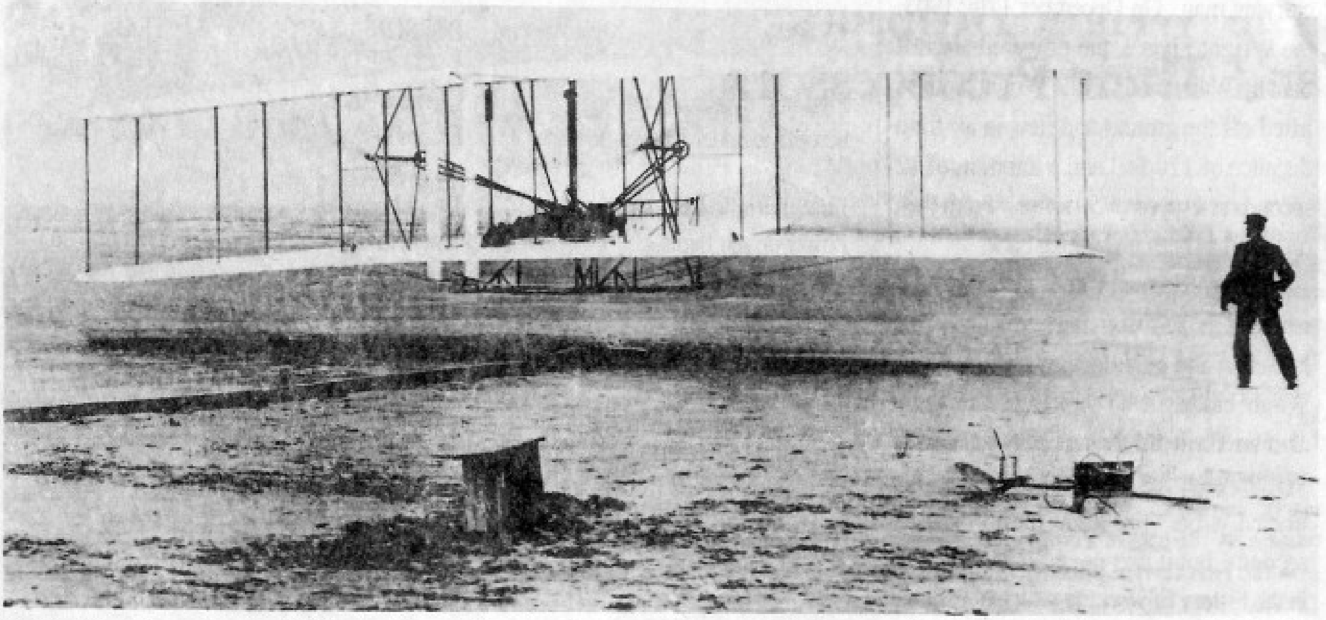
The Fascinating World of Flying Machines

Not for nothing is today's age referred to as the 'jet age'. The magnificient development in aviation technology quite about sums up the rapid pace of technological progress in this century. While commercial aircrafts like Concorde can achieve speeds twice that of sound, defence aircrafts like the stealth bombers have been able to defy the strongest of surveillance systems. Latest developments have also ensured that aircrafts could be as versatile as birds, if not more, through Gyrocopters which lift vertically upwards without a gradual altitude gain. This article explores the fascinating world of aviation, the first part of which traces the history of flying and principles of flight.

