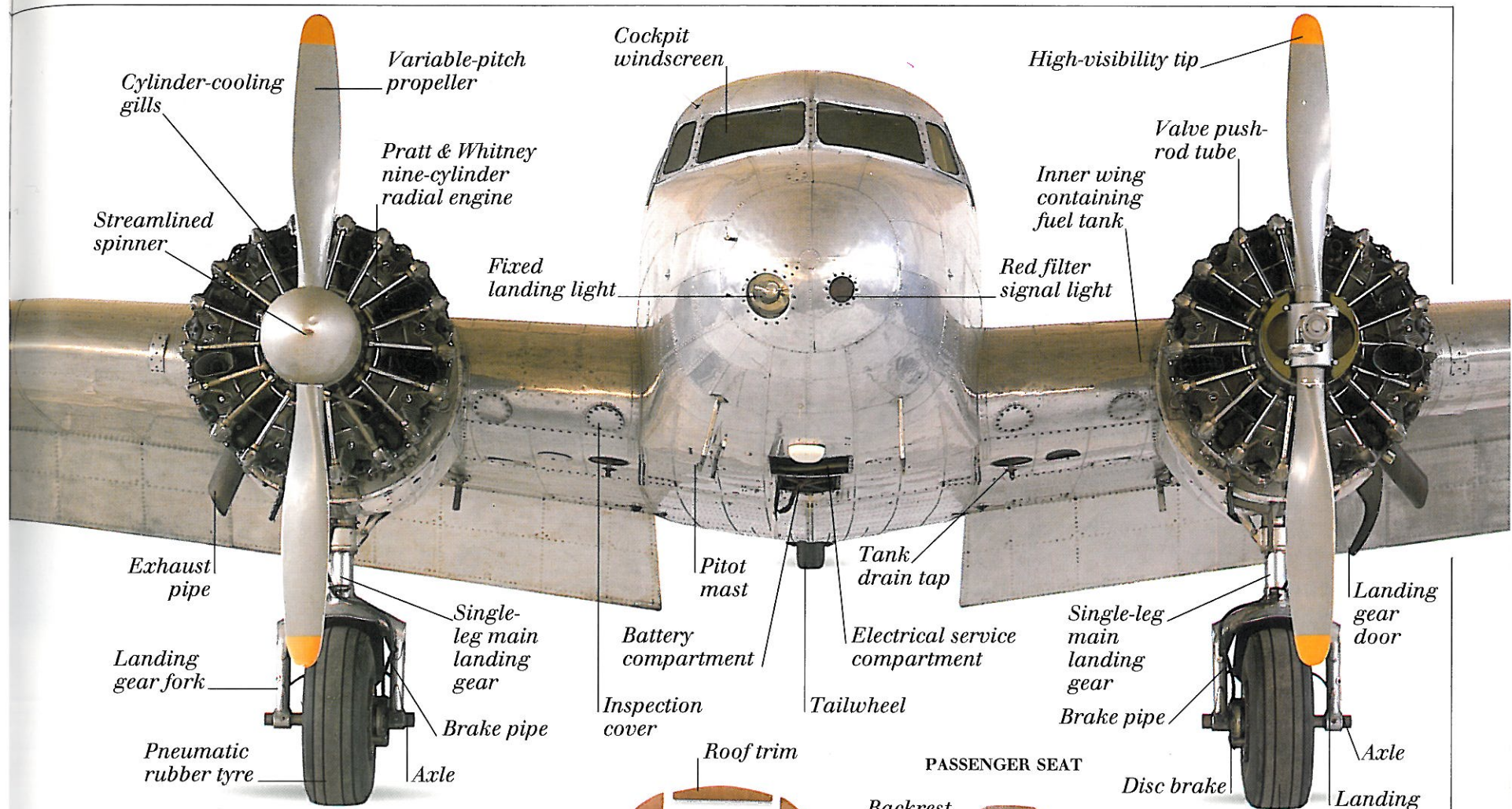
FRONT VIEW OF LOCKHEED ELECTRA, 1934

UNTIL THE 1930s, most passenger aircraft were biplanes, with two pairs of wings and a wooden or metal framework covered with fabric or, sometimes, plywood. Such aircraft were restricted to low speeds and low altitudes because of the drag on their wings. Many had an open cockpit, situated behind or in front of an enclosed – but unpressurized – cabin that carried a maximum of ten people. The passengers usually sat in wicker chairs that were not bolted to the floor, and the journey could be bumpy when flying through turbulence. Warm clothing, and ear plugs to reduce the effects of prolonged noise, were often required. During the 1930s, all-metal monoplanes, such as the Lockheed Electra shown here, became widespread. Their streamlined design, more powerful engines, and pressurized cabins (which were first used commercially in 1939) allowed fast flights at high altitudes, where there is less turbulence. Flying boats (see pp. 18-19) were still necessary on many routes until 1945 because of inadequate runways and the frequency of emergency sea-landings. World War II, however, resulted in enough good runways being built for land-planes to become standard on all major airline routes.



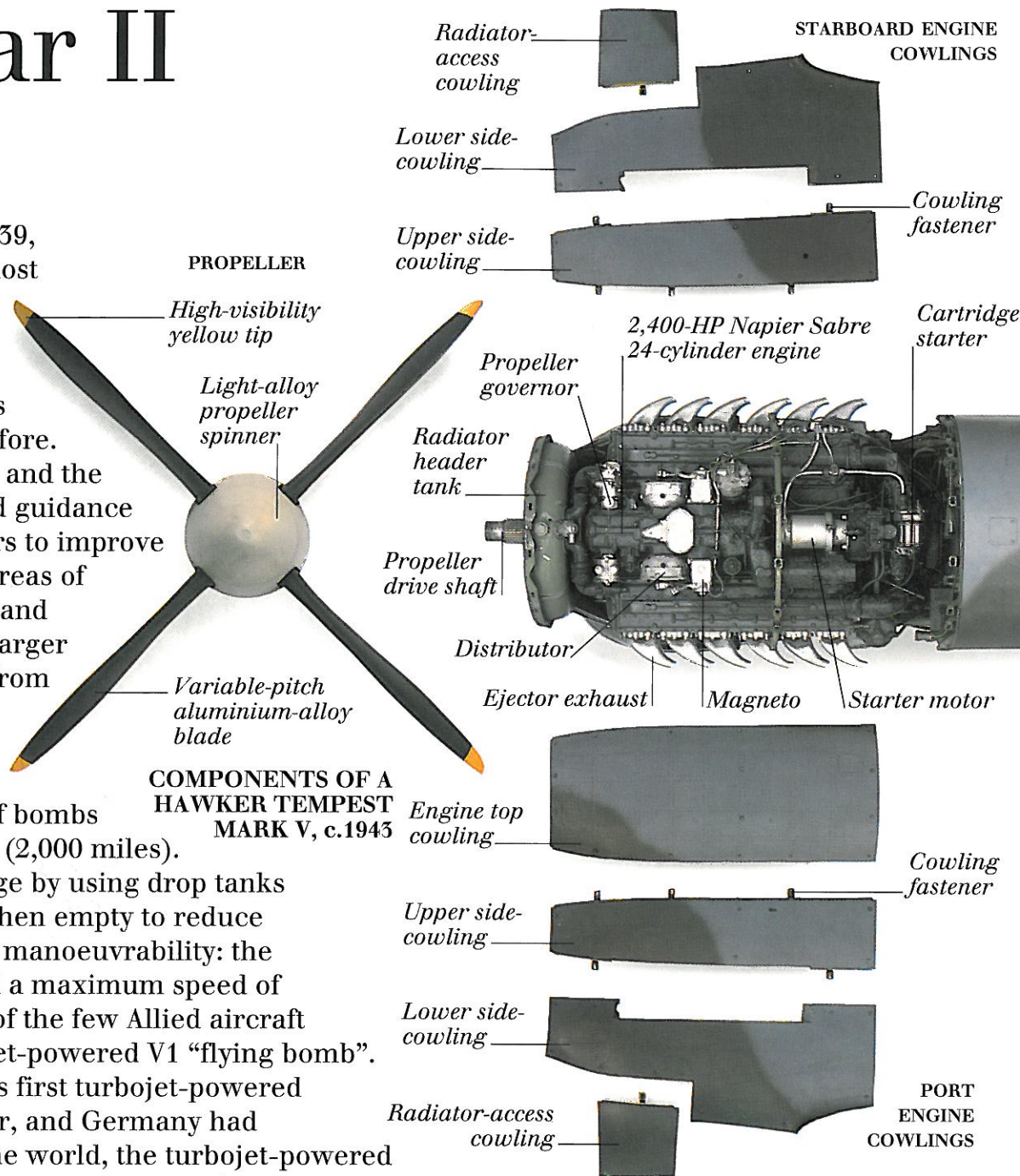
SIDE VIEW OF LOCKHEED ELECTRA, 1934



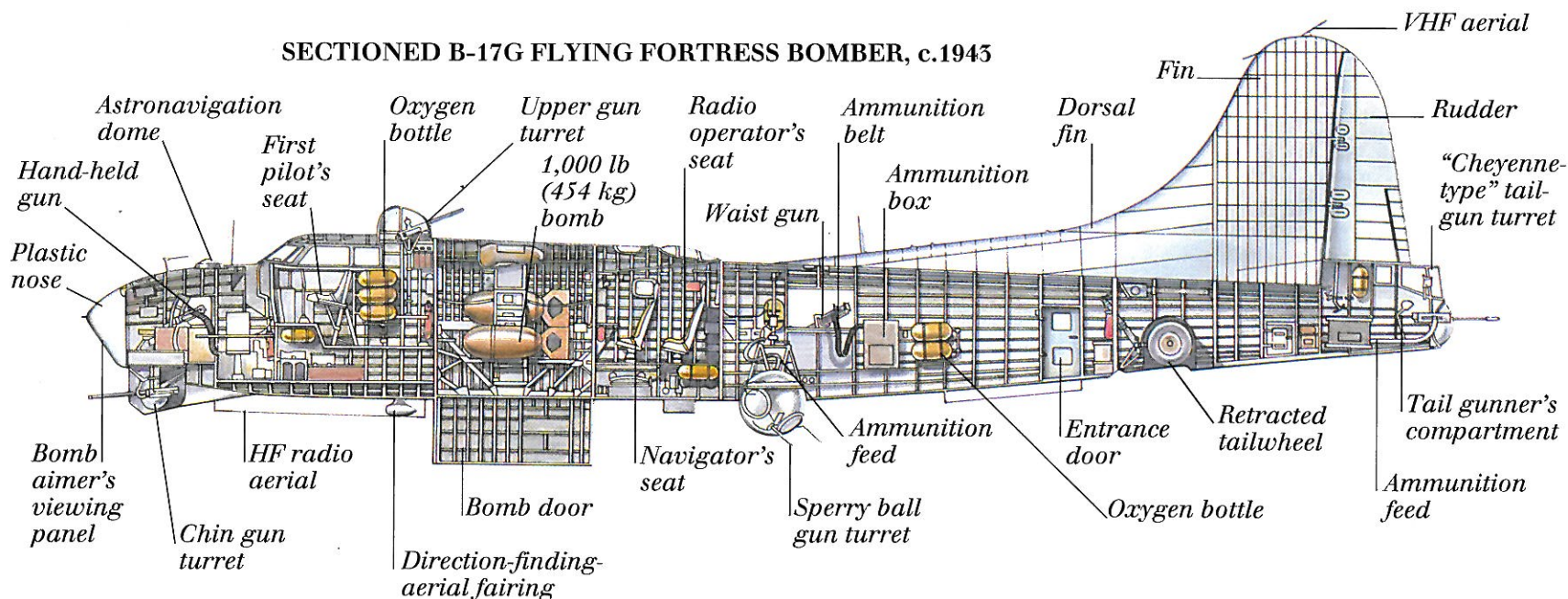


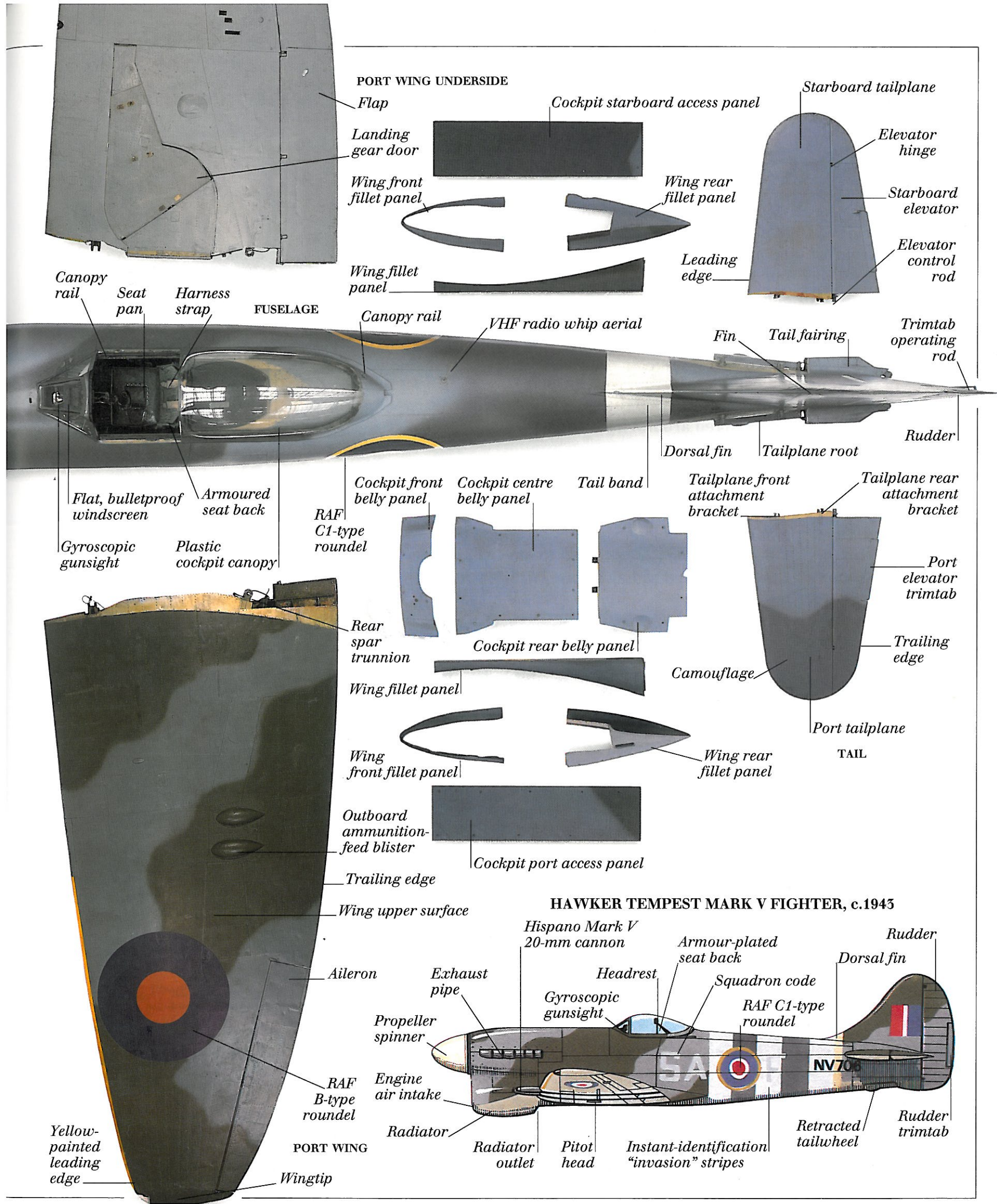
World War II aircraft

WHEN WORLD WAR II began in 1939, air forces had already replaced most of their fabric-skinned biplanes with all-metal, stressed-skin monoplanes. Aircraft played a far greater role in military operations during World War II than ever before. The wide range of aircraft duties, and the introduction of radar tracking and guidance systems, put pressure on designers to improve aircraft performance. The main areas of improvement were speed, range, and engine power. Bombers became larger and more powerful – converting from two to four engines – in order to carry a heavier bomb load; the US B-17 Flying Fortress could carry up to 6.2 tonnes (6.1 tons) of bombs over a distance of about 3,200 km (2,000 miles). Some aircraft increased their range by using drop tanks (fuel tanks that were jettisoned when empty to reduce drag). Fighters needed speed and manoeuvrability: the Hawker Tempest shown here had a maximum speed of 700 kph (435 mph), and was one of the few Allied aircraft capable of catching the German jet-powered V1 “flying bomb”. By 1944, Britain had introduced its first turbojet-powered aircraft, the Gloster Meteor fighter, and Germany had introduced the fastest fighter in the world, the turbojet-powered Me 262, which had a maximum speed of 868 kph (540 mph).



SECTIONED B-17G FLYING FORTRESS BOMBER, c.1943

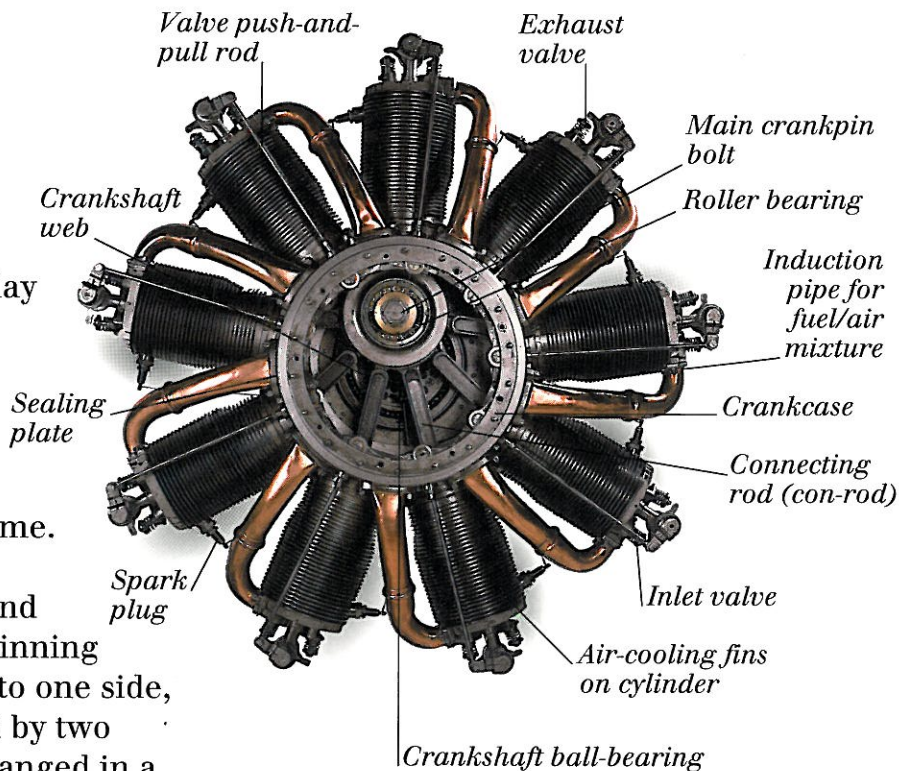




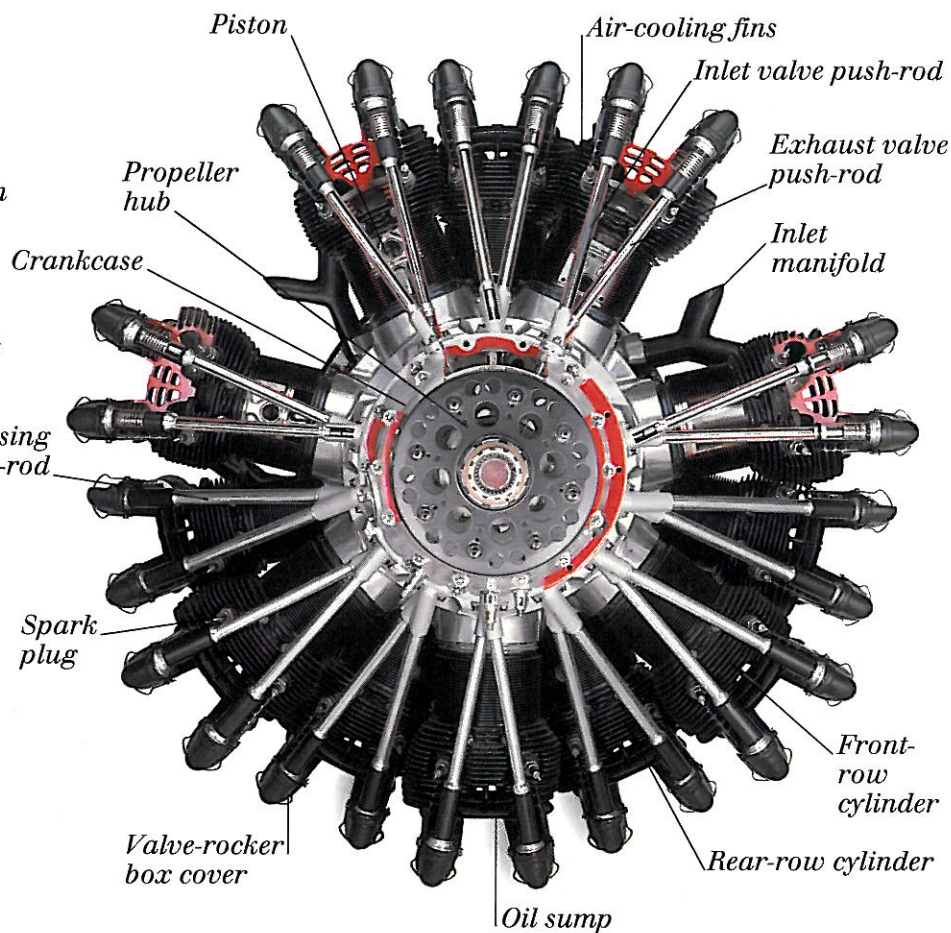
Early piston aero-engines

PETROL-DRIVEN PISTON ENGINES were used in the first powered flights. The engine used in the 1903 Wright Flyer (see pp. 8-9) for the first recorded powered flight had four water-cooled cylinders that lay horizontally side by side. The Wright brothers had built their own engine and, although it worked, it was very crude; for instance, it had an ignition system that created a spark by pulling apart two pieces of metal in each cylinder. In 1907, the French Seguin brothers built the first rotary engine, the Gnome. Its five cylinders were arranged around a stationary crankshaft like the spokes of a wheel, and spun around the crankshaft to turn the propeller. However, the spinning motion of rotary engines could cause aircraft to pull to one side, and so by 1918 these engines were being superseded by two other types. One type had water-cooled cylinders arranged in a single line (in-line) or in a V-shape (like the V12 Kestrel shown here). The other was the air-cooled radial engine, which was similar to the rotary engine but had a spinning crankshaft to turn the propeller while the cylinders remained stationary.

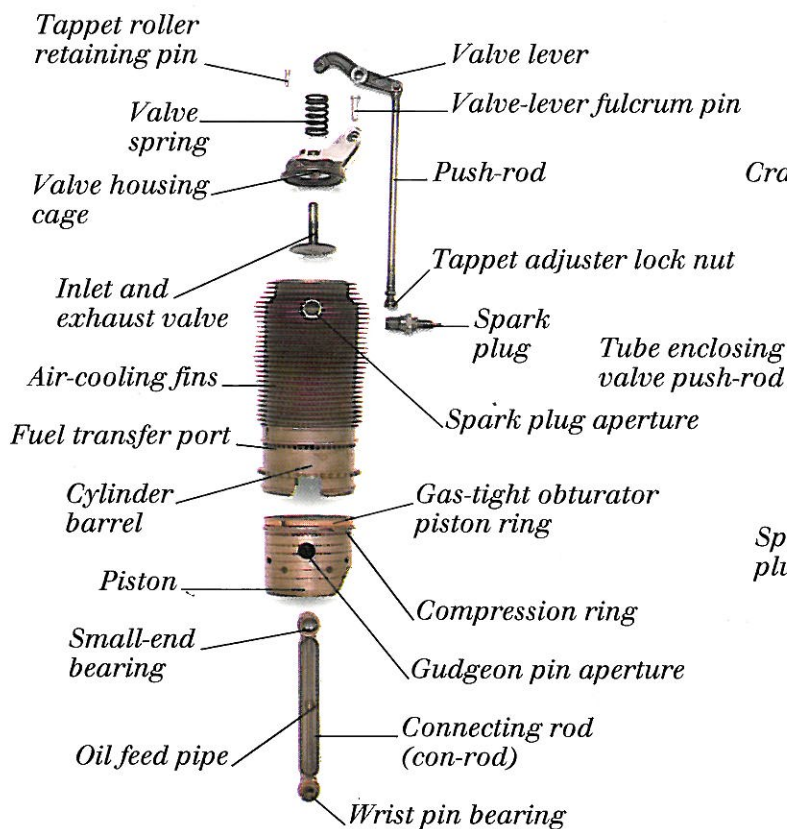
110-HP LE RHÔNE 9B ROTARY ENGINE, 1914



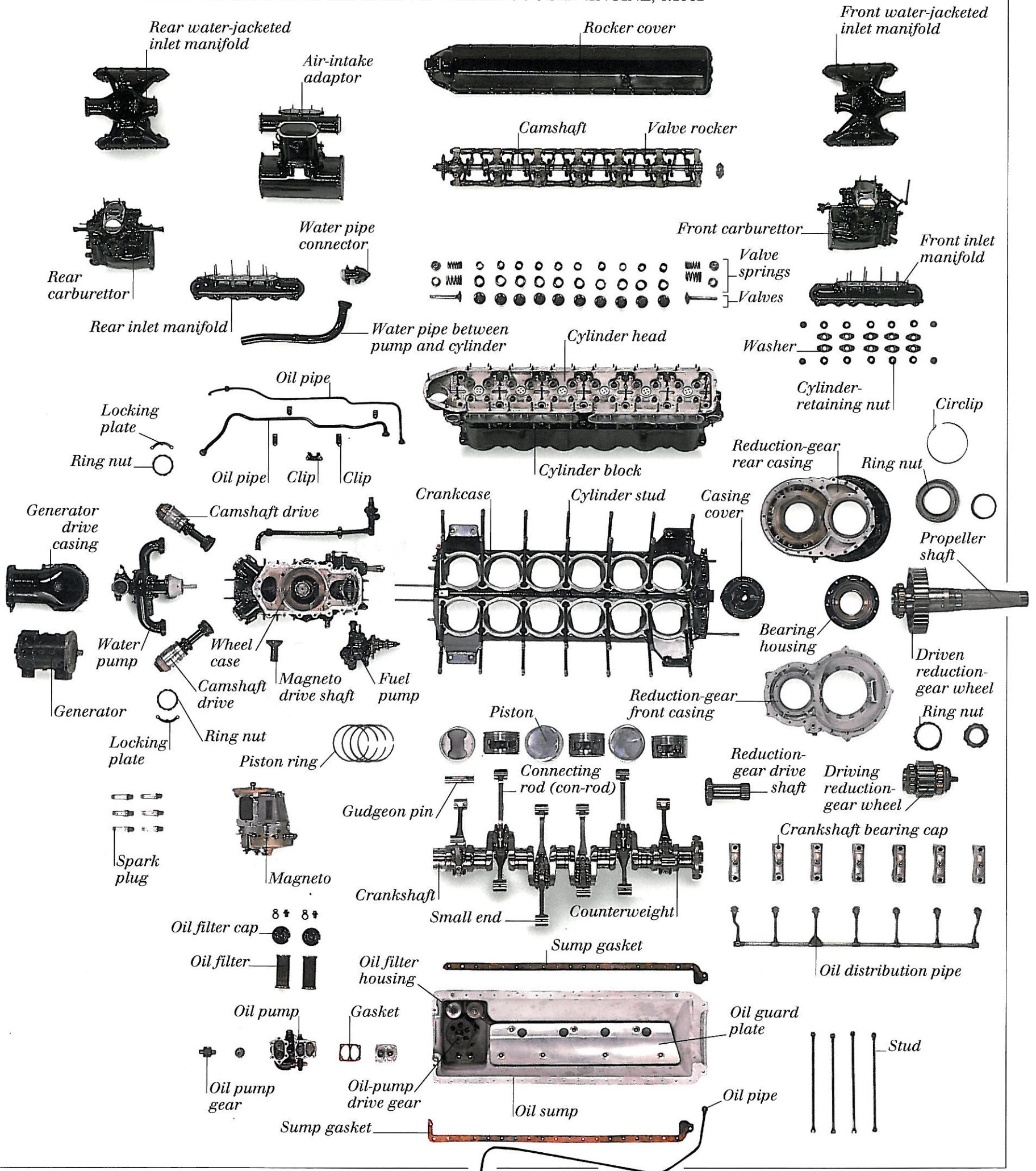
ARMSTRONG SIDDELEY TIGER
14-CYLINDER RADIAL ENGINE, 1931



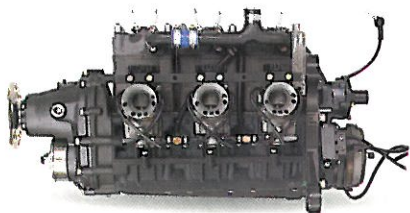
CYLINDER ASSEMBLY OF A GNOME
MONOSOUPE 100-HP ROTARY ENGINE, 1914



480-HP ROLLS-ROYCE KESTREL V12 WATER-COOLED ENGINE, c.1932



Modern piston aero-engines



MID WEST TWO-STROKE, THREE-CYLINDER ENGINE

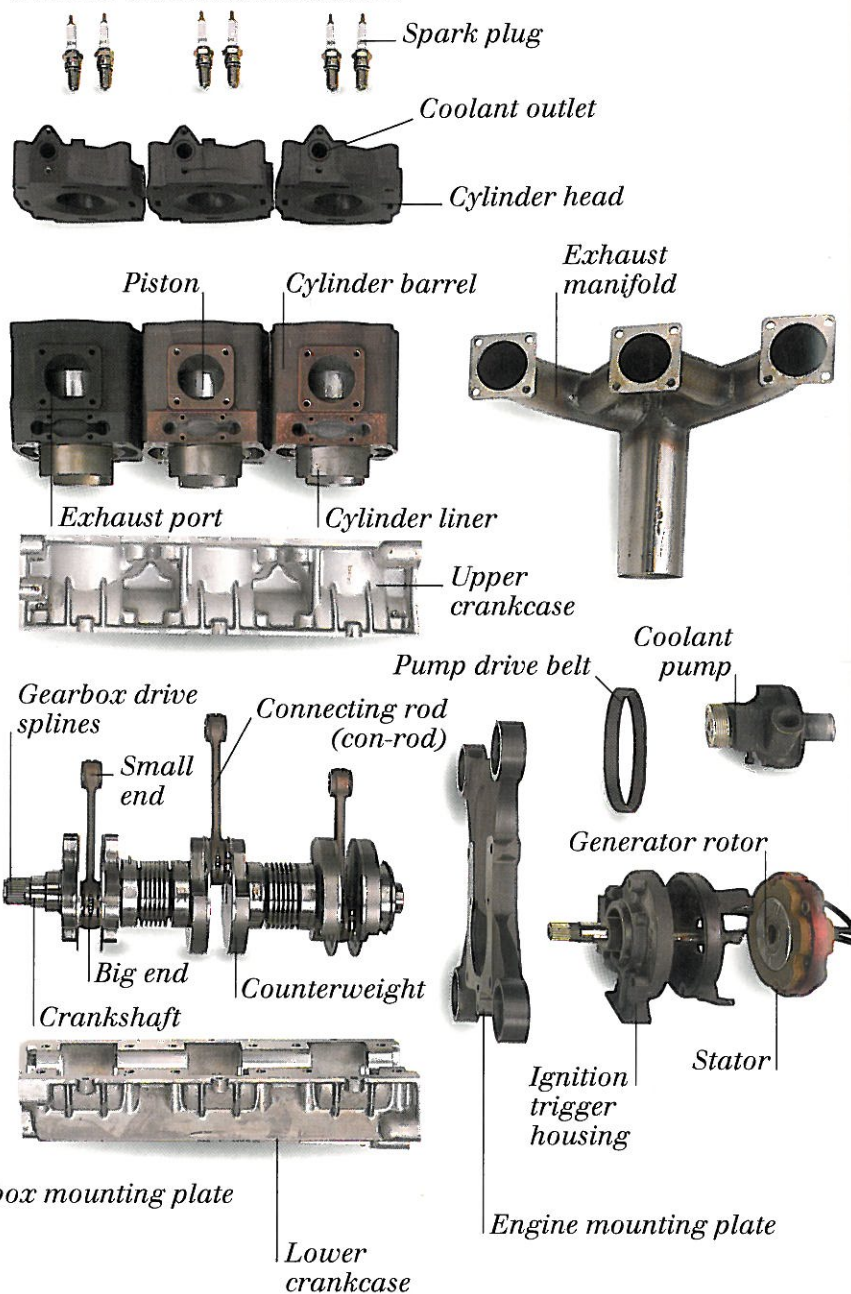
PISTON ENGINES today are used mainly to power the vast numbers of light aircraft and microlights, as well as crop-sprayers and crop-dusters, small helicopters, and fire-bombers (which dump water on large fires). Virtually all

heavier aircraft are now powered by jet engines.

