Parts of an Airplane

Airplanes are heavy and massive, which may make them seem impossible to be able to fly. Even though these metal machines, which are often also filled with many pounds of cargo, are extremely heavy, they have specialized parts and a design that allows them to lift off the ground and move through the air safely for many hours.

While there are many parts to an airplane, the basic parts include the fuselage or body, wings, tail, and jet or propeller-driven engines, depending on the size and model of the airplane. Each of these larger parts has even more specialized parts. The fuselage is made up of the cockpit, which includes the seating and instruments for the pilot and sometimes the co-pilot, and the body of the plane, which may carry passengers, cargo or both. The wings of the airplane include ailerons and wing flaps, and depending on the size and model of the plane, may have the engines attached as well. Finally the tail of the airplane is made up of two main parts, the vertical stabilizer and the horizontal stabilizer. Each of these parts has a role to play in the flight of the airplane.

The wings of an airplane generate most of its lift, the force that keeps the airplane up in the air. To generate lift, air needs to flow over the aircraft or other lifting body (such as a kite or a glider). In the case of an airplane engine, the thrust generated by the engine can help produce or increase the airflow over the airplane, helping the airplane fly. Increased airflow adds more lift. The resistance to thrust is referred to as drag. Drag is a kind of aerodynamic friction. When studying lift, the weight of an airplane is lift’s resistive force. Smaller, low-speed airplanes use propellers instead of jet engines. Lift, weight, drag, and thrust are together called the four forces of flight.
Wings are used to control and maneuver the airplane. Smaller wings located on the tail of the airplane are called stabilizers. The fixed horizontal tailpiece is called the horizontal stabilizer, and the fixed vertical tailpiece is called the vertical stabilizer. The job of the stabilizers is to keep the airplane flying straight. The vertical stabilizer keeps the nose of the airplane from swinging from side to side, a motion called yaw. The horizontal stabilizer controls pitch, or the up-and-down motion of the nose of the airplane.

On the edges of each stabilizer are small moveable flaps attached by hinges. The hinged part on the vertical stabilizer is called the rudder. The rudder directs the nose of the airplane to the left or to the right (yaw). The hinged part of the horizontal stabilizer is called the elevator, which is used to direct the nose of the airplane up or down (pitch). The wings of an airplane have similarly hinged parts: ailerons, which are used to roll the wings from side to side and the wing flaps, which are located closest to the fuselage. During takeoff as well as landing, the wing flaps are directed downward in order to increase the amount of lift produced by the wings.
Forces of Flight: Overview

The Forces of Flight
Every vehicle, whether it’s a car, truck, boat, airplane, helicopter or rocket, is affected by four opposing forces: Thrust, Lift, Drag and Weight (Fig. 1). It is the job of the vehicle’s designer to harness these forces and use them in the most advantageous way possible, providing the pilot with an efficient way to control the aircraft.

A force can be thought of as a pushing or pulling motion in a specific direction. It is referred to as a vector quantity, which means it has both a magnitude (quantity or amount) and a direction. In some cases, the goal is to remove as much of a specific force as possible. Race cars, for example, have very little weight in comparison to its thrust, while aircraft use all four forces working in harmony, although not always in equilibrium, in order to achieve successful flight.

Within this lesson we specifically refer to these principles in relation to fixed-wing airplanes. While other aircraft, such as helicopters and airships, use the same basic principles, the methods they use to harness these forces are quite different. With a helicopter for example, the rotor blades on the top of the aircraft produce both lift and thrust forces, controlling them using gyroscopic principles far outside of the scope of this lesson.

Thrust
Thrust should be thought of as the driving force and is produced by an aircraft’s propulsion system, or engine. The direction of the thrust dictates the direction in which the aircraft will move. It works using Sir Isaac Newton’s Third Law of Motion which states that “To every action, there is always an equal and opposite reaction.” He demonstrated quite simply that if Object A exerts a force on Object B, then Object B must exert an equal force on Object A but in the opposite direction. So for example, the engines on an airplane propel the aircraft forwards by moving a large quantity of air backwards. In technical terms, it is said that the airplane’s thrust vector points forwards. (Reverse thrust simply uses metal components known as clamshells to reverse the direction of the airflow, thereby reversing the thrust vector.)

The magnitude of the thrust depends on many factors such as the number and type of engines installed, environmental conditions such as temperature and air density, and the throttle or thrust setting. As a general rule of thumb, propeller-driven aircraft produce less thrust and are therefore slower than those aircraft powered by jet engines.

