Easily digestible Aerospace Principles revealed for K-12 Students and Educators. These lessons will be sent on a bi-weekly basis and allow grade-level focused learning. - AIAA STEM K-12 Committee

AIR SPEED

One of the most important pieces of knowledge for any pilot is the speed of an aircraft. There are two ways to measure the speed of an airplane: airspeed and ground speed. Airspeed is the speed of the airplane with respect to the air through which it is flying; ground speed is its speed relative to the ground over which it is flying. Airspeed is important when calculating lift and drag; ground speed is important when calculating flight times between different places. Calculating speeds is a major part of designing and flying aircraft.

GRADES K-2

Flying a paper airplane on a windy day shows the difference between airspeed and ground speed very well. Fly the paper airplane indoors—in the classroom or down the hall, if you have permission—and note how far it goes and in what direction. Then go outside to a place where the wind is blowing and fly the paper airplane again. There does not need to be much wind at all. For the clearest illustration of the difference, launch the paper airplane at right angles to the wind, so that it flies through a crosswind and gets blown sideways. The airspeed is the same as it was when it flew indoors, but the ground speed now has a serious sideways component. You can also launch it into the wind and downwind, showing that even though the airspeed is the same, the wind always adds a component to the ground speed in the direction in which it is blowing.

GRADES 3-5

Airspeed is often measured on an airplane by a device called a "Pitot-static probe." ("Pitot" is French and is pronounced as "PEE-toe"). A pitot-static probe works by measuring the pressure which air exerts on it as it flows by. Pressure is a way of describing how much force acts on a given area, or how intensely something is pushing. As a plane flies through the air, the air pushes back on it; as the plane goes more quickly, the air pushes back more. You can feel this effect yourself by sticking your hand out the window of a car. If the car is going slowly down the street, you might feel a gentle breeze around your hand, but if the car is speeding down the highway you might not even be able to hold your hand straight because of the high pressure.

Pitot-static probes allow airplanes to measure how much the air is pushing back, which lets pilots know how quickly they are moving through the air.

GRADES 3-5 (CONTINUED)

Why do pilots need to know their airspeed? The speed at which a plane is flying through the air determines how the airplane flies—how much lift it produces, how much friction there is, and many other things. However, the speed of the plane through the air is not necessarily the same as the speed of the plane over the ground. What do you think happens if the plane is flying into a strong wind? The plane slows down. In fact, it is possible for some small planes to "fly backwards" if the wind is strong enough. Pilots can use computers and GPS units to find out their speed over the ground (groundspeed), which helps them predict when they will reach their destinations.

GRADES 6-8

Airspeed is often measured on an airplane by a device called a "Pitot-static probe." ("Pitot" is French and is pronounced as "PEE-toe"). A Pitot-static probe consists of two parts: a Pitot tube and a static port. Each part measures pressure in a different way. The static port measures *static pressure*, or the kind of pressure you are probably familiar with: the pressure which still air exerts on everything it touches. Normally, the air around us has a static pressure of 14.7 pounds per square inch. (If you hold out your hand and imagine a column of air one square inch in area extending up to the top of the atmosphere, all the air in that column weighs 14.7 pounds.) If you swam to the bottom of a deep swimming pool, the pressure would be higher because of the weight of all the water above you, and if you went to the top of Mount Everest, the pressure would be much lower because there would be less air pushing down above you. In fact, it would be so low that you wouldn't be able to breathe!

However, there is a different kind of pressure you may not be as familiar with - *dynamic pressure*. Dynamic pressure comes from moving fluids. There are many everyday examples of dynamic pressure. For example, if you blow really hard onto your hand, you feel a force on your skin. Or alternatively, try sticking your hand out of the window of a moving car – as the car moves more quickly, you find it harder and harder to keep your hand in place. These are both examples of dynamic pressure. A Pitot tube measures the *total pressure* (that is, the sum of dynamic and static pressure). By subtracting static pressure from total pressure, a pitot-static tube can find the dynamic pressure, which makes it possible to determine how quickly an airplane is flying. If the dynamic pressure is high, the plane is moving quickly; if it is low, it is moving slowly (think of sticking your hand out the car window again). This is how airspeed is measured.