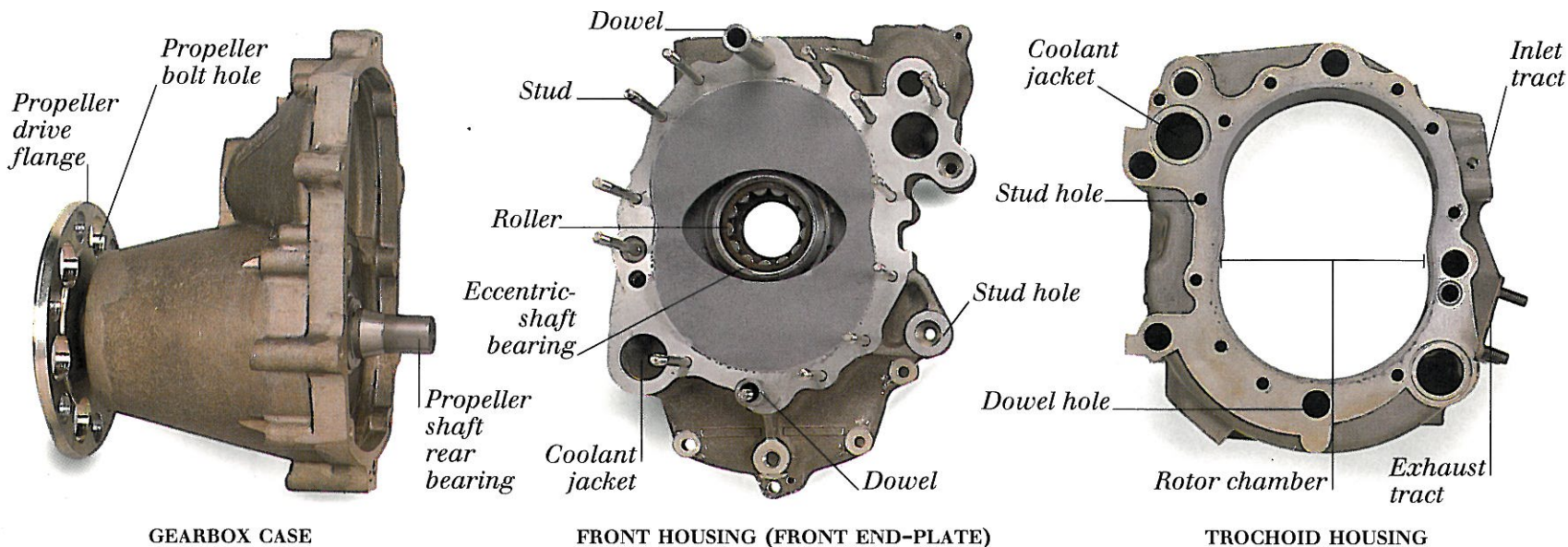
Modern piston aero-engines work on the same basic principles as the engine used by the Wright brothers in the first powered flight in 1903.

However, today's engines are more sophisticated than earlier engines. For example, modern aero-engines may use a two-stroke or a four-stroke combustion cycle; they may have from one to nine air- or water-cooled cylinders, which may be arranged horizontally, in-line, in V formation, or radially; and they may drive the aircraft's propeller either directly or through a reduction gearbox. One of the more unconventional types of modern aero-engine is the rotary engine shown here, which has a trilobate (three-sided) rotor spinning in a chamber shaped like a fat figure-of-eight.

MID WEST 75-HP TWO-STROKE, THREE-CYLINDER ENGINE



ROTOR AND HOUSINGS OF A MID WEST SINGLE-ROTOR ENGINE

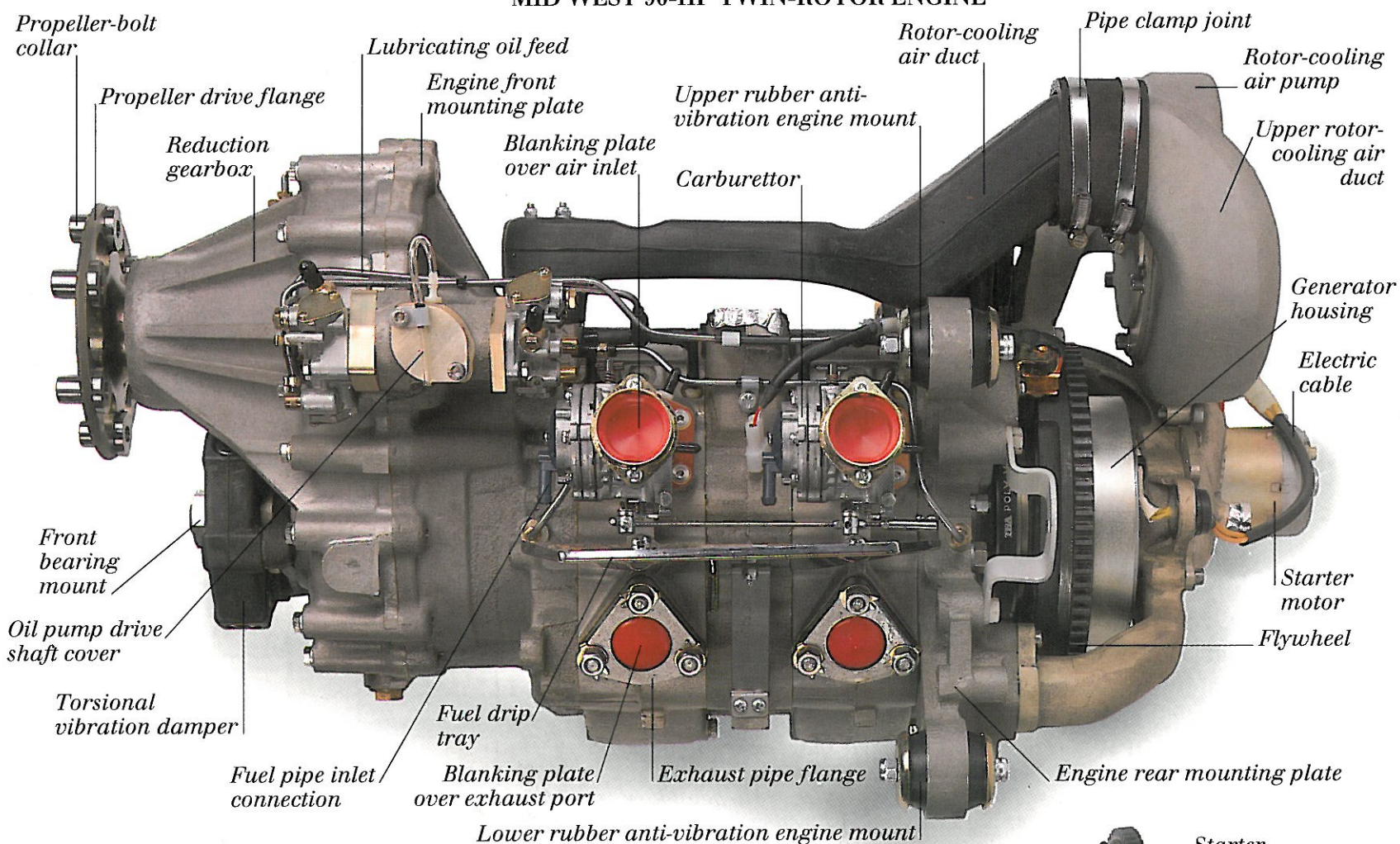


GEARBOX CASE

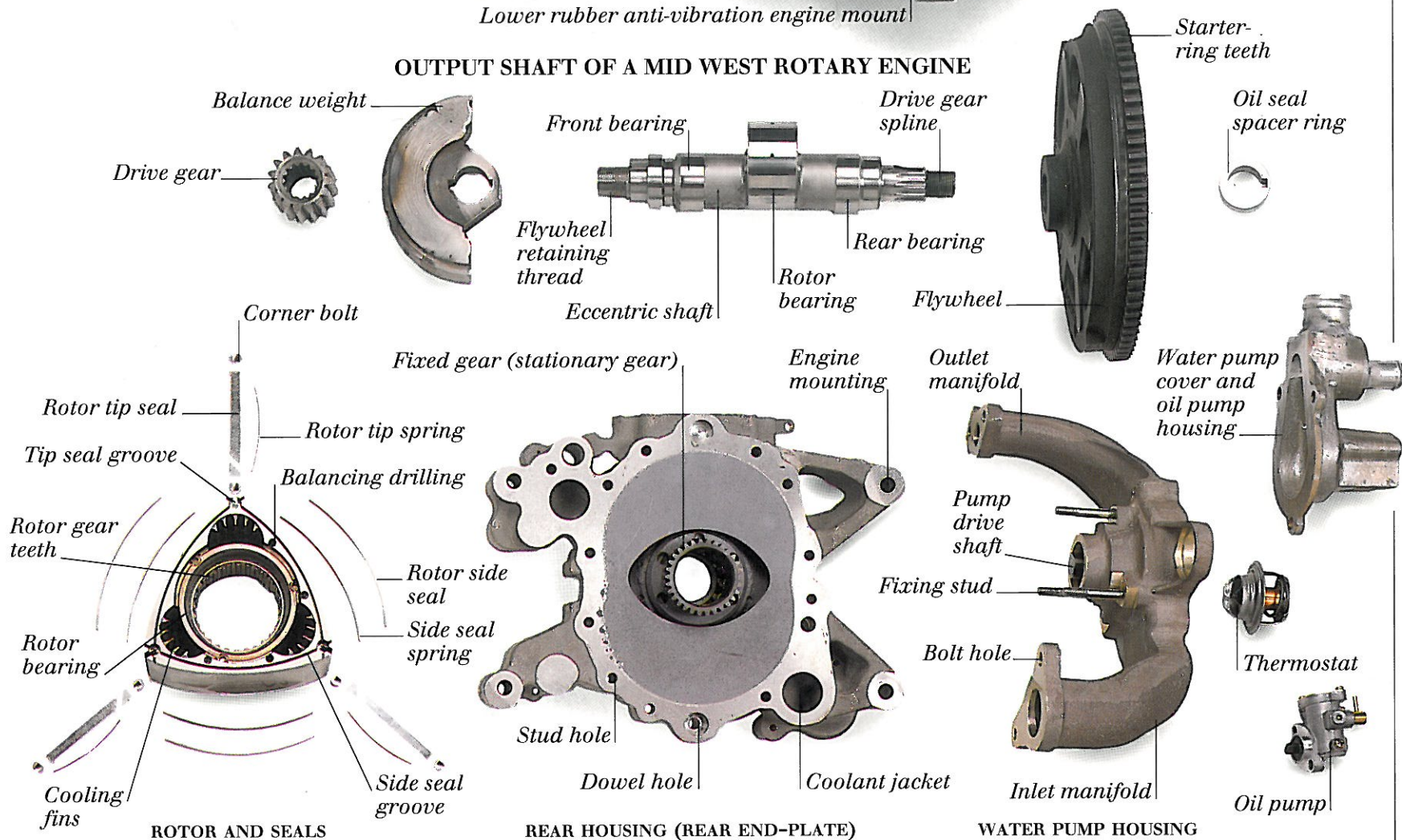
FRONT HOUSING (FRONT END-PLATE)

TROCHOID HOUSING

MID WEST 90-HP TWIN-ROTOR ENGINE

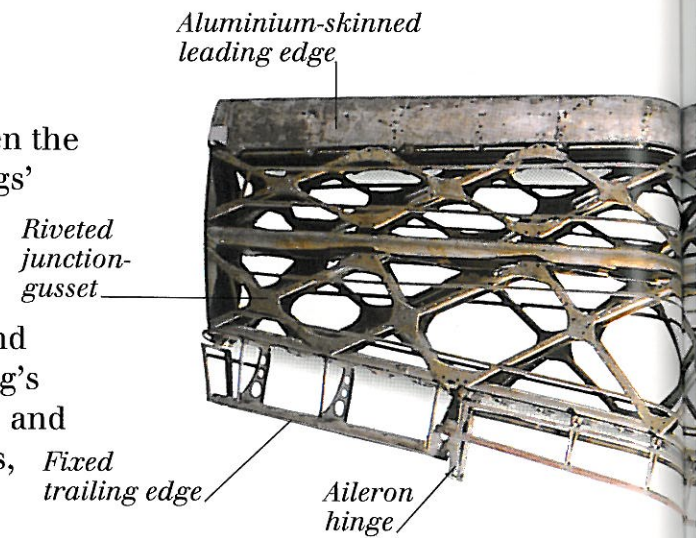


OUTPUT SHAFT OF A MID WEST ROTARY ENGINE

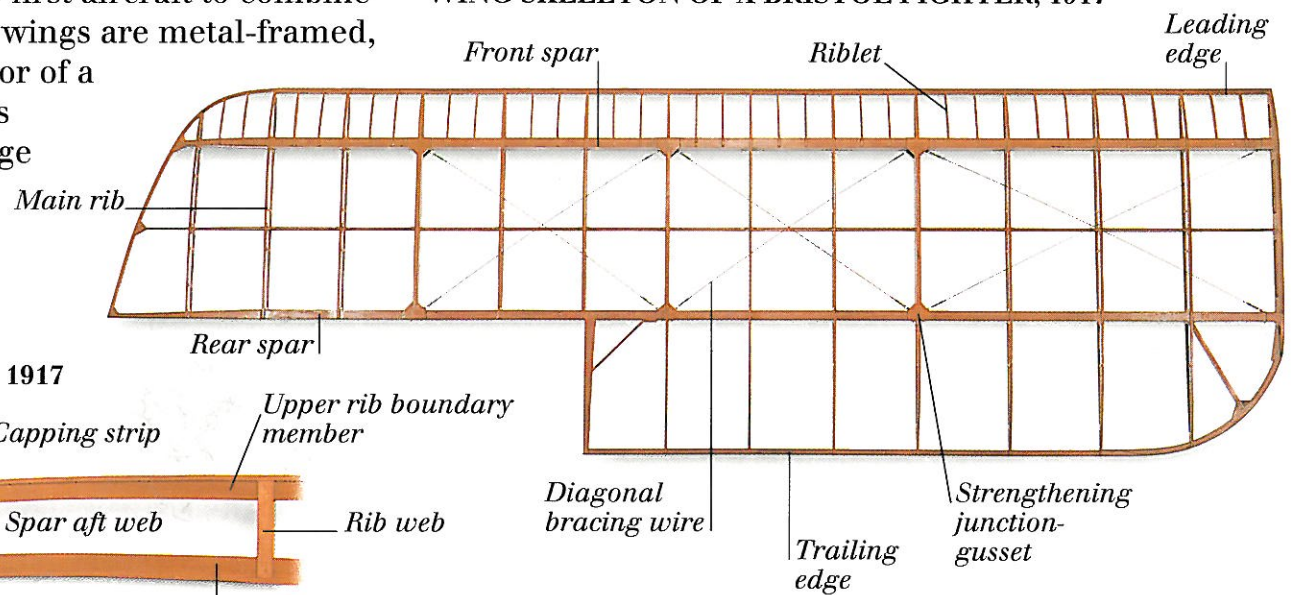


Wings

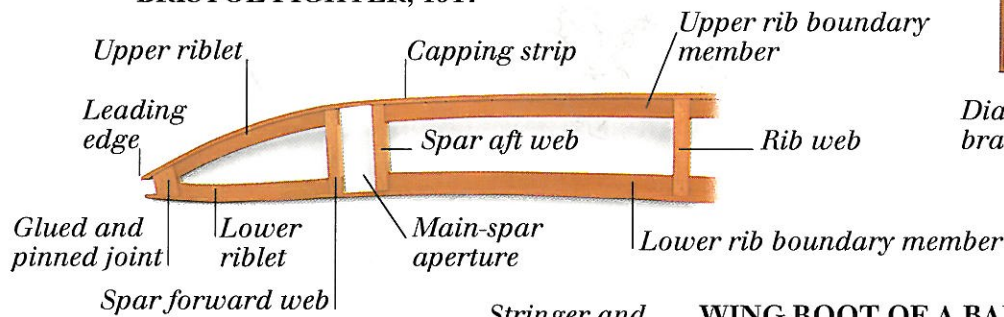
ALL AIRCRAFT, EXCEPT BALLOONS AND AIRSHIPS, rely on wings to fly; even the blades of helicopters are basically rotating wings. The airflow over wings' surfaces generates the lifting force necessary for flight. Wings are also crucial in manoeuvring. Early wings, made from wood and fabric, were warped (twisted) by wires for banking and turning. Later wings used ailerons (hinged flaps on the trailing, or rear, edge) for banking and turning. Subsequent developments were flaps and slats. Flaps, on a wing's trailing edge, are moved down to increase lift during take-off, climbing, and descent, and to increase lift and drag during the landing approach. Slats, on the leading, or forward, edge, move forwards to help prevent the aircraft from stalling. The Handley Page Gugnunc shown here was one of the first aircraft to combine all three features. Modern wings are metal-framed, with a skin made of metal or of a composite material such as carbon-fibre. Wings on large aircraft may carry fuel tanks, engines, and retractable landing gear.



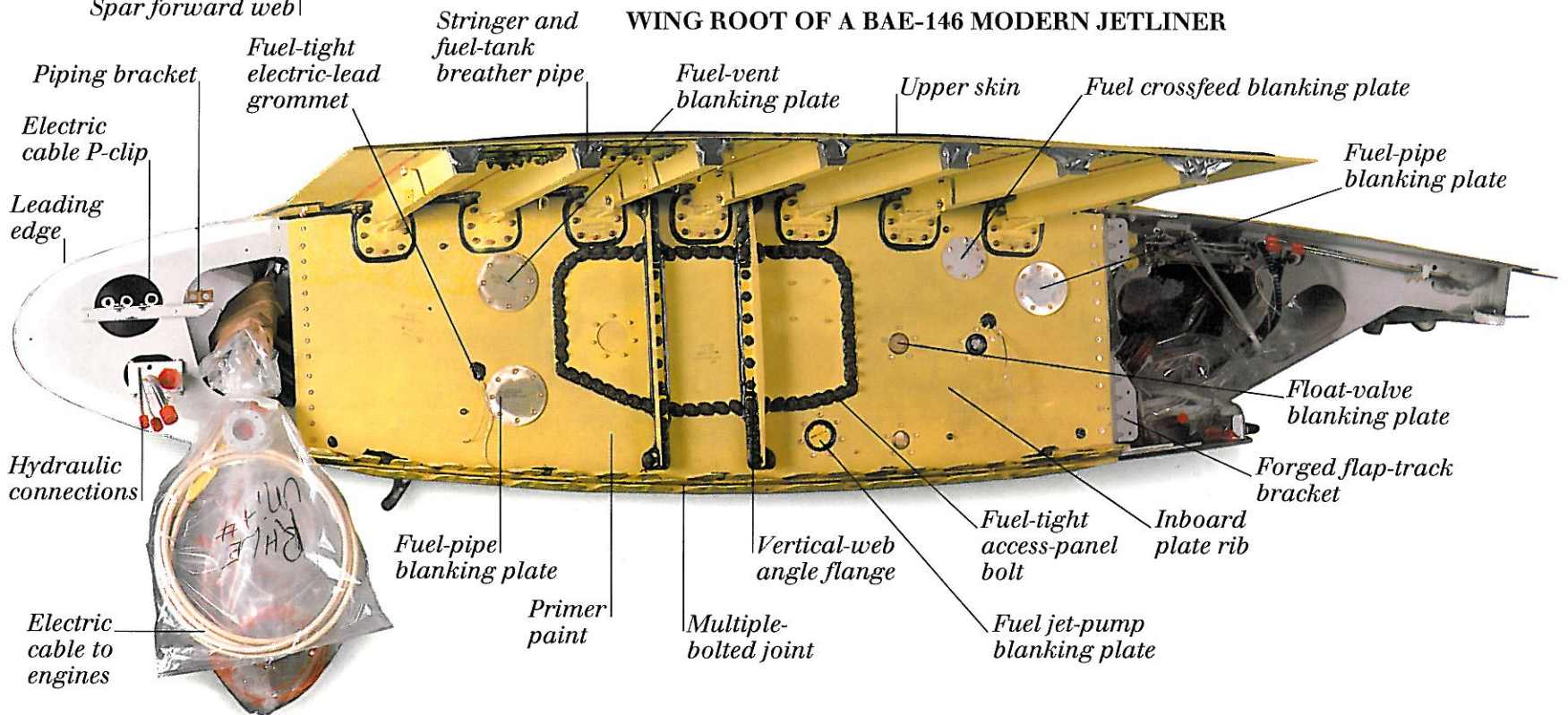
WING SKELETON OF A BRISTOL FIGHTER, 1917



WING RIB OF A BRISTOL FIGHTER, 1917



WING ROOT OF A BAE-146 MODERN JETLINER



**OUTBOARD WINGFRAME OF A
VICKERS WELLINGTON 1A, 1939**

Tank inspection
manhole

Fuel filler
frame

Fuel tank

Twin-boomed
main inboard
spar

Single-boomed
main outboard
spar

Rear spar

Rib

WINGFRAME OF AN ARV SUPER 2 MODERN LIGHT AIRCRAFT

Leading-edge strip notch

Rear spar

Strut plate

Main spar

Forward rib

Rib-lightening hole

Fixed trailing-
edge flap-shroud
structure

Outboard
flap

Light diagonal
cross-member

Wingtip

Torque tube

Aft rib

Aileron
bearing

Flap
spar

Flap
forward
rib

Flap aft
rib

Aileron
aft rib

Aileron
spar

TOP WING OF A HANDLEY PAGE GUGNUNC, 1929

Outboard
slat

Main spar

Inboard
slat

Aperture for
slat arm

Retracted
slat recess

Riblet

Slot

Centre spar

Main rib

Wingtip

Aileron
cable

Aircraft
registration code

Flap

Varnished fabric

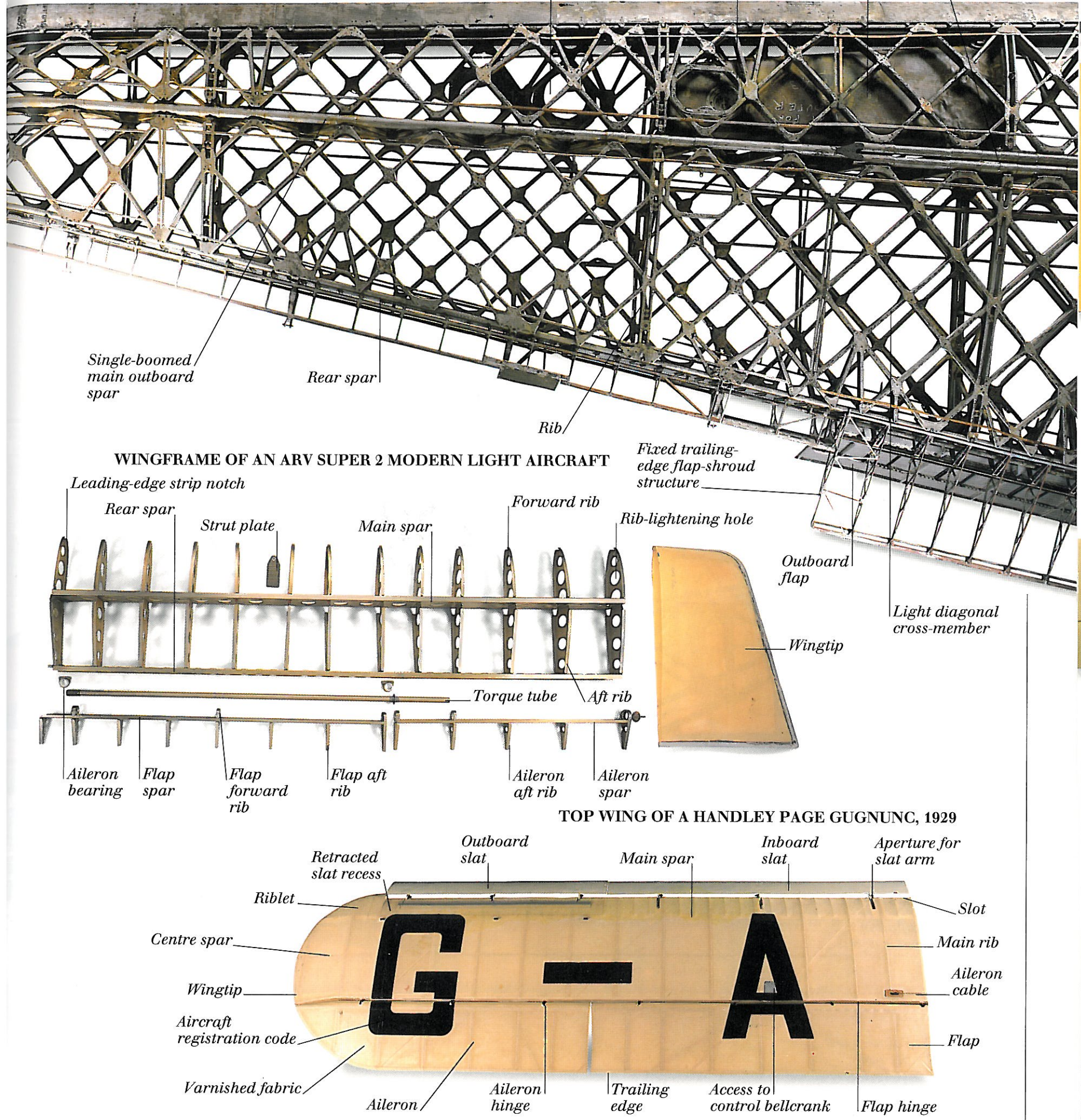
Aileron

Aileron
hinge

Trailing
edge

Access to
control bellcrank

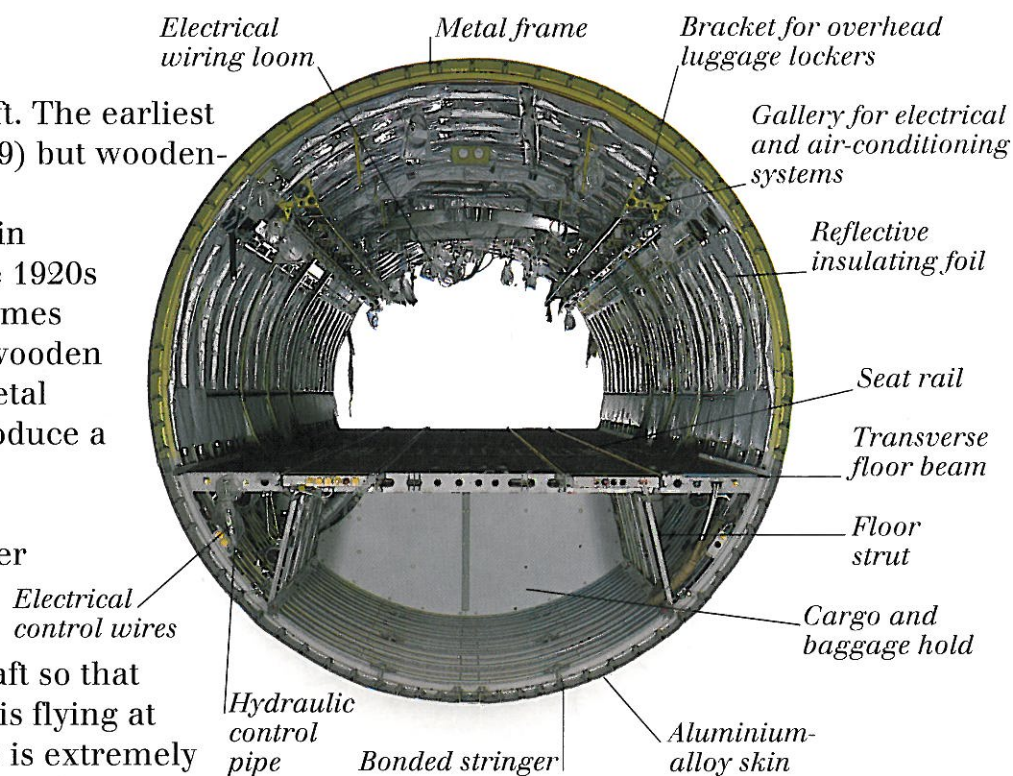
Flap hinge



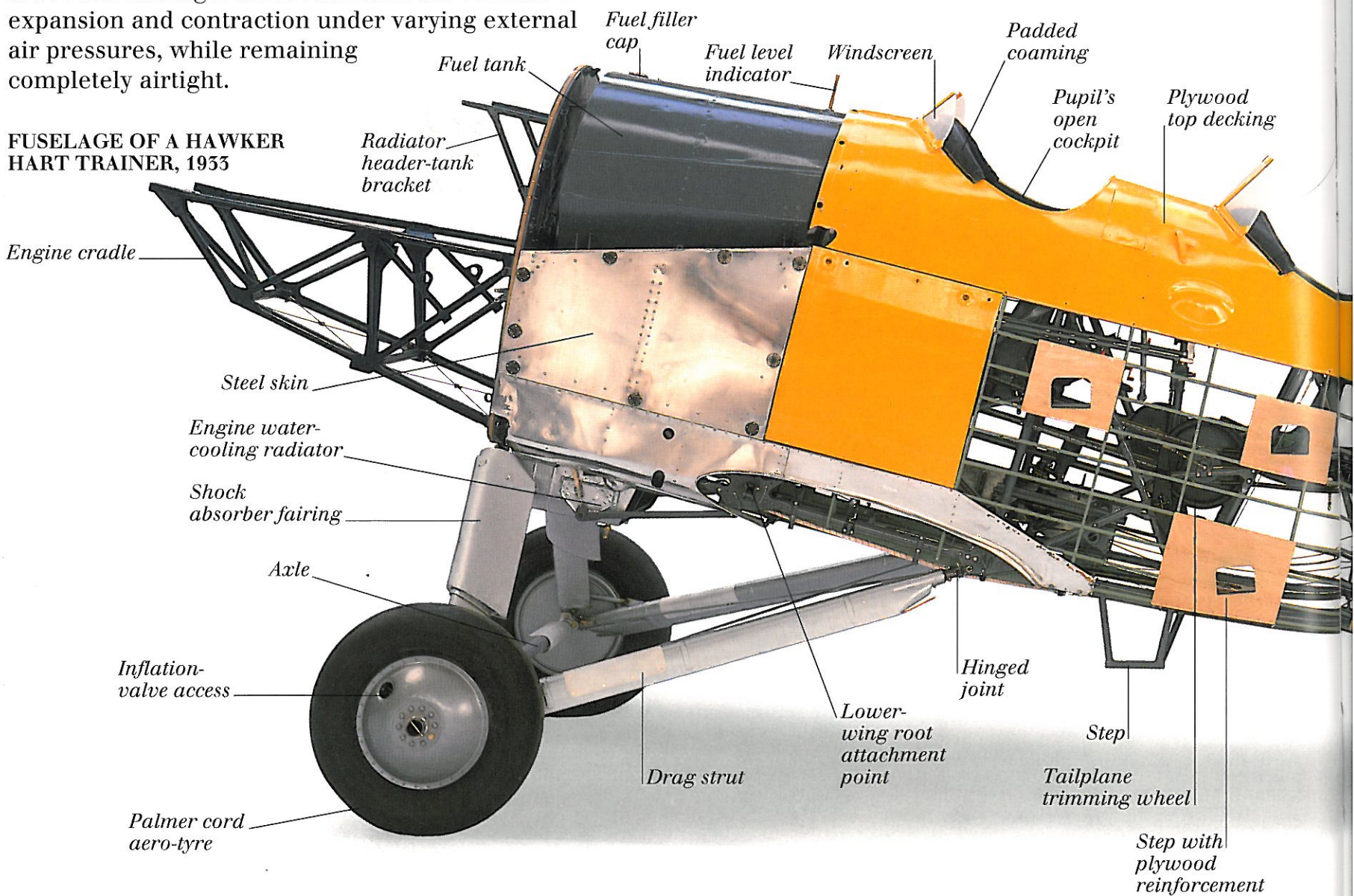
Fuselage

THE FUSELAGE IS THE MAIN BODY of an aircraft. The earliest aeroplanes did not have a fuselage (see pp. 8-9) but wooden-framed, fabric-skinned fuselages were soon adopted; in some of these early aircraft the skin covered only the nose and cockpit. During the 1920s and 1930s, most aircraft had steel fuselage frames covered with a metal skin or with metal and wooden panels. High-speed aircraft required an all-metal fuselage frame with a flush-riveted skin to produce a streamlined surface. The Vickers Wellington shown here has an unusual fuselage frame consisting of small curved rods riveted together to form a geodetic mesh. Pressurized jetliner fuselages, introduced in the 1940s, must maintain normal air pressure inside the aircraft so that the passengers can breathe while the aircraft is flying at high altitudes where the external air pressure is extremely low. Such fuselages must withstand the stresses of expansion and contraction under varying external air pressures, while remaining completely airtight.

