How do Aircraft Fly?

1 Forces

There are four forces acting upon an aircraft. These are Lift, Weight, Thrust and Drag. It is the job of an aeronautical engineer to increase lift and thrust as much as possible while, at the same time, reducing drag and weight to a bare minimum.

We shall examine these forces as individual entities although in reality, they are connected. Having said that, we begin our investigation by examining the relationship of the forces to one another. Looking at diagram 1.1 below, you can see how the four forces act upon an aircraft.

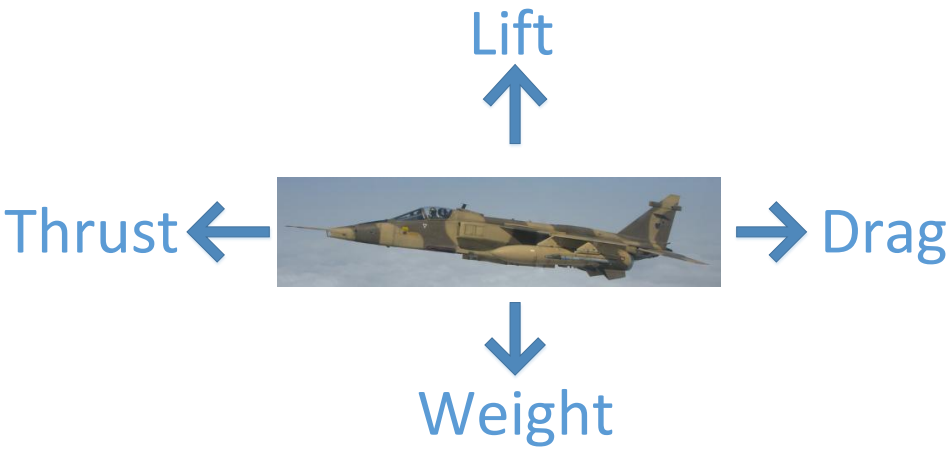

Figure 1.1: The forces acting upon an aircraft

1.1 Weight

If you have ever been on holiday on an aircraft, you will know that you have a baggage allowance which is the weight of luggage that you are allowed to take on an aircraft. This is usually between twenty and thirty kilograms for each passenger. The reason you have this allowance is to try and reduce or limit the weight that the aircraft has to carry. Weight acts to keep the aircraft on the ground and so, in order to overcome the weight, the aircraft needs to have thrust and lift. Thrust is provided by the engines, which run on fuel. So if your luggage weighs more than the allowed amount, you sometimes have to pay a surcharge to pay for the extra fuel that will be needed to transport your cases.

Weight is a large factor in determining whether or not an aircraft will fly. Experience shows that on Earth, things fall down towards the centre of the planet until they are stopped by the surface. This happens with aircraft as well and so aeronautical engineers, who design the aircraft, try to reduce the weight by:

- using light materials such as aluminum to construct the plane;
- using hollow as opposed to solid shapes to build the fuselage.

1.2 THRUST

Thrust is provided by the engines. There are two main types of engine in use on aircraft today: jet and propeller. These work in two different ways. Propellers work in a similar way to wings in that they provide lift and we shall examine this in more detail in section 1.4 below. Jets work in a slightly different way, providing thrust as a result a physical law that was discovered by Sir Isaac Newton nearly four hundred years ago. Newton's Third Law of Motion states that, 'for every action, there is an equal and opposite reaction.' This means that if you push on something, it pushes back on you. A jet pushes gases out of the back of the engine and so the engine (and anything connected to it) moves forward. In a nutshell, that is how a jet provides an aircraft with thrust.