One important item of note is that the job of the engine is to propel the aircraft, not to provide lift. It is primarily the wings that perform the task of lifting, not the engines.
Lift
Lift is generated by the motion of air passing over the aircraft’s wings. It works based on a method of fluid dynamics known as Bernoulli’s Principle, named after the Dutch-Swiss mathematician Daniel Bernoulli, who made the discovery in 1738. Put simply, he noticed that as liquid or gas increases in speed, its pressure drops proportionally.

To explain lift, imagine two joined molecules of air approaching a wing (Fig. 3), with one molecule forced to travel over the upper surface of the wing, while the other travels underneath. The laws of physics dictate that when they reach the other side of the wing, they must rejoin. Because the molecule traveling over the upper surface has more distance to travel than the molecule travelling beneath the wing, the upper molecule must move faster in order to keep up with its partner below (Fig. 4). This increase in speed lowers the pressure of the air above the wing compared to that below it (Fig. 5). Air (actually, any gas or liquid) will always attempt to maintain equilibrium, preventing this difference in air pressure. As such, the high pressure air below the wing moves towards the area of low pressure above the wing taking anything that gets in its way with it. This movement of air from high to low pressure literally pushes the wings upwards with it, creating lift.

To control the magnitude of the lift, the pilot can rotate (pitch) the aircraft forwards or backwards, changing how the airflow meets the wing and altering the speed at which the air must travel across it. This is known as changing the wing’s angle of attack (AOA). Figure 6 shows an aircraft in a climb, with a high angle of attack, producing more lift, while figure 7 shows an aircraft in a descent, which requires less lift and has a lower AOA.
The direction of lift is always perpendicular, or 90 degrees, to the direction of the wind passing over the wing. Unlike thrust however, lift is divided into two components: horizontal and vertical. In straight and level (cruise) flight (Fig. 8), 100% of the lift vector is vertical, or straight upwards, while in turning flight, some of the lift is directed horizontally, which helps the aircraft turn. In addition, some lift - around 10% of the total in a typical commercial airliner - is generated by the fuselage due to its aerodynamic shape.

**Drag**

Drag is produced any time a solid object tries to pass through a liquid or gas. In the case of an aircraft, drag is simply the resistance of the air against the aircraft. There are two types of drag, of which the first, Parasitic Drag, has three categories.

- **Skin-Friction Drag:** The resistance to movement created just by trying to pass an object through the air. It can be thought of as the same feeling a runner might experience when running into a strong wind. Just the act of physically pushing through the air creates resistance which must be overcome to move forwards. This can be reduced by polishing or smoothing the surface exposed to the air. The runner in a tightly fitted running suit would experience much less skin-friction drag than if running in a fitted fluffy coat.

- **Interference Drag:** The drag caused by two different airflows meeting and resisting each other. This is commonly seen where the wing is attached to the fuselage of an aircraft, otherwise known as the root.

- **Form Drag:** The drag caused by the design of an aircraft. While the body of an aircraft may be extremely smooth and aerodynamic, the many objects attached to it, such as radio antennas or windshield wipers, are not. These objects create drag in a similar way to sticking a hand out of a car window. The car is aerodynamic, but the hand is not.

The second type of drag is Induced Drag. It is a by-product of lift, created by the higher pressure air below the wing traveling around the side of the wing to the lower pressure area, rather than pushing upwards (Fig. 9). This causes a swirling motion of the air, creating what are known as wingtip vortices, which can occasionally be seen when flying through clouds. These vortices disturb the smooth airflow over the wing, creating additional drag. The magnitude of this drag is usually inversely proportional to the magnitude of the lift being produced.
To reduce the amount of induced drag, some aircraft have an additional part to their wings, called winglets. Winglets prevent the air from rotating around to the lower pressure area, thereby reducing the induced drag produced (Fig. 10). NASA has performed many wingtip vortex studies in an attempt to reduce or eliminate the effects of induced drag on an aircraft. Typically these tests are performed by attaching smoke generators to the wing tips of aircraft and watching the resultant formations.

**Weight**

Weight is a force that is always directed toward the center of the earth due to gravity. The magnitude of the weight is the sum of all the airplane’s parts, plus its payload, which is the sum of all the fuel, people and cargo. While the weight is distributed throughout the entire airplane, its effect is centered on a single point called the center of gravity. When an aircraft is loaded, it is vital that its center of gravity remain within certain limits. An aircraft that is too nose- or tail-heavy will either not fly, or be so difficult to control that it becomes too dangerous to try. The goal of any aircraft design is to keep the weight to a minimum. The lighter an aircraft is, the less fuel it requires for flight, and the more payload it can carry.