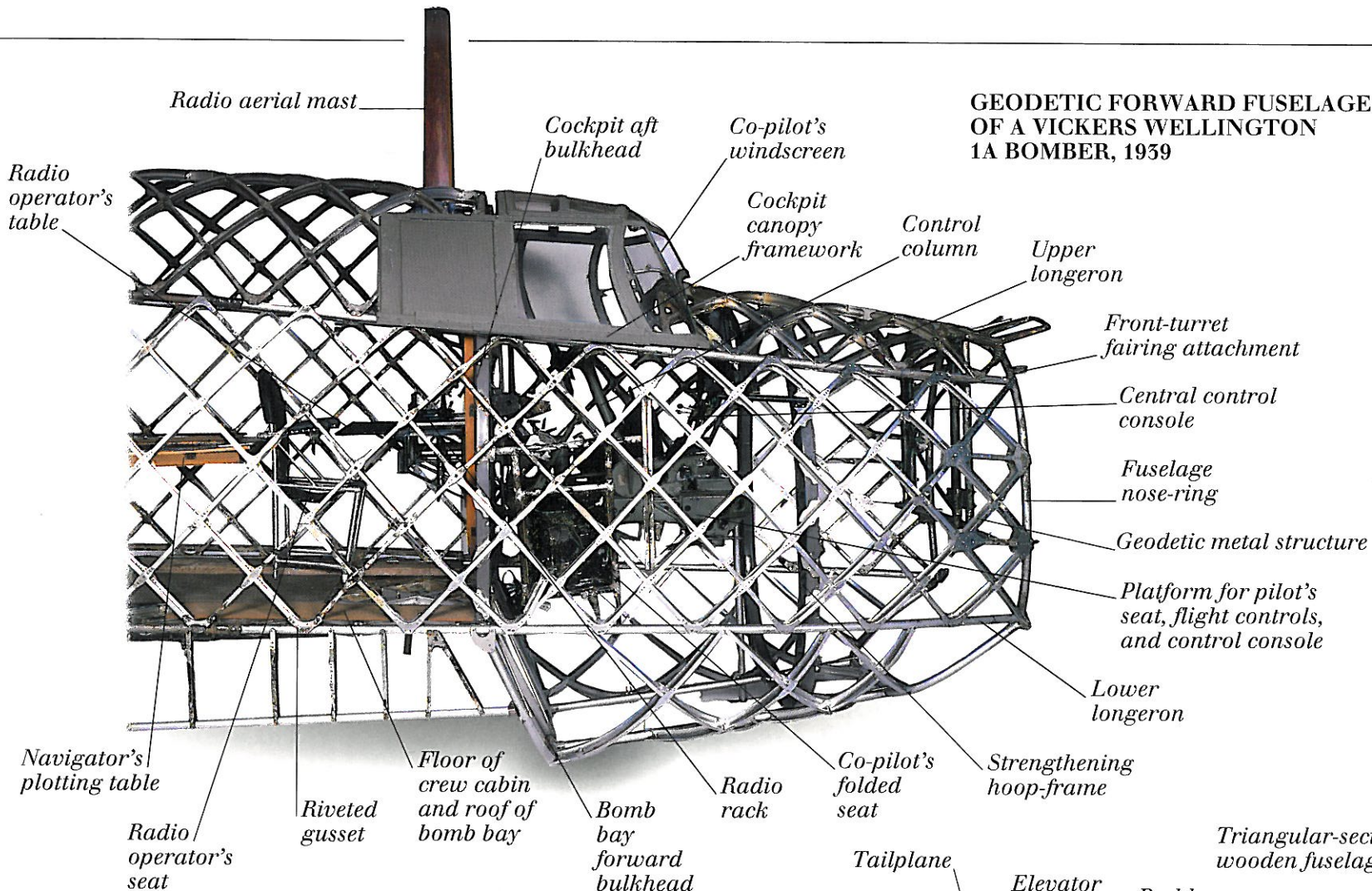
PRESSURIZED FUSELAGE OF A MODERN JETLINER



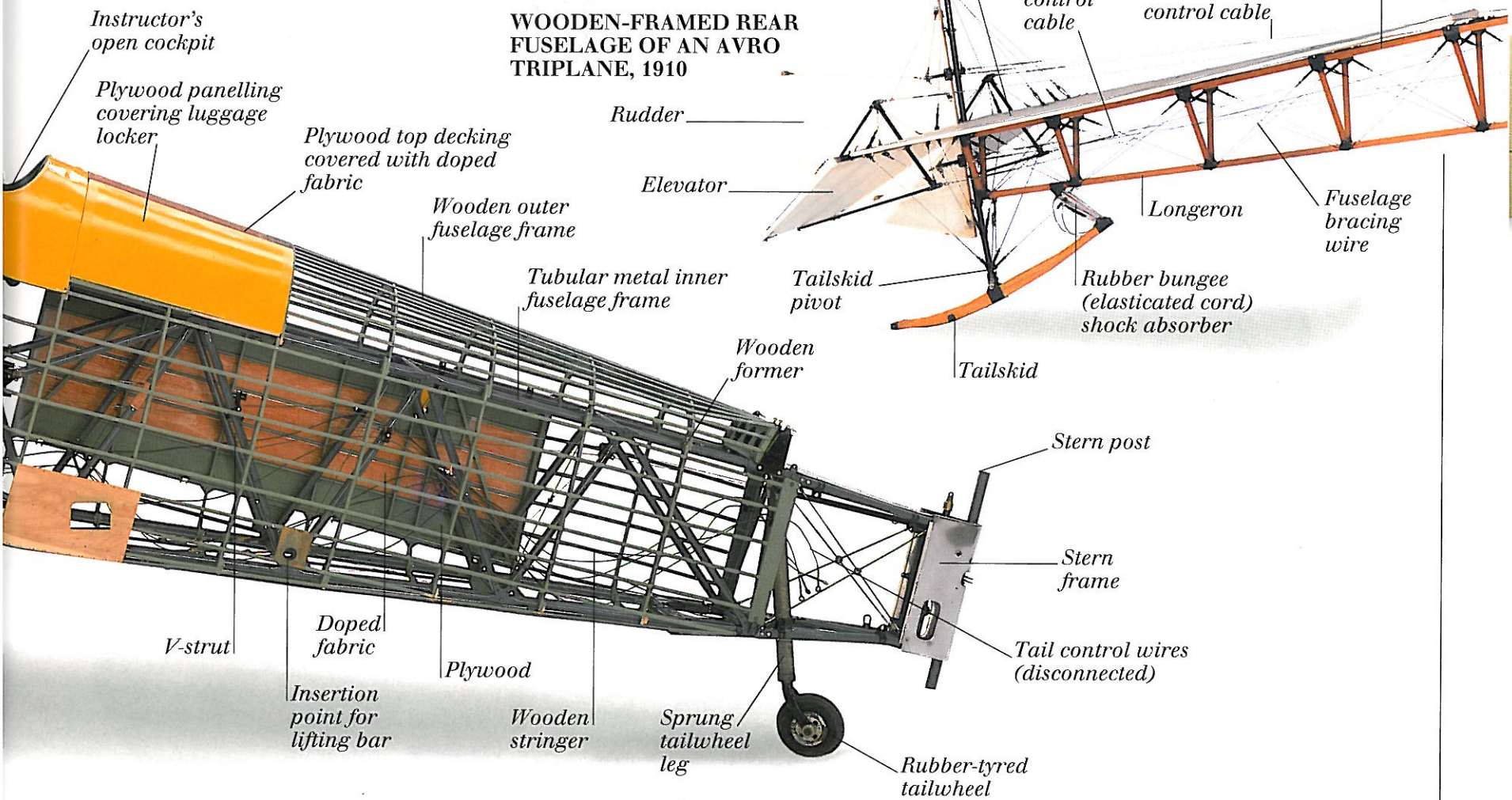
FUSELAGE OF A HAWKER HART TRAINER, 1933



**GEODETIC FORWARD FUSELAGE
OF A VICKERS WELLINGTON
1A BOMBER, 1939**



**WOODEN-FRAMED REAR
FUSELAGE OF AN AVRO
TRIPLANE, 1910**



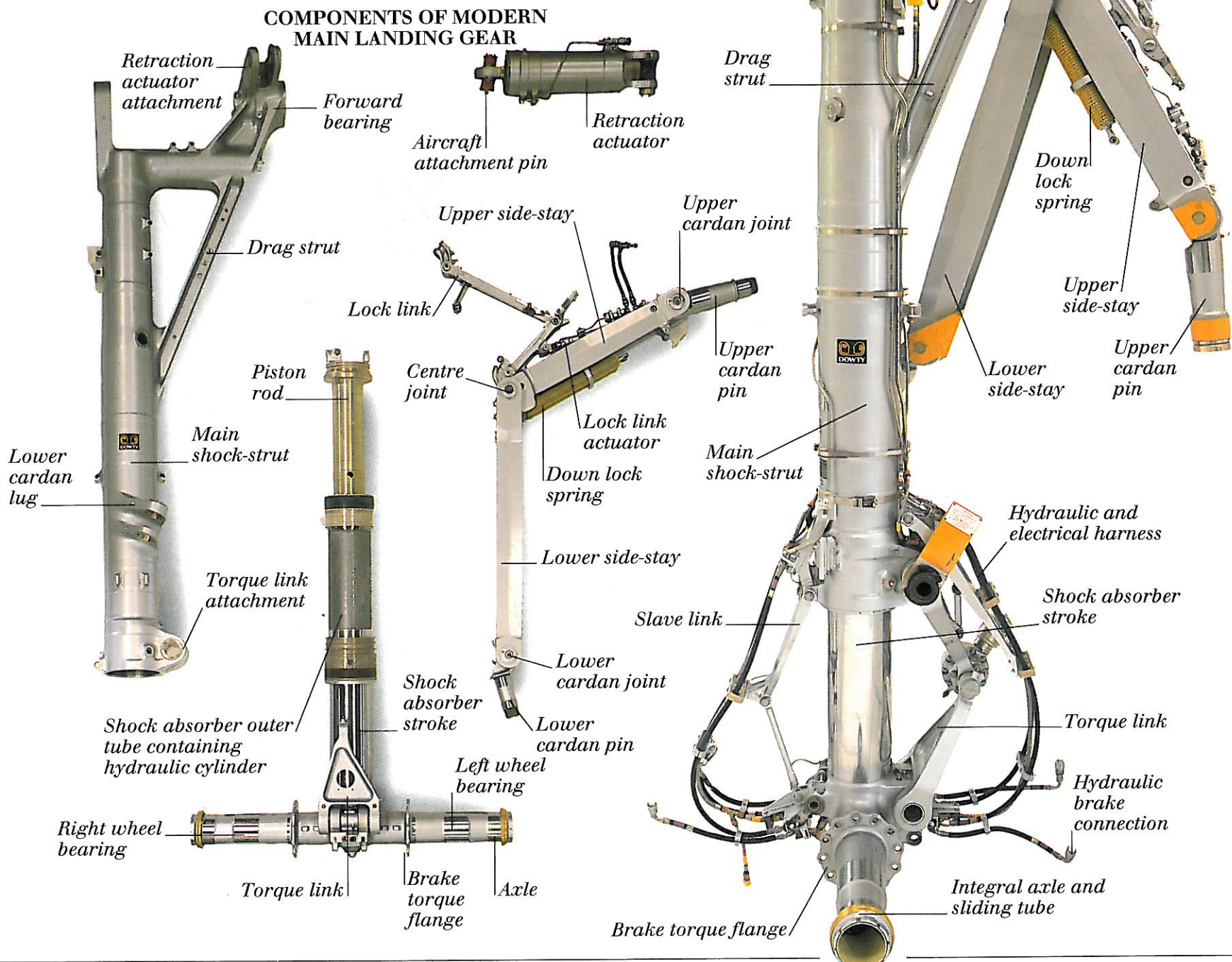
Landing gear

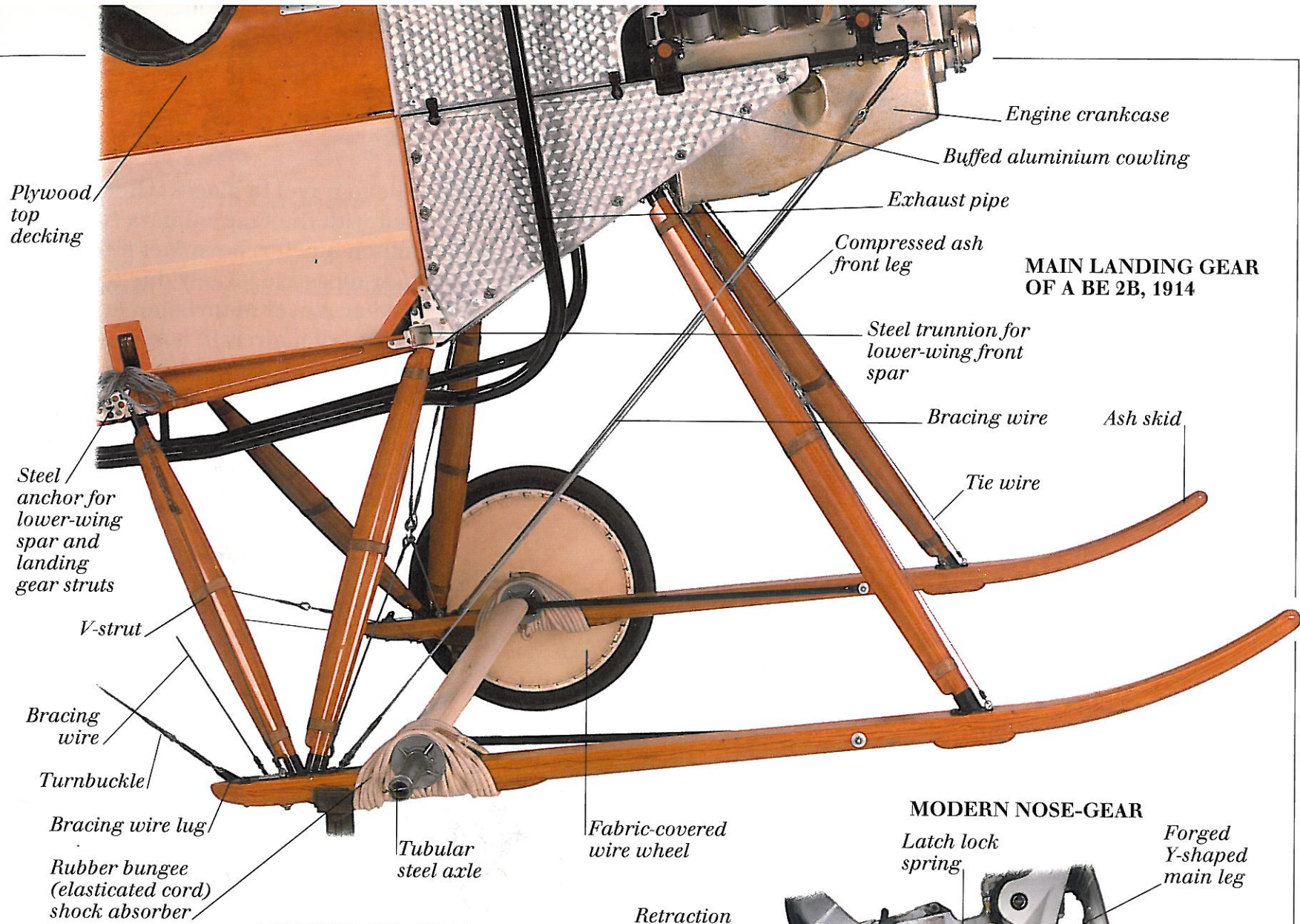


HELICOPTER LANDING SKIDS

LANDING GEAR ALLOWS AIRCRAFT to move on the ground, and absorbs shocks to enable smooth landing and take-off. The earliest aircraft used wire wheels, wooden struts to brace them to the fuselage, and, usually, a simple skid beneath the tail. Rubber bungees (elasticated cords) absorbed shocks when landing, and long, curved skids at the front prevented the aircraft from overturning. As aircraft became heavier and faster, pressed-steel wheels, metal legs, sprung shock absorbers, and fluid dampers came into use. During the 1930s, retractable landing gear was introduced to reduce drag during flight. With the coming of large, heavy jetliners, multi-wheel landing gear was adopted. This landing gear had a bogie (pivoting trolley) with up to eight wheels at the bottom of each leg. At the same time, nose landing gear, not used since 1914, became widely adopted, enabling pilots to make safer and smoother landings.

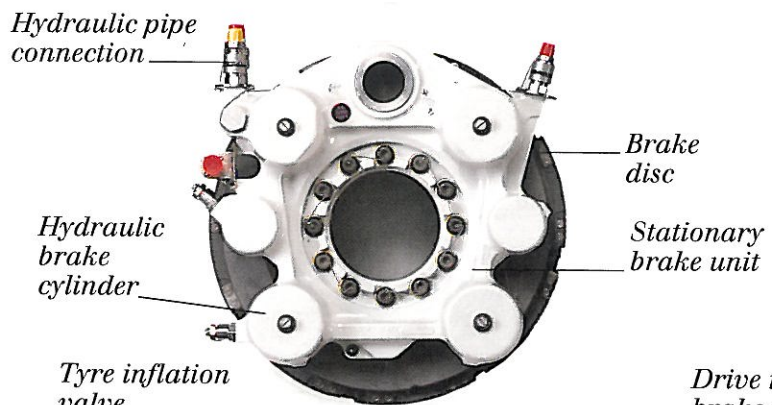
MODERN TWIN-WHEEL MAIN LANDING GEAR



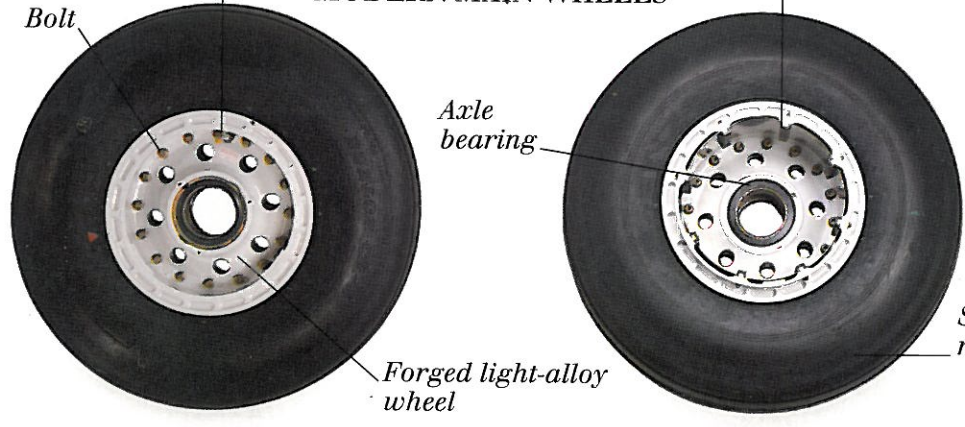


MAIN LANDING GEAR OF A BE 2B, 1914

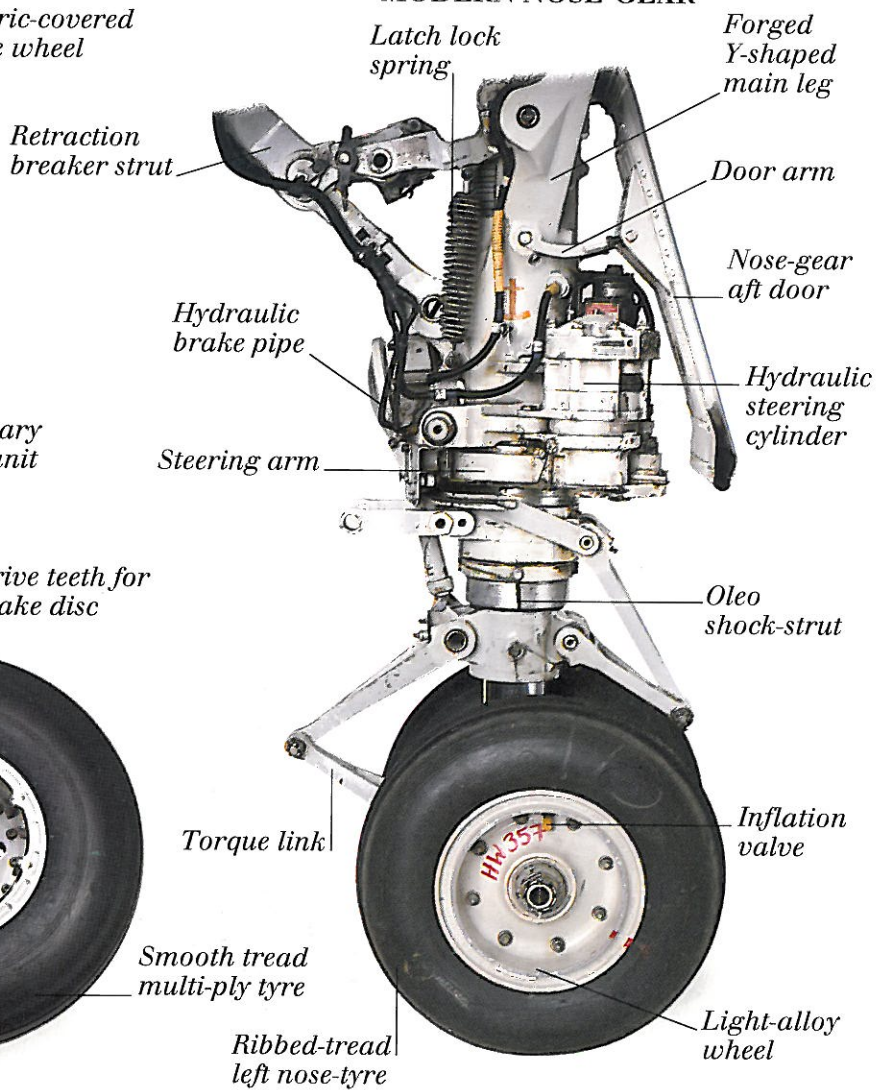
MODERN DISC BRAKE



MODERN MAIN WHEELS



MODERN NOSE-GEAR



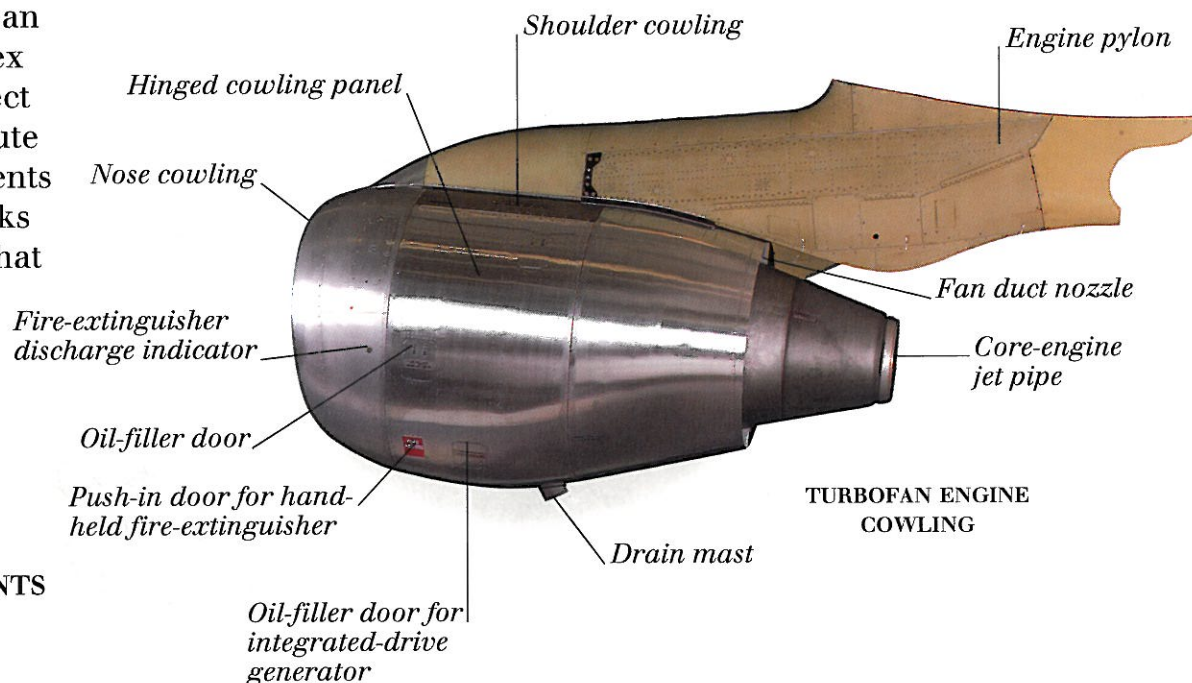
Modern jetliners 1



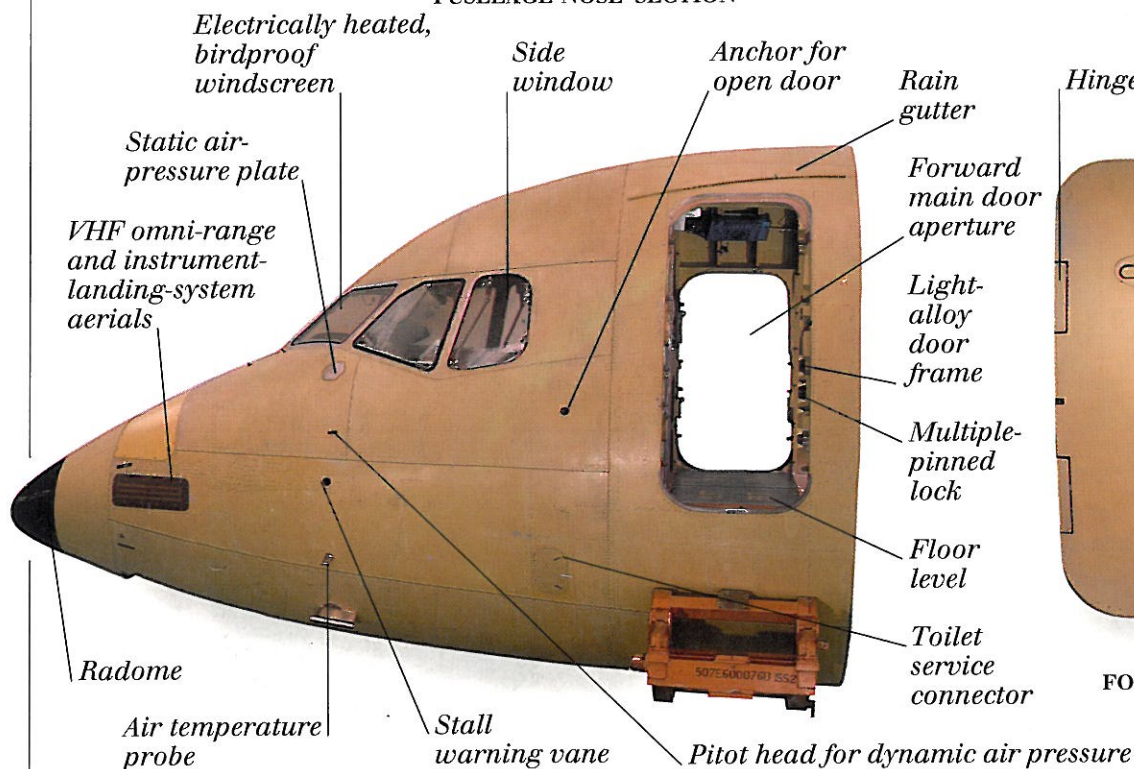
BAE-146 JETLINER

MODERN JETLINERS HAVE ENABLED ordinary people to travel to places where once only the wealthy could afford to go. Compared with the first jetliners (which were introduced in the 1940s), modern ones are much quieter, burn fuel more efficiently, and produce less air pollution. These advances are largely due to the replacement of turbojet engines with turbofan engines (see pp. 42-43). The greater power of turbofan engines at low speeds enables modern jetliners to carry more fuel and passengers than turbojet aircraft; a modern Boeing 747-400 (popularly known as a "jumbo jet") can fly 400 people for 13,700 km (8,500 miles) without needing to refuel. Jetliners fly at high altitudes, typically cruising at 8,000-11,000 m (26,000-36,000 ft), where they can use fuel efficiently and usually avoid bad weather. The pilot always controls the aircraft during take-off and landing, but at other times the aircraft is usually controlled by an autopilot. Autopilots are complex on-board mechanisms that detect deviations from an aircraft's route and make appropriate adjustments to the flight controls. Flight decks are also equipped with radars that warn pilots of approaching hazards, such as mountain ranges, bad weather, and other aircraft.