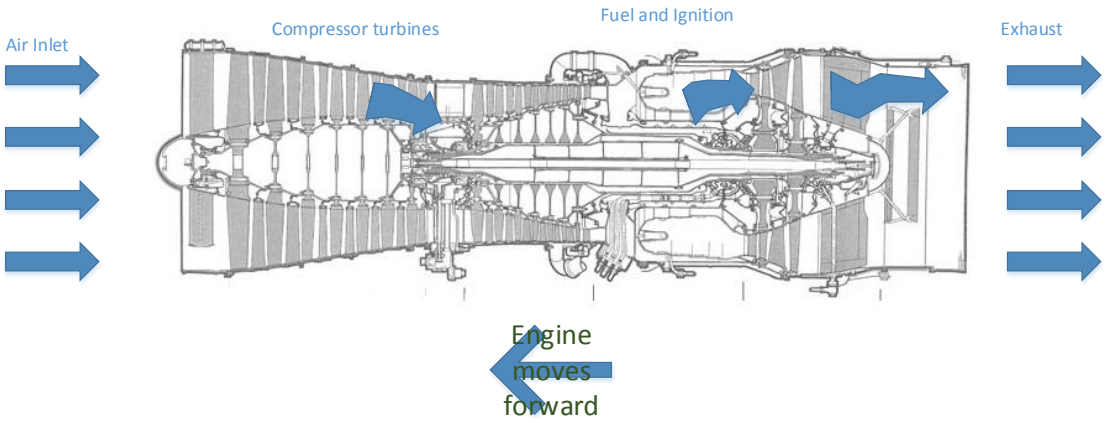

Figure 1.2 The inside of a jet engine

So how does a jet engine work? Well, if you look at figure 1.2 above, you can see a cross section of a typical jet engine. As the aircraft is moving, the airflow comes in through the air inlet. Once inside, turbines compress the air and push back towards the fuel and ignition section of the engine. Kerosene is pumped into the engine and ignited which converts the chemical energy stored in the fuel to heat and kinetic energy. The fuel and gas burns as it moves with explosive force back towards the exhaust outlet. The air-fuel combination pushing backwards is enough to push the engine forwards (by Newton's third Law of Motion).

1.3 LIFT

There are two main forms of lift which need to be considered when looking at an aircraft in flight. The first and most common is that of lift provided by the shape of the wing and Bernoulli's Principle. This principle states that a fluid in motion has less pressure than one at rest. In the case of an aircraft, the fluid is air (as fluids are either liquids or gases) and the air has to move over and under the wing surface. The shape of the wing is such that air has to move faster over the top of the wing's surface than it does at the bottom and so this means that there is less pressure above than underneath. As there is more pressure at the bottom of the wing, this pushes the wing up. Obviously, the wing is attached to the aircraft and so as the wing is pushed up, so is the aircraft. This accounts for much of the lift experienced by the aircraft, but not quite all.

Another way in which an aircraft develops lift is by sending the airflow that has gone over and under the wing in a downward direction. Newton's Third Law of Motion states that for every action there is an

equal and opposite reaction which implies that as the airflow moves down, something needs to move up. The thing that moves up is the wing hence providing the aircraft with lift.

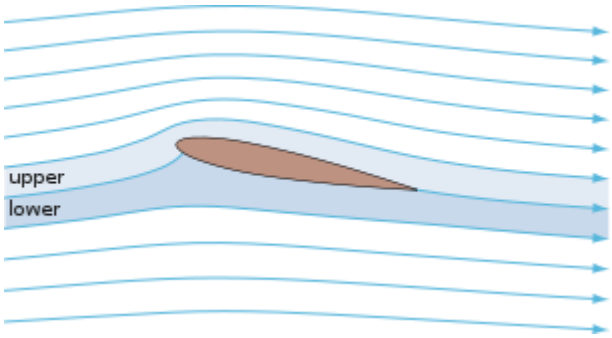

Figure 1.3 Showing how air travels passed a wing

You may remember that when discussing propulsion or thrust, we mentioned that a propeller worked in the same way as an aerofoil wing. This is true, but as the propellers are usually vertical, the "lift" that is generated is sideways and so results in the aircraft moving forwards.

1.4 Drag

The force of drag is one that seeks to impede the progress of an aircraft. It is related to friction in many ways as it always opposes the direction of travel. There are three types of drag associated with air travel and it is the job of aeronautical engineers to try to find ways of reducing the drag. The three types of drag are specified below along with some measures that can be taken to reduce their affect.

Type of Drag	Percentage of overall drag	Cause	Reduction Measures
Form drag	85%	Shape of the aircraft moving through the air.	Streamlining
Induced drag	10%	Airflow across wing surfaces moving in opposing directions creating a vertex in the air flow field.	Tabs
Skin Friction	5%	Air rubbing against the body of the aircraft.	Polishing surfaces and counter-sinking rivets etc.

Table 1: Types of Drag affecting an Aircraft

This section of the report has detailed the types of force affecting an aircraft in flight. Reference to figure 1.1 makes explicit the relationship between the four forces. As can be seen, when an aircraft takes off, lift and thrust will need to be greater than drag and weight. On the other hand, when an aircraft is coming into land, drag needs to be increased and lift reduced to allow the plane to descend safely.