Grades 6-8 (continued)

What does airspeed tell us? It tells us how quickly a plane is moving *through the air*. In reality, a plane will almost always be moving at a different speed over the ground. If a plane is flying through wind, the wind will carry the plane in a slightly different direction – a plane might be flying forwards through the air at 100 miles per hour, but wind could be carrying it over the ground at 30 or 40 miles per hour to the left or the right as well. The plane feels no difference – but you would see it drifting to one side if you watched it fly over your head. Very strong winds can make it difficult to navigate airplanes. During the Second World War, for example, people did not know about the jet stream as an organized phenomenon. The jet stream is a flow of very fast-moving air in the upper atmosphere, sometimes reaching speeds of over 200 miles per hour. Since the average bomber in the Second World War had a cruising speed of 200-250 miles per hour, the jet stream had a very significant effect. There were cases of airplanes flying into the jet stream by mistake and overshooting their targets by many miles, or if they were flying upwind, not being able to make it to their targets in the first place.

Grades 9-12

Pilots use Pitot-static probes to measure airspeed ("Pitot" is French and is pronounced as "PEE-toe"). A Pitot-static probe consists of a static port and a Pitot tube, each of which measures a different kind of pressure. The static port measures *static pressure*, or the pressure of a fluid at rest (the kind of pressure you are probably familiar with). The other kind of pressure is *dynamic pressure*, which comes from the motion of the air. A good way to visualize dynamic pressure is by sticking your hand out of a car window. If the car isn't moving, you don't feel anything because the only pressure acting on your hand is normal atmospheric (static) pressure. However, as the car accelerates, you feel more and more force on your hand; this is dynamic pressure. A Pitot tube measures the sum of the two pressures – the *total pressure*. A Pitot-static probe compares this pressure to atmospheric pressure to determine the airspeed using an equation known as Bernoulli's principle. Bernoulli's principle states that the total pressure will remain equal between two points in an airflow (technically there is also a term for gravitational forces but we can ignore it for this application).

$$p + \frac{1}{2}\rho V^2 + \rho g h = constant$$

We can solve this equation to find the speed:

$$V_2 = \sqrt{\frac{2 \cdot (p_1 - p_2)}{\rho}}$$

This is how airspeed is calculated using a Pitot-static probe. However, you may be surprised to know that there are four different measures of airspeed for an airplane at any one time! Here they are:

1. Indicated Airspeed – this is the speed indicated on the pilot's airspeed indicator, calculated directly from the Pitot-static probe.

2. Calibrated Airspeed – this is the airspeed once it has been corrected for errors resulting from the way the Pitot-static probe is installed on the plane. Often, air will not flow over the Pitot-static probe the way it is intended to (for example, if the plane is climbing or descending steeply) – calibrated airspeed corrects for this.

3. Equivalent Airspeed – at higher speeds, the airspeed indicator becomes inaccurate. This is because Bernoulli's principle, which is the underlying principle behind the Pitot-static probe, is not really valid at higher airspeeds. At higher speeds, the air starts to compress around the plane and the Pitot-static probe. This changes the static pressure in the probe and requires a different set of equations to calculate airspeed. This new airspeed is called equivalent airspeed – however, it is effectively the same as calibrated airspeed except for very fast aircraft.

4. True Airspeed – As we have learned, airspeed is calculated using Bernoulli's principle, which relates static pressure, density, and velocity. The airspeed indicator uses a constant value of air density – density at sea level – to calculate velocity from the difference in static pressure and dynamic pressure. However, atmospheric density changes as altitude (height) increases – the air gets thinner and thinner. As a result, indicated/calibrated/equivalent airspeed becomes less and less accurate as altitude increases. True airspeed is calculated by accounting for the difference in density between air at the aircraft's altitude (height) and air at sea level. However, this is usually a minor difference and is often ignored unless pilots are making precise calculations.