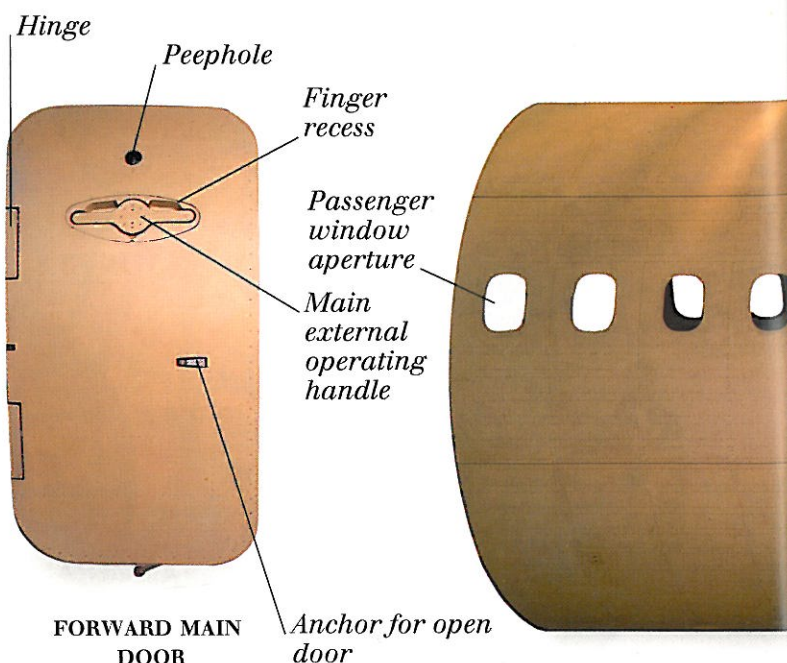
STRUCTURAL COMPONENTS OF A BAE-146 JETLINER

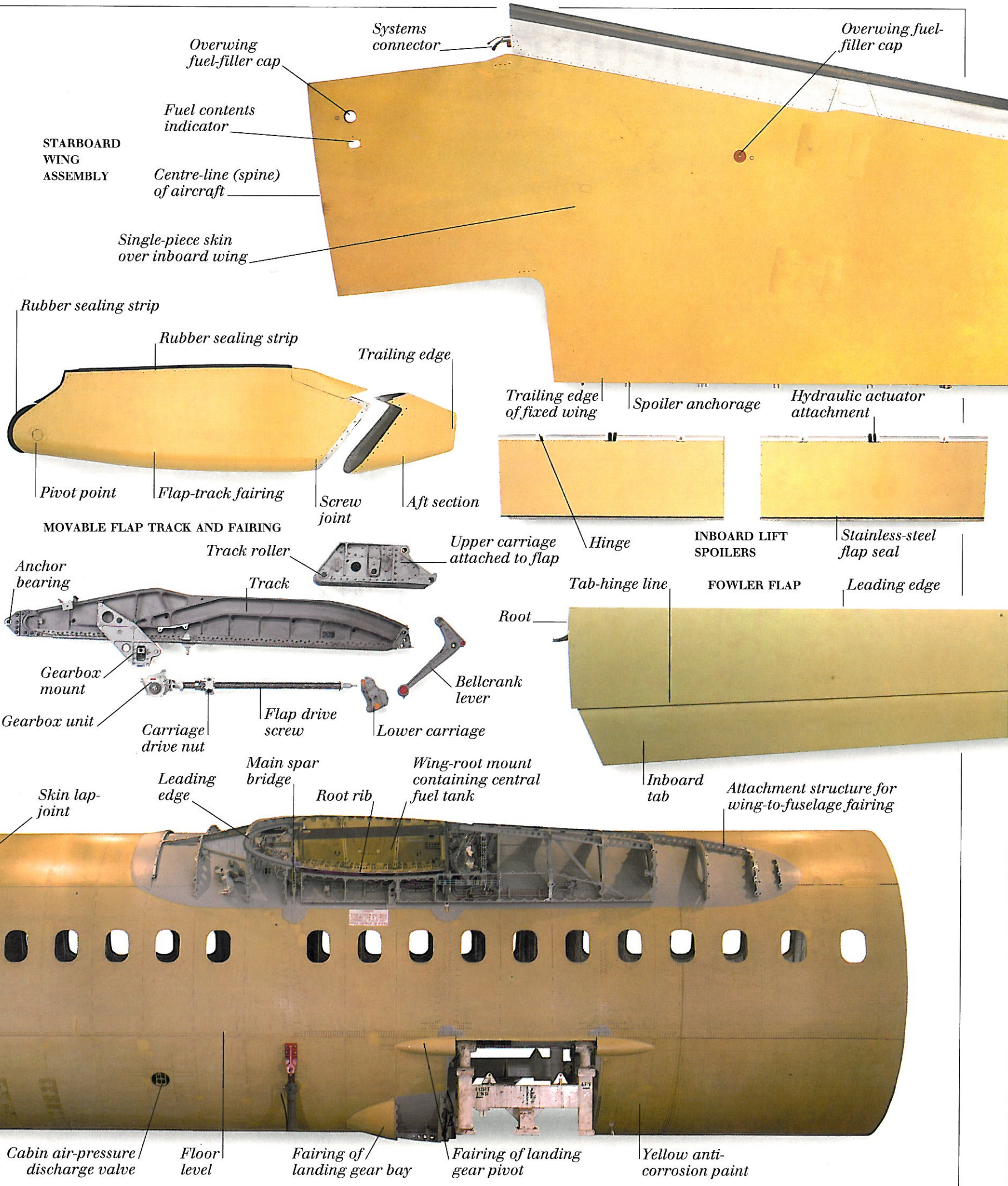


FUSELAGE NOSE-SECTION



FUSELAGE MID-SECTION





STARBOARD
WING
ASSEMBLY

Overwing
fuel-filler cap

Systems
connector

Overwing fuel-
filler cap

Fuel contents
indicator

Centre-line (spine)
of aircraft

Single-piece skin
over inboard wing

Rubber sealing strip

Rubber sealing strip

Trailing edge

Trailing edge
of fixed wing

Spoiler anchorage

Hydraulic actuator
attachment

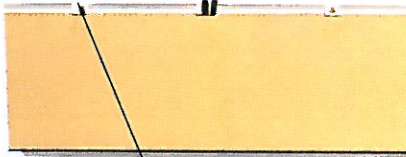
Pivot point

Flap-track fairing

Screw
joint

Aft section

MOVABLE FLAP TRACK AND FAIRING



Hinge

INBOARD LIFT
SPOILERS

Stainless-steel
flap seal

Anchor
bearing

Track roller

Track

Upper carriage
attached to flap

Hinge

FOWLER FLAP

Leading edge

Root

Gearbox
mount

Track

Bellcrank
lever

Tab-hinge line

FOWLER FLAP

Leading edge

Gearbox unit

Carriage
drive nut

Flap drive
screw

Lower carriage

Root

Inboard
tab

Attachment structure for
wing-to-fuselage fairing

Skin lap-
joint

Leading
edge

Main spar
bridge

Root rib

Wing-root mount
containing central
fuel tank

Inboard
tab

Attachment structure for
wing-to-fuselage fairing



Cabin air-pressure
discharge valve

Floor
level

Fairing of/
landing gear bay

Fairing of landing
gear pivot

Yellow anti-
corrosion paint

Modern jetliners 2

Landing and taxiing light

Heated de-icing leading edge

Roll-spoiler hinge

Roll-spoiler hydraulic actuator attachment

STARBOARD WING

Fixed trailing edge

Aileron hinge

Starboard navigation light

Hinge

Hydraulic actuator attachment

Spoiler arm

Aerodynamic balance

Hinge bracket

Horn balance

Recessed hinge

INTERMEDIATE LIFT SPOILER

Flap seal

OUTBOARD ROLL SPOILER

AILERON

Trintab

Servo-tab

MAIN FOWLER FLAP

Leading edge

Flap tip

Static discharge wick attachment

Outboard tab

Tab-hinge line

FUSELAGE SPINE FAIRING

Landing gear door

Hydraulic brake pipe

Main pivot

Finger recess

Peephole

Hot-air de-icing duct

Electrical harness

Oleo lock-jack

Skin lap-joint

Passenger window aperture

Light-alloy beam

Direction bar

Brake pipe

Main external operating handle

Shock-strut bearing

Outer wheel axle

Side brace and retraction jack trunnions

Lower pivot

Pivoted trailing-link arm

Hydraulic brake pipe

Anchor for open door

Hinge

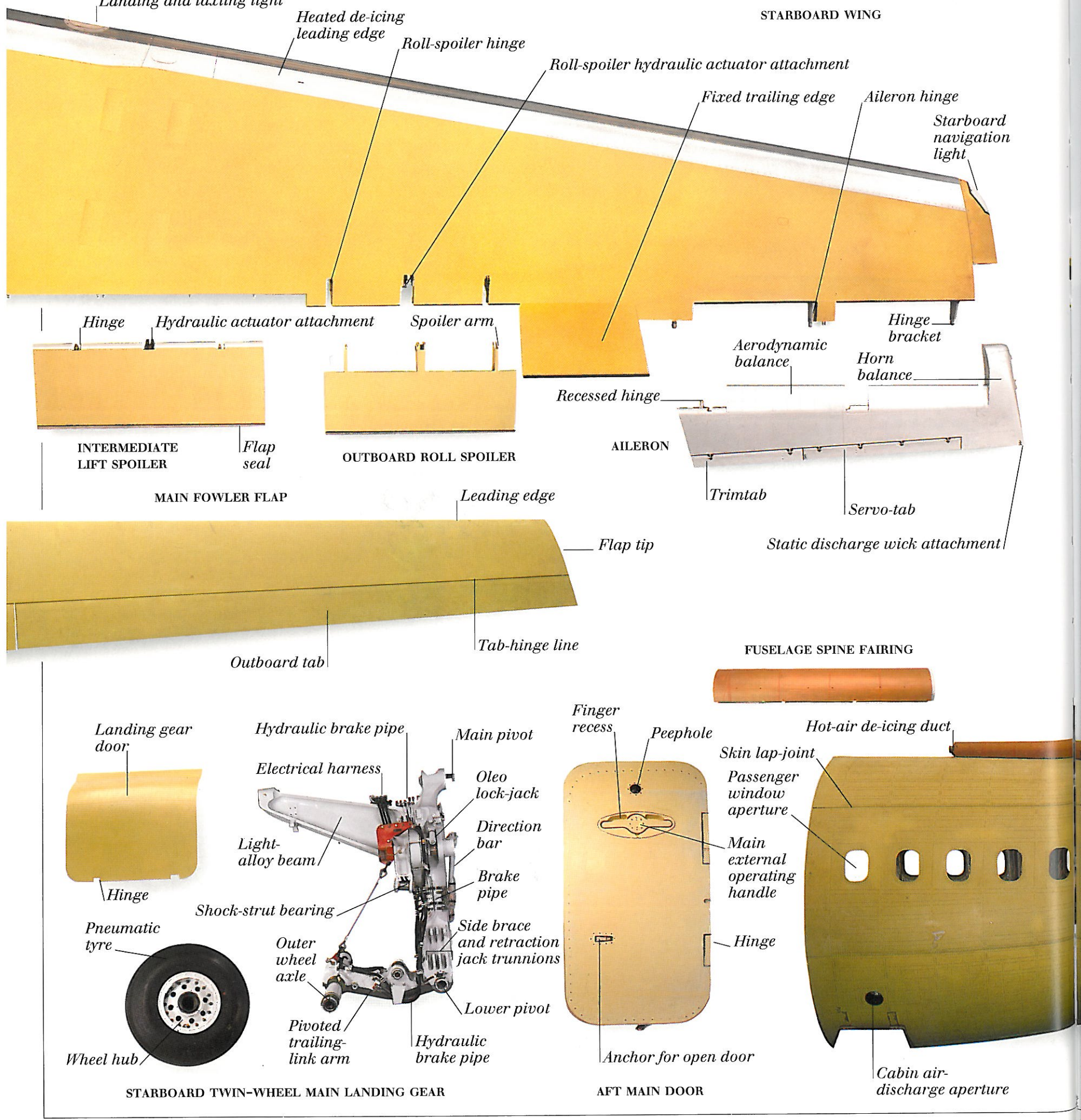
Pneumatic tyre

Wheel hub

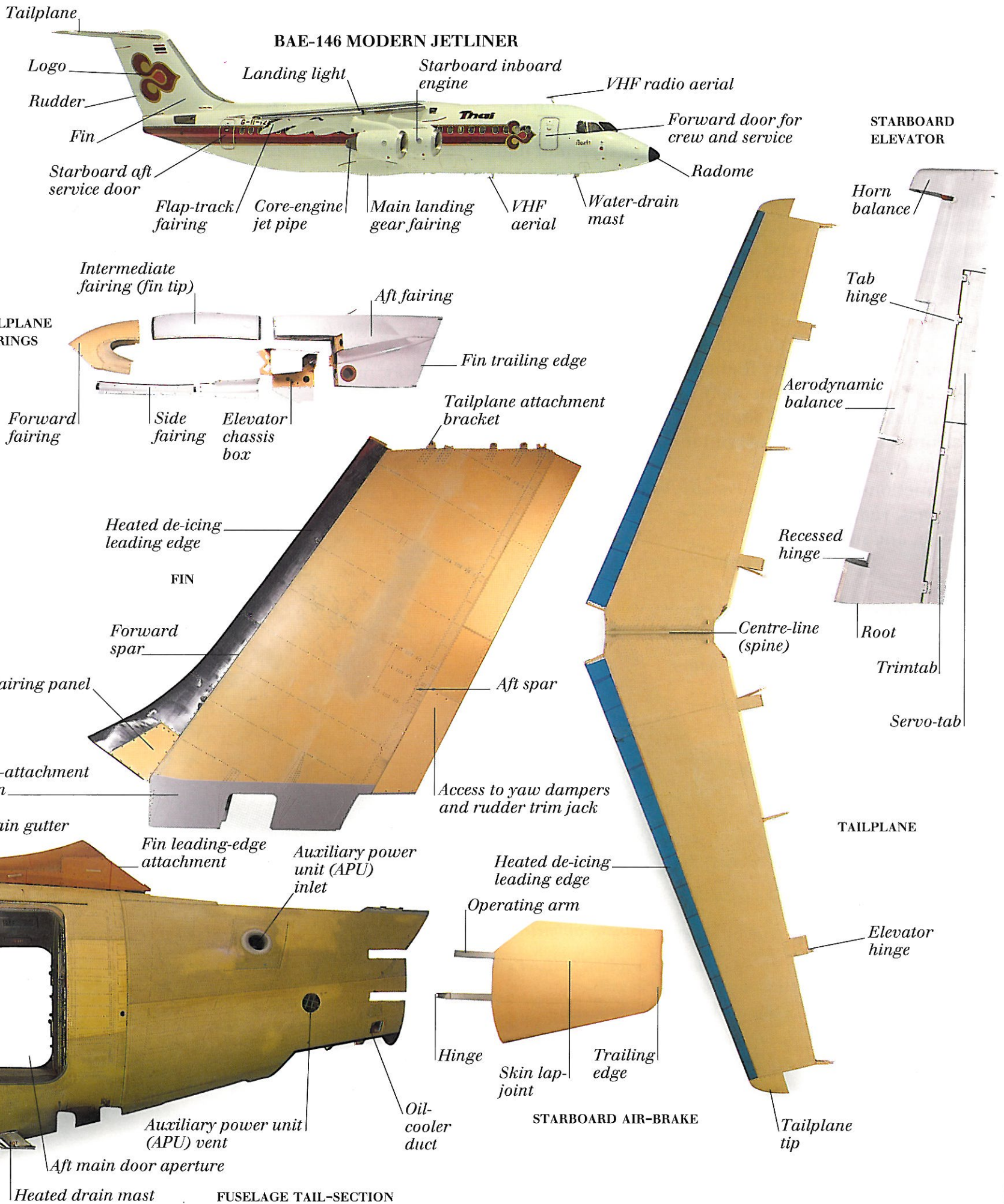
STARBOARD TWIN-WHEEL MAIN LANDING GEAR

AFT MAIN DOOR

Cabin air-discharge aperture



BAE-146 MODERN JETLINER



Modern cockpits

THE COCKPITS OF MODERN AIRCRAFT contain many data-display instruments, as well as aircraft controls. All modern aeroplanes have engine instruments (which indicate data such as fuel levels and power), and flight instruments. There are four main flight instruments: the altimeter, artificial horizon, airspeed indicator, and directional gyro. Many aircraft have two additional flight instruments: a turn-and-slip indicator and a vertical speed indicator. Some aircraft also have systems instruments, which indicate data such as the position of flaps and ailerons, and cabin pressure. In the most up-to-date cockpits, data is presented on electronic display screens. The most important screens are the primary flight display (which simultaneously shows data from all the flight instruments), and the navigational display (which combines the functions of compass, radar screen, and map).

FLIGHT DECK SIMULATOR OF AN AIRBUS A320 JETLINER

Primary flight display brightness control

Loudspeaker control

Air vent

Loudspeaker

Footrest

Standby airspeed indicator

Standby altimeter

Standby artificial horizon

Rudder pedal adjuster

Digital distance and radio magnetic indicator (DDRMI)

Rudder pedal adjustment indicator

Systems data display

Display management panel

CAPTAIN'S SIDE

Footrest

Audio control panel

Main panel floodlight control

Emergency electrics controls

Ground-proximity warning-system controls

Crew voice recorder controls

Oxygen controls

Crew communications controls

Rain repellent control

Windscreen wiper

External light controls

Navigation display mode selector

OVERHEAD PANEL

Mach (airspeed) selector

Barometric control

Navigation display in plan mode

Primary flight display

Screen transfer switch

Emergency electrics controls

Ground-proximity warning-system controls

Crew voice recorder controls

Oxygen controls

Crew communications controls

Rain repellent control

Windscreen wiper

External light controls

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Crew voice recorder controls

Oxygen controls

Crew communications controls

Rain repellent control

Windscreen wiper

External light controls

Navigation display mode selector

OVERHEAD PANEL

Mach (airspeed) selector

Barometric control

Navigation display in plan mode

Primary flight display

Screen transfer switch

Emergency electrics controls

Ground-proximity warning-system controls

Crew voice recorder controls

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Oxygen controls

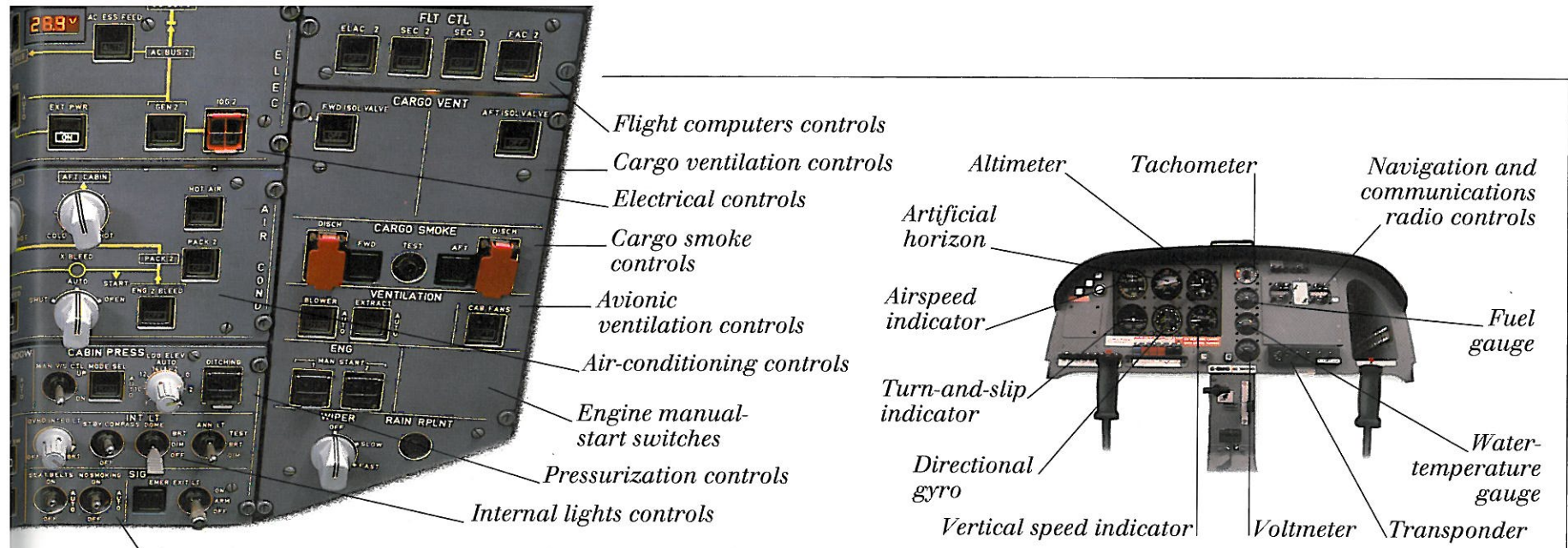
Crew communications controls

Rain repellent control

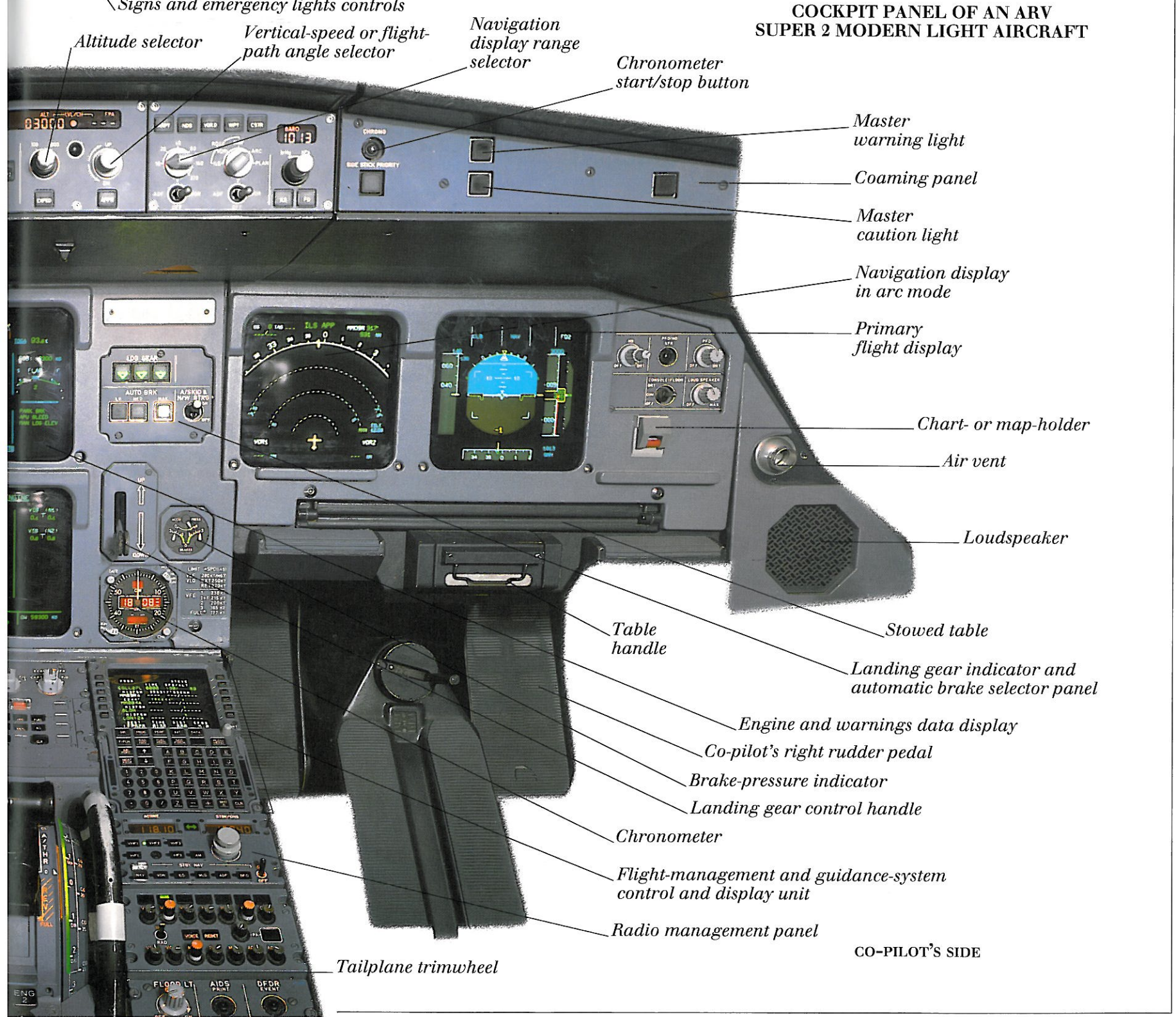
Windscreen wiper

External light controls

Navigation display mode selector



COCKPIT PANEL OF AN ARV SUPER 2 MODERN LIGHT AIRCRAFT



CO-PILOT'S SIDE

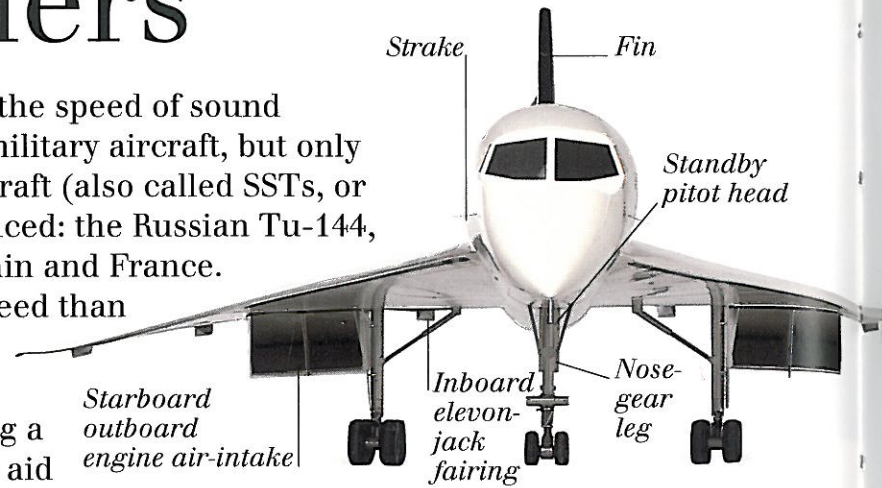
Supersonic jetliners



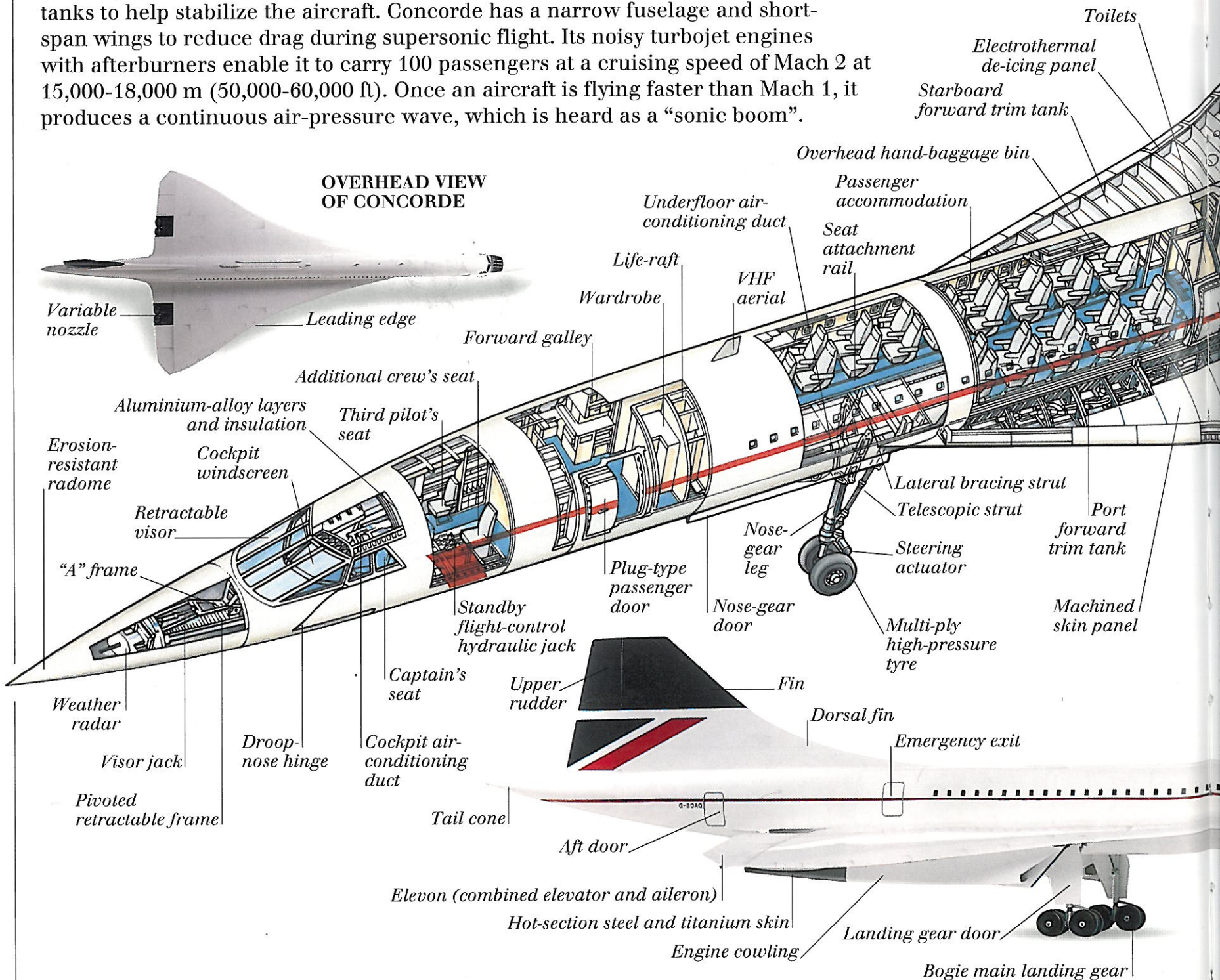
COMPUTER-DESIGNED SST

SUPERSONIC AIRCRAFT FLY FASTER than the speed of sound (Mach 1). There are many supersonic military aircraft, but only two supersonic passenger-carrying aircraft (also called SSTs, or supersonic transports) have been produced: the Russian Tu-144, and Concorde, produced jointly by Britain and France. The Tu-144 had a greater maximum speed than Concorde but was withdrawn in 1978,

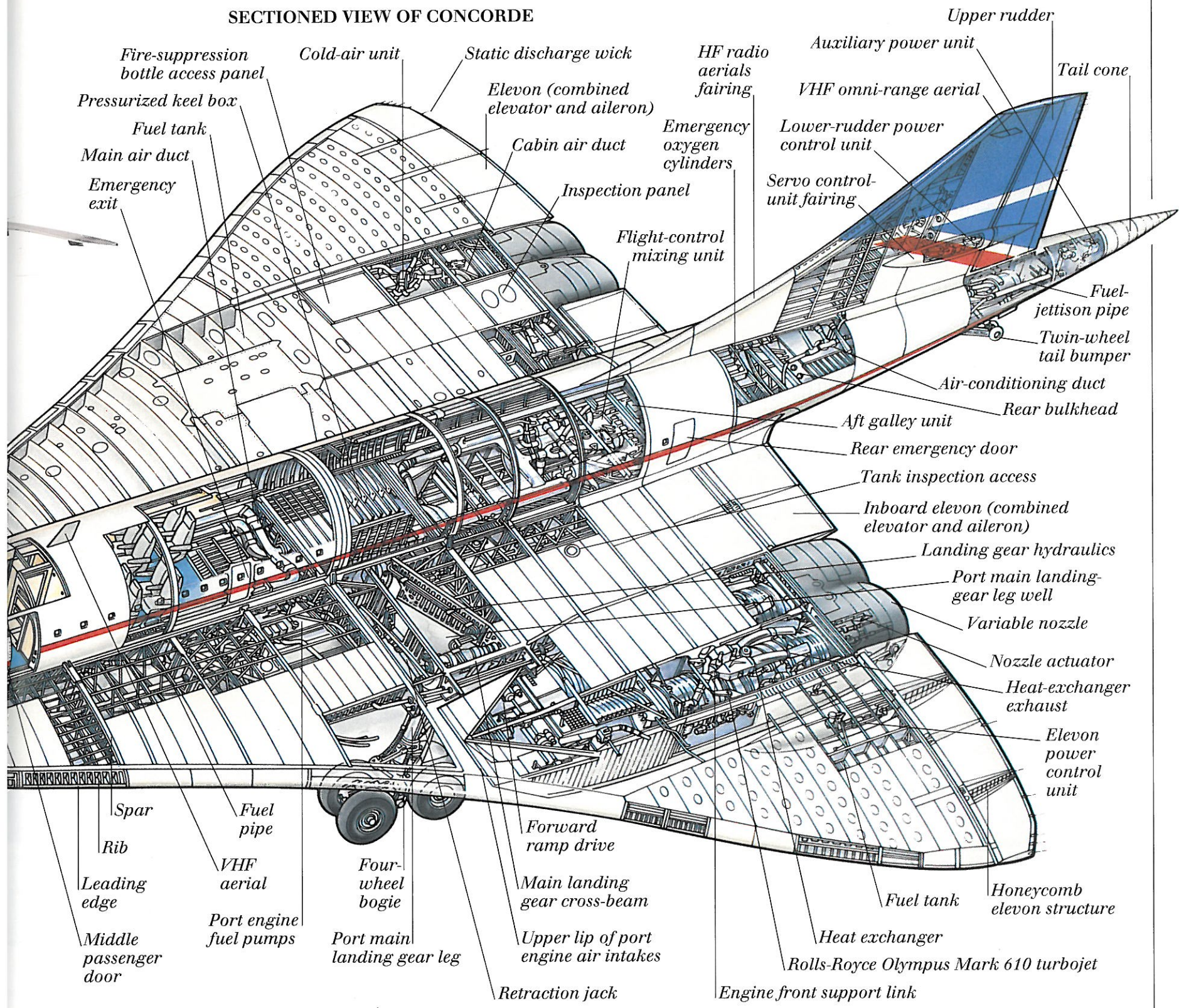
after only seven months in service. Concorde has remained in service since 1976. It features many innovations, including a droop nose, which is lowered during take-off and landing to aid visibility from the cockpit, and the pumping of fuel between forward and aft trim tanks to help stabilize the aircraft. Concorde has a narrow fuselage and short-span wings to reduce drag during supersonic flight. Its noisy turbojet engines with afterburners enable it to carry 100 passengers at a cruising speed of Mach 2 at 15,000-18,000 m (50,000-60,000 ft). Once an aircraft is flying faster than Mach 1, it produces a continuous air-pressure wave, which is heard as a "sonic boom".