G.P. Vinayababu

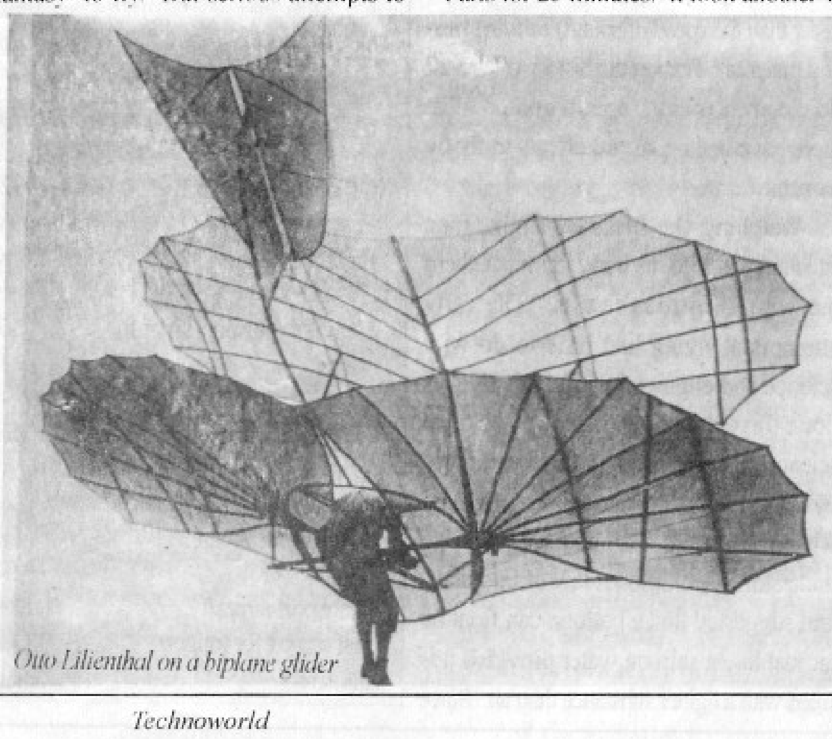
The first flight of a powered aircraft - Wright brothers 'Flyer I'



It is indeed a spectacular sight to watch the sea birds meandering in the skies hovering over the vast expanse of seas in groups. These birds not only fly in groups but show great ability in gliding, soaring and diving and making spectacular formations in sky. Watching this wonderful sight one cannot simply stop at appreciating it, but grows curious to understand how these birds glide and keep themselves afloat in air for long durations. One of the largest sea birds - 'Albatross' with a wing span of over 3.5 m (11.5 ft.) can travel at speeds ranging from 110 kmph upto 160 kmph over the oceans and can travel nonstop for thousands of kilometres. Albatross' wing design and body structure allows it to remain airborne for long hours at high speeds. The modern aircrafts can safely be described as successors of Albatross and its likes.

Man has been dreaming of flying high in the skies alongside birds from times immemorial. The Hindu epics talk about the 'Pushpaka Vimanas' - the chariots with wings carrying people across the three worlds (heaven, earth and nether). The flight of Hanuman to Lanka across Indian Ocean in the epic 'Ramayana', the flying carpet of the orient, the broom on which witches rode, the famous flight of Deadalus to escape from Crete - all suggest man's fantasy to fly. But serious attempts to build flying machines on scientific principles started only as late as 18th century.

The first time man sailed in air untethered for an appreciable time was in the year 1783 when 2 men flew in a hot air balloon constructed by Montgolfier brothers which drifted about 12 kms across Paris for 25 minutes. It took another 120



Otto Lilienthal on a biplane glider

years to realise the first flight of a machine carrying man. On December 17th, 1903, the Wright Flyer I, the powered aircraft built by Wilbur and Orville Wright brothers lifted off the ground and flew in air for a distance of 120 feet and a duration of 12 seconds at a speed of 50 kmph. From then on there has been no looking back.

Though German Otto Lilienthal who is regarded as the first flying human was able to design and manufacture gliders, it was Wright brothers who could successfully fly a powered aircraft for the first time. Orville Wright after his successful flight in the Flyer I wrote "the flight lasted only 12 seconds, but it was nevertheless the first in the history of world in which a machine carrying a man had raised itself by its own power into the air in full flight, had sailed forward without reduction of speed and had finally landed at a point as high as that from which it started".

It is an amazing reality today that hundreds of aircraft crisscross the entire globe, at high speeds (some of them even faster than the speed of sound) carrying men and material. Tracing the history of aircraft development over the ages, we observe that there have been constant efforts to fly by humans.