**The Forces in Flight**

While each of the forces is completely independent of the others, in flight they work opposite each other to guide the aircraft as directed by the pilot. In straight and level, unaccelerated flight the total amount of thrust is equal to the total drag, while the total amount of lift is equal to the total weight (Fig. 11). For the aircraft to accelerate, the pilot must add additional thrust to overpower the drag and cause the aircraft to gain speed. If the need is to slow down however, the pilot will reduce the thrust to a value less than that of the drag, allowing the drag to slowly decelerate the aircraft.

The same is true for the weight and lift vectors, although once in flight, the weight of the aircraft remains mostly constant, becoming only slightly lighter as fuel is consumed. Once again, with the aircraft at cruise altitude, it has no need to climb or descend and therefore the total lift produced equals the total weight and is sufficient to do no more than support the weight of the aircraft. If the aircraft must climb, the pilot pitches the nose of the aircraft slightly upwards, increasing the difference in air pressure between the top and bottom surfaces of the wings and therefore producing more lift. It is important to remember that changing one vector typically results in a change to the other three as well. For example, increasing thrust also increases the speed of the air over the wings, which in turn increases lift. If there was no need to climb, the pilot would have to also lower the
nose, reducing the angle of attack of the wing and therefore the lift produced, restoring the balance between lift and weight. The opposite is true for a climb where an increase in lift would also increase the induced drag, requiring the pilot to add additional thrust not to accelerate, but to simply compensate for the increased drag component.
Changes in American Society, 1941-1945

America’s entrance into World War II following the attack on Pearl Harbor led to an unprecedented level of engagement from the U.S. public on the home front. Within hours of the attack, America moved onto a war footing. As Michael Morella writes, “American attitudes about the war change[d] radically, [as do] American attitudes about the economy, about giving to the war. The war is not part of the culture; the war is the culture. Everything is viewed through the prism of the war effort.”

Salvage and Rationing

Beginning in 1942, the U.S. government set limits on the amount of certain types of basic supplies that Americans could purchase. This rationing program involved gas, food, and clothing, as well as other staples. Families received ration books that regulated the purchase of everything from meat, sugar, and butter to gas, tires, and shoes. Women and children specifically on the home front were asked to participate in recycling efforts as part of the “Salvage for Victory” program. Women were asked to save and contribute tin cans and cooking fats and grease from their kitchen; children collected scrap metal and rubber as part of school competitions, Scouting activities, and national reward programs. The scrap metal and fats were collected to produce armaments. Ladies’ silk stockings and nylons were collected for use in parachutes. Americans began to collect and reuse rubber products and collect milkweed (to replace kapok as the stuffing for life jackets), since rubber and kapok supplies were now behind enemy lines. Americans were urged to purchase war bonds, the immediate proceeds of which went to fund the war. Today, although historians debate the value of the salvaging program—there are differing opinions on whether or not the materials salvaged by Americans really made a difference in manufacturing—there is general consensus that the home front efforts were vital in creating a sense of unity that contributed to national support for the war.

Changes in the Workplace

As the war progressed, it became clear that the traditional roles of businesses and their workers would have to change. Victory would require enormous numbers of new airplanes, ships, tanks, and armaments. Factories run by Ford and General Motors no longer produced cars; they were now turning out aircraft and machine parts. As thousands of men went overseas to war, the women were encouraged to take their places in traditional “male” jobs.

Changes in Technology

The war led to sweeping technological changes as well. Beyond the obvious example of the development of the atomic bomb, advances in aviation, rocketry, radar, computers, and networking arose from the development of new military technology. The war saw the first mass production of antibiotics, as well a better understanding and application of blood transfusions and pesticides. Along with medical technology, doctors and researchers advanced our understanding of nutrition, as they worked to identify which vitamins and minerals, and how many calories, were essential to a healthy body. Guidelines for safe food preparation, storage, and handling became a military priority. Aviation medicine studies led to improvements in medical treatment and safety equipment, such as crash helmets and safety belts. New materials were developed not only to serve as weapons (including napalm), but
plastic and plywood were developed to substitute for scarce materials. Other materials that had existed in small supply before the war, such as plastic wrap and cardboard juice containers, became far more prevalent.

The changes brought about by World War II have led some historians to call it the first “high tech war” in that the war was fought with new technologies developed specifically for that purpose, and all aspects of American society changed in response. It is hoped that this program will help students to see how the technology and various aspects of their daily lives have their roots in the developments arising from World War II.

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