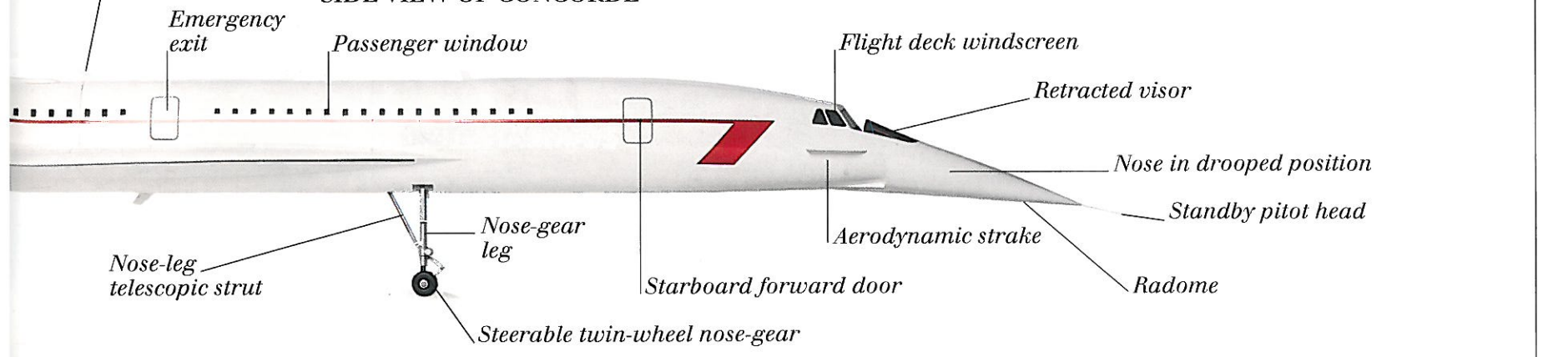
FRONT VIEW OF CONCORDE



SECTIONED VIEW OF CONCORDE



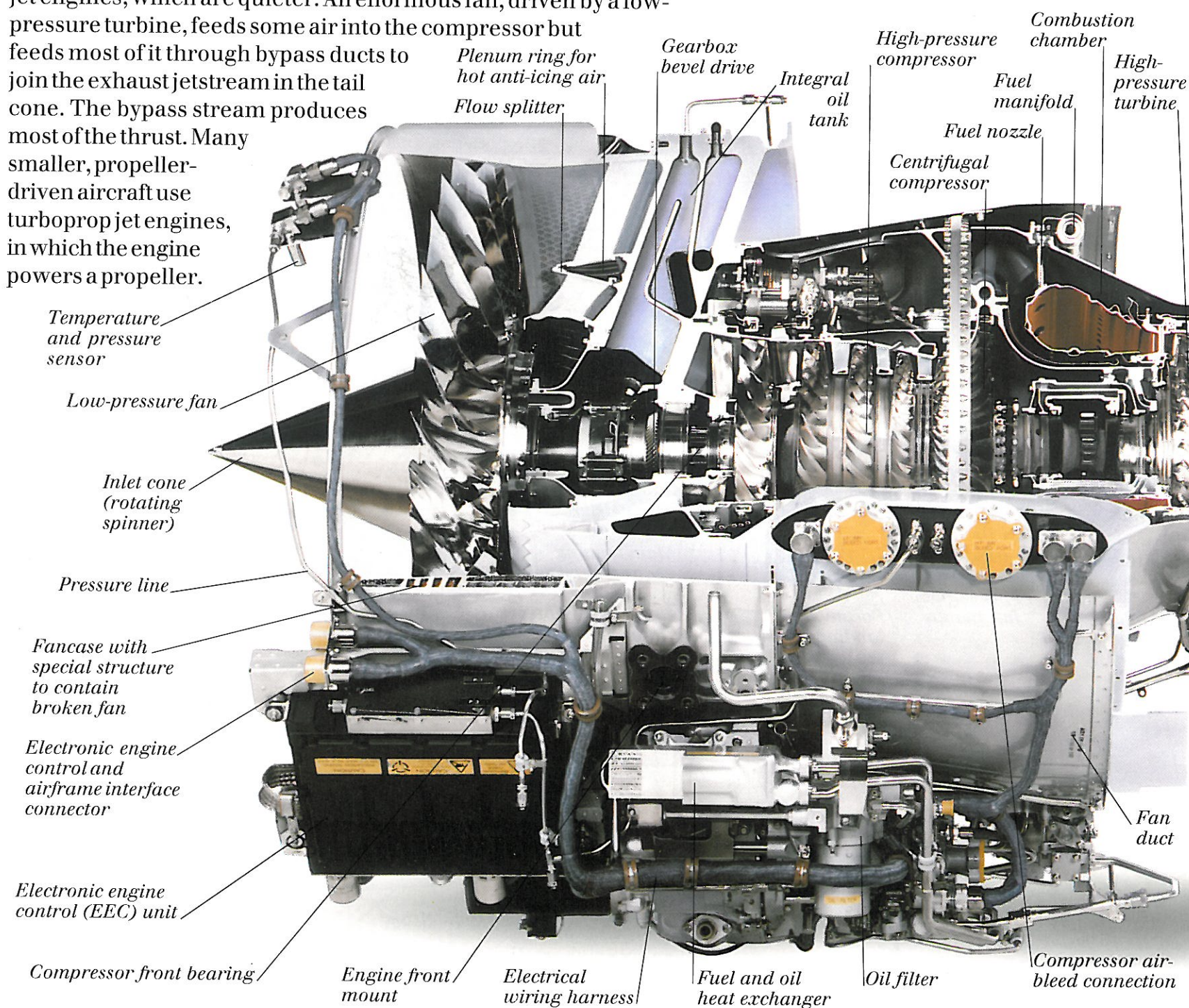
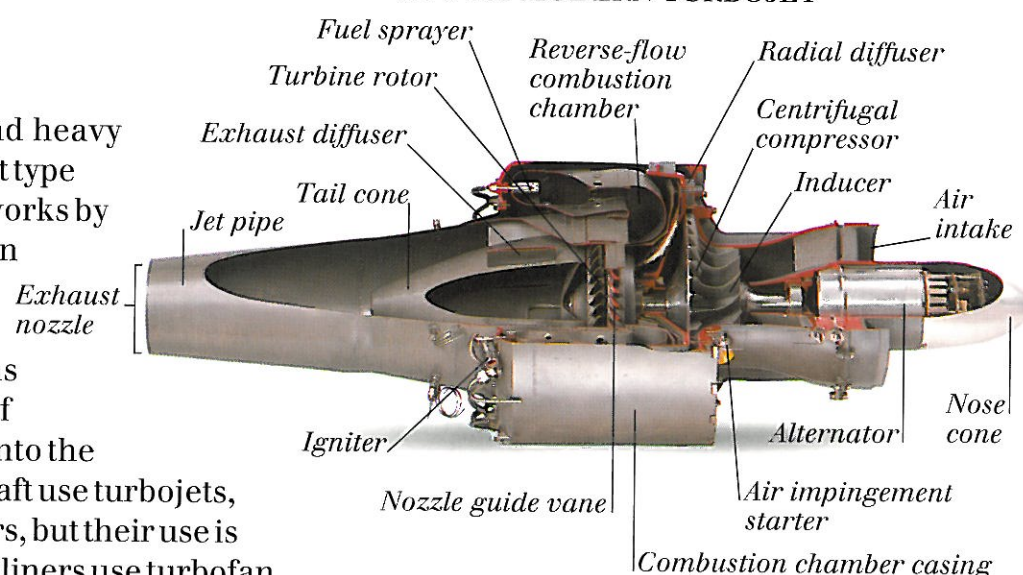
SIDE VIEW OF CONCORDE



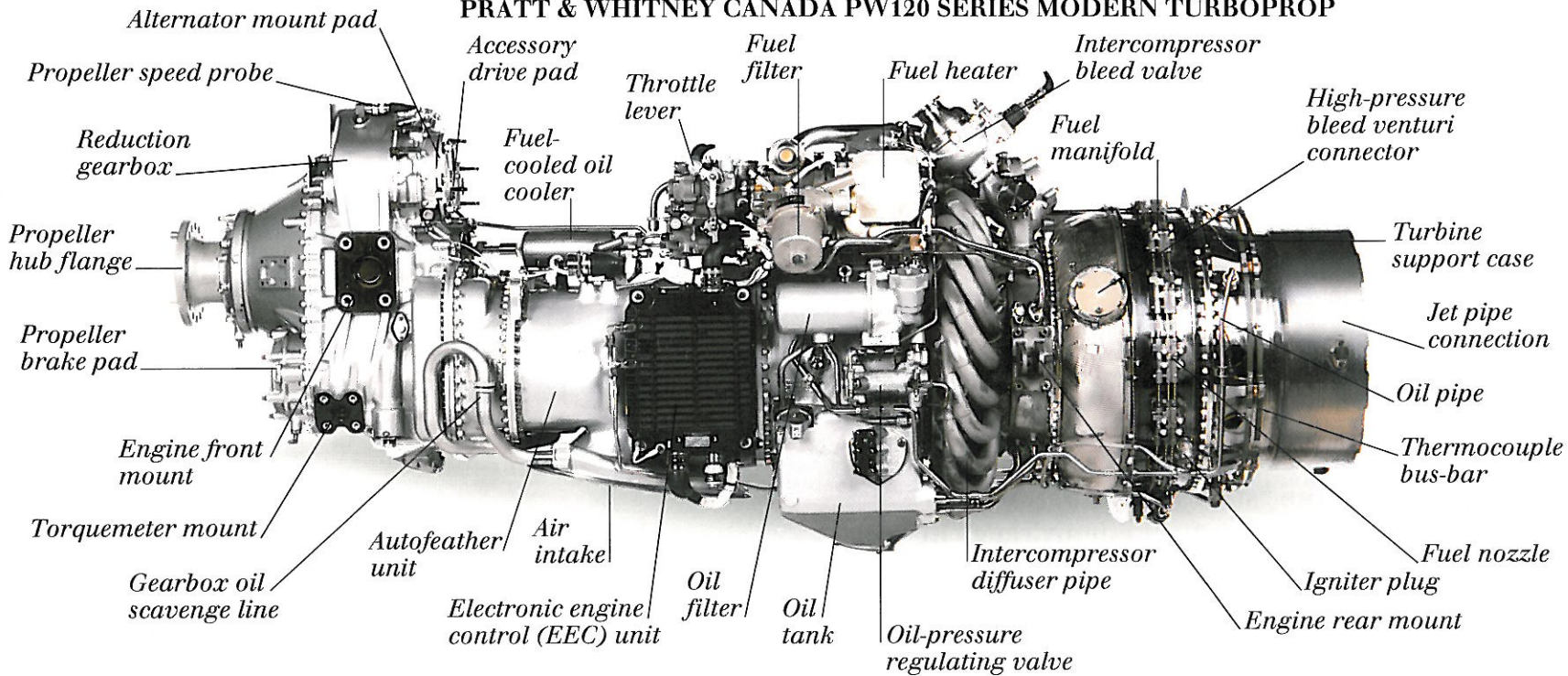
Jet engines

JET ENGINES ARE USED BY MOST MILITARY and heavy aircraft, and by many helicopters. The simplest type of jet engine, or gas turbine, is the turbojet. It works by continuously burning a mixture of fuel and air in a combustion chamber to produce a jet of hot exhaust gas that is expelled through a nozzle to produce thrust. The hot gas also spins turbine blades, which, in turn, spin the blades of an air compressor; the compressor forces air into the combustion chamber. Many of the fastest aircraft use turbojets, with additional booster units called afterburners, but their use is restricted by their high noise emission. Most jetliners use turbofan jet engines, which are quieter. An enormous fan, driven by a low-pressure turbine, feeds some air into the compressor but feeds most of it through bypass ducts to join the exhaust jetstream in the tail cone. The bypass stream produces most of the thrust. Many smaller, propeller-driven aircraft use turboprop jet engines, in which the engine powers a propeller.

NPT 301 MODERN TURBOJET

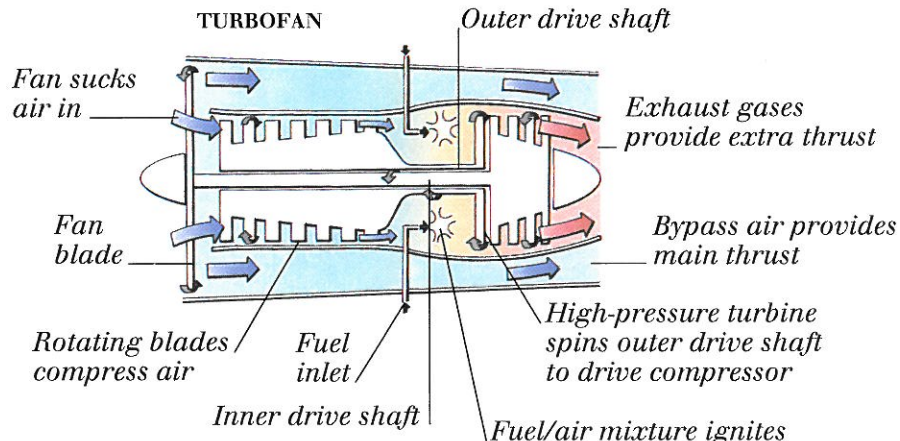


PRATT & WHITNEY CANADA PW120 SERIES MODERN TURBOPROP

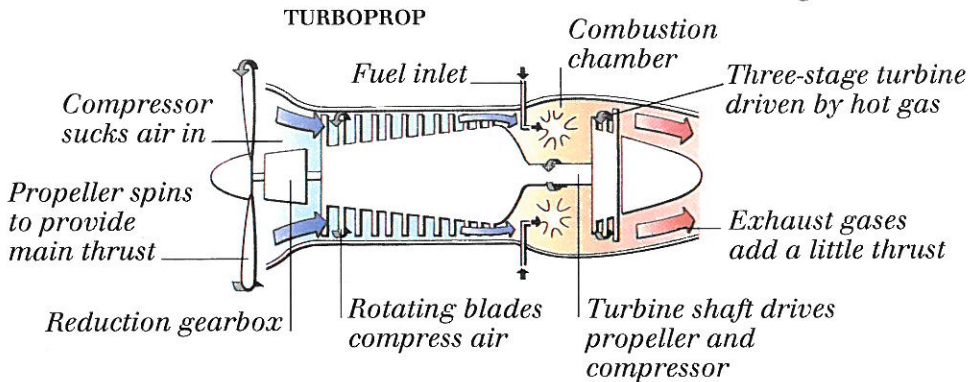


HOW JET ENGINES WORK

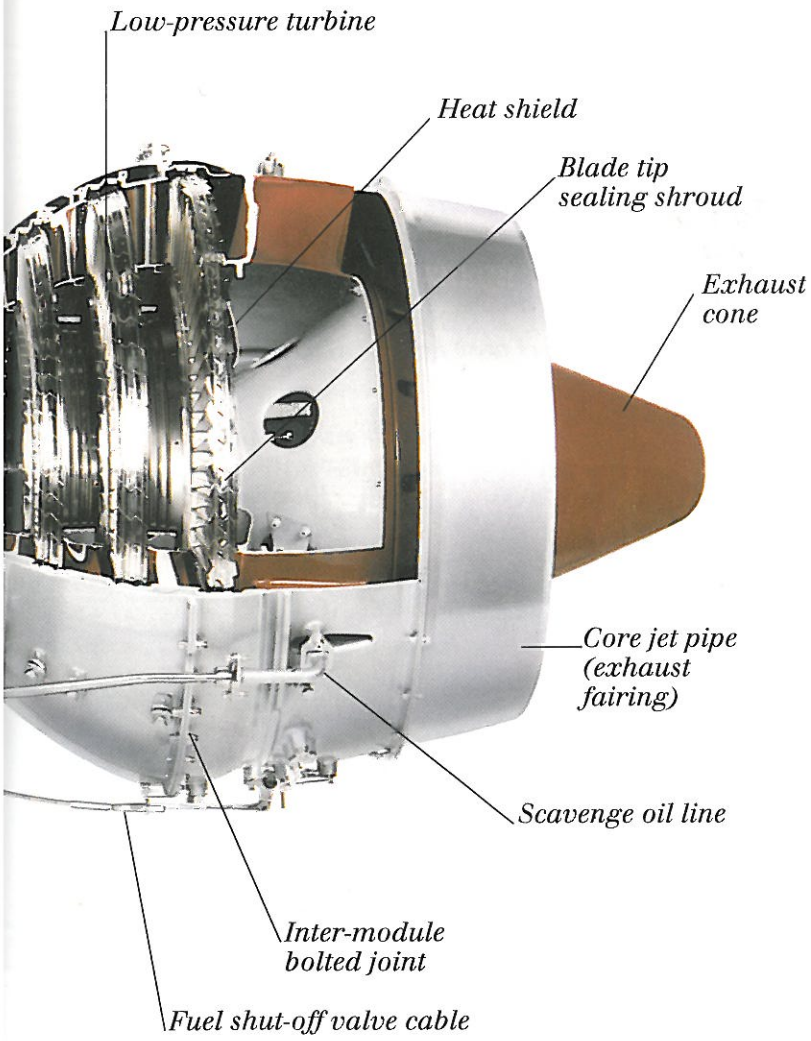
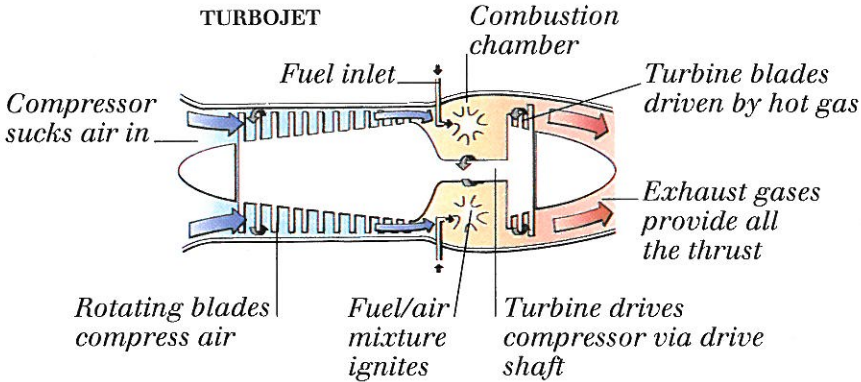
TURBOFAN



TURBOPROP



TURBOJET

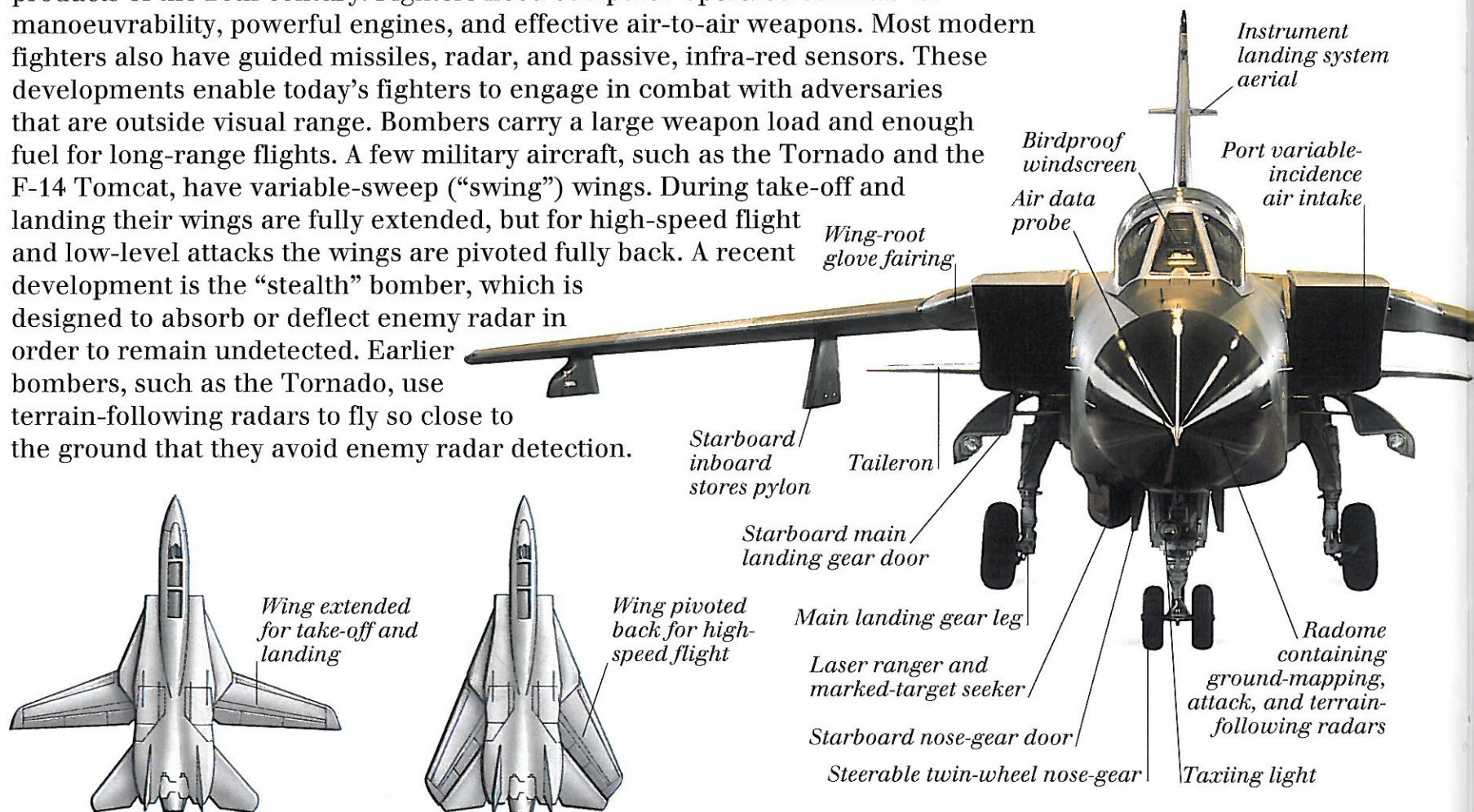


SECTIONED PRATT & WHITNEY CANADA PW305 MODERN TURBOFAN

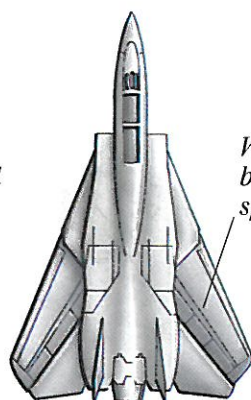
Modern military aircraft

MODERN MILITARY AIRCRAFT ARE AMONG THE MOST SOPHISTICATED and expensive products of the 20th century. Fighters need computer-operated controls for manoeuvrability, powerful engines, and effective air-to-air weapons. Most modern fighters also have guided missiles, radar, and passive, infra-red sensors. These developments enable today's fighters to engage in combat with adversaries that are outside visual range. Bombers carry a large weapon load and enough fuel for long-range flights. A few military aircraft, such as the Tornado and the F-14 Tomcat, have variable-sweep ("swing") wings. During take-off and landing their wings are fully extended, but for high-speed flight and low-level attacks the wings are pivoted fully back. A recent development is the "stealth" bomber, which is designed to absorb or deflect enemy radar in order to remain undetected. Earlier bombers, such as the Tornado, use terrain-following radars to fly so close to the ground that they avoid enemy radar detection.