Watching the birds of flight, man attached wings to his body to imitate them but with disastrous results. The early attempts at flying had little to do with science and engineering and mostly was done fascinated by birds. The first scientifical explanation to flight was given by English Franciscan monk Roger Bacon who lived in the 13th century AD. He understood Archimedes law of buoyancy and suggested that a balloon can float on air just like a ship on water provided it is filled with a lighter substance than air. Since

AVIATION MILESTONES

EVENT	PERSON	YEAR
First hop by a man carrying aeroplane under its own power	Clement Ader France in his EOLE	Oct 9, 1890
First controlled and sustained power driven flight	Wright brothers Kitty Hawk, N.Carolina USA at 10.35 a.m.	Dec 17, 1903
First crossing of English channel	Louise Bleiot of France	July 25, 1909
First non-stop crossing of Atlantic	Capt. John Alcock & Lt. Arthur Whither Brown	June 1919
First Transatlantic solo flight	Capt. Charles A.Lindbergh	May20-21,1927
First flight of a jet powered aircraft	Heinkel HE 178	Aug 27, 1927
First liquid fuelled Rocket	Dr.Robert H Goddard at Auburn, USA	March 16,1926

INDIAN AVIATION

	DATE	FROM	FLOWN BY
First flight	Feb 10,1911	Allahabad to Naini	Henry Piquet
First Indianpiloted flight	1917		Hajinder Singh Malik
First service flight	Oct 15, 1932	Karachi to Bombay	JRD Tata in Pussmoth Aircraft

AIR INDIA

First flight	Oct 15, 1932	Karachi to Bombay	JRD Tata in Pussmoth Aircraft
International operations	March 8, 1948		

INDIAN AIRFORCE

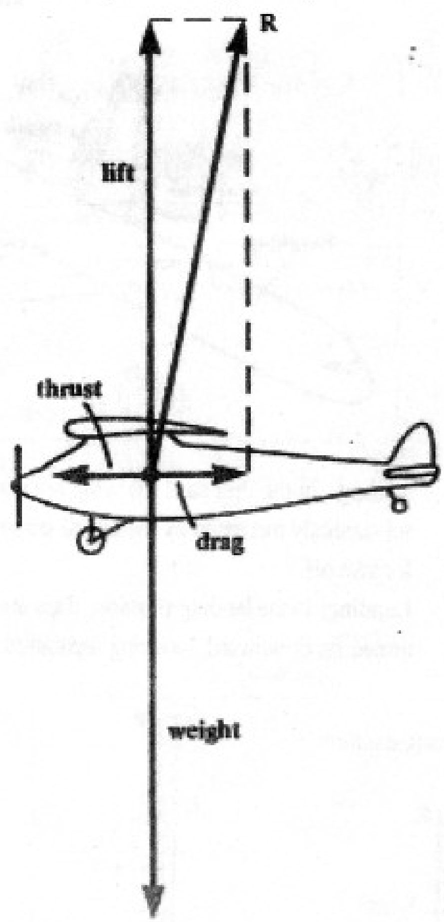
Officially established	Oct 8, 1932	
First aircraft	Westland Wapiti II A	
Fastest airplane	MIG - 25 which can fly at 3.5 Mach or 3700 kmph	
Heaviest transport aircraft	IL-76 also called Gajaraj	can carry 228 pantrooper or 40 tonnes freight
Heaviest Helicopter	Mi I - Mi - 26	can carry 70 equipped troops or 20 tonnes of pay load
Swing wing aircraft	MIG - 23 & MIG 27	
Transport aircraft that served for longest duration	Douglas C-47 DAKOTA	for 42 years

Compiled by Mr. Rajamurthy, National Aerospace Laboratories, Bangalore he didn't have the idea that hot air could be much lighter than cold air nor were the light gases like hydrogen and helium discovered, he couldn't go beyond this explanation. But with the discovery of light gases like hydrogen and helium and the formulation of gas equations later, gave rise to hot air balloons which could lift itself of the ground and stay afloat in air. But a clear understanding of the science behind flying was proposed by English scientist and engineer Sir George Cayley which was later adopted and modified by Wright brothers. The great innovators like Leonardo Da Vinci and others felt it was essential for humans to emulate the pattern of birds to fly. But Sir George Cayley who showed how it was impossible for man to fly similar to birds.

