**3-Thrust &Drag**

Thrust is the [force](https://www.grc.nasa.gov/www/k-12/airplane/forces.html), which moves an aircraft through the air. Thrust used to overcome the [drag](https://www.grc.nasa.gov/www/k-12/airplane/drag1.html) of an airplane, and to overcome the [weight](https://www.grc.nasa.gov/www/k-12/airplane/weight1.html) of a rocket. Thrust generated by the engines of the aircraft through some kind of [propulsion system](https://www.grc.nasa.gov/www/k-12/airplane/bgp.html).

 Thrust is a mechanical force, so the propulsion system must be in physical contact with a working fluid to produce thrust. Thrust generated most often through the [reaction](https://www.grc.nasa.gov/www/k-12/airplane/newton3.html) of accelerating a [mass](https://www.grc.nasa.gov/www/k-12/airplane/mflow.html) of gas. Since thrust is a force, it is a [vector quantity](https://www.grc.nasa.gov/www/k-12/airplane/vectors.html) having both a magnitude and a direction. The engine does [work](https://www.grc.nasa.gov/www/k-12/airplane/work2.html) on the gas and accelerates the gas to the rear of the engine; the thrust generated in the opposite direction from the accelerated gas. The magnitude of the thrust depends on the amount of gas that accelerated and on the [difference in velocity](https://www.grc.nasa.gov/www/k-12/airplane/thrsteq.html) of the gas through the engine.

The physics involved in the generation of thrust introduced in middle school and studied in some detail in high school and college. To accelerate the gas, we have to expend [energy](https://www.grc.nasa.gov/www/k-12/airplane/thermo1f.html). The energy generated as heat by the [combustion](https://www.grc.nasa.gov/www/k-12/airplane/combst1.html) of some fuel. The [thrust equation](https://www.grc.nasa.gov/www/k-12/airplane/thrsteq.html) describes how the acceleration of the gas produces a force. The [type](https://www.grc.nasa.gov/www/k-12/airplane/trbtyp.html) of propulsion system used on an aircraft may vary from airplane to airplane and each device produces thrust in a slightly different way. We will discuss four principal propulsion systems at this web site; the [propeller,](https://www.grc.nasa.gov/www/k-12/airplane/propeller.html) the [turbine, or jet,](https://www.grc.nasa.gov/www/k-12/airplane/turbine.html) engine, the [ramjet,](https://www.grc.nasa.gov/www/k-12/airplane/ramjet.html) and the [rocket.](https://www.grc.nasa.gov/www/k-12/airplane/rocket.html)

You can view a short [movie](https://www.grc.nasa.gov/www/Wright/podcast/Podcast_Forces_thrus.m4v) of "Orville and Wilbur Wright" discussing the thrust force and how it affected the flight of their aircraft. The movie file can be saved to your computer and viewed as a Podcast on your podcast player .

 **4-Drag**
 Drag is the aerodynamic [force](https://www.grc.nasa.gov/www/k-12/airplane/forces.html)that opposes an aircraft's motion through the air. Drag generated by every part of the airplane (even the [engines!](https://www.grc.nasa.gov/www/k-12/airplane/thrsteq.html)).As the airplane moves through the air, there is another aerodynamic force present. The air resists the motion of the aircraft and the resistance force called [drag](https://www.grc.nasa.gov/www/k-12/airplane/drag1.html). Drag is directed **along and opposed** to the flight direction. Like lift, there are many [factors](https://www.grc.nasa.gov/www/k-12/airplane/factord.html) that affect the magnitude of drag force including the [shape](https://www.grc.nasa.gov/www/k-12/airplane/shaped.html) of the aircraft, the ["stickiness"](https://www.grc.nasa.gov/www/k-12/airplane/airsim.html) of the air, and the velocity of the aircraft. Like lift, we collect all of the individual components' drags and combine them into a single aircraft drag magnitude. In addition, like lift, drag acts through the aircraft center of pressure.

**Factors that affect drag**

As with aircraft [lift,](https://www.grc.nasa.gov/www/k-12/airplane/lift1.html) there are many factors that affect drag. We can group these factors into (a) those associated with the object, (b) those associated with the motion of the object through the air, and (c) those associated with the air itself.

**The Object**

[Geometry](https://www.grc.nasa.gov/www/k-12/airplane/geom.html) has a large effect on the amount of drag generated by an object. As with lift, the drag depends linearly on the [size](https://www.grc.nasa.gov/www/k-12/airplane/sized.html) of the object moving through the air. The cross-sectional [shape](https://www.grc.nasa.gov/www/k-12/airplane/shaped.html) of an object determines the form drag created by the [pressure variation](https://www.grc.nasa.gov/www/k-12/airplane/presar.html) around the object. The three dimensional plan form shape affects the [induced drag](https://www.grc.nasa.gov/www/k-12/airplane/induced.html) of a lifting wing. If we think of drag as aerodynamic friction, the amount of drag depends on the surface roughness of the object; a smooth, waxed surface produces less drag than a roughened surface. This effect called skin friction and is usually included in the measured [drag coefficient](https://www.grc.nasa.gov/www/k-12/airplane/dragco.html) of the object.

**Motion of the Air**

Drag is associated with the movement of the aircraft through the air, so drag depends on the [velocity](https://www.grc.nasa.gov/www/k-12/airplane/vel.html) of the air. Like lift, drag actually varies with the square of the [relative velocity](https://www.grc.nasa.gov/www/k-12/airplane/move2.html) between the object and the air. The [inclination](https://www.grc.nasa.gov/www/k-12/airplane/inclind.html) of the object to the flow also affects the amount of drag generated by a given shaped object. If the object moves through the air at speeds near the [speed of sound](https://www.grc.nasa.gov/www/k-12/airplane/sound.html), [shock waves](https://www.grc.nasa.gov/www/k-12/airplane/shock.html) are formed on the object which create an additional drag component called **wave drag**. The motion of the object through the air also causes [boundary layers](https://www.grc.nasa.gov/www/k-12/airplane/boundlay.html) to form on the object. A boundary layer is a region of very low speed flow near the surface which contributes to the **skin friction**.

**Properties of the Air**

Drag depends directly on the [mass](https://www.grc.nasa.gov/www/k-12/airplane/density.html) of the flow going past the aircraft. The drag also depends in a complex way on two other [properties](https://www.grc.nasa.gov/www/k-12/airplane/airsim.html) of the air: its viscosity and its compressibility. These factors affect the **wave drag** and **skin friction** which are described above.

We can gather all of this information on the factors that affect drag into a single mathematical equation called the [Drag Equation.](https://www.grc.nasa.gov/www/k-12/airplane/drageq.html) With the drag equation we can predict how much drag force is generated by a given body moving at a given speed through a given fluid.



 D = Cd x A x 0.5 x ρ x V 2