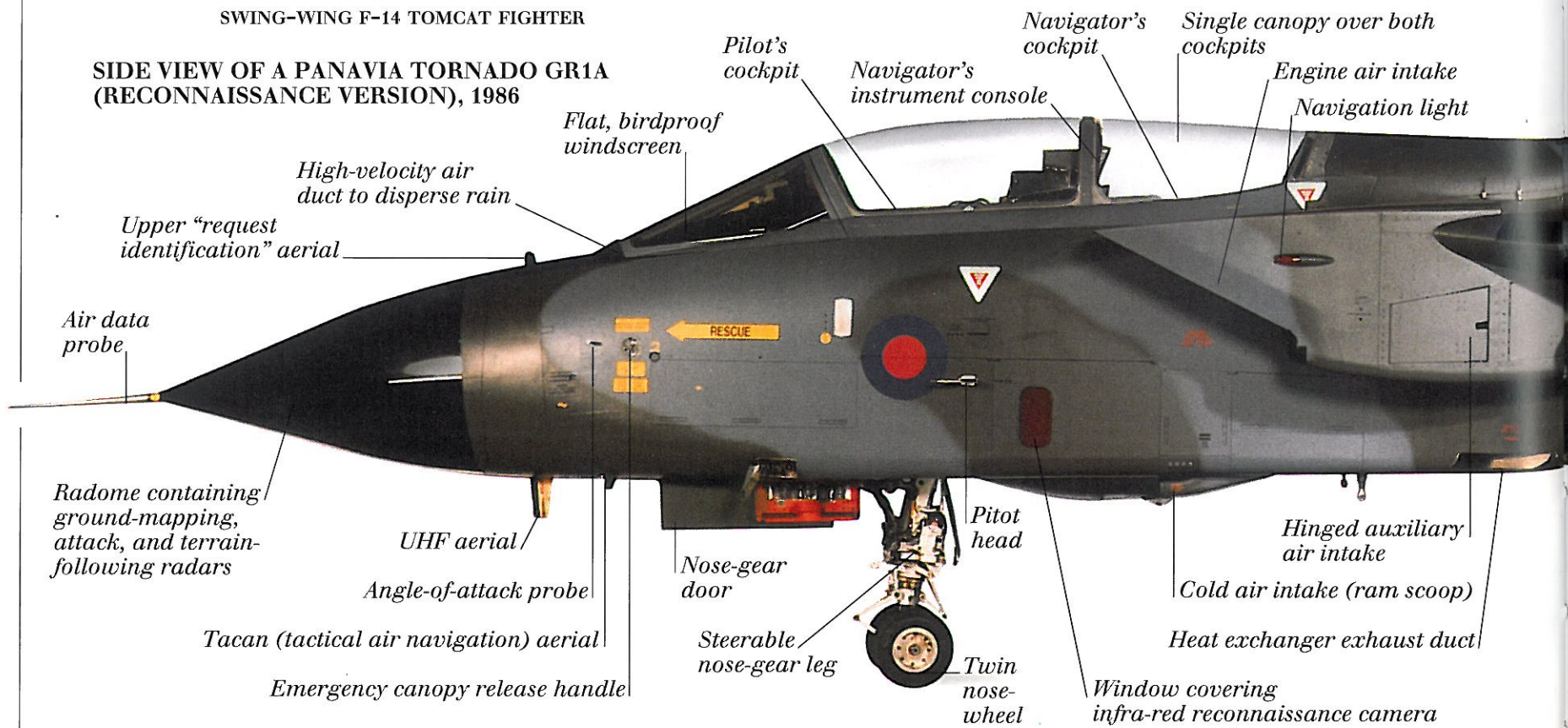
FRONT VIEW OF A PANAVIA TORNADO



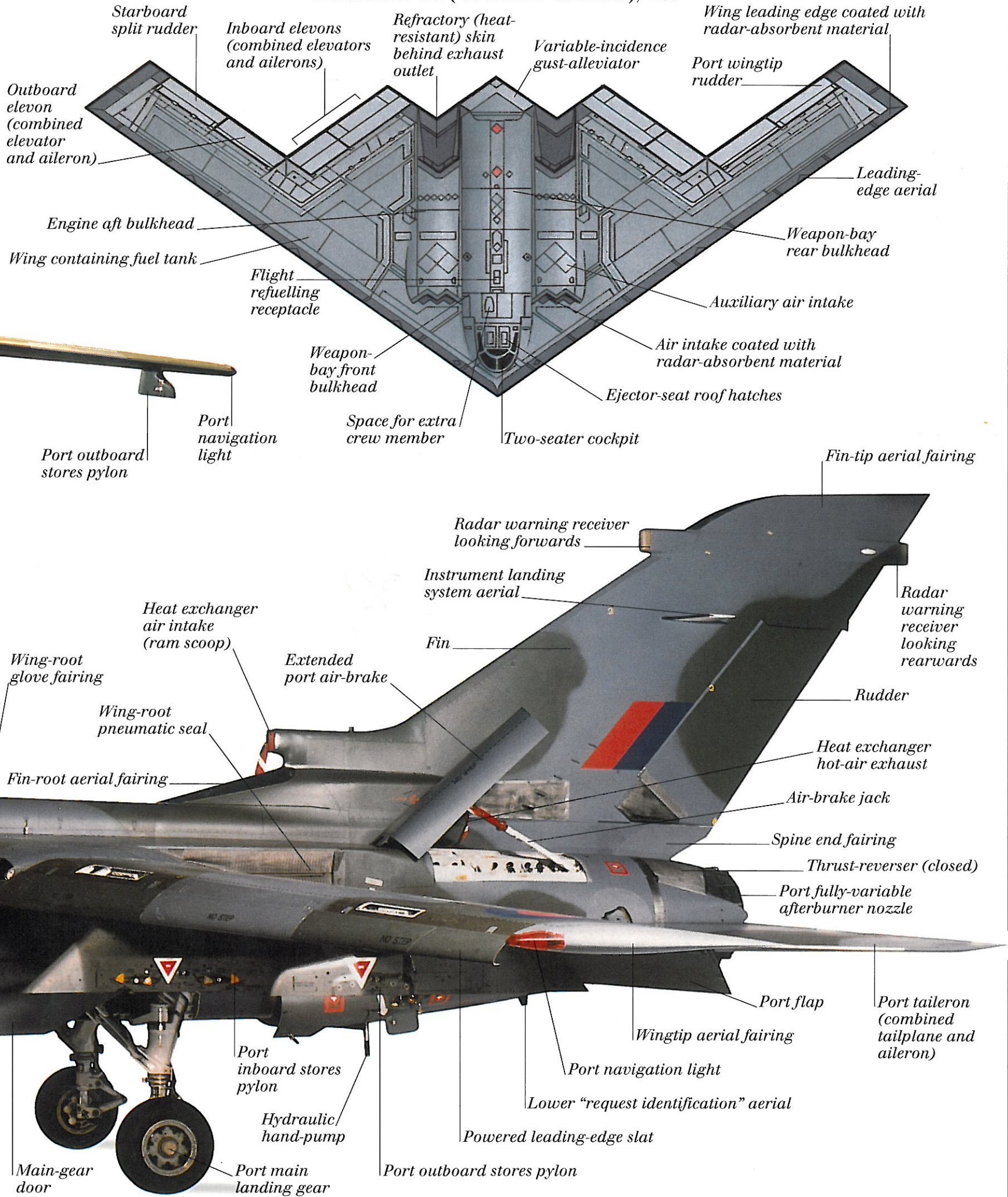
SWING-WING F-14 TOMCAT FIGHTER



SIDE VIEW OF A PANAVIA TORNADO GR1A (RECONNAISSANCE VERSION), 1986



NORTHROP B-2 ("STEALTH" BOMBER), 1989

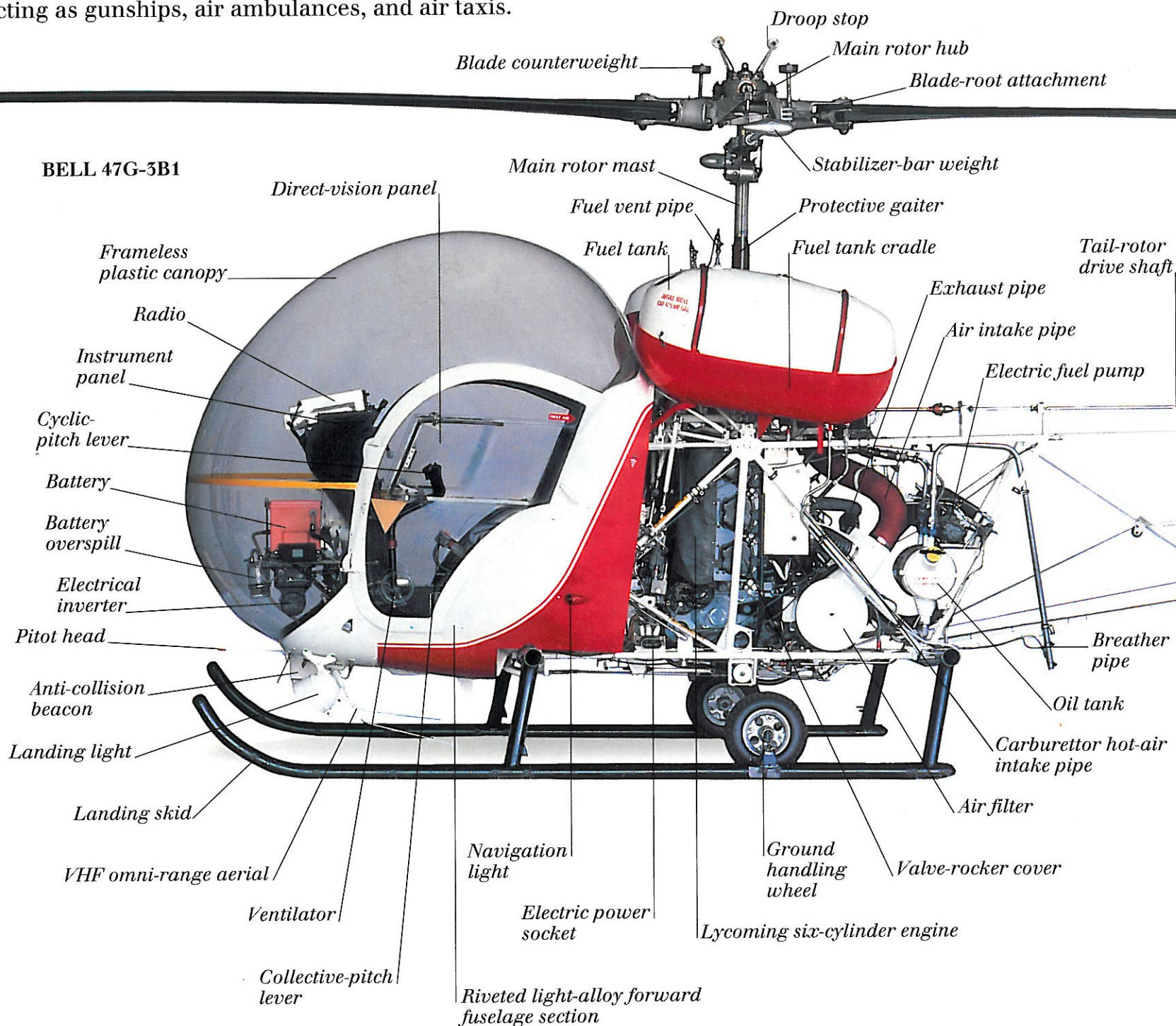


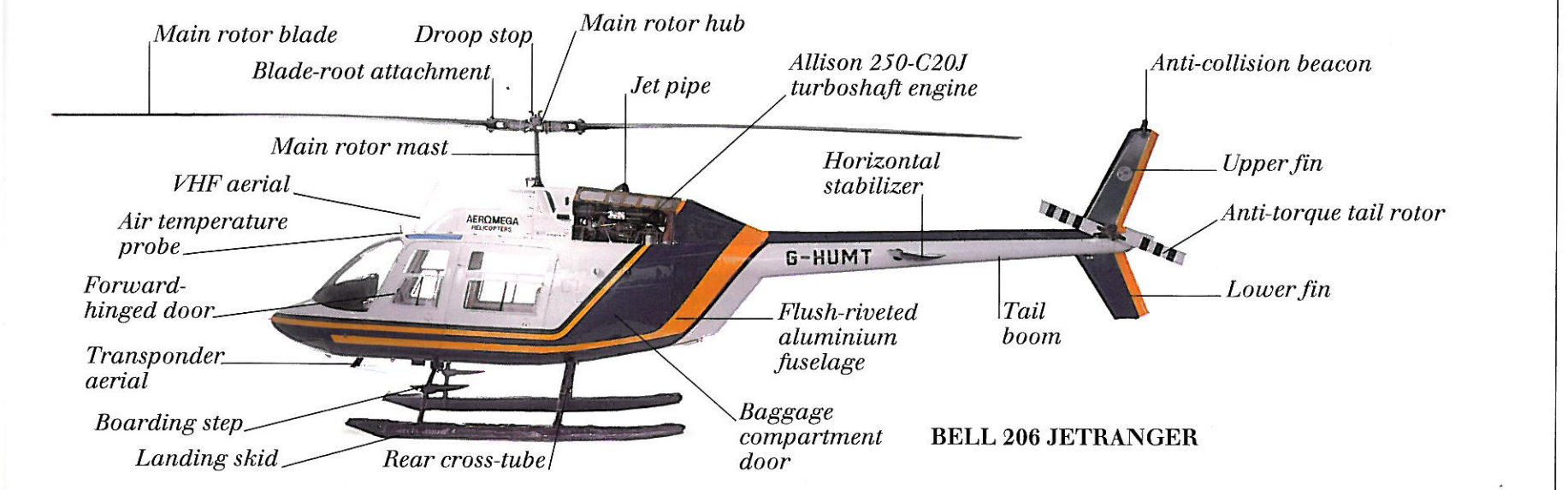
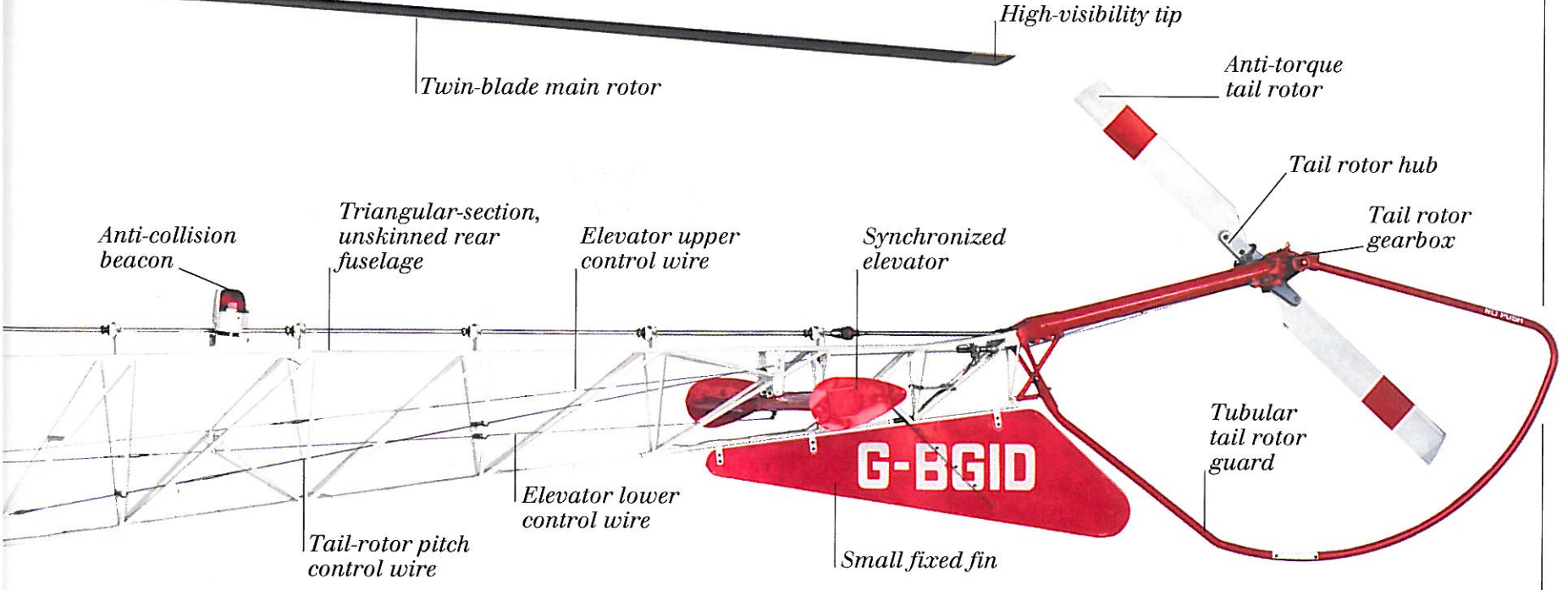
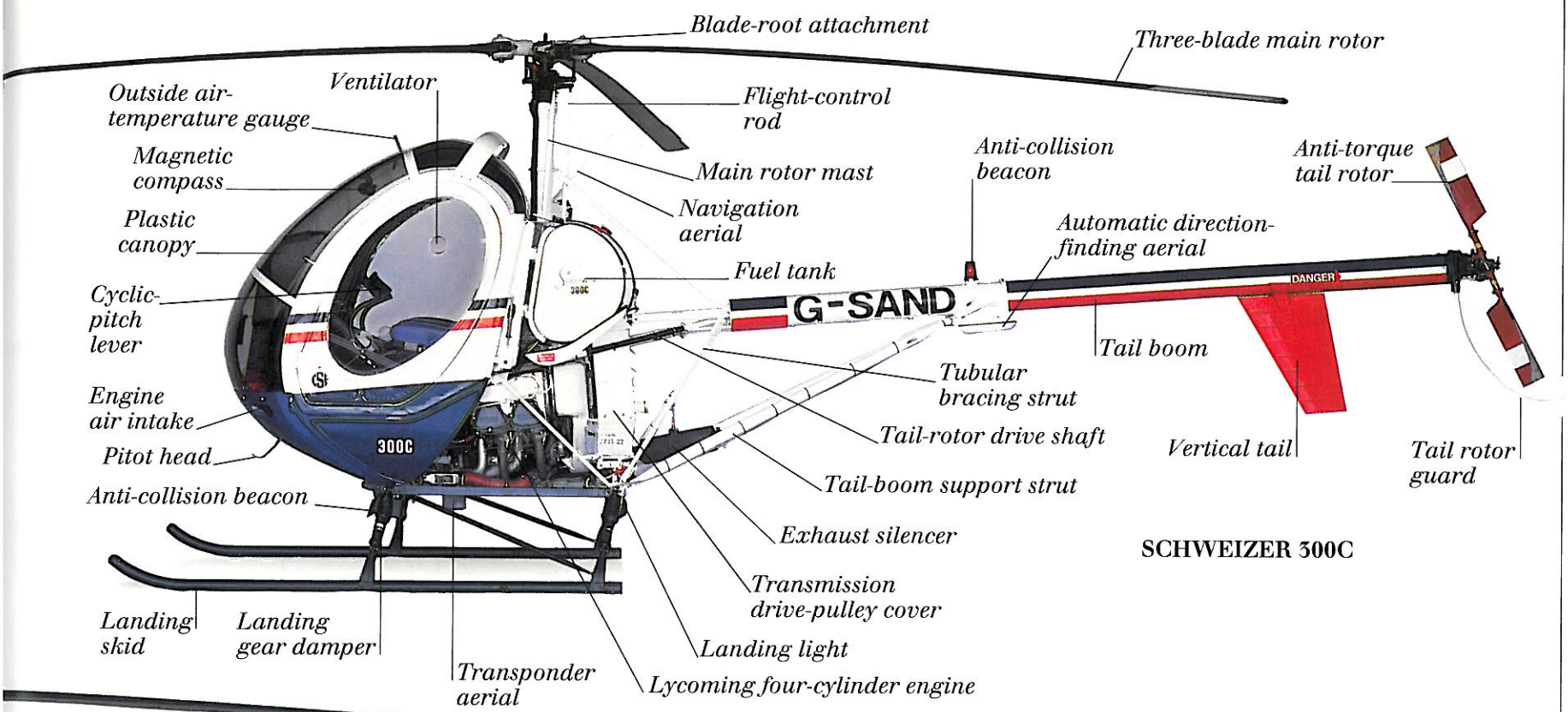
Helicopters



BELL 47G-3B1

HELICOPTERS USE ROTATING BLADES for lift, propulsion, and steering. The first machine to achieve sustained, controlled flight using rotating blades was the autogiro built in the 1920s by the Spaniard Juan de la Cierva. His machine had unpowered blades above the fuselage that relied on the flow of air to rotate them and provide lift as the autogiro was driven forwards by a conventional propeller. Then, in 1939, the Russian-born American Igor Sikorsky produced his VS-300, the forerunner of modern helicopters. Its engine-driven blades provided lift, propulsion, and steering. It could take off vertically, hover, and fly in any direction, and had a tail rotor to prevent the helicopter body from spinning (see pp. 48-49). The introduction of gas turbine jet engines to helicopters in 1955 produced quieter, safer, and more powerful machines. Because of their versatility in flight, helicopters are today used for many purposes, including crop-spraying, traffic surveillance, and transporting crews to deep-sea oil rigs, as well as acting as gunships, air ambulances, and air taxis.

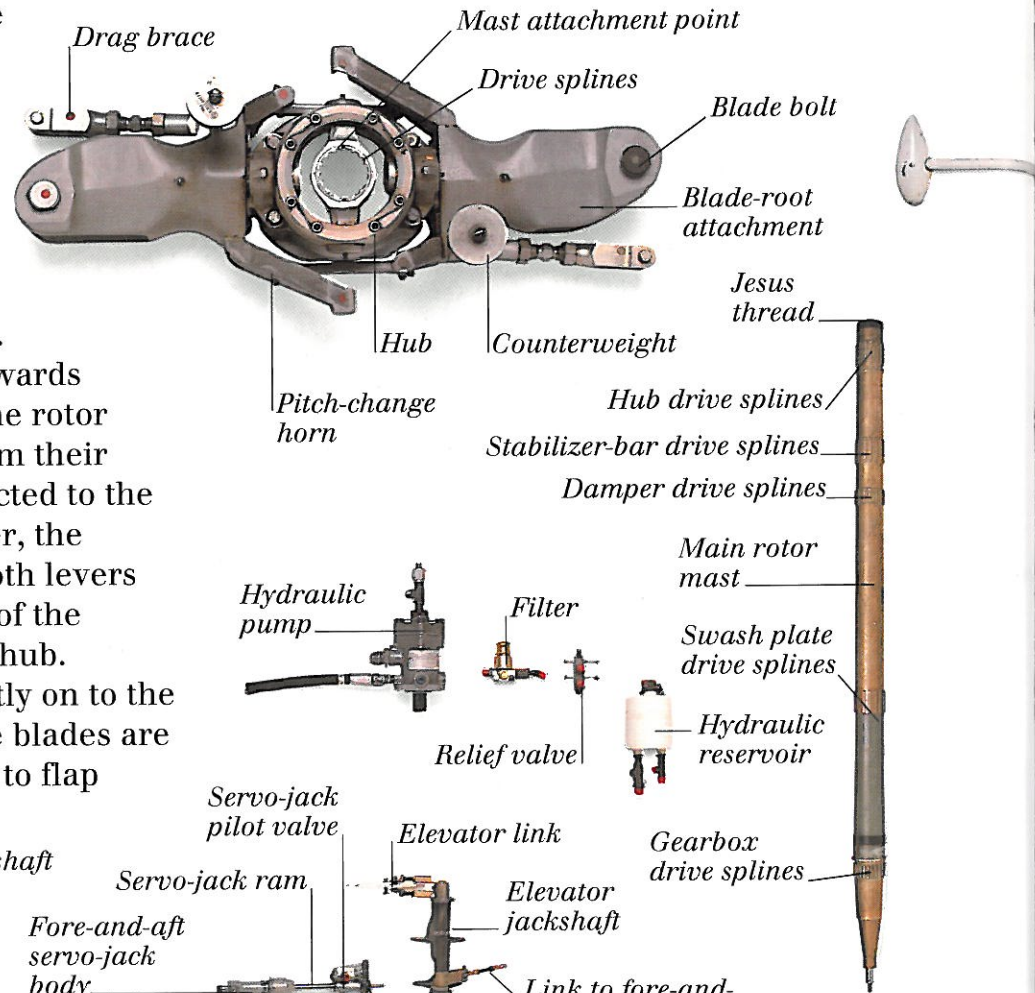




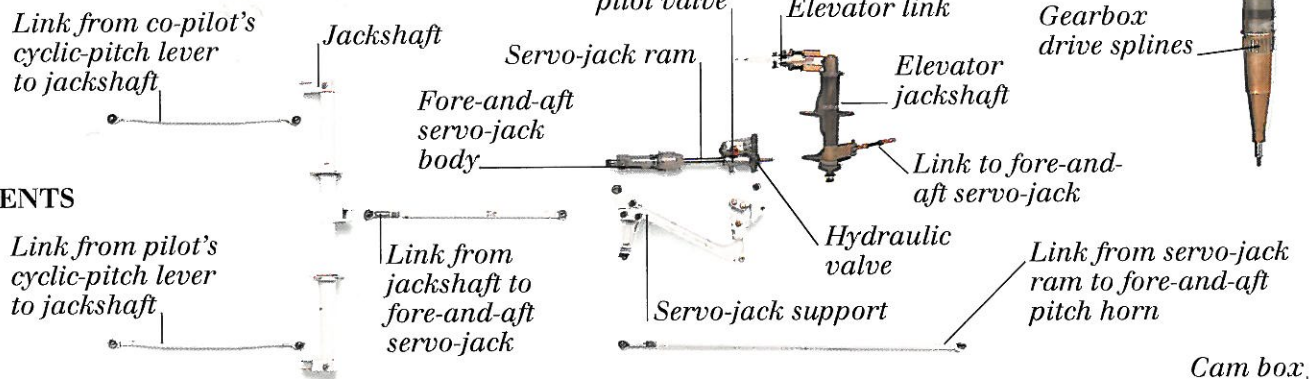
Helicopter technology

HELICOPTERS CAN FLY in any direction or simply hover. This versatility is made possible by a complex system of controls that allows the pilot to alter the angle of the blades on the main rotor and the tail rotor. The tail rotor maintains a sideways thrust to counteract the tendency of the helicopter to spin in the opposite direction to the main rotor; the pitch (angle) of the tail rotor blades is altered by rudder pedals to swing the tail left or right. To fly up or down, the pitch of the main rotor blades is adjusted using the collective-pitch lever. To fly forwards, the entire main rotor is tilted forwards using the cyclic-pitch lever; the same lever tilts the rotor to fly backwards or to the side. Both levers perform their operations via the swash plates, which are connected to the main rotor blades by push-and-pull rods. To hover, the pilot must maintain a precise balance between both levers and the rudder pedals. The complex movements of the rotor blades are made possible by the main rotor hub. On two-bladed rotors, the blades are bolted directly on to the hub, but on rotors with more than two blades, the blades are attached to hinges on the hub to allow the blades to flap slightly when rotating.

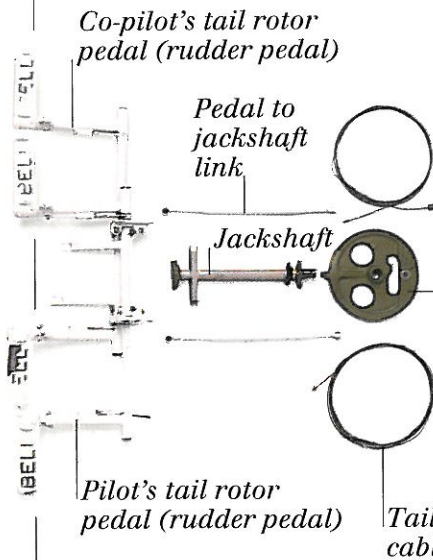
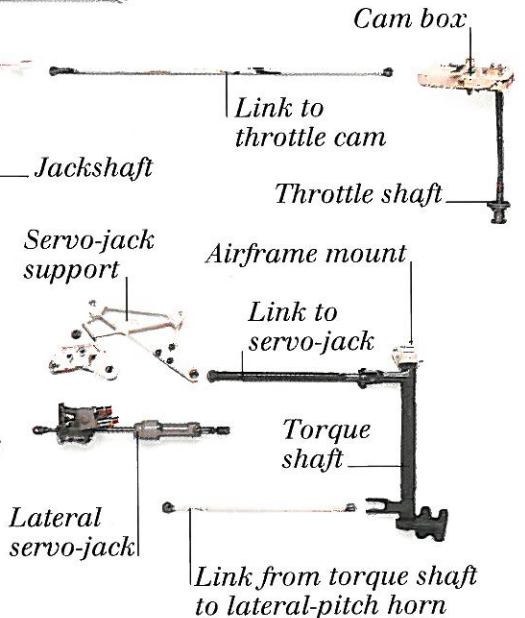
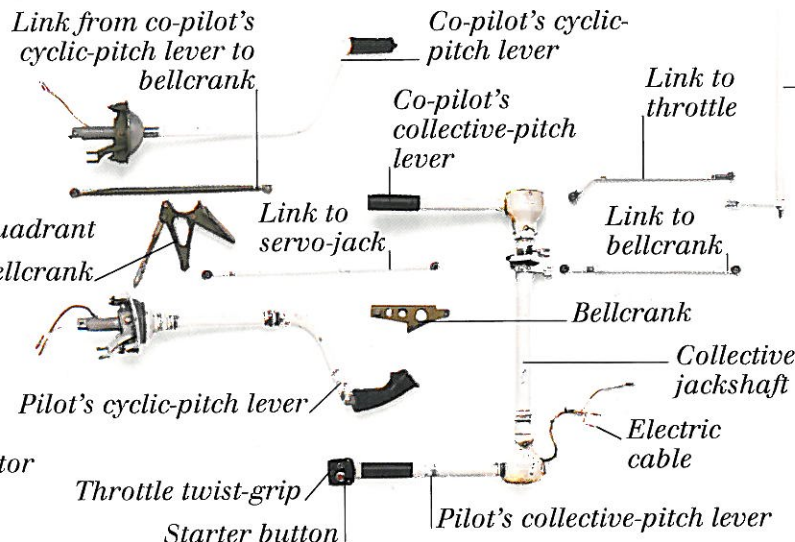
MAIN ROTOR HUB



MECHANICAL COMPONENTS OF A BELL 47 G-SERIES

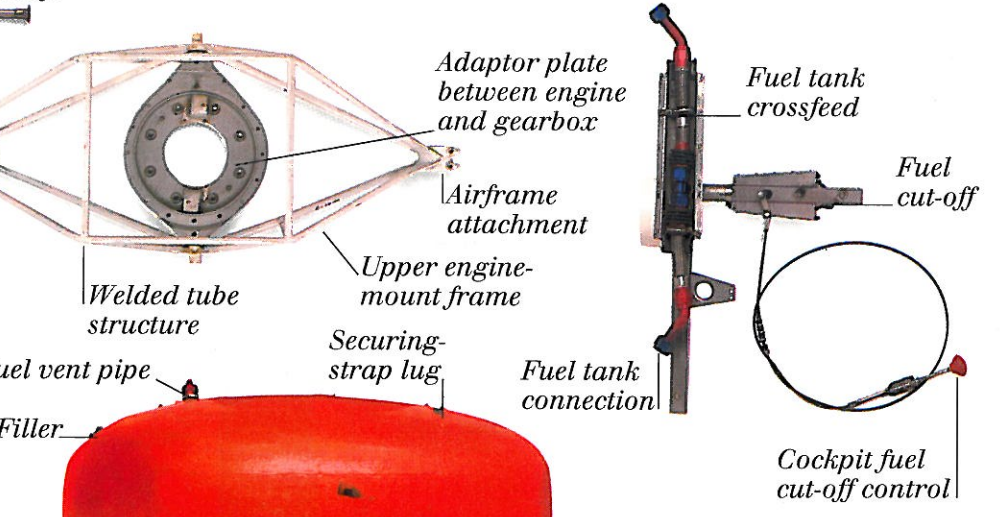
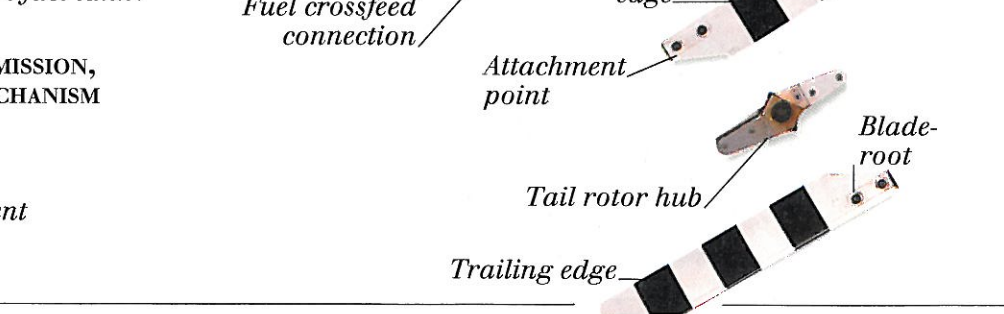
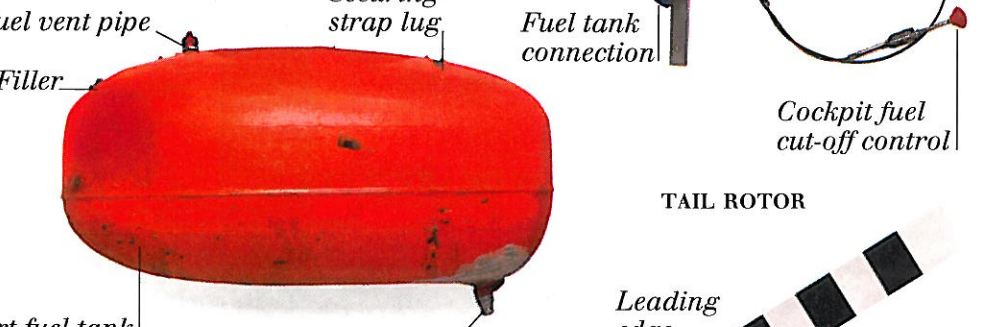
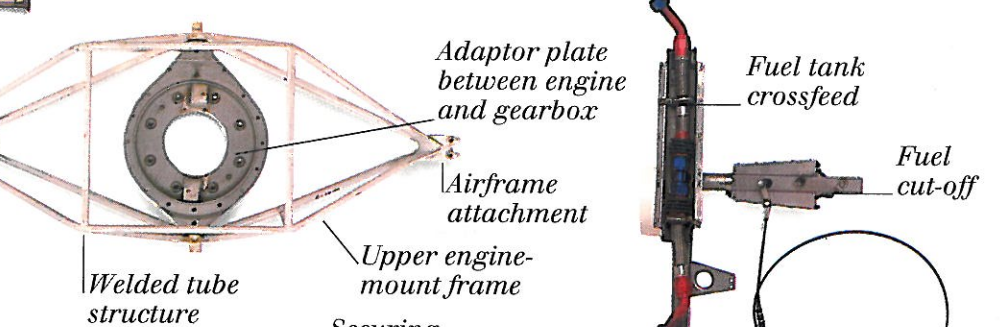
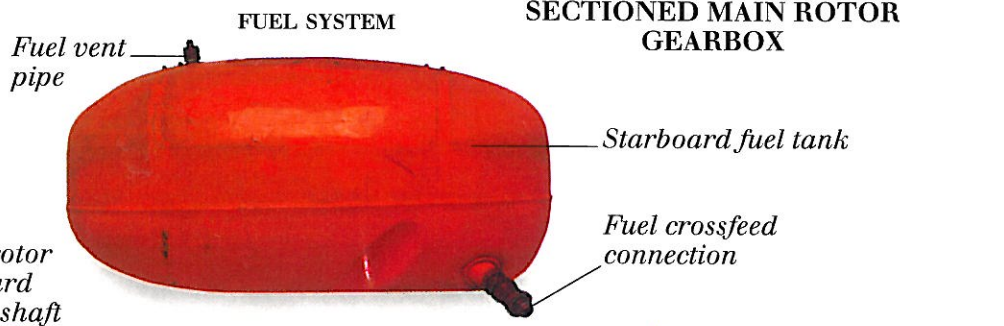
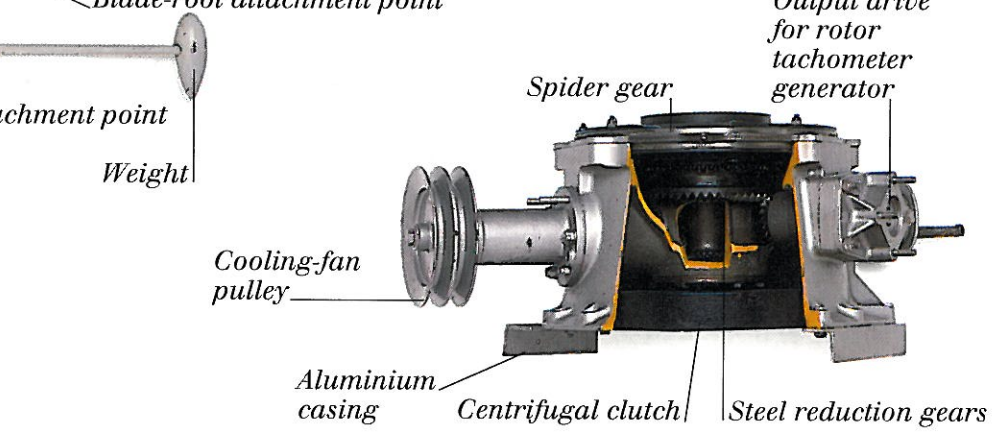
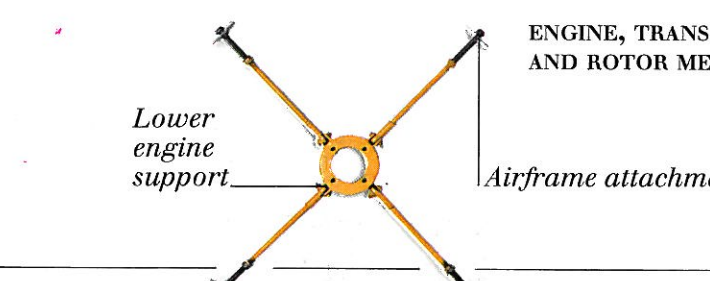
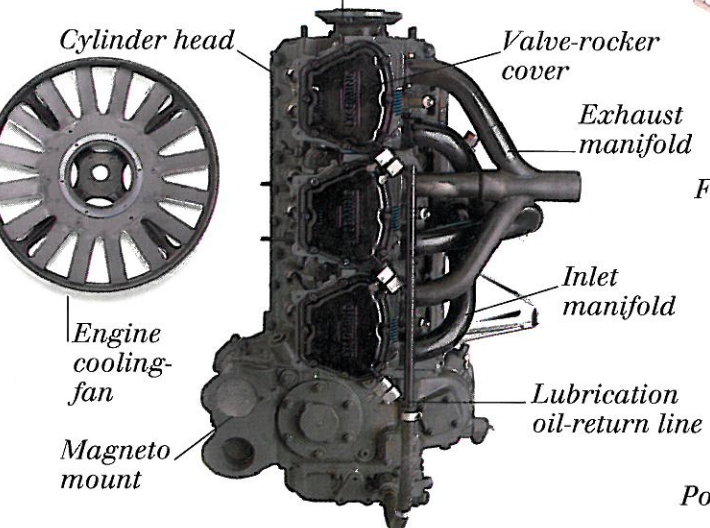
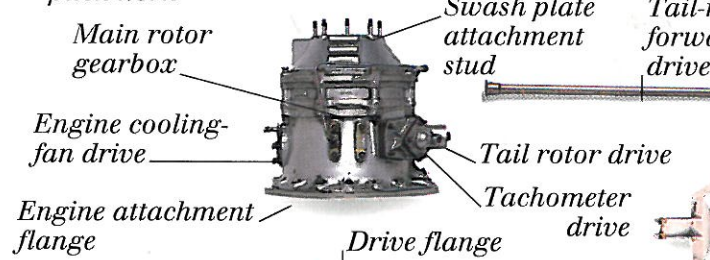
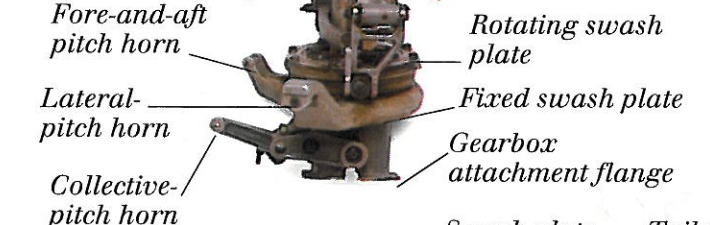
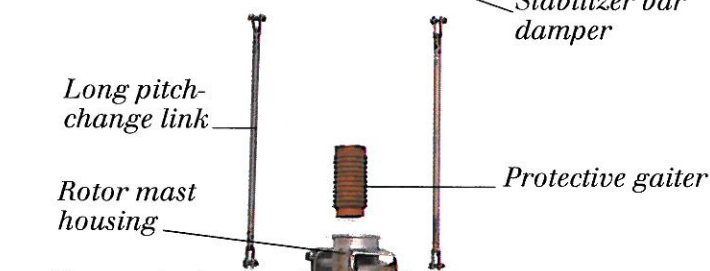
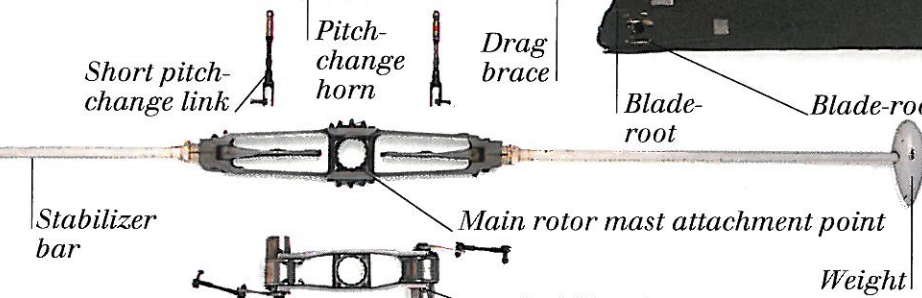
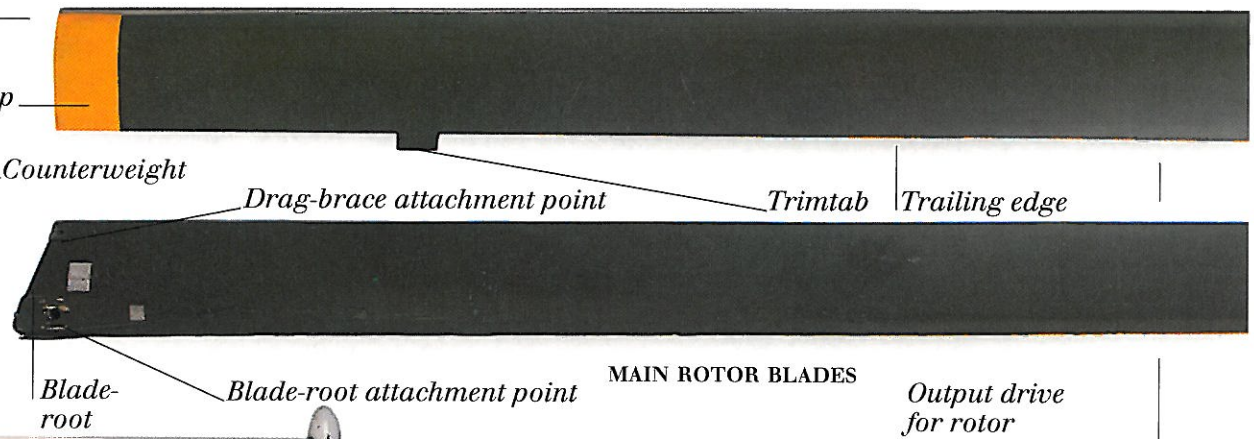
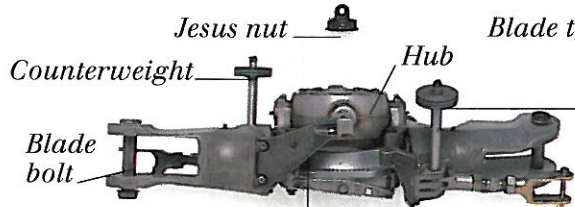