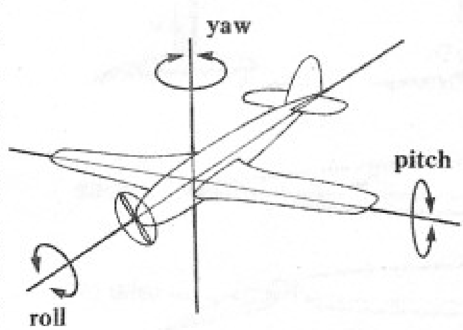
He said "the idea of attaching wings to arms is ridiculous enough, as the pectoral muscles of a bird occupy more than two thirds of its whole muscular strength. whereas in man, the muscles that could operate upon the wings thus attached, would probably not exceed one tenth of the whole mass. So if he uses his full strength on a light surface similarly proportional to his weight as that of the wing to the bird, he would fly like the bird".

Even if we had weightless wings attached to our arms, our power output would be much smaller to lift us off the ground. The stronger flying birds have flight muscles that amount to about 15 to 25% of their total weight. Also the stored energy is available in the fuel such as fat in birds. The fuel is converted by oxidation into mechanical work of skeletal and muscular action. While birds can use energy best through their wings of flight, man does so using energy through his legs.

Human power output drops with time which is not the case with birds. The comparison of human power per unit mass to that of the tiniest of birds - humming bird gives us a measure of the inadequacy of human structure to fly. Humming bird which weighs about 5 gms can produce 10 times the power per unit mass that a man can and flies 2,400 kms without pause.



The forces acting on an aeroplane in level flight



The three axes of motion

Human aviators have learnt a lot from flying birds to construct flying machines.

Wright brothers had a good knowledge of how an aircraft could be set in forward motion and made to lift off the ground and travel in air for longer durations. Infact they had assimilated the theory and practicalities of thrust, propulsion, lift and drag. Before we go any further in aviation, it is necessary for us to know what these terms mean.

How do airplanes fly?

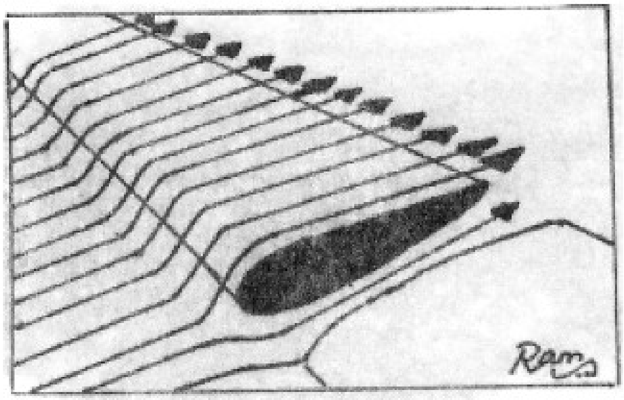
It is well known as to how an auto vehicle moves on roads in the horizontal direction with engine power. IC engines are the ones which facilitate this motion. Aircraft though can be likened to an automobile, is different in the sense that it not only moves in forward motion but also floats in air and develops extra speed. To make an aircraft float in air, aerodynamic force in the form of lift comes into picture.