DUAL FORE-AND-AFT CYCLIC CONTROLS



TAIL ROTOR CONTROLS

DUAL COLLECTIVE AND LATERAL CYCLIC CONTROLS, AND THROTTLE LINKAGE



SECTIONED MAIN ROTOR GEARBOX

FUEL SYSTEM

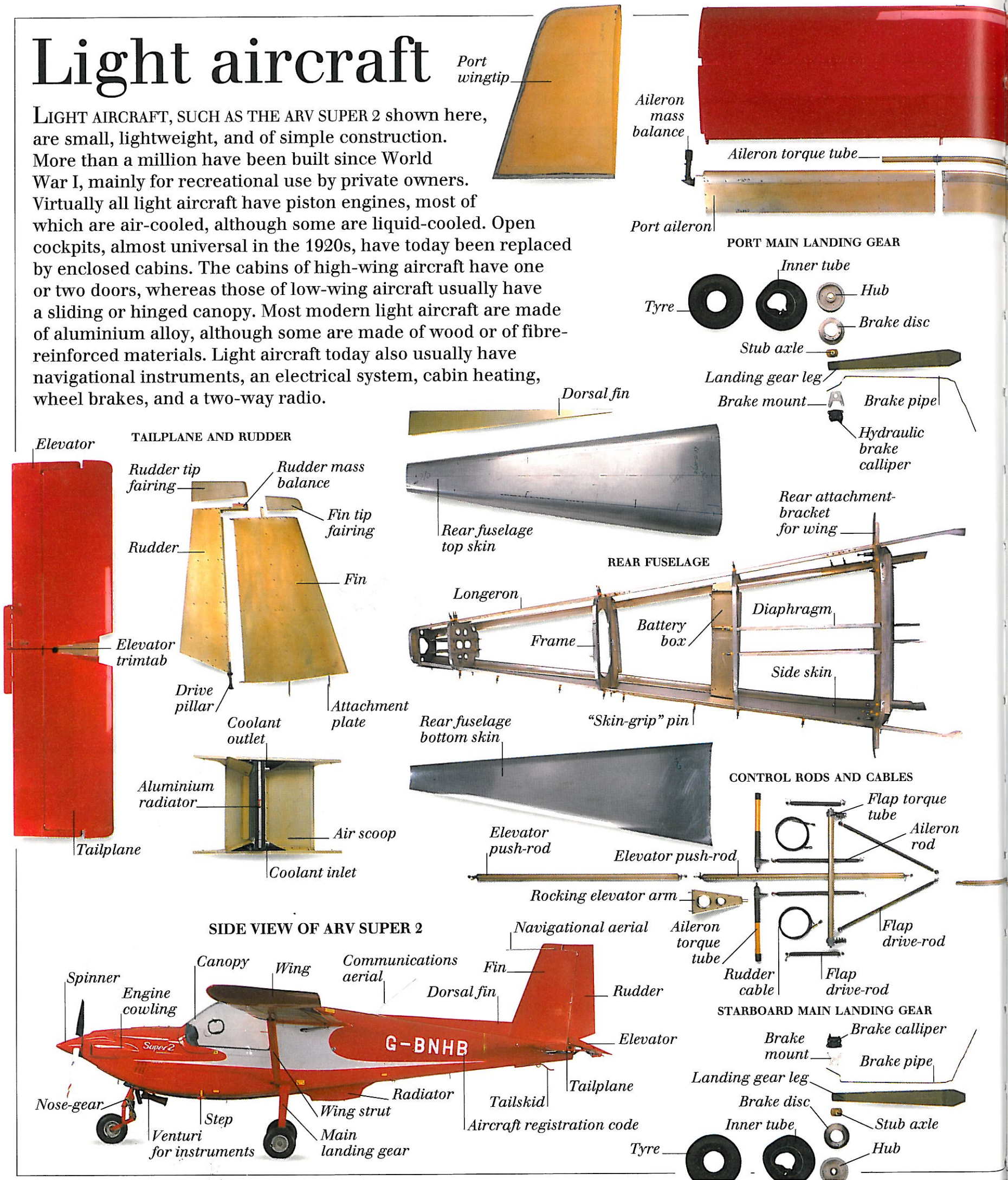
TAIL ROTOR

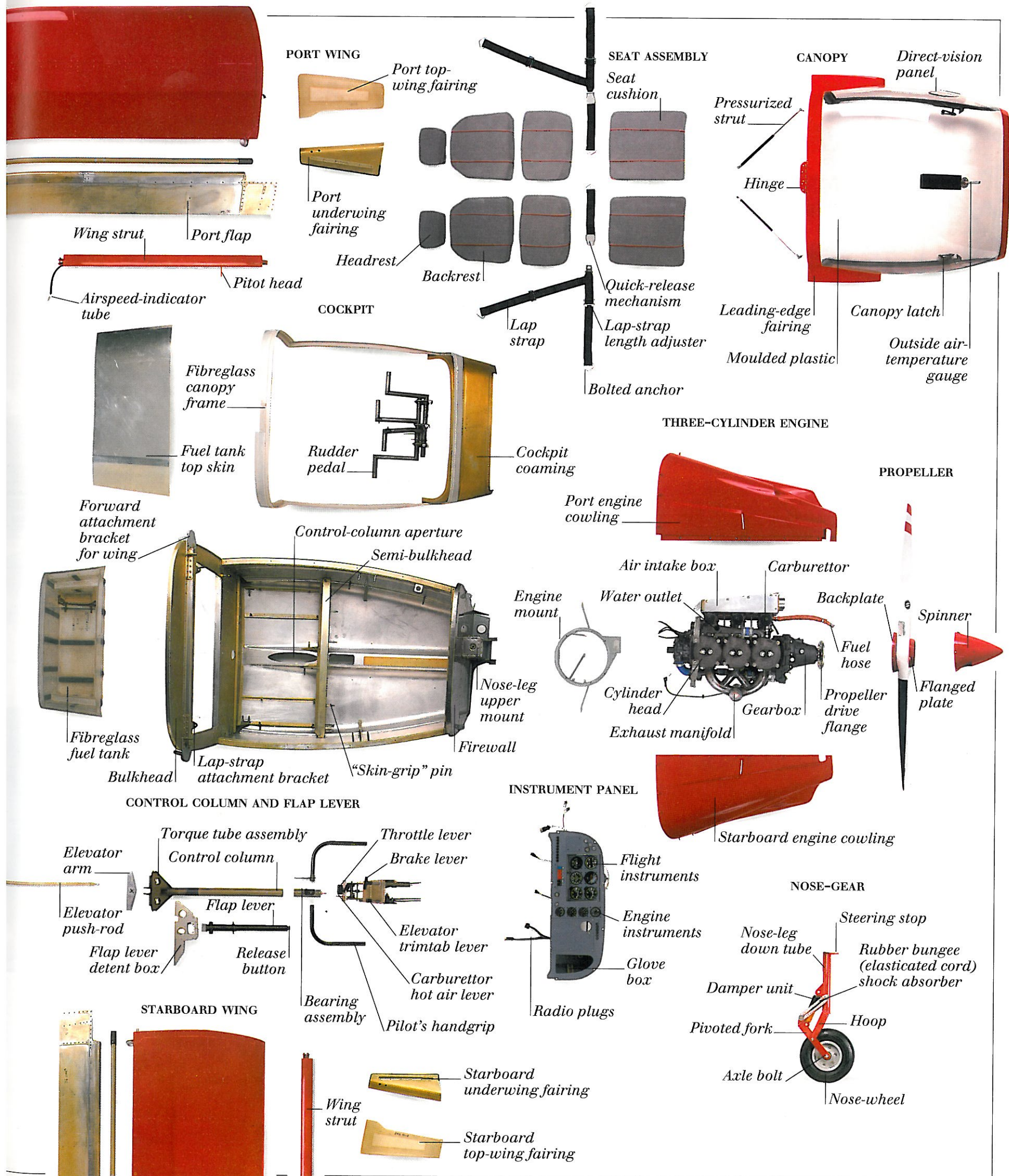
MAIN ROTOR BLADES

ENGINE, TRANSMISSION, AND ROTOR MECHANISM

Light aircraft

LIGHT AIRCRAFT, SUCH AS THE ARV SUPER 2 shown here, are small, lightweight, and of simple construction. More than a million have been built since World War I, mainly for recreational use by private owners. Virtually all light aircraft have piston engines, most of which are air-cooled, although some are liquid-cooled. Open cockpits, almost universal in the 1920s, have today been replaced by enclosed cabins. The cabins of high-wing aircraft have one or two doors, whereas those of low-wing aircraft usually have a sliding or hinged canopy. Most modern light aircraft are made of aluminium alloy, although some are made of wood or of fibre-reinforced materials. Light aircraft today also usually have navigational instruments, an electrical system, cabin heating, wheel brakes, and a two-way radio.





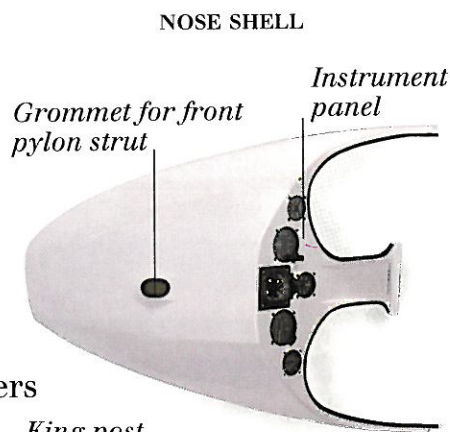
Gliders, hang-gliders, and microlights



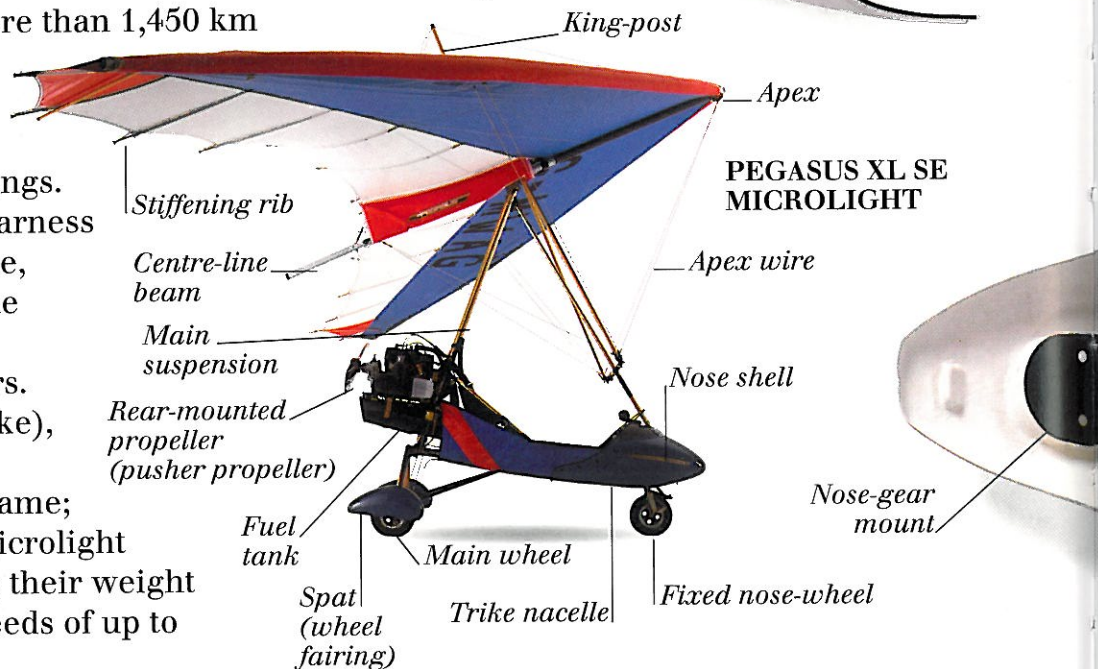
HANG-GLIDER

MODERN GLIDERS ARE AMONG the most graceful and aerodynamically efficient of all aircraft. Unpowered but with a large wingspan (up to about 25 m, or 82 ft), gliders use currents of hot, rising air (thermals) to stay aloft, and a rudder, elevators, and ailerons for control. Modern gliders have achieved flights of more than 1,450 km

(900 miles) and altitudes above 15,000 m (49,000 ft). Hang-gliders consist of a simple frame across which rigid or flexible material is stretched to form the wings. The pilot is suspended below the wings in a harness or body-bag and, gripping a triangular A-frame, steers by shifting weight from side to side. Like gliders, hang-gliders rely on thermals for lift. Microlights are basically powered hang-gliders. A small engine and an open fibreglass car (trike), which can hold a crew of two, are suspended beneath a stronger version of a hang-glider frame; the frame may have rigid or flexible wings. Microlight pilots, like hang-glider pilots, steer by shifting their weight against an A-frame. Microlights can reach speeds of up to 160 kph (100 mph).

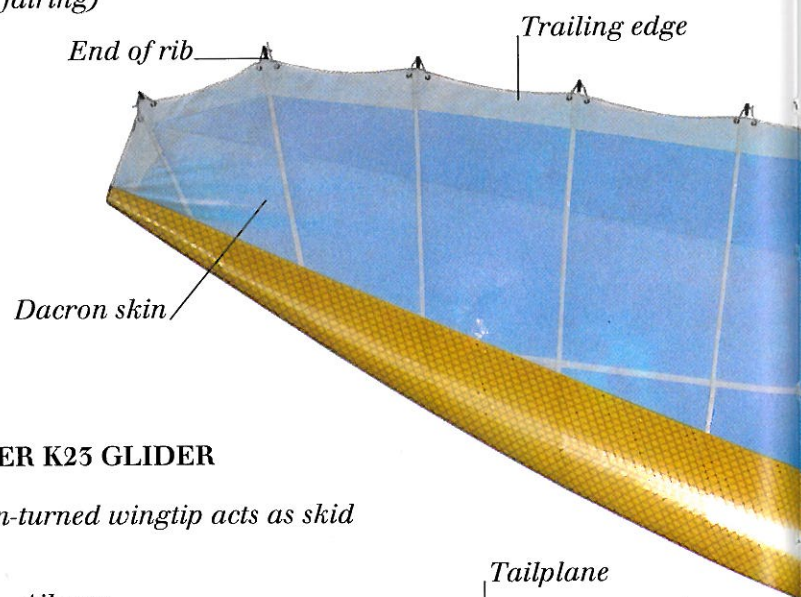
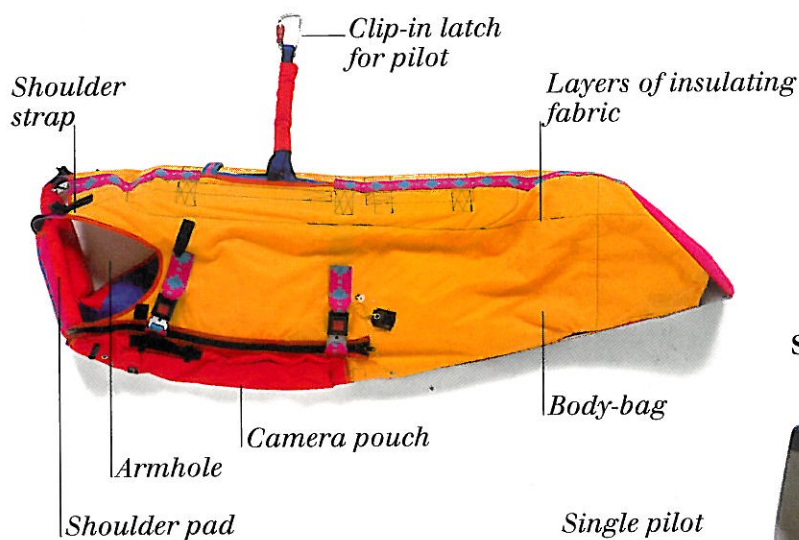


NOSE SHELL

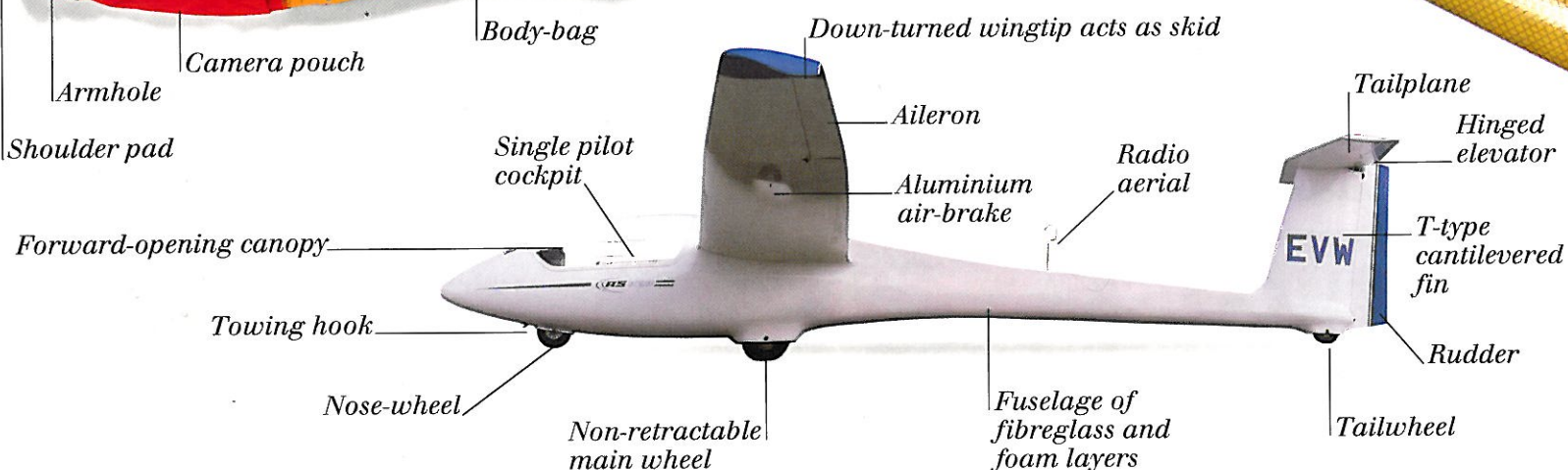


PEGASUS XL SE MICROLIGHT

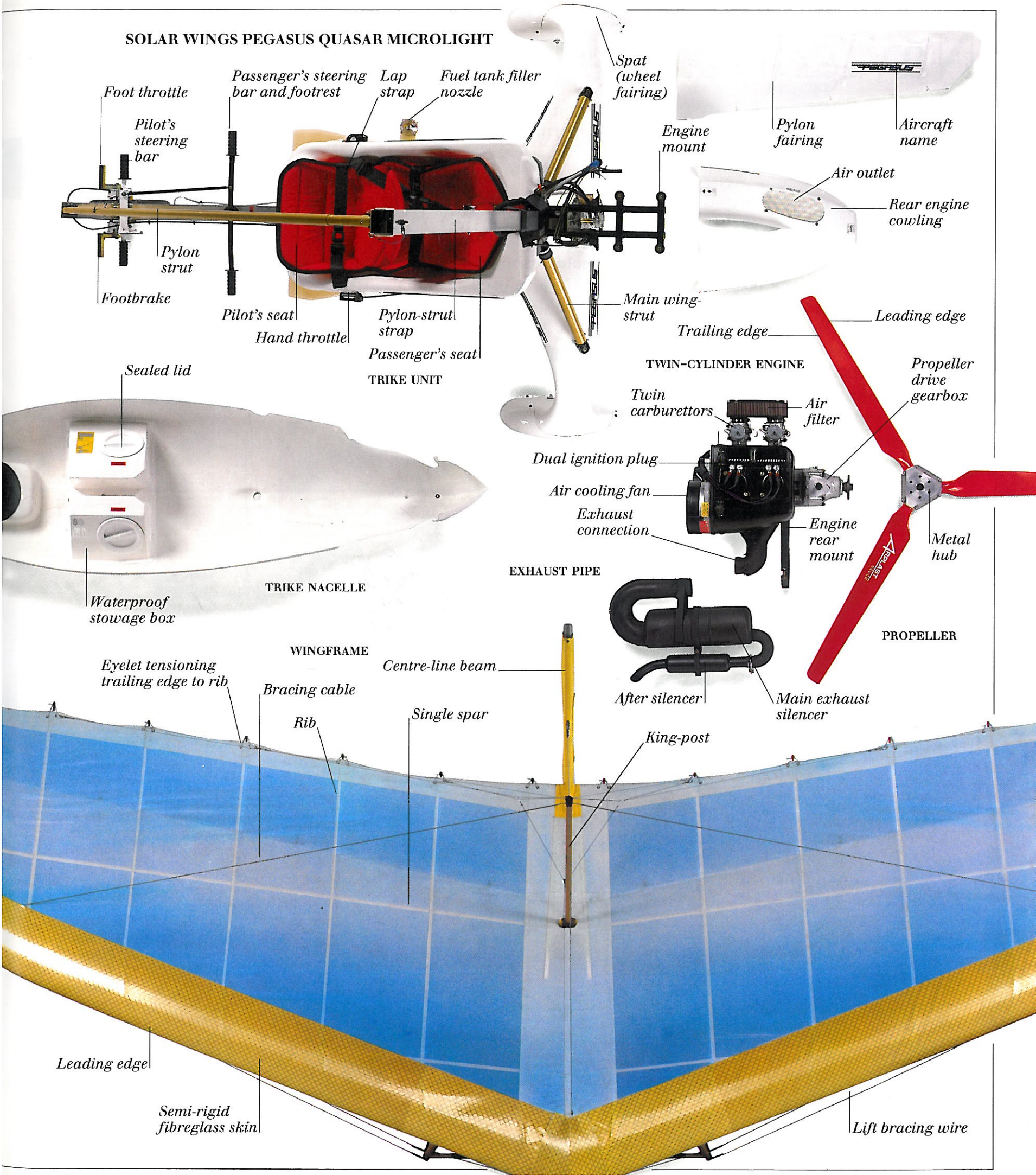
HANG-GLIDER BODY-BAG



SCHLEICHER K23 GLIDER



SOLAR WINGS PEGASUS QUASAR MICROLIGHT



Foot throttle

Pilot's steering bar

Passenger's steering bar and footrest

Lap strap

Fuel tank filler nozzle

Spat (wheel fairing)

Engine mount

Pylon fairing

Aircraft name

Air outlet

Rear engine cowling

Pylon strut

Footbrake

Pilot's seat

Hand throttle

Pylon-strut strap

Passenger's seat

TRIKE UNIT

Main wing-strut

Trailing edge

Leading edge

Sealed lid

TWIN-CYLINDER ENGINE

Twin carburettors

Air filter

Propeller drive gearbox

Dual ignition plug

Air cooling fan

Exhaust connection

Engine rear mount

Metal hub

EXHAUST PIPE



After silencer

Main exhaust silencer

PROPELLER

Waterproof storage box

TRIKE NACELLE

WINGFRAME

Eyelet tensioning trailing edge to rib

Bracing cable

Rib

Single spar

Centre-line beam

King-post

Leading edge

Semi-rigid fibreglass skin

Lift bracing wire

Navigation

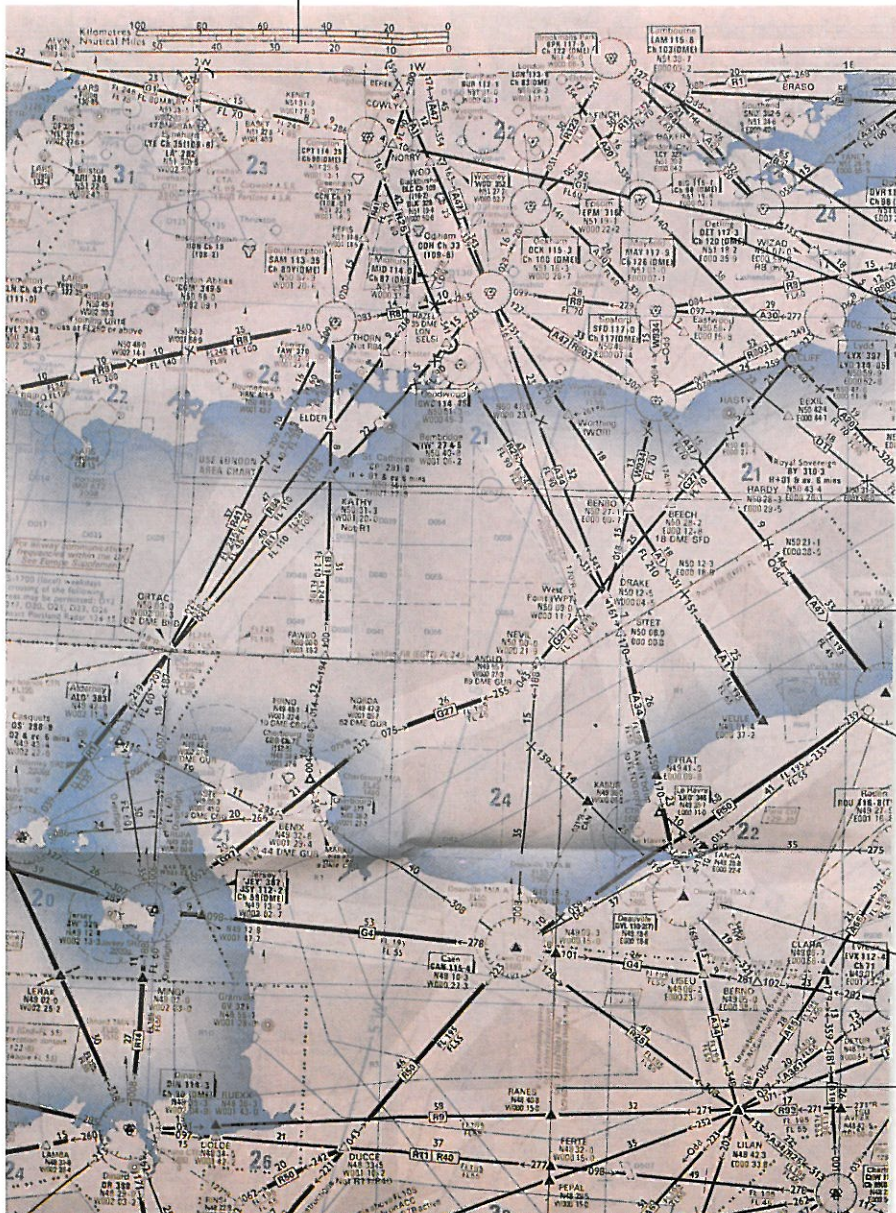


ZERO READER
(LANDING AID)

AERIAL NAVIGATION is the calculation of an aircraft's route from its point of departure to a given destination. It involves plotting the aircraft's course (heading) and airspeed, and the speed and direction of the wind (which will blow the aircraft off course). The resultant plotted line shows the track, or route, of the journey. Early pilots navigated using charts, and visual aids such as landmarks; sometimes, they also used sextants to navigate by the stars. By 1920, cockpit radios could obtain a fix on an aircraft's position from ground-stations or beacons. The introduction of radar in the 1940s made it possible to pinpoint the position of aircraft from the ground. Today, most small aircraft are still navigated using charts, radio, and simple hand-held instruments. Military aircraft and civil airliners are navigated using sophisticated on-board electronic systems, and signals from satellites that can be used to pinpoint an aircraft's position to within a few metres. The most advanced cockpits now display all navigational information on electronic screens.

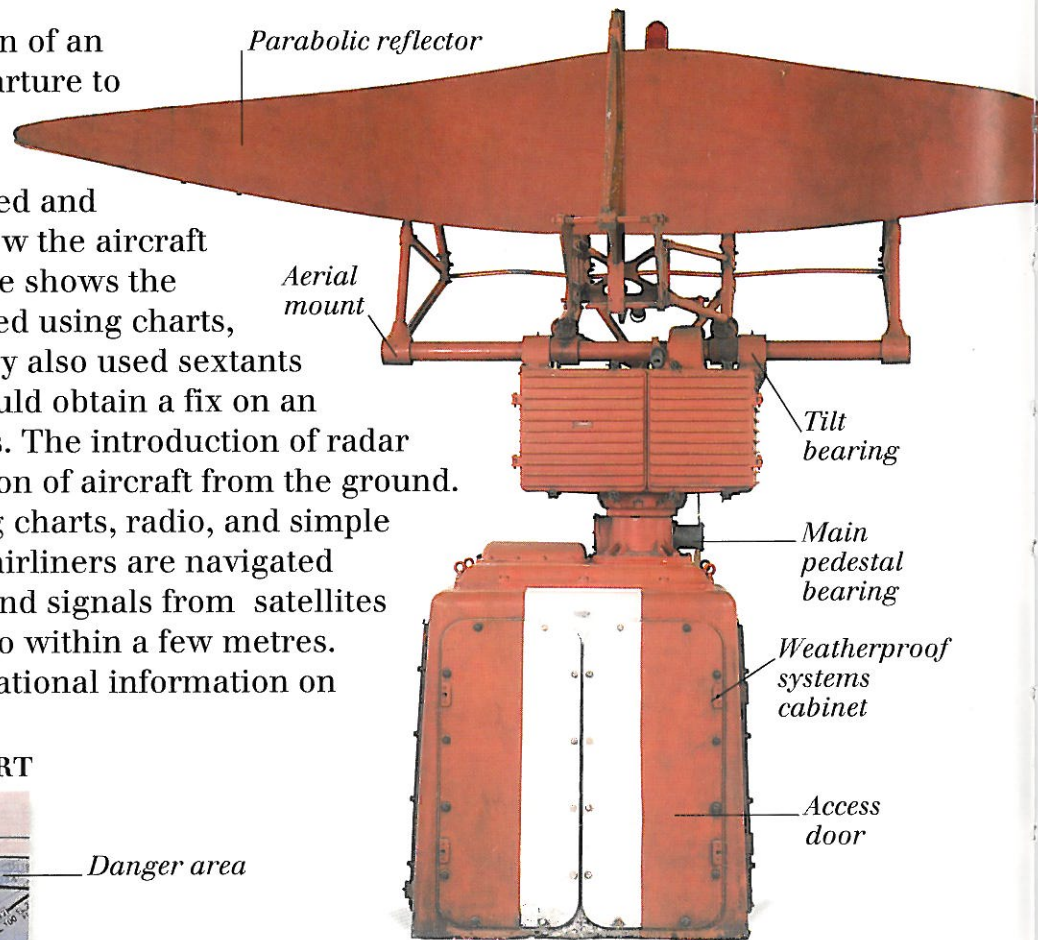
Distance scales

NAVIGATOR'S CHART



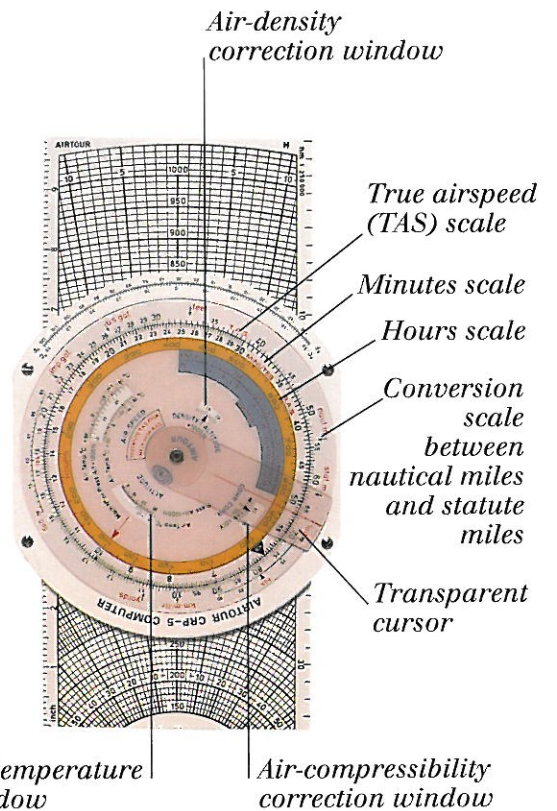
- Danger area
- VHF omni-range (VOR) beacon
- Ground-station code and radio frequencies
- Flight level of airway of 7,000 ft (2,130 m)
- Airway name ("Amber 47")
- Airway magnetic bearing of 239°
- Compass rose centred on magnetic north
- Airspace boundary

DECCA TYPE 424
AIRFIELD RADAR, 1953



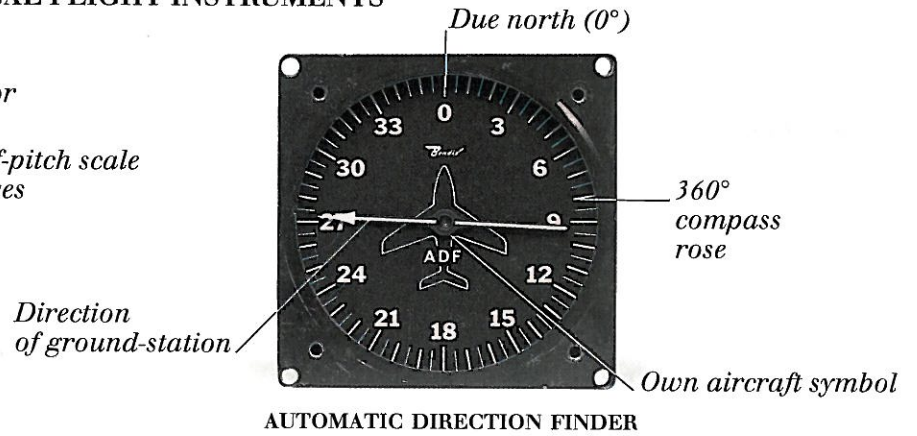
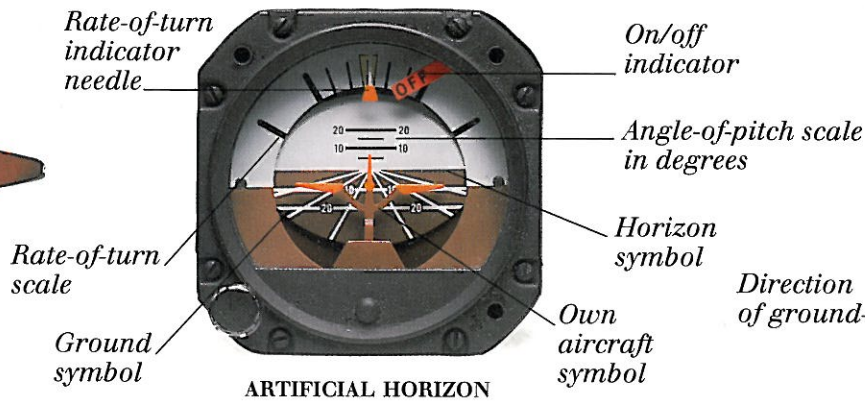
- Parabolic reflector
- Aerial mount
- Tilt bearing
- Main pedestal bearing
- Weatherproof systems cabinet
- Access door

CIRCULAR SLIDE-RULE

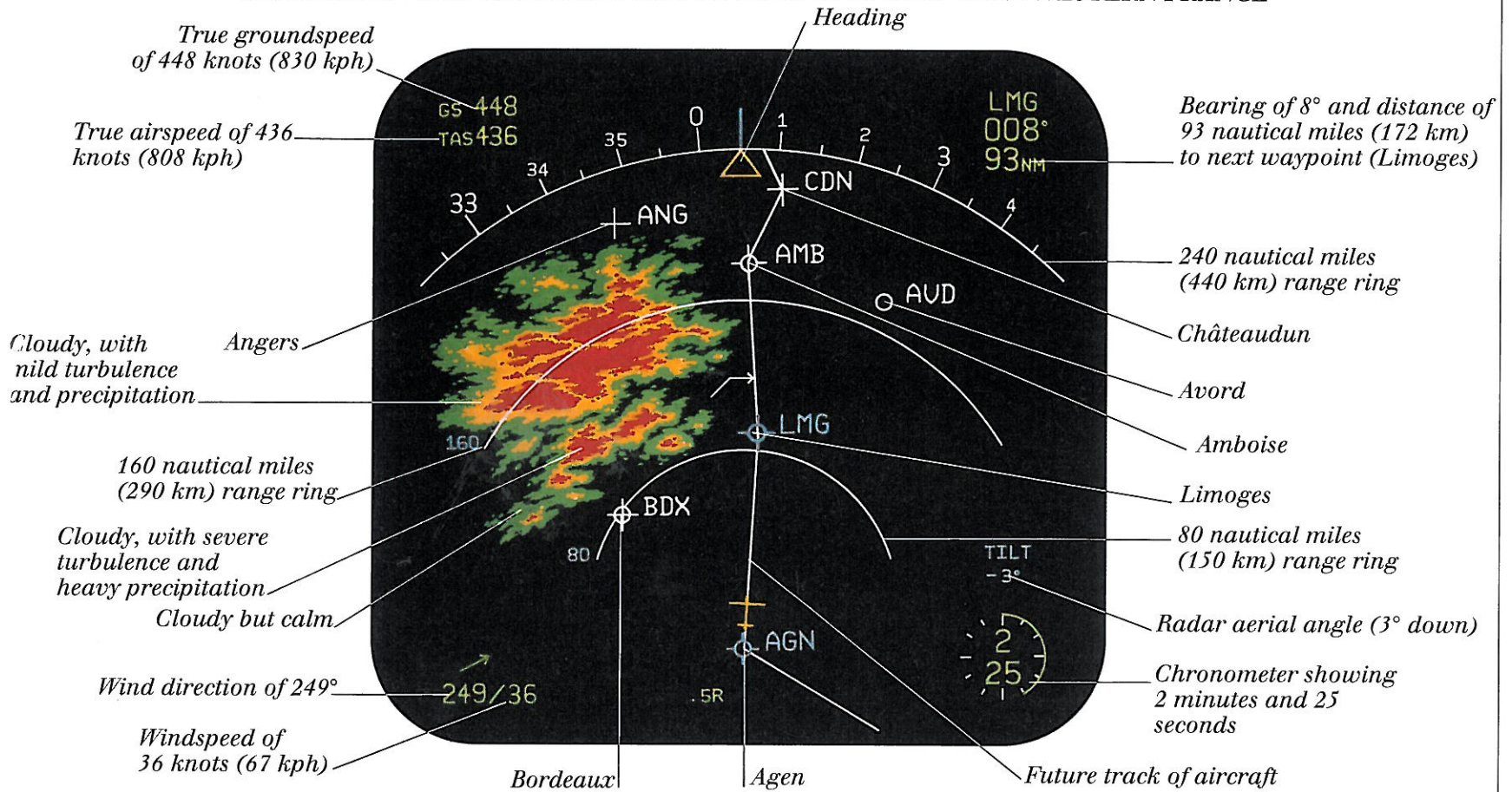


- Air-density correction window
- True airspeed (TAS) scale
- Minutes scale
- Hours scale
- Conversion scale between nautical miles and statute miles
- Transparent cursor
- Air-temperature window
- Air-compressibility correction window

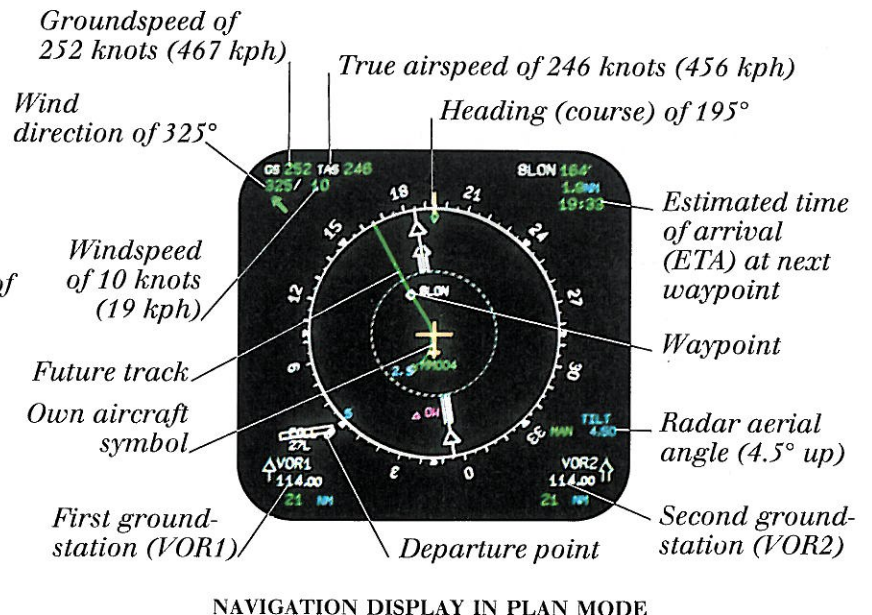
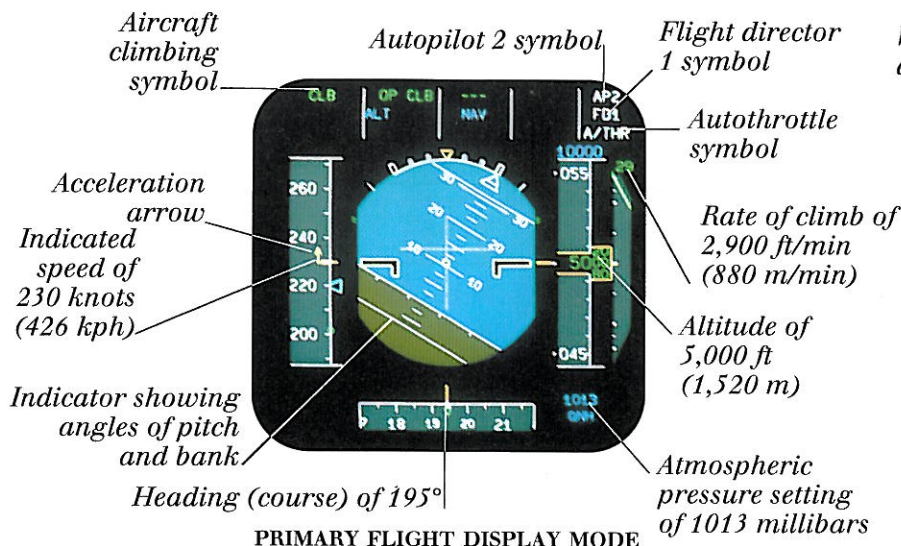
ELECTROMECHANICAL FLIGHT INSTRUMENTS



NAVIGATION DISPLAY RADAR SCREEN DURING FLIGHT OVER WESTERN FRANCE



ELECTRONIC FLIGHT INSTRUMENTS SYSTEM

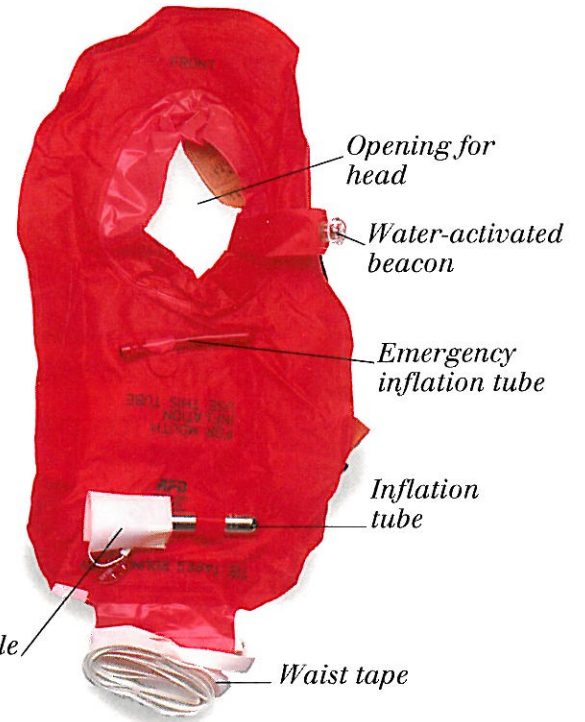


Safety and survival

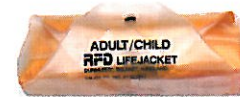


FIRST-AID KIT

SINCE WORLD WAR I, MOST AIRCRAFT have carried various types of safety and survival equipment. Among the earliest survival items were fire extinguishers, parachutes, life-jackets, and axes (for breaking out of enclosed cabins). Today, airliners also carry oxygen masks that drop automatically from the cabin roof in emergencies; rapidly inflating dinghies for use in emergency sea-landings; and inflatable escape slides to enable safe, fast descent from a grounded aircraft. Pilots of military aircraft wear pressurized suits equipped with an oxygen supply for high-altitude flight; the suits may also carry tools, rations, and weapons to aid survival in hostile environments. Combat aircraft have ejector seats that can shoot out of an aircraft at any height, even during supersonic flight. The seat's computer controls its flight and the deployment of the occupant's parachute. In addition to personal survival equipment, modern jetliners have various built-in safety features. Most mechanical parts are protected by smoke- and flame-detectors that trigger extinguishers if fire breaks out; as fuel is used, it is displaced in the tanks by non-inflammable inert gas; and every flight control system has a back-up system in case of mechanical or electrical failure. In addition, the most modern jetliners and military aircraft use computers to override commands from the pilot that could endanger the aircraft.



LIFE-JACKET



PACKED LIFE-JACKET

US AIR FORCE SURVIVAL VEST



Signal mirror

Compass

Hand-held signal flare

Tourniquet

Directional-strobe cover

Whistle

Nylon cord

Battery

Battery-powered emergency strobe

Blanket



First-aid pack

Nylon cord

Knife with sharpening stone

Razor

Drinking-water container

Revolver holster

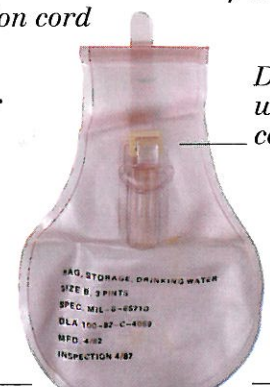
Survival vest

Multi-purpose knife

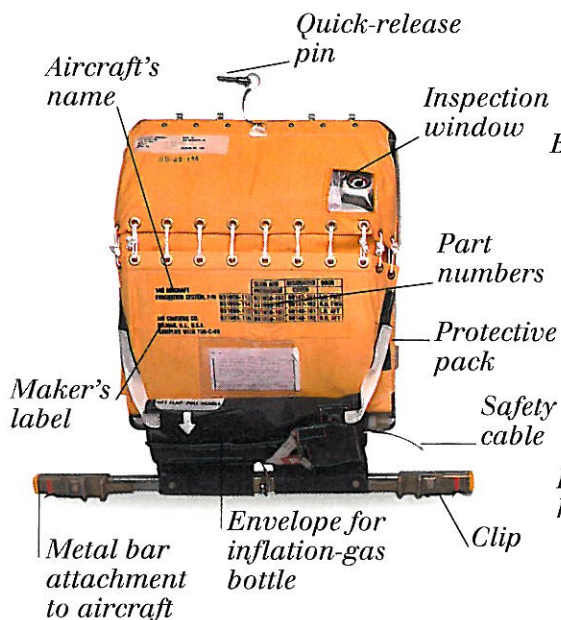
Ground-marker panels



Magnesium block with sparking insert for starting fires



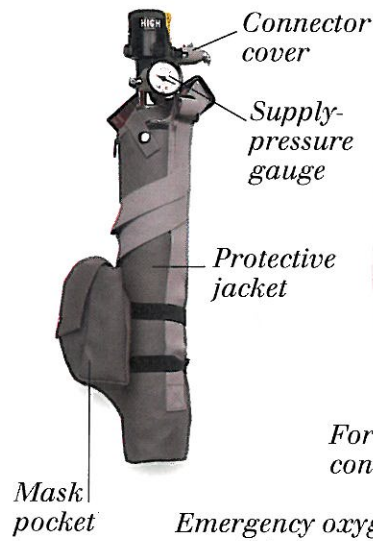
ESCAPE SLIDE



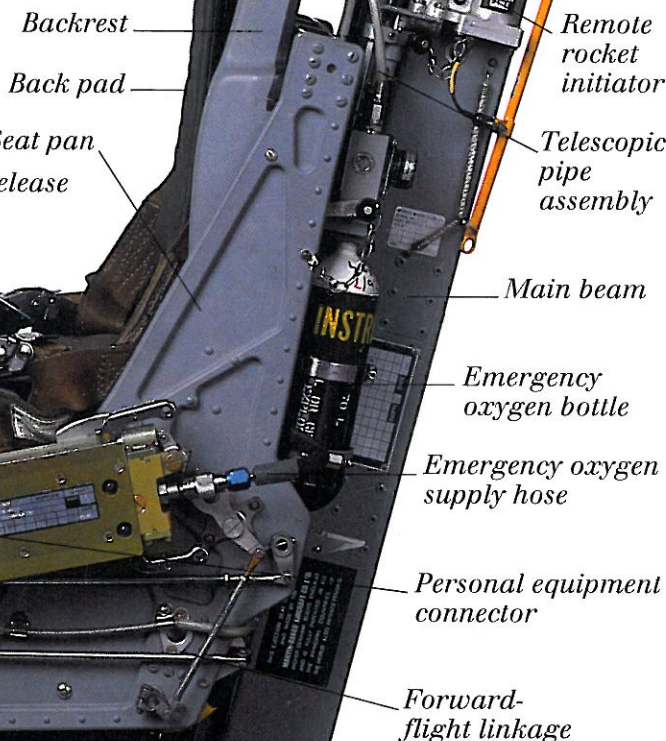
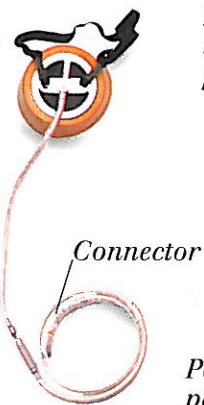
MARTIN-BAKER TYPE 10A MODERN EJECTOR SEAT



OXYGEN CYLINDER



PASSENGER OXYGEN MASK



FIRE-EXTINGUISHER



ESCAPE AXE

Leg-line taper plug

Double-garter leg restraint



TORCH

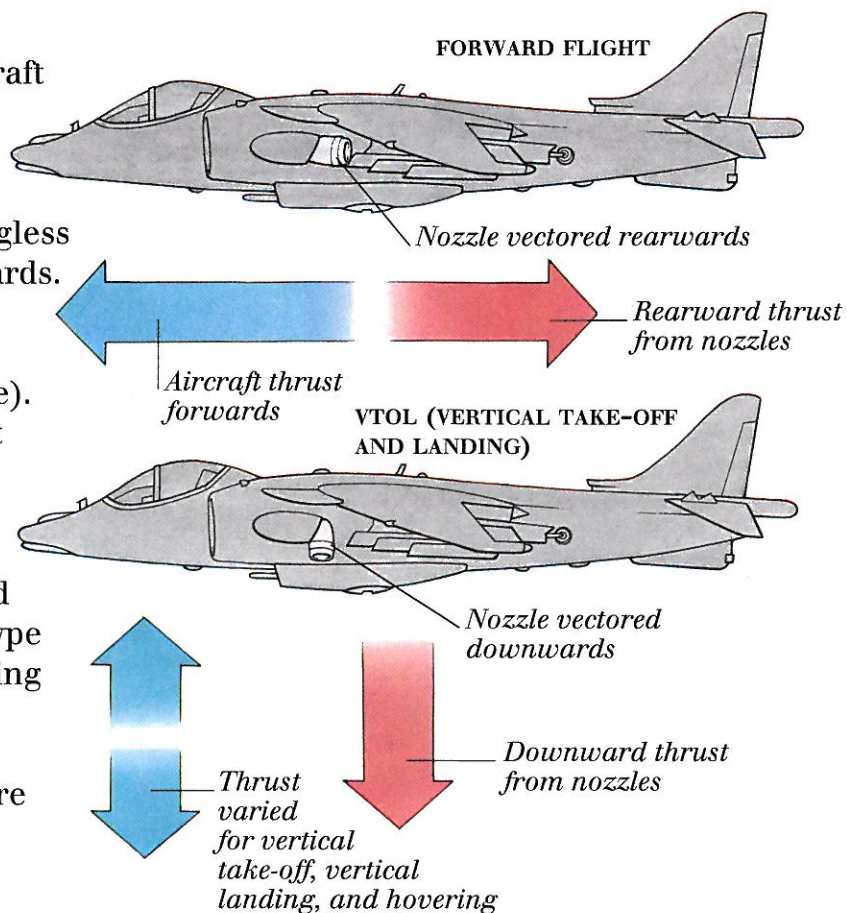


LOUDHAILER

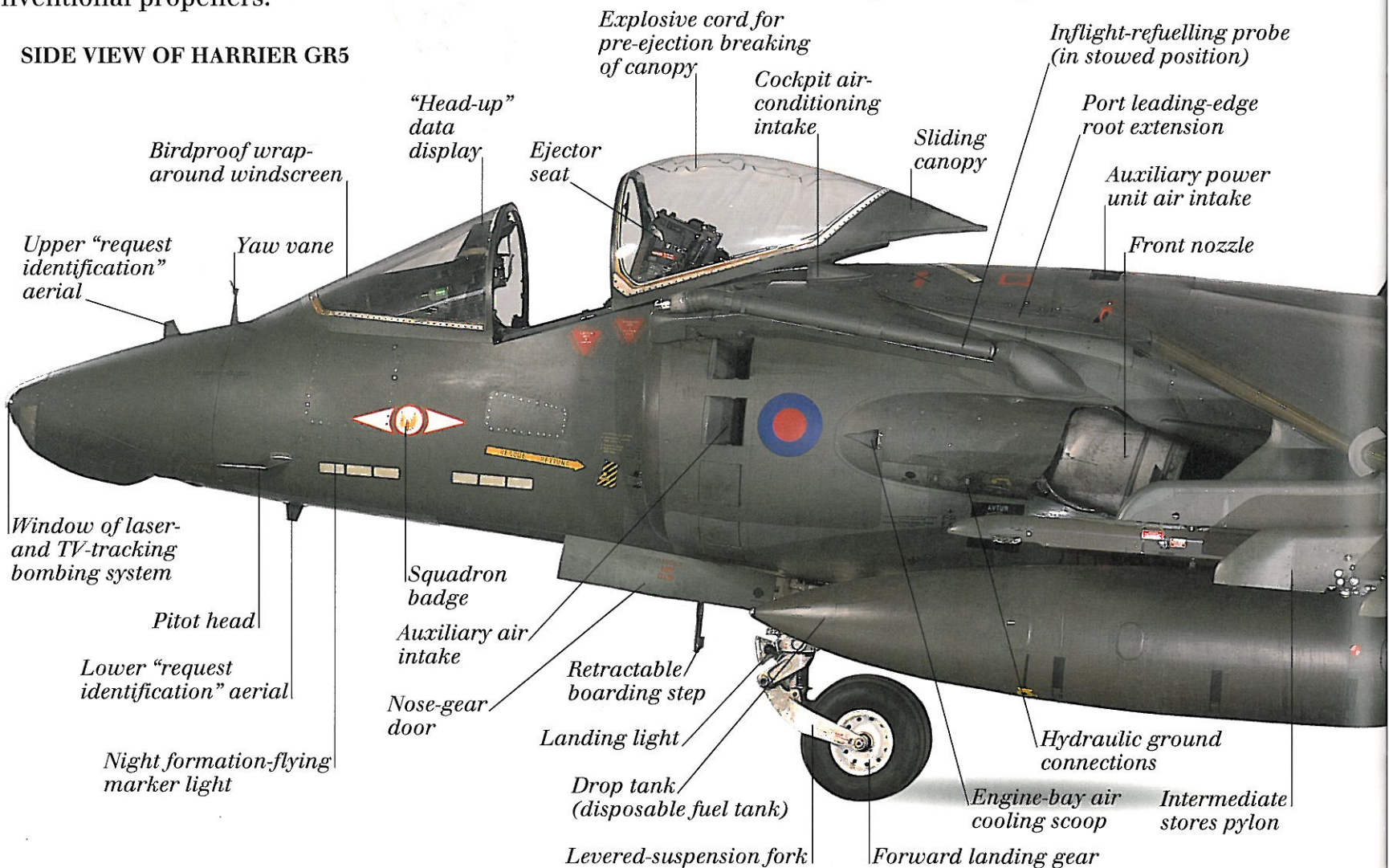
VTOL aircraft

THE FIRST VTOL (VERTICAL TAKE-OFF AND LANDING) aircraft were helicopters. For fixed-wing aircraft, VTOL became a realistic possibility when the British aero-engine manufacturer Rolls-Royce pioneered the "Flying Bedstead" in 1953. This device consisted simply of a wingless four-legged frame with two jet engines pointing downwards. It made the first ever vertical take-off using jet-power, and eventually led to the development of the British Hawker Siddeley Harrier (later built by British Aerospace). The Harrier was the first VTOL aeroplane with sufficient power and manoeuvrability to carry out the duties for which it was designed. Its single engine is a Rolls-Royce Pegasus turbofan with four nozzles. All four nozzles are vectored (rotated) downwards for VTOL or hovering, and rearwards for high-speed flight. In the USA, a different type of VTOL aeroplane has been pioneered using special tilting rotors. This aircraft – the Bell-Boeing V-22 Osprey – has a jet-turbine-powered "proprotor" on each wingtip. For vertical take-off, hovering, and landing, the proprotors are tilted upwards and act as helicopter rotors; for normal flight, the proprotors are gradually tilted forwards to act as conventional propellers.

HOW A HARRIER FLIES



SIDE VIEW OF HARRIER GR5



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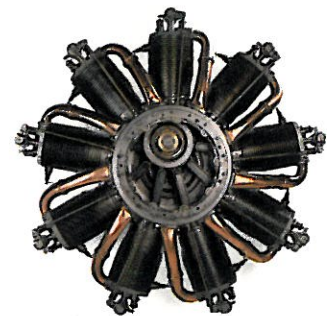
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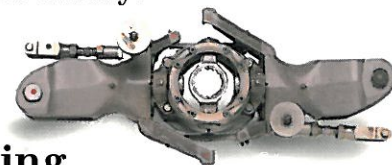
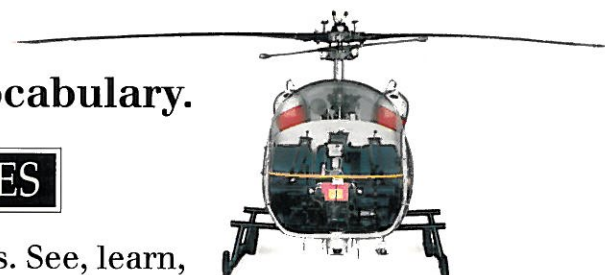
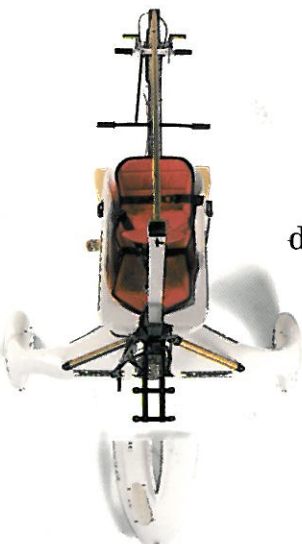
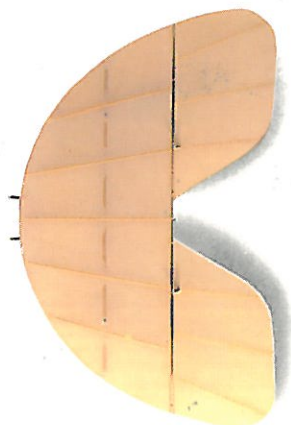
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