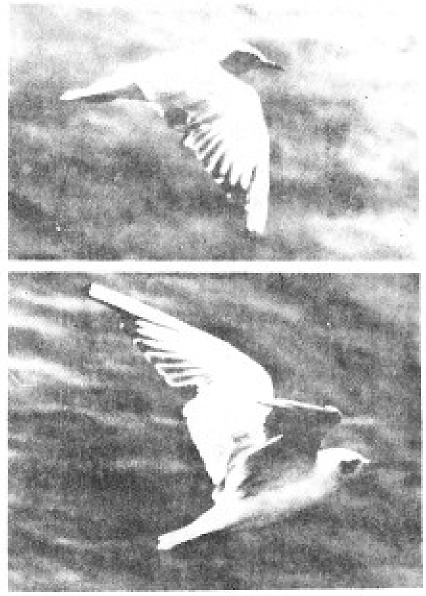
The forces acting on an aircraft are shown in the figure. These forces act on an airplane in level flight at constant cruising speed. Lift and weight cancel each other, as to thrust and drag. Lift is the force which makes an aircraft lift off the ground, thrust due to propulsion provides forward motion and drag is the net of all forces which opposes thrust.

In simple terms an aircraft which is heavier than air floats in free space due to balancing forces which act on it. In addition to having aerodynamic lift (based on wing design and structure) to counter its weight, and thrust (overcoming the aerodynamic drag), an aeroplane must be controlled about the three axes of motion as shown.

Lift: Lift is a consequence of the wing structure, its design and slenderness. As shown in the figure, for the same aspect

Wings and Birds of Flight





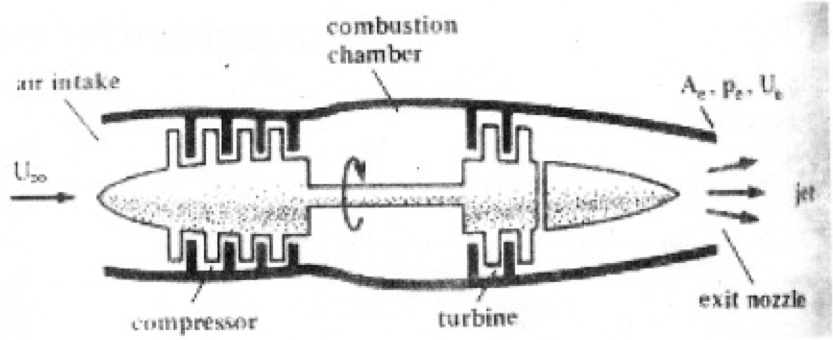
One distinct appendage which makes birds fly, apart from light body weight and aerodynamically shaped body structure is the wing. When man made his first attempts to fly, he attached wings similar to birds to make himself fly to disastrous consequences. With the passage of time, his knowledge of science and engineering grew which made him understand the principle behind the flight of birds. Aerodynamics and mechanics taught him how air was a contributing factor in flight.

Wings in an aircraft are the ones which take maximum advantage of aerodynamics which assists the aircraft in lifting off the ground. It makes use of the Bernoulli's principle, boundary layer theory and separation. As shown in the figure, a wing is shaped with the upper portion bulged and bottom portion relatively flattened. This shape of the wing with a slight inclination upwards induces separation at the edge of wing which separates the air stream into 2 parts, one passing above the wing and the other below it. Thus the airstream passing above the wing has a lower pressure than that below it. The upper low pressure airstream tends to pull the aircraft upwards while the high pressure air below the wing tends to lift it. Effectively the pressure difference induces a lift in the aircraft.

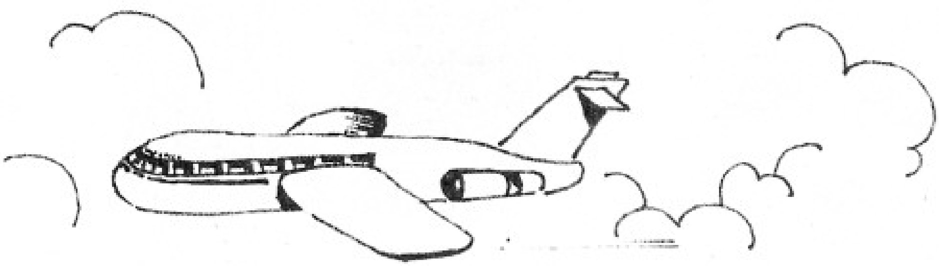
Wings not only assist in lifting the aircraft above the ground, but also helps in its landing. The different wing attachments in aircraft are shown below. Though the basic design is same, the position of these wings are different depending on the position of engines.

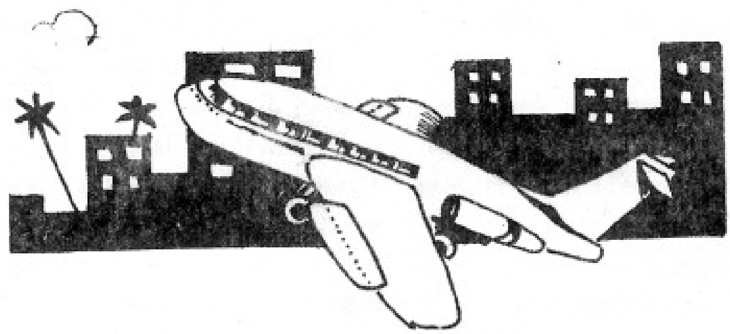
Wings in an aircraft help in its lifting, gliding and landing. But power for an aircraft is provided by the aeroengines. This is not the case with birds. Birds have to develop lift and power together, for their flight. Birds flap their wings to gain altitude and forward motion. Once they reach a particular altitude, birds like eagles and albatross glide in air with their wings wide open. Birds of prey like eagles which glide at high altitudes use wings to their ultimate advantage. When eagles sight their prey, they fold their wings in such a way that the front portion of their wings act as airbrakes. Due to gravity they descend downwards at great speed, catches the prey and expands its wings widely increasing surface area to gain lift. This is similar to the take off and landing of modern aircraft. With all the technological advances humans haven't been able to follow the flight pattern of birds. Birds lift off the ground, soar upwards at any angle and again land at any altitude (like on trees) at any angle without any problems. Man hasn't been able to achieve this versatility even to this day, though latest developments have shown that aircraft could take off vertically upwards without a gradual altitude gain.

is mainly due to windforce opposing the moving body. This is experienced when you extend your hand outside the window in a moving bus. Drag on a body is measured in terms of drag coefficient. Drag coefficient depends on the shape of a body and Reynolds number. As the drag coefficient increases the opposing forces on a body is more. (Reynolds number is the ratio of inertial to the viscous forces). Drag on an aircraft is directly proportional to the

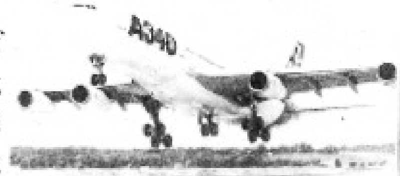


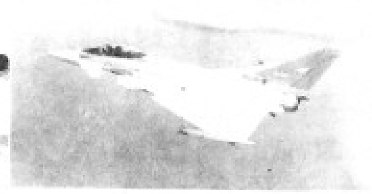
Schematic diagram of turbojet engine





Defence and commercial aircraft





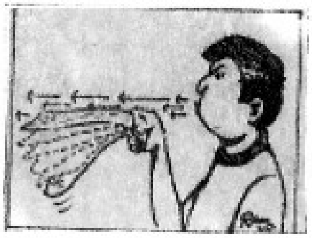
Within a decade after the first powered aircraft took off the ground, they were used extensively in wartime during the First World War. Its utility in carrying soldiers and ammunition during wartime was fully exploited by waring nations especially the US. Aircrafts later became an important component of any country's defence strategy. Defence aircrafts (or fighter aircrafts) and commercial air passenger carriers have different design considerations. While passenger aircrafts have safety as a prime consideration with speed taking the back-seat, in a fighter jet, speed is of prime importance and the design is based on increasing speed. It also has provision to carry arms and ammunition and high tech sensors to detect the attack of surface to air missiles. Passenger aircrafts are bigger in size compared to defence jets because of its requirement to carry passengers in large numbers and facilities for their sojourn. The defence aircraft of today are highly sophisticated which can not be detected even by Radars.

Principles of Flight - Simplified

by RVM Chokkalingam.

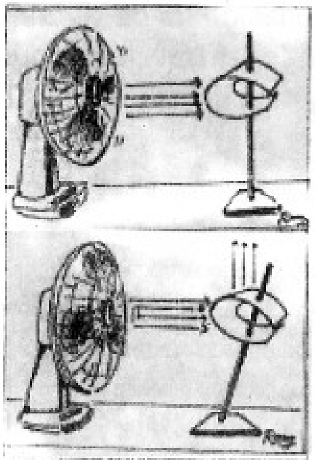
A piece of paper is a versatile material for activities concerned with basic principles of flight - Resistance, lift and drag.

Resistance: Hold a piece of paper parallel to the floor and drop it. Notice the rate of



descent. Wad the paper up and drop it. Notice again the rate of descent. Both fall on the floor, but air slowed down the fall of flat sheet. This simple activity brings the idea of air resistance.

Lift: Hold a piece of paper of 30 mm width and 150 mm length between the thumb and fore finger. Bring the holding end of the paper near the mouth and blow strongly over its top surface. The free end of the bent paper rises, lifted by the reduced pressure over the top of the paper. The difference in pressure between the two surfaces creates this lift.

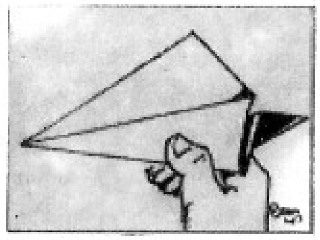


Similarly the higher pressure from below pushes the wing of an aeroplane into the air. (This is also called as Bernoulli effect which affirms hat as the velocity of fluid increases the less pressure it exerts).

Lift can be explained in simple terms with the help of another experiment. Take an invitation card (a thin card board sheet) and join the 2 ends of the card as shown in the figure. This forms aerofoil structure (Wing c.s. shape). Make a hole right at the centre of this structure. Pass a straw into this hole and insert a string into it. Now place a fan in front of this model so that the air stream strikes it exactly at the centre. We observe that the aerofoil remains stationary. Now tilt the model upwards slightly. Now there is differential air stream striking the structure. This makes the model to lift up. This is exactly the principle adopted in the construction of wings of an aircraft. The differential air pressure setup due to the aerofoil structure and the angle of its placement and the subsequent lift is a consequence of Bernoulli's principle.

Drag: To demonstrate the force of drag, have a child hold a piece of cardboard flat against its chest as it runs against the wind. It can easily point at the resistance the air provides, which appear as drag acting in the direction opposing that of the motion.

A simple paper airplane can be prepared and the above scientific concepts of lift, thrust and drag can be introduced. The three important axes of



aircraft such as longitudinal (roll), vertical (raw) and lateral (pitch) can be pointed out. It can be found that for a successful gliding the centre of gravity must remain ahead of the centre of lift.

Aircraft elevator control

Stick a folded post card to one end of light drinking straw as below. Find the point of balance of the whole thing and push a pin through at that point. It blows against the model tail plane the front of the straw will rise like an aircraft's nose when increasing the lift.

square of its speed.

The aerodynamic drag has a number of components, of which the distribution of pressure about the vehicle - the drag due to shape - accounts for about 85% of the total. The figure shows how an aerodynamically shaped automobile will be less effected by drag. This is the principle used in aircraft wings. If we observe carefully the 3rd model of the car (from below) has the lowest drag coefficient which is similar to the shape of an aircraft wing in cross section. But due to practical difficulties like lower fuel efficiency and parking problems the most aerodynamically shaped cars cannot be used on roads. But this shape is most advantageous in an aircraft wing which decreases drag at the same time increasing the lift.

Propulsion

Powered aircrafts need thrust to propel them. Thrust is the force that pushes an aircraft through the air. The propeller (driven by motor) in an aircraft speeds up the incoming air. The resultant increase in the momentum produces the force of the thrust.

A simplified cross section of a turbojet shows the method of its operation and how propulsion is brought about. At the intake the cross sectional area increases (diffuser), decreasing pressure and increasing speed (as per Bernoulli's principle). The pressure is further increased along the stages of a compressor. This high pressure air enters combustion chamber where fuel is sprayed and gets ignited due to the presence of high pressure air. The combustion chamber has a high pressure mixture of air and products of combustion at a temperature of over 1000 degree C. The turbine is driven by these hot gases and in the expansion through the stages of turbine, shaft power is produced. So Turbine drives the axial compressor. These gases are expelled at high speed at the exit nozzle, providing thrust to push the airplane through air. Decrease in cross sectional area increases speed decreasing pressure (which is principally opposite to the action of a diffuser on the inlet).

In a nutshell an aircraft (which is heavier than air) lifts off the ground taking advantage of aerodynamic properties of pressure gradient, propels through air using Newton's III law of motion on mechanics and lands taking advantages of the aerofoil structure with flaps and slats of the wings.

Man's supremacy lies in his ability to make use of laws of nature to his advantage. He realised his long cherished dream of flying in the skies by understanding the science of aerodynamics. In the next part of the article we discuss the important parts of an aircraft, latest trends in aeronautics and flying as a hobby.

(To be continued)

Picture courtesy: What makes airplanes fly?

ATC
Celestial traffic police

Unlike automobiles on roads, aircraft doesn't have physical demarcation for airtravel. It requires a fully integrated signalling system in the form of ATC to monitor its flight course.

Whenever we hear the whirring sound of an aeroplane flashing across the sky, it is a reflex action to most of us to look up the sky. What we don't see are the red, green and amber lights (except of course during nights) and the traffic policemen who are essential for that speck that we see in the sky to reach its destination.

The airspace in which aircrafts fly is very much like a road, except that it is bigger and longer. To avoid collision and to facilitate expedious and safe air travel are the vital missions of any ATC. Besides, it provides a Flight Information Service for all flights and an Alerting Service during emergencies.

What this involves is clearing take-offs and landings and guiding pilots informing pilots about weather conditions, aerodrome facilities. The reason ATC comes into picture is because the pilot has limited visual coverage and limited information on aerodrome conditions and other aircrafts and at that speed and position is unable to access the myriad information he needs to fly. Information regarding weather changes or other contingencies is also necessary and needs to be relayed to him.

Air Traffic is controlled from many positions - The Approach Control Office and the Aerodrome Control Tower, area controller. The approach control office directs the aircraft within a vicinity of 50 nautical miles and upto a level of 7,000 - 10,000 ft. The Aerodrome Control Tower is responsible for guiding the aircraft in a range of 5 nautical miles and 1000 - 1,500 feet. To do all this, ATC (in India) uses three devices in tandem. The first of these is the VHF Communication Network. This is not similar in operation to the high frequency signal with differences in range and frequency. The VHF has a range of 250 nautical miles or 400 km. A VHF signal allows an air traffic controller to talk to the pilot and also receive his messages irrespective of atmosphere.

A failure of the electronically operated communications systems is entirely possible and would lead to catastrophies if it didn't have an stand-by system. (ADF or Automatic Direction Finder is the back-up system). The pilot uses battery back-up to relay messages to the ATC Controller. VDF determines, using the speech signals, the direction of the aircraft. The direction from where the aircraft is calling may be monitored w.r.t. other aircrafts to know if they are on a collision course.

Radars are the third device used. They are used for navigation, surveillance and approach.

The path of an aircraft or a flight is